Respiratory Support of Adults in the Emergency Department

A thesis presented in fulfilment of the requirements for the degree of

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Abstract

Introduction:

Adult emergency department (ED) patients frequently require respiratory support (RS), yet limited research on RS, particularly nasal high-flow (NHF) therapy, is available in this setting. This doctoral research aimed to analyse the nature of ED-based RS and its impact on adult patient outcomes, focusing on NHF therapy. Grounded in an evidence-based practice (EBP) framework, this research proposes to bridge a theory-practice gap and inform NHF clinical decision-making in the ED.

Methodology:

This thesis was informed by a positivist philosophical paradigm and methodology underpinned by an EBP theoretical framework. The research approach was quantitative, the research strategy was non-experimental, the design was multi-method, and the time horizon was cross-sectional, using two methods. The two methods were a systematic review (SR) with meta-analysis (MA) and a point prevalence study (PPS). Each method was conducted in parallel and as per the multi-method design, and the results were integrated to form the thesis findings and answer the research questions.

Results:

In the first method, the SR provided five MAs involving 18 ED RCTs reporting on 1874 participants. A 45% reduction in escalation relative risk (RR) was seen for NHF vs conventional oxygen therapy (COT) (RR 0.55; 95% CI, 0.33 to 0.92; $p = 0.02$), with no difference in mortality or adverse event risk. For NHF vs non-invasive ventilation (NIV), NHF increased escalation risk by 81% (RR 1.81; 95% CI, 1.19 to 2.75; $p < 0.01$). Mortality risk was not different for NHF vs NIV.

In the second method, the PPS characterised 76 patients receiving RS from a total of 898 ED-presenting patients. The PPS was underpowered and unable to support its planned inferential analyses. The mean age of the participants was 67.38 years (SD ± 17.4); 52% ($n = 40$) were male, 48.6% ($n = 37$) had greater than three comorbidities, and 44% ($n = 34$) had primary respiratory diagnoses.

By ethnicity, the Indigenous New Zealand Māori were overrepresented in the data ($n = 18$, 23%). Of those receiving RS, the minority ($n = 12$, 15.7%) received NHF; however, all these required subsequent hospitalisation. The absolute prevalence of the requirement for escalation of RS was $n = 22$ (28.9%).

The hospitalisation rate was 22% higher, and the hospital length of stay was 42% longer for those requiring RS escalation in the ED. Māori demonstrated a 5.8% higher risk of requiring escalation of care on an absolute scale (n = 6, 33.3%) vs (n = 16, 27.5%), and a 22% increased risk on a relative scale (RR 1.22; 95% CI 0.56 to 2.67; p = 0.60) than non-Māori.

Conclusions:

When the results from the two methods were integrated, the main finding was that nearly a third of those receiving RS required escalation of their RS, with those receiving NHF requiring less escalation than those receiving all other forms of RS combined. These findings align with the meta-analysis of studies for the comparison of NHF compared to COT but not the comparison of NHF compared to NIV.

Acknowledgements

I started my PhD study during the COVID-19 global pandemic. This period of uncertainty presented numerous challenges for us all. Personally, my PhD served as a welcome distraction and compelled me to take the opportunity to make a meaningful contribution to front-line clinical practice.

“It takes a village to raise a child” is a well-known saying; I believe that completing a PhD also requires the support of a village. I express my deepest gratitude to my village of extraordinary individuals who supported and guided me on this transformative journey.

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Finally, I thank my husband, Robin, for your love, understanding, patience, and pride throughout this selfish endeavour of mine. To my children, I will always “love you more..”

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Publications and Presentations

*O'Donnell, J., Pirret, A., & Hoare, K. (2021a). How do nurses better predict outcomes for adult COVID-19 patients receiving nasal high-flow therapy in the emergency care setting? *International Emergency Nursing, 57*, 101011. https://doi.org/10.1016/j.ienj.2021.101011

*O'Donnell, J., Pirret, A., Hoare, K., McDonald E., Fenn, R. (2021b). Respiratory support strategies for adult emergency care patients: a systematic review and meta-analysis. Prospero Protocol.https://doi.org/https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42 021222517

*O'Donnell, J., Pirret, A., Hoare, K., & McDonald, E. (2022). Respiratory support of adults in the emergency department: A protocol for a prospective, observational, multicenter point prevalence study. *Health Science Reports, 6*(1), e966. https://doi.org/10.1002/hsr2.966

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Submitted Publications

**O'Donnell, J., Pirret, A., Budhathoki, C., McDonald, E., Hoare, K., Kruger, M. (2024b). Knowing How Expensive it is to Be Poor in Aotearoa, New Zealand. Submitted to *Journal of Racial and Ethnic Health Disparities.* April 2024. *See* Appendix C.

*O'Donnell, J., Pirret, A., Budhathoki, C., McDonald, E., Hoare, K., Kruger, M. (2024c). The Epidemiology of Respiratory Support in the Emergency Department: A Prospective Point Prevalence Study. Submitted to *Australasian Emergency Care*. April 2024.

Presentations

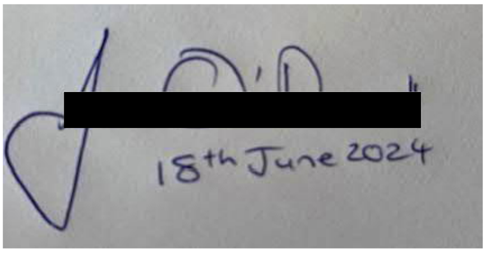
*O'Donnell, J., Pirret, A., Hoare, K., & McDonald, E. (2023). An Evaluation of the Reporting Quality of Emergency Department Systematic Reviews ACEP Research Forum. *Annals of Emergency Medicine, 82*(4), A1-A2. https://www.annemergmed.com/article/S0196-0644(22)01098-8/pdf. Presented American College Emergency Physicians (ACEP), Philadelphia 2023.

O'Donnell, J., Pirret, A., McDonald, E., Hoare, K. (2024). Respiratory Support in the Emergency Care Setting-Meta-analyses of Randomised Controlled Trials. Accepted for Presentation European Society of Emergency Medicine (EUSEM), Copenhagen 2024.

Note. * Embedded as published within the thesis body, ** Included as an appendix.

Attestation of Authorship

I hereby declare that this submission is my own work. Note that this thesis and its graphics have been professionally formatted and proofed for grammatical correctness. To the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements) nor material which, to a substantial extent, has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.



Signature	Date

Abbreviations

A-A	Alveolar-Arterial Gradient
ABG	Arterial Blood Gas
AH	Absolute Humidity
ACEM	Australasian College of Emergency Medicine
AE	Adverse Event
AECOPD	Acute Exacerbation of Chronic Pulmonary Disease
AHRF	Acute Hypoxic Respiratory Failure
ALI	Acute Lung Injury
ANZICS	Australian And New Zealand Intensive Care Society
APO	Acute Pulmonary Oedema
APACHE	Acute Physiologic And Chronic Health Evaluation
ARDS	Acute Respiratory Distress Syndrome
ARF	Acute Respiratory Failure
BiPAP	Bi-Level Positive Airway Pressure
BMI	Body Mass Index
BP	Blood Pressure
BR	Breath Rate
CI	Confidence Interval
Cm H_2O	Centimetres Of Water
CO_2	Carbon Dioxide
COPD	Chronic Obstructive Pulmonary Disease
COT	Conventional Oxygen Therapy
COVID-19	Coronavirus Disease Of 2019
CRF	Case Report Form
CT	Computerised Tomography
CVD	Cardiovascular Disease
CVS	Cardiovascular System
CXR	Chest X-Ray
2,3-DPG	2,3-Diphosphoglycerate
DS	Dead Space
EAdi	Electrical Activity of The Diaphragm
EBP	Evidence-Based Practice
eCRF	Electronic Case Report Form
ED	Emergency Department
EDEN	Emergency Department Epidemiology Network
EELI	End-Expiratory Lung Impedance

EELV	End-Expiratory Lung Volume
EIT	Electrical Impedance Tomography
EPAP	Expiratory Positive Airway Pressure
ERV	Expiratory Reserve Volume
EWS	Early Warning Score
FEV1	Forced Expiratory Volume in One Second
FiO_2	Fraction Of Inspired Oxygen
FM	Face Mask
FRC	Functional Residual Capacity
FVC	Forced Vital Capacity
HDU	High Dependency Unit
HF	Heart Failure
HFFM	High Flow Face Mask
HFNC	High Flow Nasal Cannulae
HHFNC	Humidified High Flow Nasal Cannulae
HMN	High Material Need
H_2O	Water
HR	Hazard Ratio
HVNI	High-Velocity Nasal Insulation
ICU	Intensive Care Unit
IHD	Ischaemic Heart Disease
INV	Invasive Ventilation
IPAP	Inspiratory Positive Airway Pressure
IQR	Inter-Quartile Range
IRV	Inspiratory Reserve Volume
ITT	Intention To Treat Analysis
L/Min	Litres Per Minute
LOS	Length Of Stay
LR	Likelihood Ratio
MA	Meta-Analysis
MD	Mean Difference
M	Mean
Mdn	Median
Mmhg	Millimetres of Mercury
MV	Minute Ventilation

MV	Mechanical Ventilation
NCPAP	Nasal Continuous Positive Airway Pressure
NC	Nasal Cannula
NHF	Nasal High Flow Therapy
NIV	Non-Invasive Ventilation
NNH	Number Needed to Harm
NNT	Number Needed to Treat
NP	Nasal Prongs
NRM	Nonrebreather Mask
O2	Oxygen
OR	Odds Ratio
OSA	Obstructive Sleep Apnoea
P	P-Value
$PACO_2$	Partial Pressure of Carbon Dioxide in The Alveoli
$PaCO_2$	Partial Pressure of Carbon Dioxide in Arterial Blood
PaO_2	Partial Pressure of Oxygen in Arterial Blood
PAO_2	Partial Pressure of Oxygen in The Alveoli
PEEP	Positive End-Expiratory Pressure
PPS	Point Prevalence Study
PR	Pulse Rate
P-SILI	Patient-Self-Inflicted Lung Injury
RCT	Randomised Controlled Trial
RF	Respiratory Failure
RH	Relative Humidity
ROX	Respiratory Rate-Oxygenation
RR	Relative Risk
RS	Respiratory Support
SaO_2	Arterial Oxygen Saturation
SD	Standard Deviation
SpO_2	Peripheral Oxygen Saturation
SpO_2/ FiO_2 Ratio	Ratio Of Peripheral Oxygen Saturation to the Fraction of Inspired O2
SOFA	Sequential Organ Failure Assessment
SR	Systematic Review
TA	Thoracoabdominal Asynchrony
TLC	Total Lung Capacity
TNI	Trans Nasal Insufflation

VT	Tidal Volume
VM	Venturi Mask
V/Q	Ventilation (V) Perfusion (Q) Ratio
WOB	Work Of Breathing

Chapter One

Introduction

The purpose of this first Chapter *Introduction* is to introduce the doctoral research and its thesis. This thesis is presented in seven chapters and includes seven supporting manuscripts presented as submitted for publication or as published.

This chapter provides an overview of the background, context, thesis aims, questions, methodological approach, and thesis structure overview. This introductory chapter has ten sections:

- Background
- Significance of the Research
- Statement of the Problem
- Research Aim
- Research Questions
- Research Theoretical Framework: Evidence-Based Practice
- Research Methodology Overview
- Research Assumptions, Delimitations, and Limitations
- Overview of the Thesis Structure
- Chapter One Conclusion.

1.1 Background

Adults requiring respiratory support (RS) routinely present to the emergency department (ED). Clinicians in the ED, including doctors, nurses, and nurse practitioners, provide RS to optimise patient oxygenation and mitigate the need for escalation of care. Historically, ED clinicians have provided RS using one or a combination of conventional oxygen therapy (COT) with simple face masks or cannula, non-invasive ventilation (NIV), or invasive ventilation (INV). Today, nasal high-flow (NHF) therapy presents a fourth option for providing RS.

My doctoral research aimed to improve understanding of the nature of RS provided to adults in the ED. My academic and research background was informed when, as a practicing clinician, I specialised in ICU and emergency nursing. In the ICU, I observed the efficacy of the RS that I provided to my patients. Contemporaneously, a novel non-invasive form of RS, known as NHF, emerged. With NHF, I witnessed improved ICU patient outcomes. Therefore, in my doctoral research, I was compelled to investigate the nature of the RS, particularly RS with NHF, as provided in the ED.

Over the last twenty-five years, researchers have primarily determined the NHF mechanisms and benefits of action and then determined how these mechanisms and benefits might positively affect physiological outcomes; collectively, these findings apply to the ED patient. The current focus for NHF research was on how or indeed whether these mechanisms, benefits and physiological effects might collectively improve clinical outcomes.

Historically, NHF clinical outcome research has emerged from the ICU setting and, most recently, from anaesthesia; however, remarkably, little from the ED, which has led to an NHF evidence gap. This NHF evidence gap likely means that ED clinicians must rely heavily on their professional expertise and practice in an NHF evidence grey zone. On this basis, an evidence-based practice (EBP) approach must be further enabled (Kelly & Horsley, 2000).

1.2 Significance of the Research

The setting for this doctoral research was the ED. Therefore, this research is significant for ED clinicians and their patients. In the New Zealand (NZ) ED, care is delivered to patients randomly presenting to a hospital facility independently or by ambulance (MOH, 2015). In many countries, the hospital ED provides vital access to care for those patients without other means (Razzak & Kellermann, 2002). The ED is also known as an accident and emergency department, emergency room, emergency ward, or casualty department.

In New Zealand, there are 38 publicly funded hospital-based EDs, all operating 24 hours per day. Each year, these EDs deliver support and treatment for over one million patients with life-threatening injuries or illnesses (MOH, 2015). This support often includes triage, resuscitation, and stabilisation of patients, some emerging from primary health care and 33% requiring hospital admission for ongoing care (MOH, 2015). Ordinarily, primary health care providers deliver routine and urgent health care in New Zealand.

In contrast, it is intended that NZ EDs provide intermittent 'crisis' care for those needing acute care, including hospital admission. New Zealand EDs straddle primary and tertiary care; however, the overlap between primary and ED care is increasing (MOH, 2015).

The ED waiting room has been described as a health service barometer, where the consequences of primary and tertiary service stress are often demonstrated (Kraus, 2020). For example, tertiary hospital bed blocks or inadequate primary care access frequently manifest as ED overcrowding (Sartini et al., 2022). Overcrowding in the ED is a global phenomenon impacting patient care quality. In New Zealand, the healthcare system attempts to function at or over capacity, with ED crowding and hospital inpatient bed blocks ubiquitous. Many factors affect health service delivery: some are directly related to consumers of health, while others are not, for example, low ED staffing levels (Saaiman et al., 2021) and the novel coronavirus disease 2019 (COVID-19) pandemic (Kurt et al., 2023). Globally, ED presentations were significantly reduced during the COVID-19 pandemic. However, hospital and ICU admission rates increased (Kurt et al., 2023). The variation among NZ hospitals and their EDs is significant. This variation relates to the structure, staffing, and workload; these aspects impact performance and capacity to manage waves in acute care demand safely and, obviously, global pandemics (Jones et al., 2021).

The focus of this doctoral research was the adult ED patient. The ED patient population demonstrates a wide-ranging series of presentations, with some necessitating urgent intervention (MOH, 2015). Consequently, ED clinicians and their patients must navigate complex and diverse clinical pathways. Complexity is derived from multifaceted symptomology, emerging diagnoses, and probable outcomes requiring consideration (MOH, 2015). The needs of ED patients are increasing, and so is the complexity of the care necessary to support them (Augustine, 2020). As a result, the number of those presenting to the ED who require some form of RS is also increasing. Failure to provide efficacious RS will likely positively impact patient outcomes and increase healthcare burden.

Historically, high-need ED patients have received RS with either or a combination of conventional oxygen therapy (COT), non-invasive ventilation (NIV), or invasive ventilation (INV). However, NIV and INV have known complications, including increased mortality and morbidity (Davidson et al., 2016; Fan et al., 2017). The delivery of NIV or INV is also resource-draining and usually requires admission to a specialist ward or an ICU. By contrast, NHF appears less burdensome for clinicians to deliver when compared to NIV (Stephan et al., 2015); this may explain why NHF has been increasingly used in the ED despite the limited evidence to support it. An EBP approach to clinical decision-making around the RS provided in the ED will achieve efficacy and preserve precious healthcare resources.

In March 2020, the COVID-19 global pandemic was declared. During this pandemic, the need for all forms of RS in ED, including NHF, was amplified (Alhazzani et al., 2020; Burnim et al., 2022), with up to 30% of patients with COVID-19 developing secondary acute hypoxaemic respiratory failure (Xia et al., 2020). During this time, the lack of robust evidence to inform clinical decision-making around the delivery of RS in the ED was exposed. As a result, nonpeer-reviewed evidence emerged. The state of the evidence, when combined with contrasting opinions, panic, and resource constraints, paralysed care delivery in many countries (Leone et al., 2021). Whilst this doctoral research was not focused on COVID-19, the pandemic has further confirmed the significance of ongoing research to informing practice with reliable, valid, and applicable evidence for the provision of RS in the ED.

1.3 Statement of the Problem

The specific problem was that the nature of the RS provided in the heterogeneous ED patient population needs to be fully described and understood. This problem stems from the paucity of robust prospective ED-focused RS research, notably NHF RS, which, as said, forces clinicians to operate in an evidence 'grey zone' (Kelly & Horsley, 2020). The grey zone is where evidence is either lacking or contradictory, and operating in this zone will likely see clinicians more reliant on their professional expertise; hence, an EBP approach for NHF in the ED must be further enabled. This doctoral research looked to inform clinical practice and future research to improve understanding of the nature of the RS, notably RS with NHF, as provided to adults in the ED.

1.4 Research Aim

The doctoral research aimed to analyse the nature of ED-based RS and its impact on adult patient outcomes, focusing on NHF therapy-based RS.

1.5 Research Questions

Given the doctoral research aims, two overarching and four core thesis questions were determined.

The two overarching thesis questions were:

- What is the nature of the NHF delivered to adults in the ED setting?
- What influence does the delivery of NHF have upon adult ED patient outcomes?

The four core thesis questions were:

- Who receives NHF in the ED?
- How is NHF delivered in the ED?
- Which patients receiving NHF require escalation of RS in the ED?
- What are the effects seen with NHF on physiological and patient-centred outcomes?

1.6 Research Theoretical Framework- Evidence-Based Practice

This thesis utilised the Evidence-Based Practice (EBP) framework, a theoretical approach that bridges the theory-practice gap, focusing on improving patient outcomes. The EBP framework and Louis Pasteur's germ theory are described as some of the most influential theories in health (Dickersin et al., 2007). Research is a crucial component of all theories and frameworks, including EBP, and research itself is a necessary component of these systems; "In any discipline, science is the result of the relationship between the process of inquiry (research) and the product of knowledge (theory)" (Saleh, 2018, p. 18). Here, there is a cyclical pattern with research generating new knowledge, which may lead to the development of new theories; collectively, this new knowledge and theory may help guide future research (McEwan & Wills, 2021).

The origins of the EBP framework are much debated. Some suggest that Florence Nightingale was the first to advocate EBP in the 1800s; when using evidential data, she described hospital and battlefield infections and drove practice change (Mackey & Bassendowski, 2017). In the 1970s, an epidemiologist and physician, Archie Cochrane, emerged as an 'EBP prophet'. Cochrane expressed concern that clinicians were not using evidence perceptibly, judiciously, or in context. Cochrane promoted the importance of rigorously appraising healthcare interventions and the evidence that supports their efficacy (Cochrane, 1989). It has been said that "it is curious, even shocking, that the adjective ‘evidence-based’ is needed” (Dickersin et al., 2007, p. 1), assuming that all patient interventions should indeed be efficacious as determined by the best evidence.

In the 1990s, David Sackett defined EBP as the “conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients.” (Sackett, 1997, p. 3). Detractors of this definition of EBP described EBP as cookbook healthcare, arguing that EBP focuses on evidence at the expense of human experience. However, three years later, Sackett revised this definition of EBP to include patient values, thus defusing these detractors (Sackett, 2000). Today, the EBP framework proposes that patient outcomes can be enhanced when clinician practice is based on the *best evidence*, is informed by *professional expertise*, and reflects *consumer values* (Sackett, 2000) (Figure 1). The evidence used must be reliable, valid, and applicable. Additionally, the EBP framework has broad utility across different outcomes. For example, the framework can be applied to both patient and health economic outcomes, where financial considerations may inform the allocation of healthcare resources.

Figure 1

The Evidence-Based Practice Framework

Note. The EBP framework describes the conscientious use of current best evidence in conjunction with professional expertise and consumer values to inform clinical decisions. The EBP Framework and its Component Parts (adapted from Sackett, 2000).

Like all clinicians, the ED clinician is obliged to reflect EBP to improve the outcomes of patients in their care. Evidence-based practice strategies, such as developing and implementing ED clinical guidelines, are now evident. However, some EBP barriers remain (Kirk & Nilsen, 2016). Barriers to implementing

EBP typically manifest at the individual clinician level (Estabrooks et al., 2003). It has been suggested that the ED has unique obstacles to address should ED-appropriate research methodologies be employed. Kelly and Horsely (2000) outline these obstacles as multiple clinical questions, time, systems/process analysis, teams and the grey zone (Table 1). These ED-appropriate research methodologies should consider whole systems of care rather than single interventions alone (Kelly & Horsley, 2000).

Table 1

Emergency Department Evidence-Based Practice: Barriers Named and Explained and Assumptions Described (Kelly & Horsley, 2000)

ED Barrier	Explanation	Assumption
Multiple clinical questions	ED patients often present multiple clinical problems which may be undifferentiated.	EBP[a] assumes a single question.
Time	Critical decision-making in the ED is often time-critical	EBP is time-consuming
Systems/process analysis	ED clinicians work with systems, pathways, or processes of care.	EBP considers a single intervention
Teams	ED clinicians practice in teams both internally and externally with other disciplines.	EBP assumes a single clinician-single patient relationship
The Grey Zone	ED clinical decision-making is multifactorial and dynamic; much evidence must be more available and consistent.	EBP contributes to the grey zone

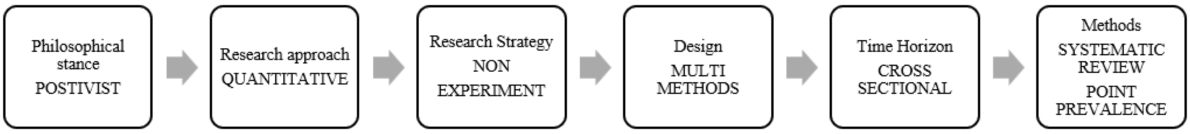
Note. [a] Evidence-Based Practice.

1.7 Research Methodology Overview

The methodology employed in this doctoral research was informed by a positivist philosophical paradigm and as outlined previously, its methodology underpinned by an EBP theoretical framework. The research approach was quantitative, the research strategy was non-experimental, the design was multi-method, and the time horizon was cross-sectional, using two methods: 1) a systematic review and meta-analysis and 2) a point prevalence study. (Figure 2).

Figure 2

Thesis Research Methodology: A Summary of the Methodological Components of the Thesis



Note. This figure demonstrates the six interlinked methodological components of the thesis.

The methodology involved a multi-method research design using two quantitative methods: 1) a systematic review (SR) with meta-analysis (MA) and 2) a point prevalence study (PPS). These methods were completed in parallel. The two study methods were a priori protocolised; these protocols were published and are presented in Chapter Four, *Methodology* (O'Donnell et al., 2021b; O'Donnell et al., 2022).

In the first method, the SR provided a narrative synthesis and five MAs of NHF ED RCTs. In the second method, a PPS prospectively captured comprehensive epidemiological data. These real-world data profiled adult ED patients who received RS at four NZ EDs in 2023. These data provided a 'snapshot' of the nature of the RS, including some with a focus on NHF RS.

Their published protocols guided the PPS and the SR with MA (O'Donnell et al., 2021b; O'Donnell et al., 2022). The findings from each study are presented in Chapters Five and Six (O'Donnell et al., 2024a; O'Donnell et al., 2024c). As per the multi-method research design, the results from the two methods were integrated and presented as the final thesis findings.

1.8 Research Assumptions, Delimitations, and Limitations

The researcher acknowledges this multi-method design's collective assumptions, delimitations, and limitations, distinct from the two individual quantitative methods' assumptions, delimitations, and limitations. As is often the case, some of these aspects were under the researcher's control, and others were not (Simon, 2011). However, both methods were protocolised, which enabled consideration and, where possible, control of the respective assumptions, delimitations, and limitations in the research overall.

For the first method, a SR with MA, the researcher understood the potential contribution a rigorous SR with MA can make as an essential building block for informing EBP and research. As such, MA authors have a duty of care to produce valid and reliable evidence, just as they would in a controlled study. The researcher was aware of the numerous potential flaws in the conduct, methods, and reporting of SRs with MAs. Firstly, a valid and reliable SR with MA must be updated and comprehensive and include all qualifying research. Secondly, a SR with MA must use rigorous and reproducible methods; finally, an SR with MA should be objective and non-biased (Uttley et al., 2023).

For the second method, the PPS, the researcher assumed that the prospective sample obtained using the cross-sectional method was real-world and representative of the adult ED population requiring RS. This assumption supports the generalisability of the findings, even when the internal validity of this method is typically low (Carlson & Morrison, 2009).

Additionally, the researcher limited the study to align with the primary outcomes and the variables measured with the PPS research questions to optimise the external validity, which is typically high (Carlson & Morrison, 2009). Finally, the researcher acknowledges the limitations of observational studies. Unlike controlled studies, the observational PPS methods cannot be used to attribute cause and effect. However, the PPS method has the utility of being a hypothesis generator for testing in future research (Eltorai et al., 2023); each of the two *Results* and the *Discussion and Conclusion* Chapters (Chapters 6–7) will present these aspects in depth.

1.9 Overview of the Thesis Structure

The thesis consists of seven chapters:

Chapter One, *Introduction*, overviews the doctoral research and the thesis.

Chapter Two, *Anatomy and Physiology and Respiratory Support*, provides an overview of respiratory anatomy, physiology, and respiratory support.

Chapter Three, *Literature Review*, provides a narrative review and summary of the literature regarding respiratory support, focusing on NHF therapy in the emergency department (O'Donnell et al., 2021a).

Chapter Four, *Methodology*, presents and discusses the methodology underpinning the doctoral research (O'Donnell et al., 2021b; O'Donnell et al., 2022; O'Donnell et al., 2023).

Chapter Five, *Results*—presents the first doctoral research findings—method one: Systematic Review with Meta-Analyses (O'Donnell et al., 2024a).

Chapter Six, *Results*—presents the second doctoral research findings—method two: Point Prevalence Study (O'Donnell et al., 2024b), and the thesis findings from the integration of the results of both methods.

Chapter Seven, *Discussion and Conclusion* —discusses the implications of this work for clinical practice and future research and presents a conclusion of doctoral research and the thesis.

Seven manuscripts have been included in this thesis with publication (O'Donnell et al., 2021a; O'Donnell et al., 2021b; O'Donnell et al., 2022; O'Donnell et al., 2023; O'Donnell et al., 2024a; O'Donnell et al., 2024b; O'Donnell et al., 2024c). These manuscripts are presented precisely as they were submitted for publication. However, the manuscript pages, tables, and figures have been numbered sequentially within the thesis for continuity. The reference lists supporting these manuscripts are combined within the one thesis reference list. Fourteen sets of supporting documents are included as appendices.

1.10 Chapter One Conclusion

In summary, the *Introduction* Chapter has overviewed the doctoral research and its thesis. The significance of the research has been defined, and the research objectives, questions, scope, and structure have been presented.

This thesis was informed by its positivist philosophical paradigm, and an EBP theoretical framework underpins its methodology. The research approach was quantitative, the research strategy was non-experimental, the design was multi-method, and the time horizon was cross-sectional, using two methods. The two methods were a SR with MA PPS. Each method was conducted in parallel, and as per the multi-method design, the results were then integrated to form the thesis findings and answer its six research questions. The anticipated research assumptions, delimitations, and limitations of the doctoral research have been declared.

The subsequent second Chapter, *Anatomy and Physiology and Respiratory Support* provides an overview of respiratory anatomy, physiology, and support. Here, the overview of RS focuses on RS with NHF, as provided to adults in the ED.

Chapter Two

Anatomy and Physiology and Respiratory Support

The previous Chapter, *Introduction*, overviewed all aspects of the doctoral research, providing background and context, stating the thesis questions, and defining its aim, scope and structure. The purpose of this second Chapter*, Anatomy and Physiology and Respiratory Support,* is to provide the scientific background and context for the thesis. This chapter begins by overviewing respiratory anatomy and physiology and its primary functions, oxygenation and ventilation, which are both essential for gas exchange. Then, this chapter covers contemporary RS therapies; these therapies are designed to enable optimal oxygenation and ventilation. This second chapter, *Anatomy and Physiology and Respiratory Support,* has four sections:

- Respiratory Anatomy: An Overview
- Respiratory Physiology: An Overview
- Respiratory Support Therapies
- Chapter Two Conclusion.

2.1 Respiratory Anatomy: An Overview

The respiratory anatomy comprises conducting and respiratory zones. (Edwards & Annamaraju, 2024). The conducting zone includes the nose, mouth, sinuses, pharynx, larynx, and trachea, which reflect the upper airway anatomy, and the right and left bronchi and bronchioles, which terminate in the alveoli, and reflect the lower airway anatomy; the alveoli are the destination for inspired gas. The conducting zone is not directly involved in gas exchange and is aptly known as the anatomical dead space (Intagliata et al., 2023).

Goblet cells within the conducting zone secrete mucus-trapping inhaled foreign bodies, which ciliated cells then propel as mucus-coated foreign bodies from the conducting zone to be expectorated (Bustamante-Marin & Ostrowski, 2017). Within the conducting zone, the dead space-inspired gas is filtered, heated, and humidified to body temperature (37°C) and 100% relative humidity (44 mg water/L of absolute humidity) (Williams et al., 1996).

The alveoli are the only part of the respiratory system directly involved in gas exchange. They have three cell types: Type I and II pneumocytes and alveolar macrophages. Type I pneumocytes line 70% of the inner alveolus, supporting gas exchange and maintaining biochemical balance within the zone. Type II pneumocytes line 7% of the inner alveolus and produce surfactant, which decreases surface tension and alveolar collapse. The alveolar macrophages support the immune system by scavenging inhaled foreign bodies within the lung (Brandt & Mandiga, 2024). The physiological functions of these respiratory structures shall now be considered.

2.2 Respiratory Physiology: An Overview

The physiology of breathing supports oxygen (O_2) uptake (oxygenation) and carbon dioxide (CO_2) elimination (ventilation) and enables acid-base buffering and speech. Respiratory physiology has four considerations: neurological control, pulmonary diffusion, O_2 transportation, and ventilation (Brinkman et al., 2024).

2.2.1 Neurological Control of Breathing

Breathing requires a coordinated effort between the central neural respiratory centre, the peripheral sensory input system, and the mechanoreceptor systems (Brinkman et al., 2024). The central chemoreceptors within the brain typically serve as the primary determinant of ventilation by detecting abnormal changes in the partial pressure of CO_2 in arterial blood ($PaCO_2$), manifesting as alterations in the cerebrospinal fluid pH. As a result, the ventilation rate will adjust to attain a normal $PaCO_2$ (Brinkman et al., 2024).

Approximately 15% of the respiratory drive is informed by the peripheral receptors within the carotid and aortic bodies (Brinkman et al., 2024), which detect low partial pressures of arterial oxygen (PaO_2) levels (<75 mmHg) (hypoxaemia). The central neural respiratory centre receives data from these peripheral receptors via cranial nerves IX and X; these trigger early clinical responses, such as increasing heart and respiratory rates. Changes in pH and $PaCO_2$ impact the sensitivity of these receptors. Usually, the neural respiratory centre responds to rising $PaCO_2$ levels as detected by central chemoreceptors rather than decreasing PaO_2, except in cases of hypoxaemia. These collective efforts (between the central neural respiratory centre, the peripheral sensory input system, and the mechanoreceptor systems) typically synchronise respiratory rate and inspired tidal volumes (VT) to meet respiratory demands.

Adults normally exchange about 350 mL of gas from the conducting airways to the alveoli (with VT of 150 mL) in each breath (Hallett et al., 2024). For adults, the respiratory rate is usually 12 to 20 times per minute. Therefore, the usual resting minute ventilation rate is approximately 7.5 litres per minute (L/min) (Hallett et al., 2024).

2.2.2 Pulmonary Diffusion

During normal respiration, inspired VT diffuses from these alveoli to capillary blood, migrating through alveolar surfactant and epithelium, basement membranes, and the pulmonary capillary endothelium (Patel et al., 2024). Approximately 250 mL/minute (min) of alveolar O_2 diffuses to the pulmonary capillaries; this alveolar O_2 is exchanged for approximately 200 mL/min of CO_2. In summary, the normal volume of CO_2 expired is 200 mL/min, and the volume of O_2 transferred is 250 mL/min (Patel et al., 2024).

The cardiovascular and respiratory systems collectively are responsible for diffusing O_2 and CO_2 from the alveoli to the surrounding alveoli capillaries. Diffusion relies on the respiratory system to ensure the alveoli are well-ventilated and perfused. The respiratory system is perfused via the bronchial and pulmonary arteries, which requires the cardiovascular system to provide adequate pulmonary circulation. The pulmonary circulation originates in the right ventricle and eventually forms a network of alveolar capillaries. Well-perfused lungs have sufficient blood flow to facilitate the uptake of O_2 for transport to the rest of the body.

Fick's law of diffusion suggests that partial pressures of gases between the blood and the inhaled air, the diffusion surface area (normally 100 m^2), and the thickness of the alveolar-capillary membrane (normally 0.6 μ) all impact diffusion (Powers & Dhamoon, 2024).

The ventilation-perfusion ratio quantifies the matching of diffusion and perfusion. Ventilation (V) refers to airflow into and out of the alveoli, while perfusion (Q) refers to the blood supply to alveolar capillaries (Mirza & Hashmi, 2024). A typical V/Q ratio is 0.8L, the ratio related to the average size of a lung being ventilated by four litres of air and perfused by five litres of blood per minute (Mirza & Hashmi, 2024). Poor perfusion or ventilation may result in a V/Q mismatch when V does not match Q. After a normal exhalation, a volume of gas remains in the lungs; this volume is the functional residual capacity (FRC) (Hopkins & Sharma, 2024). A change in FRC will result in a change in V/Q matching (Hopkins &

Sharma, 2024).

2.2.2.1 Pressure Gradients.

Pressure gradients are related to the movement of gas from a region of higher concentration to an area of lower concentration and mainly consider the exchange of O_2 and CO_2. In humans, gas exchange occurs during alveolar ventilation. Gas exchange has three considerations: gas partial pressures, the oxyhaemoglobin dissociation curve, and oxygen transport.

The gas composition of air is 78.08% nitrogen, 20.95% O_2, 0.93% argon, and <0.038% for CO_2 and other gases. Dalton's law dictates that the total pressure of a gas mixture, such as air, equals the sum of the partial pressures of each gas present. (Dutton, 1961). Therefore, the partial pressure of a gas such as O_2 (PO_2) depends on atmospheric pressure and the fraction of gas inspired (FiO_2), which breathing room air is 0.21%.

Once the air is inhaled into the alveoli, a slight pressure gradient exists, referred to as the alveolar-arterial (A-a) gradient, enabling the diffusion of O_2 into the pulmonary capillaries and CO_2 from the pulmonary capillaries. The A-a gradient describes the difference between the partial pressure of O_2 in the alveoli (PAO_2) and the PaO_2 caused by the loss of O_2 as it diffuses across the alveoli wall, through the interstitial space, alveolar-capillary wall, pulmonary capillary wall, and finally into the plasma. The A-a gradient usually is 5 to 10 mm. Hg. An increased A-a gradient characterises a V/Q mismatch and a change in the V/Q ratio, suggesting gas exchange dysfunction, leading to hypoxaemia (Powers & Dhamoon, 2024). Gas exchange primarily aims to maintain normal arterial O_2 and CO_2, measured by arterial blood gas (Trulock, 1990).

The lungs play an essential role in excreting CO_2, the waste product of cellular respiration in the organs (Brinkman et al., 2024). The CO_2 transport from the cell to the red blood cells is aided by carbonic acid (H_2CO_3), which quickly dissociates to bicarbonate (HCO_3) and is transported to the lungs via the systemic circulation. When red blood cells reach the lungs, the process is reversed. While CO_2 will diffuse from the alveoli capillary into the alveoli via a pressure gradient (from an area of high concentration to a low concentration), it depends on exhalation to remove it from the lung. Hence, normal PaO_2 and $PaCO_2$ rely on not only the pressure gradients but also the quality of ventilation, including inhalation and exhalation (Brinkman et al., 2024).

2.2.3 Oxygen Transportation

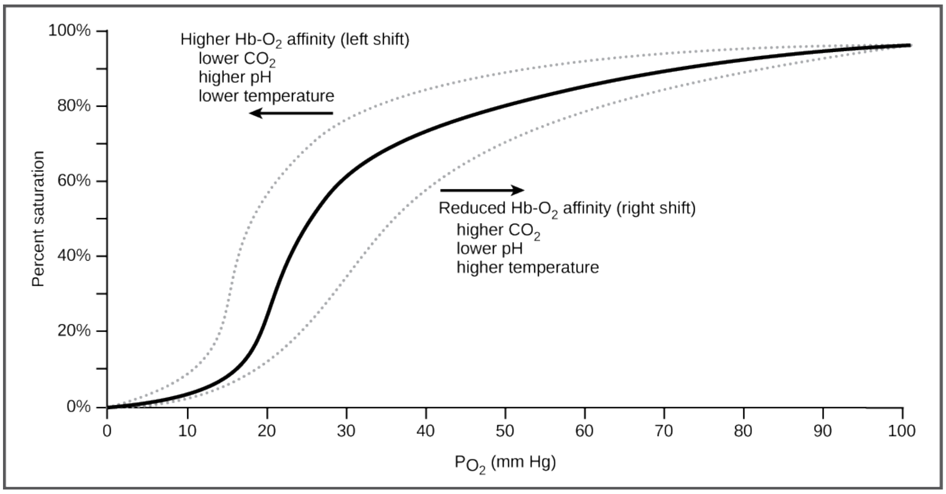
The PO_2 impacts O_2 transport around the body. Once inspired, diffused O_2 is transported in plasma (2%) and bound to haemoglobin (Trulock, 1990). The O_2 bound to haemoglobin is known as oxyhaemoglobin. The amount of O_2 bound to haemoglobin is expressed as a percentage and is referred to as the O_2 saturation. In the normal adult lung, the normal O_2 saturation of arterial blood is 96 to 98% (Haffen & Sharma, 2022). The O_2 percentage, when measured by a pulse oximeter, is denoted as SpO_2, and when measured by an ABG, is denoted as SaO_2 (Trulock, 1990). When the PAO_2 is increased, the PaO_2 increases, which increases the SaO_2. Hence, oxygen therapy aims to improve the PAO_2, PaO_2 and O_2 saturation. Thus, the pressure gradient impacts the amount of O_2 bound to haemoglobin. If the cardiac output (the combination of blood pressure and heart rate) is adequate, the amount of O_2 available to the organs will also be adequate (Pittman, 2011).

2.2.3.1 Oxyhaemoglobin Dissociation Curve.

Based on a normal anatomical shunt, the PaO_2 of 75 to 100 millimetres of mercury (mmHg), the $PaCO_2$ of 35 to 45 mmHg, SpO_2: > 95 and <100%, pH (7.35 to 7.45), HCO_3 (22 to 26 meq/L) and a varying base excess/deficit (-4 to +2) are deemed normal (Castro et al., 2024). The kidneys control blood bicarbonate levels, and both kidneys and lungs control blood pH. Once the O_2 diffuses from the alveoli into the surrounding alveolar capillary, the plasma readily receives O_2. When the plasma is exposed to increasing amounts of oxygen, the PaO_2, when measured, shows a linear relationship. However, the PaO_2 is a poor transporter of O_2. For O_2 to be delivered to cells via circulation, it needs to be bound to haemoglobin and then circulated to the tissues; therefore, a normal SaO_2 is required (Haffen et al., 2022). The relationship between the PaO_2 and SaO_2 is not linear but reflects an S-shaped curve called the oxyhaemoglobin dissociation curve, which describes the PaO_2 and SaO_2 relationship (Figure 3).

Figure 3

Oxyhaemoglobin Dissociation Curve: SpO_2 vs PO_2 (Unknown Author Licensed by CC BY)



Note. This figure demonstrates the curve plots the proportion (%) of haemoglobin in its saturated (oxygen-laden) form on the vertical axis against the prevailing oxygen tension on the horizontal axis (PO_2). This curve aids in understanding how blood carries and releases oxygen. Specifically, this curve relates oxygen saturation (SaO_2) and partial pressure of oxygen in the blood (PaO_2) and is determined by what is called "haemoglobin affinity for oxygen"; that is, how readily haemoglobin acquires and releases O_2 into the surrounding blood.

Many factors can impact this relationship, including pH, temperature, and amount of 2,3-diphosphoglycerate (2,3-DPG), causing the curve to shift to the left or right. A right shift in the curve means the haemoglobin has a decreased affinity for O_2, and O_2 unloads; a shift to the left indicates the reverse, an increased reluctance to release O_2, which impacts cellular respiration (Patel et al., 2024).

2.2.4 Ventilation

Ventilation is the movement of gas in and out of the upper and lower respiratory tracts (Patwa & Shah, 2015). The following section explains the four elements that influence the mechanics of ventilation: air pressure variance, lung volumes, airway resistance, and compliance.

2.2.4.1 Air Pressure Variance.

The air pressure variance between the atmosphere and the intrapleural cavity creates a pressure gradient. Respiratory gases naturally exchange from high-pressure to low-pressure areas; O_2 and CO_2 follow these pressure gradients. Inspiration is an active process, and expiration is usually passive. The diaphragm is the largest inspiratory muscle. This thin (± 2.0 mm) disc-like sheet of muscle divides the thorax and abdomen (Troyer & Wilson, 2016). As the diaphragm contracts, the ribs and sternum supported by the scalene and intercostal muscles elevate, creating a negative pressure in the lung responsible for inhalation. As the lungs naturally tend to recoil, the intercostal muscles maintain the architecture of the chest wall and lung volumes during these pleural pressure changes to enable inhalation without collapsing (Edwards & Annamaraju, 2024).

2.2.4.2 Lung Volumes.

Lung volumes and capacities are surrogate ventilatory mechanics measures used in clinical practice and research (Table 2) (Delgado & Bajaj, 2024). Following a normal VT, gas volume at the end of expiration persists, known as the FRC. The FRC volume is usually about three litres and is a reserve gas supply. (Hopkins & Sharma, 2024). The FRC is physiologically significant because it prevents the complete emptying of the lungs during each respiratory cycle while maintaining the patency of the small airways. The FRC acts as a safeguard, reducing significant alveolar PO_2 and PCO_2 fluctuations during respiration and compromising respiratory gas diffusion (Selvi et al., 2013). Lung volumes are influenced by airway resistance and compliance, which improves VQ matching and the VQ ratio (Patwa & Shah, 2015). These lung volumes are described in Table 2.

Table 2

A Description of Lung Volumes and Their Response to Stress (Delgado & Bajaj, 2024)

Volume Measure	Description	Mean Volume Litres	Response to Stress
Tidal Volume [a]	Volume of air breathed in or out each breath	0.5	Volume increases
Inspiratory Reserve Volume [b]	Volume of air that can be forcibly inspired after a normal breath	3.1	Volume decreases
Expiratory Reserve Volume [c]	Volume of air that can be forcibly expired after a normal breath	1.2	Volume decreases
Functional Residual Capacity [d]	Volume of gas remaining in lungs after maximum expiration	1.2	No change
Vital Capacity [e]	Volume of air that can be forcibly inspired in one breath	4.8	No change
Minute Ventilation [f]	Volume breathed in or out per minute	6	Volume increases
Total Lung Capacity [g]	Vital capacity + FRC	6	Volume decreases

Note. [a] Tidal Volume = VT; [b] Inspiratory Reserve Volume = IRV; [c] Expiratory Reserve Volume = ERV; [d] Functional Residual Capacity = FRC; [e] Vital Capacity = VC; [f] Minute Ventilation = MV; [g] Total Lung Capacity = TLC

2.2.4.3 Airway Resistance.

Airway resistance is the relationship between pressure and flow, determined by the conducting airways' diameter and airflow rate (Campbell & Sapra, 2023). The upper conducting zone demonstrates the most significant airway resistance to gas flow (nose, trachea, and main bronchi). Typically, airway resistance is about 1cm H_2O/L/sec (Hallett et al., 2024). However, lung conditions, such as asthma, constrict the bronchioles, increasing airway resistance. Conditions that result in increased secretions in the airway, such as pneumonia or cystic fibrosis, also increase airway resistance. Any increase in airway resistance increases the muscular effort required to breathe, referred to as the work of breathing (Cabello & Mancebo, 2006). The work of breathing optimises the respiratory rate and VT, but this work of breathing must be sustainable. Increases in chest wall recoil and airway resistance all increase the work of breathing.

2.2.4.4 Compliance.

The respiratory muscles must work to overcome lung and chest wall compliance and airway resistance. Lung compliance reflects the expansion of the lung, whereas chest wall compliance reflects the expansion of the chest wall. The lung and chest wall compliance, known as thoracic compliance, maintains normal lung volumes (Edwards & Annamaraju, 2024). The compliance or expandability of the lung reflects the change in lung volume brought about by a unit change in transpulmonary (intrapleural) pressure. The normal compliance ranges from 0.1 to 0.4 L/cm H_2O. Low compliance suggests high elastic recoil; in contrast, high compliance suggests low elastic recoil. The net result of inspiratory muscle contraction generates negative intrapleural pressures (-10 cm H_2O). These negative pressures prompt air to move through the upper respiratory tract into the thorax to restore pressure equilibrium. Expiration relies on the elastic recoil of the subcostal and intercostal thoracic muscles and generates a negative intrapleural pressure (-5 cm H_2O) (Hallett et al., 2024).

Usually, the sophisticated respiratory system functions well; however, if the system fails, O_2 deprivation will likely follow. Oxygen deprivation may manifest as hypoxaemia (reduced PaO_2), hypoxia (inadequate tissue O_2), or ischaemia (decreased blood perfusion to tissues) (Bhutta et al., 2024). Failure of the respiratory system results in hypoxaemia (Type I respiratory failure) and/or hypercarbia (a $PaCO_2$ above normal, referred to as Type II respiratory failure). Patients demonstrating respiratory failure will likely then require RS.

2.3 Respiratory Support Therapies

Respiratory support is an umbrella term for any intervention or therapy that supports the respiratory status of those with or at risk of respiratory failure. Respiratory support can improve oxygenation and reduce the work of breathing (Sztrymf et al., 2011). Respiratory support can augment respiratory mechanisms that enable gaseous exchange.

Respiratory support is achieved with one or a combination of respiratory therapies. The varying types of respiratory therapies and the advantages and disadvantages of each type are outlined in Table 3. These therapies can be delivered either noninvasively or invasively. The selection of RS therapy should reflect patient acuity and type of respiratory failure, aiming to reduce patient morbidity and mortality where possible. Each RS therapy has inherent advantages and disadvantages. These aspects influence patient tolerance and compliance and burden the healthcare system, with some RS being technically more challenging to manage. Cost-benefit considerations for RS therapies are multidimensional; some forms of RS appear materially substantially more costly than others, but their use may mean a reduction in an escalation of care (Frat et al., 2015). The following sections now describe both low- and high-flow respiratory support therapies.

Table 3

Possible Advantages and Disadvantages of Respiratory Support Therapies Compared (Hardavella et al., 2019; Popowicz & Leonard, 2022)

[a]RS therapy	[b]Flow L/min	[c]FiO_2%	Indications	Possible Advantages	Possible Disadvantages
Nasal Cannula	1-6	24 – 40 Varies with entrainment	Spontaneous breathing Domiciliary O_2	Low cost Easy to use Mouth not obstructed	Gas not heated & humidified, Unknown FiO_2, Limited effect on [d]WOB, No dead space washout
Face Mask	5-10	35 – 60 Varies with entrainment	Spontaneous breathing Nebulisation	Low cost Easy to use	Gas not heated & humidified, Unknown FiO_2, Claustrophobic Limited therapy, Mouth obstructed, Limited effect on WOB, No dead space washout
Venturi Mask	2-15	24 – 50 Varies with entrainment	Spontaneous breathing	Low cost Easy to use	Gas not heated & humidified, Variable FiO_2, Claustrophobic, Mouth obstructed, Limited reduction in WOB, No dead space washout
Nonrebreather Mask	10-15	24 – 50 Varies with entrainment	Spontaneous breathing	Low cost Easy to use	Gas not heated & humidified, Variable FiO_2, Claustrophobic, Mouth obstructed, Limited effect on WOB, No dead space washout
Nasal High Flow	10-70	21 – 100	Spontaneous breathing Respiratory failure	Fixed FiO_2Open system Gas heated & humidified, improves mucous clearance, mouth not obstructed, may meet inspiratory flow demand, provides [e]PEEP, Flushes dead space, Can reduce WOB	Complex, Noise, Possible High cost
Non-Invasive Ventilation	5-7 mL/kg	21- 100	Spontaneous breathing Respiratory failure	Fixed FiO_2 Closed system, gas conditioned, meets inspiratory flow demand, provides PEEP, may improve mucous clearance, can reduce WOB	Known AE, High cost, Complex, Uncomfortable, Increases dead space
Invasive Ventilation Intubation	5-7 mL/kg	21 – 100	Not spontaneous breathing Oral or tracheal intubation	Fixed FiO_2 Closed system, gas conditioned, meets inspiratory flow demand, provides PEEP, may improve mucous clearance, can reduce WOB	Known AE, High cost, Complex, Uncomfortable, Increases dead space

Note. [a] Respiratory Support= RS; [b] Flow of gas litres per minute=Flow L/min;[c] Fraction of Inspired Oxygen Percentage= FiO2 ;[d] Work of Breathing= WOB;[e] Positive End Expiratory Pressure= PEEP; [f] Adverse Event= AE; [g] Inspiratory Positive Airway Pressure= IPAP; [h] EPAP= Expiratory Positive Airway Pressure.

2.3.1 Low Gas Flow Respiratory Support

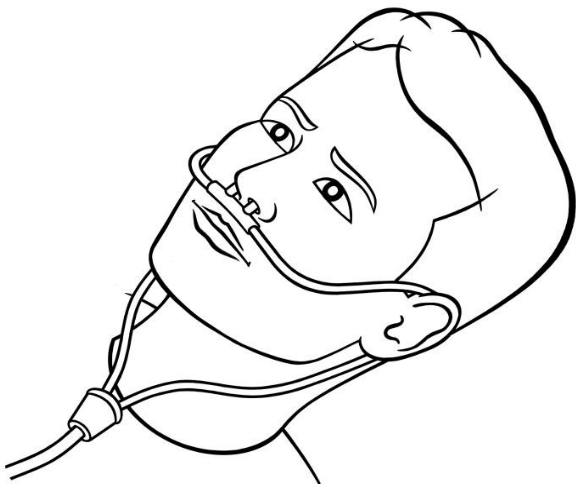
Low gas flow RS includes nasal cannulas (NC), face masks (FM), and non-rebreathing masks (NRM). These low-flow interfaces are known collectively as conventional oxygen therapy (COT) or standard oxygen therapy (SOT). Typically, the O_2 provided is not heated and humidified; it is dry and cool. These interfaces are ubiquitous, relatively inexpensive, and easy to use.

2.3.1.1 Nasal Cannula.

The NC consists of simple tubing normally looped behind the ears. The NC delivers gas up to 6 L/min (Popowicz & Leonard, 2022). Cannula use is common and allows O_2 delivery while maintaining the ability to use the mouth (Figure 4) (Hardavella et al., 2019). However, patient nasal drying and discomfort are commonly reported (O'Driscoll et al., 2008).

Figure 4

Nasal Cannula



Note. This figure depicts the simple nasal cannula (NC). The NC consists of simple tubing normally looped behind the ears. The NC delivers gas up to 6 L/min. O'Donnell, B. (2024). Nasal Cannula. [Electronic Image]. Wellington

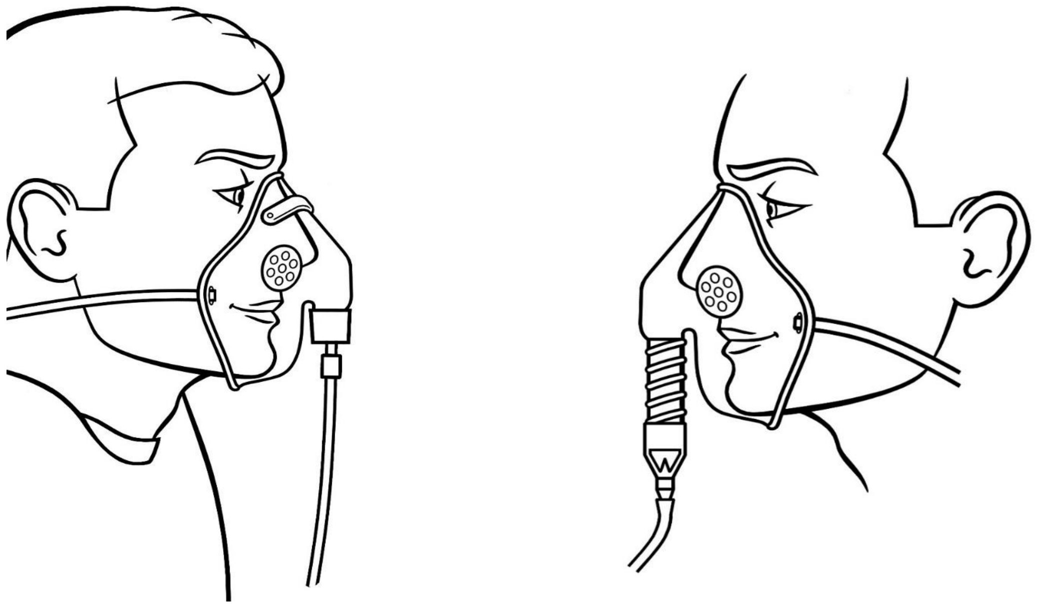
2.3.1.2 Face Masks.

Face masks are classified as simple, air-entrainment, or non-rebreather masks. A simple FM is sometimes called conventional O_2 therapy (COT) or standard oxygen therapy (SOT). The FM interface has no reservoir bag attached. This simple interface can deliver gas up to 15 L/min (Figure 5A) (Hardavella et al., 2019). An air entrainment or venturi mask (VM) uses jet mixing to increase the FiO_2 with flow rates up to 15 L/min (Figure 5B). Different-sized ports change the FiO_2. Theoretically, if the patient's inspired flow rate is lower than the flow rate delivered by the VM, this will impact the maximum FiO_2 potentially provided. However, this will be affected by the patient's work of breathing.

Figure 5

Face Masks: Simple A) and Venturi B)

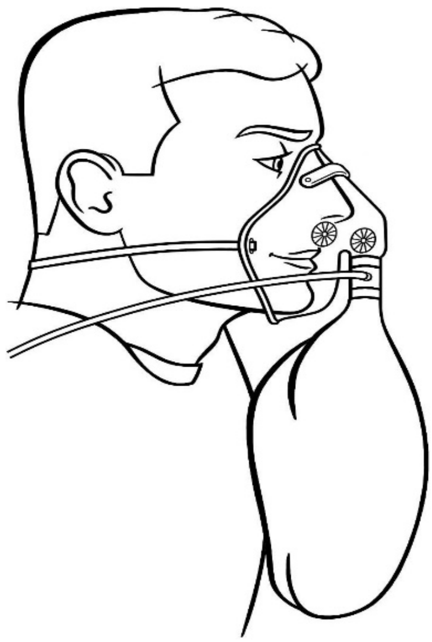
A) Face Mask *B) Venturi Face Mask*



Note. These figures depict two face masks. A) A simple FM is sometimes called COT or SOT. The FM interface has no reservoir bag attached. This simple interface can deliver gas up to 15L/min. B) An air entrainment or VM uses jet mixing to increase the FiO_2 to 15L/min. Different-sized ports change the FiO_2 (Hardavella et al., 2019). O'Donnell, B. (2024). Face Masks. [Electronic Image]. Wellington

Figure 6

Nonrebreather Mask



Note. This figure depicts the non-rebreather mask (NRM), which has a reservoir bag attached to a non-vented FM. The reservoir bag's O_2 capacity is usually 100mL. The NRM allows the potential delivery of a higher FiO_2 at up to 15L/min (Hardavella et al., 2019). O'Donnell, B. (2024). Nonrebreather Mask. [Electronic Image]. Wellington.

2.3.2 High Gas Flow Respiratory Support

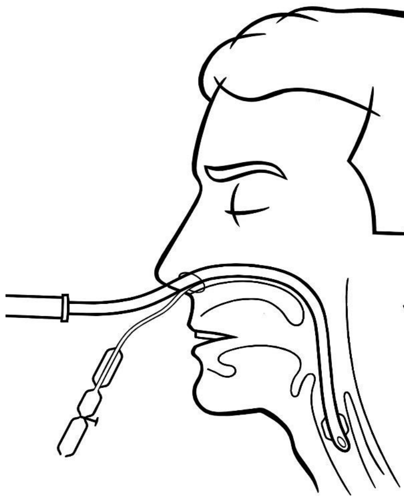
High-gas flow RS includes invasive ventilation (INV), non-invasive ventilation (NIV), and NHF. These therapies deliver high gas flows that meet or exceed the inspiratory demands of patients with high inspiratory flow needs, thereby ensuring a more accurate FiO_2. Usually, inspired air is heated and humidified. These interfaces are becoming more common; they are relatively expensive and require expertise to deliver (Hardavella et al., 2019; Popowicz & Leonard, 2022).

2.3.2.1 Invasive Ventilation.

Respiratory support with INV requires intubation by bypassing the upper airway and delivering RS via a mechanical ventilator (MV). A tube is inserted directly into the trachea or via the nasal or oral cavity (Figure 7). Invasive ventilation requires a ventilator to provide titrated positive pressure RS. Ventilators are sophisticated and allow RS titration. The titration options include respiratory rate, VT, trigger sensitivity (for spontaneous breathing response), gas flow rate, pressure waveform inspiratory/expiratory ratio, FiO_2, and positive end-expiratory pressure (PEEP) (Potchileev et al., 2024).

Figure 7

Invasive Ventilation with an Oral Endotracheal Tube



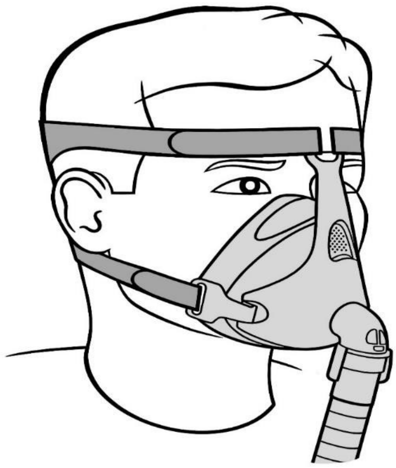
Note. This figure depicts invasive (INV) RS. An INV tube is inserted directly into the trachea or via the nasal or oral cavities. Invasive ventilation requires a ventilator to provide titrated positive pressure RS. O'Donnell, B. (2024). Invasive Ventilation with an Oral Endotracheal Tube. [Electronic Image]. Wellington.

2.3.2.2 Non-invasive Ventilation.

Non-invasive ventilation RS provides pressurised gas flows to spontaneously breathing patients. The options for RS pressure include continuous positive airway pressure (CPAP), where the pressure delivered is constant, or bi-level positive airway pressure (BiPAP). The term BiPAP is sometimes used in practice to mean NIV. During BiPAP, there are two pressure settings: inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP). These enable a selected amount of gas to remain in the alveoli at the end of expiration, thereby increasing FRC. The NIV interfaces are positioned on the face or nose, including helmets, total FM, and nasal masks (Figure 8). Non-invasive RS requires a reliable interface seal. Non-invasive ventilation is challenging for patients and involves clinician expertise to deliver (Popowicz & Leonard, 2022) safely.

Figure 8

Non-invasive Ventilation Mask



Note. This figure depicts an example of a non-invasive (NIV) interface positioned on the face or nose, including helmets, total FM, and nasal masks. O'Donnell, B. (2024). Non-invasive Ventilation Mask. [Electronic Image]. Wellington.

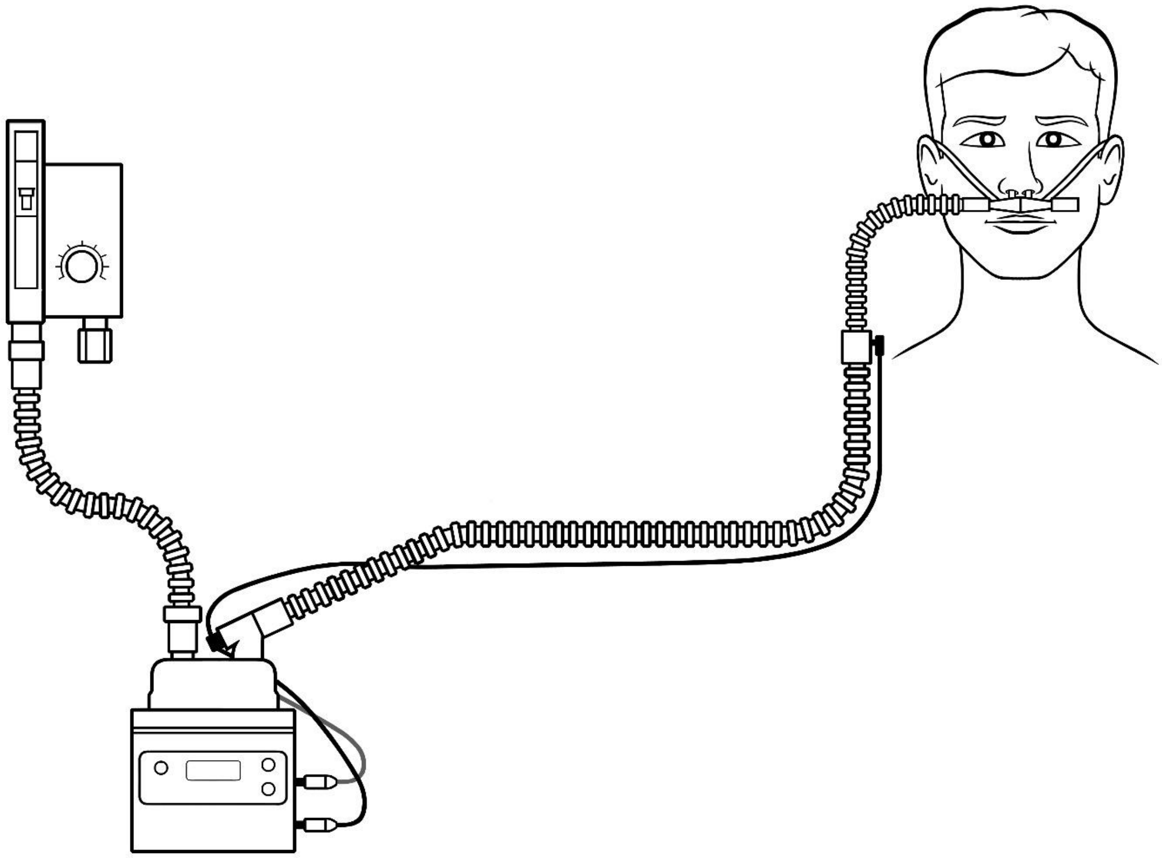
2.3.2.3 Nasal High Flow.

Nasal high flow is the most novel RS therapy. Today, there are many NHF brands available. However, all NHF devices, regardless of brand, have five components: a gas mixer, a flow meter, a humidifier, a heated breathing circuit, and a specialised nasal cannula (Figure 9).

Most NHF therapies deliver up to 70L/min of heated and humidified blended air and O2 (Basile et al., 2020). A flow source generates the flow of gas ready for inspiration. A specialised humidifier within the flow source heats and humidifies this same gas and delivers it via a tube from the humidifier to an unsealed specialised nasal cannula. The tube providing the gas to the cannula is warmed to reduce condensation accumulation and prevent airways from drying (Mauri et al., 2017a). The heating and humidification of inhaled gases are designed to enhance mucociliary clearance and comfort. The NHF gas flow, FiO_2, and temperature may all be independently adjusted (Nishimura, 2016). Oxygen can be added upstream of the humidifier to increase the supplemental FiO_2 (D'Cruz et al., 2020).

Figure 9

Nasal High Flow System Setup



Note. This figure depicts a nasal high-flow system, including a gas blender, a humidifier, gas tubing and a nasal cannula. O'Donnell, B. (2024). Nasal High Flow System Setup. [Electronic Image]. Wellington.

Compared to other forms of RS used in clinical practice today, NHF is a relative newcomer. In the early 2000s, NHF was first successfully used to provide non-invasive RS to neonates with apnoea and then to paediatric patients with respiratory failure secondary to bronchiolitis (Sreenan et al., 2001). Prompted by these early NHF successes, ICU clinicians and researchers in Aotearoa, NZ, began using NHF on adults (Williams et al., 2006).

Research soon demonstrated that NHF could be an alternative to NIV for selected respiratory failure patients in the ICU (Spoletini & Hill, 2016). Nasal high-flow researchers have evaluated its mechanisms and benefits of action and clinical outcomes in various populations and conditions (O'Donnell, 2019). Researchers have proposed NHF efficacy for acute respiratory failure (Rochwerg et al., 2019), preoxygenation (Ricard et al., 2019), apnoeic oxygenation for intubation (Ricard et al., 2019), preventing reintubation (Hernandez et al., 2016), chronic obstructive respiratory disease (Pisani & Vega, 2017), for palliative care (Ruangsomboon et al., 2020), and postoperative recovery (Futier et al., 2016) all of which present in the ED. Consequently, NHF use and research have rapidly expanded across all settings, from the home to the operating theatre, ambulances, and ED (Spicuzza & Schisano, 2020). While the heterogeneous ED patient population frequently requires RS (Kelly et al., 2017), evidence to support NHF use in the ED has been slow to emerge.

In 2012, the first controlled ED study comparing NHF to conventional oxygen therapy (COT) demonstrated reductions in dyspnoea and respiratory rate ($p \leq 0.001$) with NHF (Lenglet et al., 2012). Two subsequent controlled studies confirmed Lenglets' findings (Bell et al., 2015; Makdee et al., 2017). These three early studies alluded to the efficacy and feasibility of NHF for dyspnoeic ED patients. However, these results may have limited broad applicability in the heterogeneous ED patient population (Marjanovic et al., 2020). In a patient cohort with severe acute respiratory failure (ratio of partial pressure of oxygen in arterial blood to the $FiO_2 \leq 200$ ($PaO2/FiO_2$)), NHF was associated with a reduction in the need for invasive ventilation (INV) and admission to the ICU, $p \leq 0.01$ (Frat et al., 2015). Despite being an ICU-focused study, these findings are continuously cited in the ED literature and demonstrates the need for the ED to rely on non-ED evidence.

2.4 Chapter Two Conclusion

This second chapter has referred to the disciplines of anatomy and physiology as relevant to RS, particularly RS with NHF. The purpose of this second Chapter, *Anatomy and Physiology and Respiratory Support,* was to provide the scientific background and context for the thesis in two parts. Here, an overview of respiratory anatomy and physiology has provided a foundation for the in-depth comparison of the possible advantages and disadvantages of contemporary RS therapies, including COT, NHF, NIV, and INV. This chapter concludes with a summary which describes the emergence of NHF in practice and research; these aspects will be considered more fully in the subsequent chapter.

The third and subsequent Chapter, *Literature Review*, provides a narrative summary of the available relevant evidence for RS with NHF for adults in the ED. This review exposes the gaps and shortcomings in the ED NHF evidence, thus confirming the significance of this doctoral research and, more broadly, for EBP in the ED.

Chapter Three

Literature Review

The previous Chapter, *Anatomy and Physiology and Respiratory Support,* provided the scientific background and context for RS for this thesis in two parts, with part one addressing respiratory anatomy and physiology and part two RS therapies.

The purpose of this third chapter, *Literature Review*, is to present a narrative literature review of the current NHF evidence relevant to adults in the ED. The rationale and purpose of this narrative literature review is to provide a conceptual frame for the thesis and to define the scope of this doctoral research. Here, the objectives are to confirm, firstly, the novelty of the study, secondly, the aggregated avenues of inquiry, and finally, an indirect justification for the objectivist epistemological approach (Pare et al., 2017) thereby endorsing the scholarship of this doctoral research by indirectly validating its positivist perspective, its EBP theoretical foundation, and its multi-method design (Randolph, 2019).

This narrative summary in this literature review has employed systematic and transparent processes to locate, assess, and characterise evidence. The chapter begins by describing the methods used to conduct the literature review. The review findings have been organised according to the three emergent themes in the evidence: mechanisms and benefits of action, physiological outcomes, and clinical and safety outcomes.

This chapter incorporates the first of the publications that have emerged from this doctoral research; this publication aligns with the third theme, clinical and safety outcomes. The publication describes a validated scoring system for predicting NHF clinical and safety outcomes (O'Donnell et al., 2021a). Chapter three concludes by describing the ED context and considering the implications of the review findings for EBP and research in the ED.

This third chapter has nine sections; one section is a published commentary (O'Donnell et al., 2021a):

- Respiratory Support with Nasal High Flow in the Emergency Department: A Review of the Literature
- Nasal High Flow Mechanisms and Benefits of Action
- Nasal High Flow Physiological Effects
- Nasal High Flow Clinical and Safety Outcomes Across All Settings
- Publication: Use of an index to predict NHF outcomes (O'Donnell et al., 2021a)
- The Emergency Department Described
- Nasal High Flow Clinical and Safety Outcomes in the Emergency Department
- Implications for Evidence-Based Practice and Research for Nasal High-Flow in the Emergency Department
- Chapter Three Conclusion.

3.1 Respiratory Support with Nasal High Flow in the Emergency Department: A Review of the Literature

This narrative literature review provides a comprehensive summary of the evidence reporting on RS with NHF and as deemed relevant to adults in the ED. The methods used to complete this review reflect the systems approach described by Bandara and colleagues (2011). Therefore, the literature review of NHF has employed methodical and transparent processes to search for evidence and then assess and characterise the results of the search.

3.1.1 Searching for Nasal High Flow Evidence

A structured search for evidence was developed and executed (Pare et al., 2015). The search involved a staged process involving three databases and one web search engine. The databases searched were PubMed, Embase, Cochrane Central, and the web search engine Google Scholar. The searches were executed within each database, and the process was finalised in January 2024. A search scientist at The Johns Hopkins University confirmed the search strategies' validity. Search strategies for three databases reflected the keywords and inclusion and exclusion criteria outlined in Table 4. The inclusion and exclusion criteria informed decisions regarding the relevancy of the evidence to the ED, where practice and research rely upon and refer to a conglomeration of specialities. Therefore, a pragmatic search approach was employed, and evidence was included if deemed relevant to the ED using the criteria:

1) research completed in the ED involving ED participants and outcomes; and

2) research completed elsewhere but involving participants or outcomes that apply to the ED, with some ICU research being a typical example.

Additionally, the terminology describing NHF is inconsistent, with more than 20 terms and more than ten abbreviations, complicating the search process (Heikkilä & Korppi, 2019). The final limitations to the search were to include studies from peer-reviewed journals written in English, reporting on adults, and published after 1980, when NHF was introduced into practice.

Table 4

Literature Review: Criteria for Inclusion and Exclusion of Studies and the Keywords Used to Search for Evidence

Inclusion Criteria	Exclusion Criteria
Nasal High Flow (NHF) [a]	Non-peer-reviewed literature
and combinations of 'nasal,' 'high,' 'heated,' 'humidified,' and/or 'oxygen.'	Non-English
	Non-adult <16 years
Optiflow™	Opinion Pieces
High-velocity nasal insulation (HVNI ™)	Editorials
Transnasal insufflation (TNI)	Letters
Date limited to post-1980 [b]	Case reports
All human study methods	
Airvo™	
All settings that are ED-relevant [c]	
All populations that are ED-relevant	
All patient conditions that are ED-relevant	
Keywords	
"nasal high flow respiratory", "nasal high flow system", nasal high flow cannula", "nasal high flow device", "nasal high flow hf", "nasal high flow humidification"[All Fields] OR "nasal high flow humidification and oxygen", "nasal high flow humidification oxygen", "nasal high flow oxygen", "nasal high flow respiratory", "nasal high flow system"	

Note. [a] Nasal high flow is regarded as delivering humidified medical gas via the nasal route, >20 L/ minute. [b] NHF was not available in practice or research before 1980.[c] ED relevant is specifically or generally applicable to the ED.

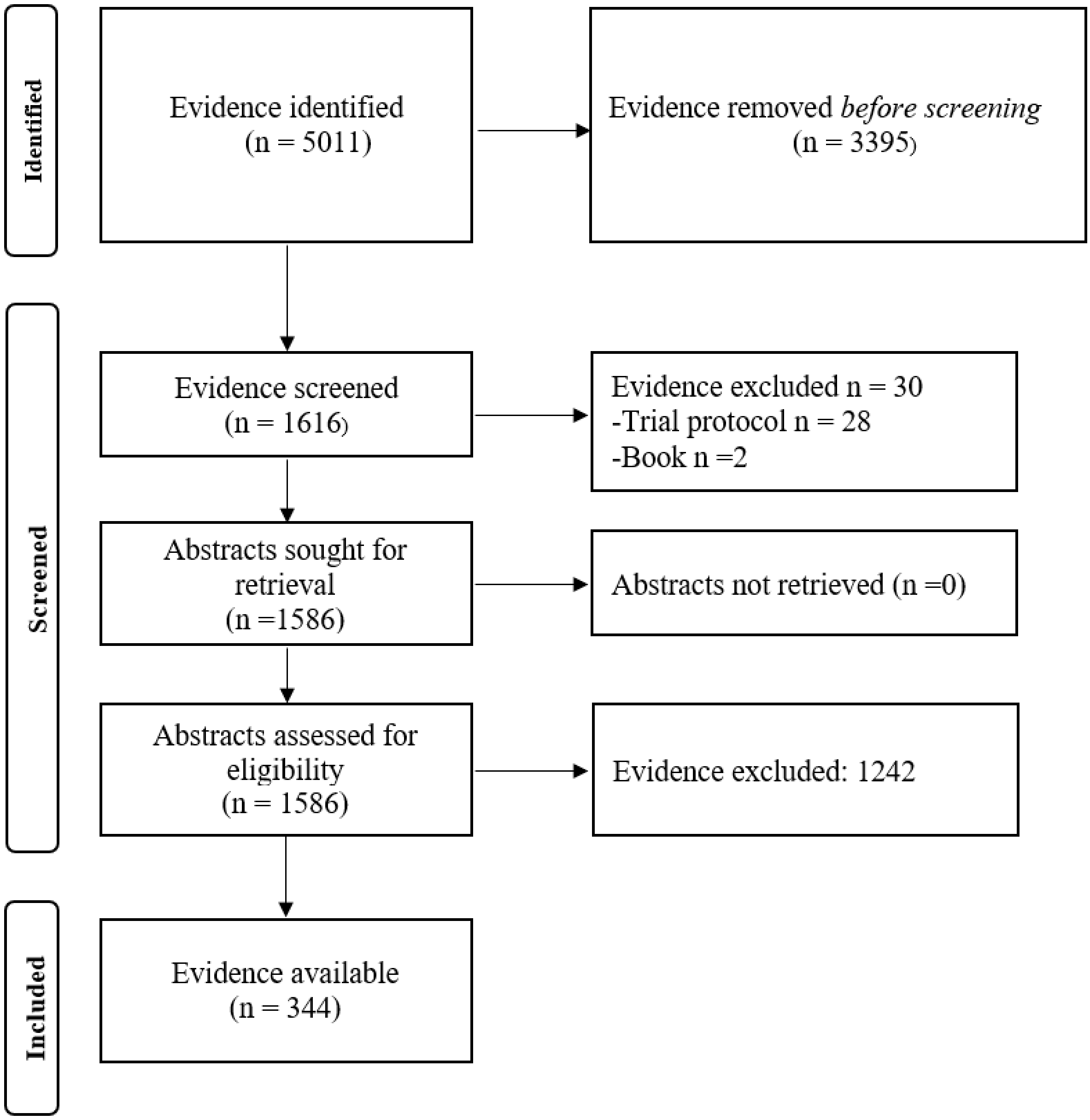
3.1.2 Results of the Search for Nasal High Flow Evidence

The search identified 5011 pieces of evidence; these 5011 were screened for inclusion. The search outputs were exported from the sources into Endnote© Version 21. All duplicates were removed, with the remaining titles and abstracts then screened again for relevance based on the criteria for inclusion and exclusion (Table 4).

Three hundred and forty-four pieces of NHF-ED relevant evidence qualified for inclusion. Of these 344, there were 259 clinical trials, including 223 randomised controlled trials (RCTs) and 17 trial protocols, 81 reviews, some with meta-analysis (MA), and five clinical guidelines (Figure 10). The quality of the included studies varied considerably; this variation is reflected in the synthesis of evidence in this literature review. However, none of the evidence was excluded based on quality alone. Data were extracted from the included evidence, tabulated for narrative synthesis, and presented according to the emergent themes identified.

Figure 10

The Process of Identifying Studies for Inclusion in the Literature Review from Study Databases and Registers (Adapted from Page et al., 2020)



Note. This figure depicts the process used for the identification of included studies

Three NHF themes emerged from within the evidence: mechanisms and benefits of action, physiological effects, and clinical and safety outcomes; the literature will now be summarised and presented accordingly.

3.2 Nasal High Flow Mechanisms and Benefits of Action

Five mechanisms and benefits supporting the efficacy of NHF are consistently reported: dead space clearance, generation of positive pressure, heating and humidification of gases, accurate FiO_2, and comfort. A combination of bench, animal, and human studies describe these mechanisms. The first of many narrative reviews describing these NHF mechanisms and benefits was published in 2016 (Dysart, 2016).

3.2.1 Dead Space Clearance

Each VT has a dead space volume not involved in gas exchange. Dead space refers to anatomic and alveolar dead space within the conducting airways. However, it is anatomical dead space for which NHF is relevant. This anatomic dead space fills with air on inspiration; this same redundant air is exhaled on exhalation. About 30% of a normal VT of 500 ml is therefore not involved in gas exchange (Murias et al., 2014).

Quantifying dead space informs clinical decisions, for example, around the titration of RS therapies. Ironically, NIV face masks and INV tubes add an apparatus dead space (Murias et al., 2014). The dead space, known as apparatus dead space, will increase dead space volume, which can then increase $PaCO_2$, which may require management through minute ventilation adjustments (Hinkson et al., 2006).

Restoring dead space equilibrium requires a multi-pronged approach. When the respiratory system is impaired, gas exchange is disrupted; the PaO_2 reduces, initially causing a low $PaCO_2$, which increases the PAO_2. A high PaCO2 level only occurs when the patient cannot compensate further and then tires. High NHF gas flows are designed to exceed patient peak inspiratory flow demand. These flows flush accumulated CO_2 from the dead space and reduce rebreathing volumes. The flushed CO_2 is replaced with O_2; this increases PAO_2, PaO_2, and SaO_2 (Pinkham et al., 2022; Mauri et al., 2019a).

Quantifying respiratory gases in the airways and their clearance is challenging in vivo (Möller et al., 2015). This mechanism has been confirmed in benchtop study findings suggesting that flushing of expired CO_2 in airway models depends on airflow (Moore et al., 2019; Möller et al., 2015; Onodera et al., 2017). When investigating the value of NHF oxygen therapy, a lung-injured animal study reported decreasing $PaCO_2$ with increasing NHF flow rates ($r^2 = 0.92$, $p < 0.01$ (Frizzola et al., 2011).

Human NHF studies of CO_2 clearance have employed a variety of approaches, including oesophageal catheters and scintigraphy with krypton gas. These human studies report significant decreases in CO_2 rebreathing in healthy participants (Delorme et al., 2020; Möller et al., 2017; Pinkham et al., 2019; Pinkham et al., 2022) and those with a tracheostomy (Möller et al., 2017). For those with chronic obstructive pulmonary disease, NHF at 20 and 30 L/min was seen to reduce $PaCO_2$ and work of breathing (Bräunlich et al., 2016). The reported time and flow-dependent clearance of CO_2 may increase alveolar O_2, confirming the significance of this mechanism (Mauri et al., 2019a).

3.2.2. Generation of Positive Pressure

Ventilation relies on the pressure differential between the lungs and the ambient atmosphere. Extrinsic PEEP is usually provided with NIV and INV RS. Extrinsic PEEP increases FRC, thereby optimising the movement of O_2 across the alveolocapillary membrane and increasing PaO_2. In INV and NIV RS, PEEP has been known to cause pressure-related adverse events, including barotrauma and gastric distension. However, NHF is an open system, and these events are prevented. During inspiration, nasal high flow delivers a flow-dependent pressure within the patient's nasopharynx (Parke et al., 2013a). Varying NHF pressures result in a dynamic process as increases in intra-breath pressure fluctuate between peak expiratory and minimum inspiratory pressure. Cannula size relative to the nares, gas flow rates, and whether the patient's mouth is open influence the pressure generated. One of the first controlled studies reported an NHF pressure effect in ten healthy volunteers. Significant expiratory pressures were demonstrated at 20, 40, and 60 L/min compared to no flow ($p < 0.001$). These effects increased when participants' mouths were closed compared to open ($p < 0.001$) (Groves & Tobin, 2007).

Human nasopharynx pressure studies have described a modest 1 cm H_2O pressure for every 10 litres of NHF gas flow (mean nasopharyngeal airway pressures were 1.5 ± 0.6, 2.2 ± 0.8, and 3.1 ± 1.2 at 30, 40, and 50 L/min using NHF (Parke et al., 2013b). In a study of NHF with flows ranging from 30 to 100 L/min, the mean airway pressures were 2.7 ± 0.7 to 11.9 ± 2.7 cm H_2O (Parke et al., 2015). This study used flows greater than the standard in current clinical practice, which are limited to 70 L/min (Basile et al., 2020). This pressure effect reduces airway resistance, thus reducing resistance to incoming gas flows (Mündel et al., 2013). The pressure effect within the alveoli increases the FRC, thereby improving VQ matching and reducing the risk of atelectasis during exhalation.

Surrogate measures of the NHF effect seen within the alveoli have relied on electrical impedance technology (EIT). Using EIT, cumulative statistically significant increases in end-expiratory lung volumes (EELV) are reported, indicating positive alveolar pressure at end-expiration (Corley et al., 2011; Parke et al., 2015; Riera et al., 2013). Corley (2011) reported a strong correlation between airway pressure and increases in EELV ($r = 0.7$). In a later study of healthy participants, the improved global EELV with NHF was statistically significant ($p < 0.001$) (Plotnikow et al., 2018). Increases in EELV are correlated with increases in NHF flow rates (Mauri et al., 2017a). For every litre of increased NHF flow, a 0.7% increase in EELV is seen (Corley et al., 2011).

3.2.3. Heating and Humidifying Delivered Gases

Medical gases must be liquefied or compressed for storage. Stored gases are cold and dry. Studies of piped medical gases report mean temperatures at least 15°C less than average body temperature. The mean relative humidity of piped O_2 is 2.1% (Dawson et al., 2014). Unlike COT and often NIV, RS with NHF is heated and humidified (Esquinas Rodriguez et al., 2012) via the NHF humidifier and heated inspiratory circuit, delivering heated and humidified inspiratory gases.

Airway humidification depends on gas flow rate, patient breathing patterns, and the device used to deliver RS. Recently, NHF devices have delivered flows up to 70 L/min, although this has not yet been reliably reflected in the published literature (Basile et al., 2020). At NHF flows of 20–60 L/min, a 100% relative humidity can be achieved when the inspiratory gases are heated to 37 °C (Chikata et al., 2014). Inhaling inadequately humidified gas dries the upper airway, increases airway resistance, and causes discomfort (Salah et al., 1988). As the airway dries, its mucosa dries, the mucus thickens, and the ciliary function slows; the net result is mucociliary escalator failure, which causes retained airway secretions and increased airway resistance.

The conditioning of NHF gas on mucociliary clearance has been studied for those with bronchiectasis. Researchers have demonstrated that NHF gas heating and humidification helped improve the clearance of inhaled radio aerosol tracers, with the area under the tracheobronchial retention curve decreasing from 319 ± 50 to 271 ± 46% over six hours ($p < 0.07$) (Hasani et al., 2008). In contrast, the heating and humidification of these gases complement the mucociliary escalator, maintaining gas exchange and defence. Gas heating and humidification is standard practice for INV RS, where the upper airway and its mucociliary escalators are bypassed. The evidence describing this mechanism mainly relies on bench or non-human studies (Williams et al., 1996).

3.2.4 Regulation of the Fraction of Inspired Oxygen

Typically, RS involves O_2 supplementation to improve hypoxaemia. Hypoxaemia is a low PaO_2 and SaO_2. The SaO_2 reflects the percentage of oxygen-carrying (saturated) haemoglobin relative to haemoglobin not carrying O_2 (deoxygenated haemoglobin) (Hafen & Sharma, 2024); however, measurements require arterial blood gas sampling. The SpO_2 is easy to measure regularly, and in healthy humans, the target SpO_2 in high acuity areas, such as intensive care, is usually set at 92 to 98%. The SpO_2 target is usually 88 to 92% for those with chronic respiratory conditions. However, debates over the effects of supplementary O_2 persist (Hochberg et al., 2021). Respiratory support with COT has flow limitations and inconsistent FiO_2 (Wagstaff & Soni, 2007). With COT, every breath, inspiratory flow, and FiO_2 vary.

For those with respiratory failure, the inspiratory flow demand may exceed the O_2 delivered with conventional low-flow oxygen therapies, resulting in entrainment of room air. Entrainment of room air dilutes FiO_2. Nasal high flow can resolve COT flow limitations; for example, NHF systems can deliver at least 60 L/min of blended gases. An air and oxygen blender allows O_2 titration from 21% to 100%, independent of flow. However, NHF flow must meet or exceed the patient's inspiratory flow demand to avoid FiO_2 dilution by entrainment (Helviz & Einav, 2018). A bench study of NHF at 30 to 50 L/min reported consistency between the set FiO_2 and O_2 measured in the lower airways (Ritchie et al., 2011).

3.2.5 Comfort

As with any RS therapy, comfort relates to tolerance and efficacy. Comfort is a crucial NHF therapy benefit. As such, it is not an actual mechanism of action (He et al., 2023). Nasal high flow is often delivered to patients over prolonged periods, and their comfort is essential; without it, patient tolerance will likely wane, and escalation of care may be required. Logic would suggest that heating and humidifying NHF gas flows would guarantee comfort; however, findings conflict. A heterogeneous collection of interventions, assessment tools, and patient groups is reported in at least five RCTs (Bell et al., 2015; Lemiale et al., 2015; Mauri et al., 2018; Rittayamai et al., 2015; Vourc'h et al., 2020). Some have suggested the superiority of NHF over VM (mean comfort score 2.6 ± 2.2 vs 5.1 ± 3.3 at 24 hours, $p = 0.006$), whilst others do not (median [Mdn] discomfort score 3 [IQR = 1 to 5 vs 3, 0 to 5], $p = 0.88$) (Lemiale et al., 2015). For comparisons with NIV, NHF was superior for discomfort (NIV [28%] vs NHF [4%], $p = 0.001$) (Vourc'h et al., 2020); when compared to COT, some reports suggest NHF is inferior (1.6 ± 1.7 vs 3.7 ± 2.4, $p = 0.01$) (Rittayamai et al., 2015) and in a second study (mean 9.1 ± 1.3 vs 6.1 ± 1.6, Mdn = 3 (95% CI, 2 to 4, $p < 0.0001$) (Ruangsomboon et al., 2021).

Some authors report higher flow rates are less comfortable post-extubation, r^2 0.88; $p < 0.001$ (Butt et al., 2021), whilst others report the reverse, with NHF at 60 L/min having higher comfort scores in acute hypoxic respiratory failure ($p < 0.01$) (Mauri et al., 2018). A NHF network meta-analysis of five RCTs reported a non-statistically significant difference in comfort for low vs moderate gas flows (Mdn = 1.98, 95% CI, -3.98 to 0.01; very low-quality evidence) (He et al., 2023). Patient comfort is undoubtedly related to patient adherence; improved patient adherence with NHF has been reported at 31 °C vs 37 °C at two flow settings, 30 and 60 L/min ($p < 0.0001$) (Mauri et al., 2018).

There is apparent heterogeneity in the evidence supporting the five mechanisms and benefits of NHF action. Variations in the quality of execution, which have implications for clinical practice, can be observed in some NHF studies. While the research methods utilised differ, many retrospective observational methods are illustrated. Nevertheless, the current body of evidence regarding the mechanisms and benefits of NHF may offer a credible explanation for the physiological effects observed with the application of NHF therapy.

3.3 Nasal High Flow Physiological Effects

Many studies have reported the physiological effects seen with NHF. The published evidence consistently describes five categories of physiological effects (Table 5), which support the efficacy of NHF. Some additional effects remain under consideration, including improved matching of FiO_2 and alveolar PAO_2, mucociliary cell function, CO_2 production from the mucosal epithelium and inspiratory muscles, respiratory drive, and transpulmonary and alveolar pressure considerations. The pressure considerations may be relevant to patient-self-inflicted lung injury (P-SILI), a secondary effect arising from excessive inspiratory effort straining and damaging the lung (Carteaux et al., 2021). Targeted gas flows that meet or exceed the patient's inspiratory demands may avoid some P-SILI and requirements to escalate clinical care.

Table 5

Physiological Effects of Nasal High Flow Therapy, Their Relevant Mechanisms & Benefits with Supporting Evidence

Physiological Effect	Relevant Mechanism or Benefit	Evidence
Respiratory Rate	Dead space clearance	Pinkham et al., 2022
	Generation of positive pressure	Parke et al., 2015; Ritchie et al.., 2011; Delorme et al., 2020
	Heating and humidifying delivered gases	Pisani et al., 2017
	Accurate FiO_2[a] titration of delivered gas.	Ritchie et al.., 2011
Oxygenation	Dead space clearance	Pinkham et al., 2022
	Generation of positive pressure	Parke et al., 2015; Ritchie et al.., 2011; Delorme et al., 2020
	Heating and humidifying delivered gases	Pisani et al., 2017
	Accurate FiO_2 titration of delivered gases	Ritchie et al., 2011
CO_2[b] flushing	Dead space clearance	Jeong et al., 2015; Pisani et al., 2017
	Accurate FiO_2 titration of delivered gases	Möller et al., 2017; Ritchie et al.., 2011
PEEP[c] like effect	Generation of positive pressure	Natalini et al., 2019; Parke et al., 2013b
Reduces WOB[d]	Dead space clearance	Mauri et al., 2017a; Delorme et al., 2020
	Generation of positive pressure	Mauri et al., 2017a; Delorme et al., 2020; Di Mussi et al., 2018
	Accurate FiO_2 titration of delivered gases	Itagaki et al., 2014
	Comfort	Mauri et al., 2018

Note. Fraction of Inspired Oxygen = FiO_2 [a]; Carbon Dioxide=CO_2 [b]; Positive End-Expiratory Pressure =PEEP [c]; Work of Breathing = WOB

3.3.1 Effect on Respiratory Rate

Studies of NHF vs COT or NIV typically report respiratory rate per minute. The respiratory rate is an independent predictor of adverse outcomes and an essential element of most hospital risk prediction algorithms (Badawy et al., 2017). With rare exceptions, studies report statistically significant respiratory rate decreases when NHF is compared to COT. A reduced respiratory rate combined with an increased VT at a constant minute volume suggests a clinically meaningful improvement in breathing efficiency (Mündel et al., 2013; Riera et al., 2013). A study involving healthy volunteers demonstrated a median respiratory rate of 14 (IQR = 10 to 18) vs 9 (IQR = 7 to 10) ($p < 0.001$) when NHF was delivered at flow rates > 100 L/min; no impact on SpO_2 was observed (Parke et al., 2015). In a study of those with acute exacerbations of chronic respiratory disease, the respiratory rate seen was greater with COT vs NHF ($p < 0.001$) and NIV ($p = 0.003$). However, no difference was seen between NHF and NIV ($p = 0.626$) (Longhini et al., 2019).

3.3.2 Effect on Oxygenation

The process of oxygenation aims to supply cells with O_2. Usually, studies of NHF vs COT or NIV report oxygenation as PaO_2 or SpO_2. Some studies have reported no differences in oxygenation between NHF and COT PaO_2 (82.2 ± 24.9 vs 81.6 ± 21.7 mm Hg, $p = 0.89$) (Lee et al., 2018). In contrast, others have reported a difference between NHF and NIV mean PaO_2 (82.97 ± 9.04 vs 92.06 ± 11.11 mmHg, $p = 0.05$) (Jing et al., 2019). However, it should be noted that the COT FiO_2 was likely overestimated in many of these studies, and participant groups were heterogeneous.

3.3.3 Effect on Carbon Dioxide Flushing

A reservoir of O_2 is created in the dead space, reducing the CO_2 that is rebreathed and increasing alveolar oxygenation. Studies of NHF vs COT or NIV typically report CO_2 flushing using $PaCO_2$. A study of ED patients with dyspnoea reported a significant decrease in mean PaCO2 with NHF (54.7 ± 26.4 mmHg to 51.3 ± 25.8 mmHg; $p = 0.02$) (Jeong et al., 2015).

3.3.4 Effect on Positive End Expiratory Pressure

Usually, studies of NHF vs COT or NIV report a PEEP-like effect using surrogate measures such as EELV, as the PEEP effect manifests as changes in lung volume. Respiratory support with NHF has been associated with increased EELV, suggesting a PEEP-like effect, which can decrease respiratory rate and support more homogeneous alveolar ventilation across the lungs. This increase in EELV may not be affected by the position of healthy volunteers (Riera et al., 2013); however, it may be affected by gas flow rates. In a study of NHF vs COT in post-operative cardiothoracic patients, increasing the NHF gas rate increased EELV by 25.6% (95% CI, 24.3 to 26.9) while reducing the respiratory rate by 3.4 breaths per minute (95% CI, 1.7 to 5.2) (Corley et al., 2011).

3.3.5 Effect on Work of Breathing

An increased work of breathing is a compensatory mechanism seen in hypoxaemia. This mechanism increases metabolic rate and the production of CO_2. The clinical signs of abnormal work of breathing include nasal flaring, gasping, accessory muscle use, and thoracoabdominal asynchrony (TA) (Tulaimat & Trick, 2017). Studies of NHF vs COT or NIV commonly report the effect of work of breathing using these clinical signs and measures of respiratory drive, such as the surrogate measure of electrical activity of the diaphragm (EAdi).

In principle, improving these signs should reduce the work of breathing. High work of breathing can precede exhaustion and a need to escalate care. Those with chronic lung disease, such as chronic obstructive pulmonary disease, and those with acute respiratory failure typically demonstrate a high work of breathing. This outcome is hard to quantify in practice. One study of ICU patients with TA reported an improved TA over time (Sztrymf et al., 2011) and was confirmed in a second study (Itagaki et al., 2014). Studies have compared NHF to NIV and COT for those with acute exacerbations of chronic obstructive pulmonary disease. The surrogate EAdi has assessed the respiratory drive of those with acute chronic obstructive pulmonary disease exacerbations. These EAdi assessments suggest that the mean respiratory drive and work of breathing increased with COT vs NHF (15.4 ± 6.4) to COT (23.6 ± 10.5 µV) (Di Mussi et al., 2018). The current evidence reporting on the work of breathing outcomes for NIV and NHF is inconsistent. In summary, these mechanisms and benefits of action of NHF and the physiological effects seen collectively likely explain the clinical outcomes seen across various settings.

3.4 Nasal High Flow Clinical and Safety Outcomes Across All Settings

The clinical efficacy of NHF has been rapidly established. Published evidence and clinician preference have driven this process. The COVID-19 pandemic has recently impacted healthcare delivery, forcing RS approaches to evolve. The evidence suggests that NHF RS provides favourable clinical outcomes to spontaneously breathing patients with various respiratory conditions in many settings (Table 6)

Table 6

Nasal High Flow Therapy- Described Conditions and Supporting Evidence by Setting and Study Methods

Condition	Evidence	Study Methods	Setting
Acute Hypoxemic Respiratory Failure	Mauri, et al., 2017b	Cross Over RCT[a]	ICU[b]
Acute Hypoxemic Respiratory Failure	Colombo et al., 2022	Observational Study	Ward
Acute Hypoxemic Respiratory Failure	Rochwerg et al., 2020	Clinical Guideline	All
Acute Hypoxemic Respiratory Failure	Pitre et al., 2023	Network Meta-Analysis	All
Acute Hypercapnic Respiratory Failure	Pilcher et al., 2017	Cross Over RCT	Ward
Acute Hypercapnic Respiratory Failure	Ovtcharenko et al., 2022	SR with MA	All
Acute Respiratory Distress Syndrome	Messika et al., 2015	Observational Study	ICU
Postsurgical / Postoperative	Stéphan et al., 2017	Noninferiority RCT	ICU
Postextubation	Hernández et al., 2016a	RCT	ICU
Postextubation	Rochwerg et al., 2020	Clinical Guideline	All
Peri intubation (RSI)[c]	(2015).	Controlled Trial	OT[d]
Peri Intubation	Rochwerg 2020	Clinical Guideline	All
Immunocompromised	Azoulay et al., 2018	RCT	ICU
Immunocompromised	Wang et al., 2020	SR	All
Dyspnoea / Breathlessness	Bell et al., 2015	RCT	ED[e]
Pneumonia	Frat et al., 2015	RCT	ICU
Chronic Obstructive Pulmonary Disease	Bräunlich et al., 2019	RCT	Ward
Cariogenic Pulmonary Oedema	Makdee et al., 2017b	RCT	ED
Heart Failure	Makdee et al., 2017a	RCT	ED

Table 6 cont.

Condition	Evidence	Study Methods	Setting
Trauma	Mu et al., 2020	Retrospective Study	Hospital
Cystic Fibrosis	Sklar et al., 2018	Cross Over RCT	Ward
Carbon Monoxide Poisoning	Tomruk et al., 2019	Observational Study	ED
Atelectasis	Suzuki & Takasaki, 2014	Case Report	Ward
Palliative (Do Not Intubate)	Peters et al., 2013	Cohort Study	Ward
Bronchiectasis	Rea et al., 2010	RCT	Home
Interstitial Lung Disease	Al Chikhanie et al., 2021	Controlled Trial	Non-Hospital
Asthma	Ruangsomboon et al., 2021	RCT	ED
As an alternative to NIV	Doshi et al., 2018	RCT	ED
Conscious Sedation	Ayuse et al., 2020	RCT	For ERCP [f]
Resting During NIV	Rochwerg et al., 2020	Clinical Guideline	All
Postoperative	Rochwerg et al., 2020	Clinical Guideline	Postoperative
Dyspnea in cancer pts	Hui et al., 2021	RCT	All
Endoscopy	Nay et al., 2021	RCT	Outpatients
Bronchoscopy COPD	Sharma et al., 2023	RCT	Outpatients
Bronchoscopy	Lucangelo et al., 2012	Prospective Controlled Study	ICU

Note. Randomised Controlled Trial = RCT [a]; Intensive Care Unit = ICU [b]; Rapid Sequence Intubation = RSI [c]; Operating Theatre = OT[d]; Emergency Department = ED[e]; Endoscopic Retrograde Cholangio Pancreatography= = ERCP[f].

The NHF evidence describing the documented clinical outcomes is highly cited. The top 48 publications have been cited 8670 times (mean 180), with the most cited and one of the first major studies considering acute respiratory failure being that of Frat et al., 2015, cited 2371 times. The common themes considered in NHF research were: COVID-19 62%, acute respiratory failure 19%, post-extubation care 6%, prediction outcomes 4%, supporting intubation 4%, delaying escalation 2%, and post-operative support 2%.

Acute hypoxemic respiratory failure occurs when gas exchange is impaired, and hypoxaemia with or without hypercapnia occurs. Hypoxaemia varies considerably, from mild- to moderate-to-severe hypoxaemia ($PaO_2/FiO_2 \leq 200$). Acute respiratory failure can be classified as Type I or Type II. As stated earlier in this thesis, Type I respiratory failure occurs when the PaO_2 is below normal, while Type II occurs when the $PaCO_2$ is above normal; patients can have both Type I and II respiratory failure. Those with respiratory failure may have dyspnoea, anxiety, confusion, tachypnoea, tachycardia, and cardiac dysfunction if left uncorrected, which leads to respiratory and cardiac arrest. Numerous studies have considered NHF for those with acute Types I and II respiratory failure. More than ten RCTs have been compared to NHF for patients with acute Type I respiratory failure. Most trials have been set in the ICU (Azoulay et al., 2018), some in the ED (Jones et al., 2016), and some in both the ICU and ED (Frat et al., 2015).

Less than ten RCTs have compared NHF for acute Type II respiratory failure, with most trials comparing NHF to NIV (Cong et al., 2019; Cortegia et al., 2020; Doshi et al., 2020), with fewer comparing NHF to COT (Pilcher et al., 2017). Most trial participants had an acute exacerbation of chronic obstructive pulmonary disease, with participants with mild hypercapnic respiratory failure being the minority (Cortegia et al., 2020).

Subsequently, systematic reviews reporting these primary studies of Types I (Rochwerg et al., 2019; Rochwerg et al., 2022; Pitre et al., 2023) and II respiratory failure have emerged (Alnajada et al., 2021; Xu et al., 2021; Ovtcharenko et al., 2022). The SR methods and findings vary significantly. The most recent SR with network meta-analysis of Type I respiratory failure data from 36 RCTs reported a reduced need for intubation with NHF (103.5 fewer events per 1,000; 95% CI, 40.5 to 157.5) compared with COT (Pitre et al., 2023). No evidence of effect was found between NHF and COT for mortality, ICU length of stay, hospital length of stay (LOS), patient-reported dyspnoea, and comfort (Pitre et al., 2023). Nasal high-flow therapy is now often recommended over COT for those with Type I respiratory failure (Rochwerg et al., 2022). In contrast, the most recent SR of Type II respiratory failure concluded that, based on the available data, NHF should not be used as an initial approach over NIV. This SR also recommended that further research be completed (Alnajada et al., 2021).

3.4.1 Post-Extubation Support

Some patients develop post-extubation respiratory failure and require further RS. This failure may progress, and reintubation is needed, increasing morbidity and mortality risk (Epstein, 2002). Many studies have compared NHF to COT or NIV to prevent reintubation. In a heterogeneous population at negligible risk, NHF significantly reduced reintubation (NHF 4.9% vs COT 12.2%, absolute difference [AD], 7.2%; 95% CI, 2.5 to 12.2, p = 0.004) (Hernández et al., 2016b). However, the role of post-extubation RS with NIV to avoid reintubation has been debated (Rochwerg et al., 2017). In the high-risk group, NHF was reported as non-inferior to NIV (NHF 22.8% vs NIV 19.1% reintubated, AD -3.7%; 95% CI, -9.1 to ∞) (Hernández et al., 2016a). For those with ≥ four risk factors and, therefore, very high-risk, NIV was reported as superior to NHF for preventing reintubation differences (AD−15.5%; 95% CI, −28.3 to −1%) (Hernández et al., 2022). Two MAs considered reintubation and identified that reintubation was reduced with NHF compared to COT (RR 0.46; 95% CI, 0.30 to 0.70). However, no effect was seen when comparing NHF vs NIV, with NHF highlighting the need for more research (Rochwerg et al., 2017).

3.4.2 Peri-Intubation Support

Adverse effects may complicate pre-oxygenation and emergency rapid sequence of intubation of high-acuity patients. Oxygen desaturation is the most common adverse event (AE), which may lead to cardiac arrest. Peri-intubation AEs are associated with poor patient outcomes (Downing et al., 2023). Respiratory support can pre-empt these AEs by extending safe apnoea time for peri-intubation and RS during procedural sedation. Peri-intubation currently dominates the NHF research arena.

Numerous trials have compared NHT to COT or NIV for peri-intubation. The COT comparators have included FM or bag-mask ventilation. Many trials have involved non-hypoxaemic patients undergoing elective intubation (Vourc'h et al., 2019). A minority of trials have involved critically ill hypoxemic patients requiring intubation (Guitton et al., 2019). In a MA of data considered serious peri intubation AE, comparing NHF to COT, no effect was seen (RR 0.87; 95% CI, 0.71 to1.06) (Chaudhuri et al., 2020). A SR considered the benefits and adverse events of apnoeic oxygenation with NHF before intubation in adults in four settings (prehospital, ED, ICU, and operating theatre environments) compared to no apnoeic oxygenation during intubation. This SR found limited studies demonstrating the lowest recorded SpO_2 improvement; however, this improvement was unlikely to have any clinical significance (White et al., 2023). As mentioned, peri-intubation currently dominates the NHF research arena. Examples include exploring the use of NHF to support those receiving short periods of sedation without laryngeal masks; also, in general anaesthesia, NHF may extend the safe apnoea time during intubation and likely reduce operator stress and failed intubation rates.

3.4.3 Post-Operative Care Requiring Representing to Hospital

Following anaesthesia, there is a risk of respiratory failure; some of these patients then present to the ED following their initial hospital discharge. Common causes of respiratory failure include aspiration and atelectasis (Summers et al., 2022). Several trials have compared NHF to COT, while very few have compared NHF to NIV. The trial participants were post-cardiac, thoracic, and abdominal surgeries. A meta-analysis reported a significantly reduced reintubation rate (RR 0.32; 95% CI, 0.12 to 0.88) and the need to escalate (RR 0.54; 95% CI, 0.31 to 0.94) with NHF compared to NIV (Rochwerg et al., 2019). In addition to this MA, the prioritised scenarios are acute hypoxaemic respiratory failure, NHF vs NIV, NHF for NIV breaks, NHF for chronic obstructive pulmonary disease and hypercapnic acute respiratory failure, palliation, and conscious or procedural sedation. The debate on NHF vs COT for acute hypoxaemic respiratory failure is largely resolved; however, NHF compared to NIV warrants further consideration.

The RS of choice for hypercapnic respiratory failure is NIV; however, this NIV is often poorly tolerated. One option may be to complement NIV RS with intermittent NHF; for NHF chronic obstructive pulmonary disease and hypercapnic acute respiratory failure, NIV failure may occur in up to 64% of these patients, with INV being an unlikely next step. Many of those with chronic obstructive pulmonary disease may have care limitations, so INV is not an option, and NHF may be. NHF may be an option for those requiring palliative care to improve the quality of palliative care and patient comfort outcomes.

In a ward-based study of fifty individuals receiving palliative care, NHF improved mean SpO_2 from 89.1 to 94.7% and levels of dyspnoea (Peters et al., 2013). The efficacy of NHF in the ED for palliative care patient outcomes requires exploration.

Finally, for conscious or procedural sedation, some interventions that require sedation, including bronchoscopy and endoscopy, may cause hypoxaemia. Respiratory support is often necessary to improve patient safety. In one of several studies, differing flow rates in healthy volunteers, NHF reduced mean transcutaneous CO_2 by up to 3.6 ± 3.4 mmHg ($p = 0.024$) and reduced the mean respiratory rate by 4 ± 3 breaths/min ($p = 0.003$), all with a constant SpO_2 (Mishima et al., 2020). This arena is of significant interest to anaesthesia, interventional radiology, and the ED. The safety of any therapy, including NHF, relates to unintended harm risk. The safety considerations for NHF across all settings, including the ED, are now presented.

3.4.4 Nasal High Flow Safety Considerations

Harm related to NHF is possible; however, the harm is often treatment-limited, and therapy can continue (Rochwerg et al., 2019). No NHF RCTs have established contraindications as a primary endpoint (Park, 2021). The safety considerations noted include airway pressure, soft tissue damage, thermal effects, infection control, interface failure, and masking of deterioration with failure to escalate care. As with any RS therapy, contraindications for NHF have been described (Cooper et al., 2018) as outlined in (Table 7).

Table 7

Nasal High Flow Contraindications for Use in Adults (adapted from Cooper et al., 2018)

Contraindications
• Full or partial blockage of the nares which impedes inspiratory of expiatory gas flow • Trauma to the cranium and/or airway anatomy, e.g., laryngeal fracture, mucosal or tracheal rupture. Especially where there is connection of the nasal to the intracranial anatomy • Use of concomitant therapies or techniques that are contraindicated in environments with high levels of ambient O_2, e.g., laser or diathermy • Significant epistaxis • Contraindications to high FiO_2, e.g., prior bleomycin chemotherapy • In operating theatre: an inability to tolerate hypercarbia when NHF is used with prolonged apnoea, e.g. sickle cell anaemia, pulmonary or intracranial hypertension

The high gas flow rates possible with NHF produce positive airway pressure. Nasal high flow is an open and unsealed system; however, NHF-related barotrauma has been reported (Piastra et al., 2018). Barotrauma has included pneumothorax, pneumomediastinum and gastric distension in post-cardiac surgery. Compared to NIV, the reported rates of pneumothorax with NHF were not statistically different (Stéphan et al., 2015; Stéphan et al., 2017) or were significantly lower with NHF (0% vs NIV 22.2%, $p = 0.042$) (Tu et al., 2017). However, in a case series of three COVID-19 patients with reported pneumothoraces, it was unclear whether these events could be attributed to the provided NHF RS (Nalewajska et al., 2021).

In chronic obstructive pulmonary disease, patients' lower rates of aerophagia, AE, and serious AE were reported with NHF than with NIV (0 vs 5; 17 vs 21; 33 vs 55) (Bräunlich et al., 2019). These reports suggest that barotrauma risk with NHF is no worse than NIV.

There are concerns about an increased risk of aspiration with NHF, stressing the importance of an intact swallow reflex. In a study of healthy volunteers, NHF > 40 L/min was associated with an increased risk of aspiration; 30% of participants had issues during swallow testing at flow rates of 10, 40, and 50 L/min ($p < 0.05$) (Arizono et al., 2021). Chest or cervical discomfort is not unusual and is possibly related to elevated airway pressures and increased expiratory airway resistance (Bräunlich et al., 2019; Rittayamai et al., 2015).

Soft tissue injuries to the face, head, and nostrils have been reported. The pressure and friction of the interface on the soft tissue and poor nursing care may cause these issues. Compared to NIV, reports of soft tissue injury are less with NHF (NHF 0% vs NIV 22.2%; $p = 0.042$) (Tu et al., 2017) and NIV 10% vs NHF 3% (95% CI, 7.3 to 13.4 vs 1.8 to 5.6; $p < 0.001$) (Stéphan et al., 2015).

Conditioning the inspiratory gases has been deemed responsible for the reported thermal effects, including eye and airway dryness, nasal congestion, pain, and discomfort. When NHF was compared to VM, participants rated mean mouth dryness, throat dryness, difficulty swallowing, and throat pain significantly better with NHF (2.6 ± 2.2 vs 5.1 ± 3.3 at 24 hours, $p = 0.006$) (Maggiore et al., 2014).

Infection control has been perceived as a major concern with NHF. High gas flows are provided within an open NHF system, so it is conceivable that aerosolisation of pathogens occurs, thus increasing nosocomial risk to all those in the vicinity. The COVID-19 pandemic has heightened these concerns. No cases of NHF-related COVID-19 transmission to healthcare workers were seen in a single-centre retrospective cohort study (Schwartz et al., 2022). Nasal high-flow therapy is no longer considered to represent an increased risk of infection for healthcare workers (COVID-ICU group, 2021). Interface displacements can lead to loss of anticipated RS, which may lead to serious adverse events. This risk can be mitigated by correctly positioning and monitoring the patient and the interface. Compared to VM, fewer interface displacements were seen with NHF (32% vs VM 56%; $p = 0.01$) (Maggiore et al., 2014).

A perceived risk of delivering high FiO_2 to those who retain CO_2 needs to be corrected. Historically, O_2 therapy was attributed to loss of hypoxic drive, resulting in hypoventilation and Type II respiratory failure, which is unfounded (Abdo & Heunks, 2012). Whilst NHF effectively reduces respiratory fatigue in patients with acute exacerbations of chronic obstructive pulmonary disease, close monitoring is required to identify early deterioration due to hypercapnia. In the well chronic obstructive pulmonary disease patient, gas exchange is enhanced by hypoxaemic pulmonary vasoconstriction in poorly ventilated lung areas, improving the V/Q ratio in relatively normal lung regions. However, while NHF oxygen improves hypoxaemia and work of breathing, there is a risk of reversing that vasoconstriction, reducing perfusion and VQ matching in relatively normal lung areas (Abdo & Heunks, 2012; Brill & Wedzicha, 2014). Additionally, O_2 prompts a right shift of the CO_2 dissociation curve due to the Haldane effect. For those who cannot increase their MV, the Haldane effect accounts for about 25% of the total $PaCO_2$ increase seen with O_2 therapy (Abdo & Heunks, 2012; Brill & Wedzicha, 2014).

Clinical deterioration of patients with respiratory failure needs to be recognised, and the escalation of care needs to be managed. The inability to escalate care promptly can lead to adverse outcomes and increased service impacts (Gerry et al., 2020). The adverse events may include premature death, unanticipated cardiac or respiratory arrest, and ICU admission (O'Neill et al., 2021). Escalation of RS is the focus of this doctoral research.

Identifying deterioration is challenging in all settings, including the ED (Ricard et al., 2020). Achieving accurate and timely diagnoses is an ED priority; however, NHF therapy may disguise physiological decline, complicating diagnosis, or a need for escalation of care (Mauri et al., 2019b). One of the most cited NHF publications is a retrospective observational study of mortality outcomes (Kang et al., 2015). The findings suggest that those receiving NHF and then intubated earlier vs later had better overall ICU mortality outcomes (39.2% vs 66.7%; $p = 0.001$). However, actual cause and effect cannot be attributed using observational methods. A qualitative thematic analysis of escalation barriers proposes two themes: governance and clinical experience (O'Neill et al., 2021). For example, NHF use was initially restricted to high-acuity areas such as the ICU, where staff training and patient ratios are usually optimal. However, NHF is now used across all clinical settings where resources and clinical experience differ.

Escalation of care is usually triggered by circumstance (Table 8). Escalation warning systems have emerged; some are validated, while others are not (Considine et al., 2016). Warning systems enable patient screening and triage. The ROX index is a NHF warning system, which was developed to help better predict deterioration for those receiving NHF. The calculation of the index is as follows: SpO_2/FiO_2)/respiratory rate. An index of ≤ 3.85 at 12 hours of NHF predicts significant deterioration requiring escalation. A prospective cohort study validated the ROX index for those receiving NHF in any setting, including the ED (Roca et al., 2016).

Table 8

Possible Triggers for Escalation of Care

Trigger	Evidence
Staff concern	(Odell et al., 2009)
Vital sign deterioration	(Cotter et al., 2019)
Patient feels unwell	(Ede et al., 2020)
Poor response to therapy	(Cotter et al., 2019)
Clinical sign deterioration	(Leuvan & Mitchell, 2008)

A publication on the ROX index was completed as part of this doctoral research (O'Donnell et al., 2021a). The publication aimed to describe the possible utility of the ROX index in the ED and to highlight that the validity of this index is yet to be formally established for the ED. An ED clinical trial considering the ROX index is currently registered as TCTR20180829006. The objective was to provide a publication as an opinion piece that profiles the ROX index and describes its potential utility in the ED setting (O'Donnell et al., 2021a). The rationale for this publication is that the ROX index may complement ED EBP clinical decision-making when delivering NHF therapy. This publication aligns with the of doctoral research and its questions and justifies the focus of the thesis on the 'escalation of respiratory support', whereby this index informs clinical decision-making around the escalation of NHF RS. The publication is now presented as published (O'Donnell et al., 2021a).

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STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

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Student name:	Jane O'Donnell
Name and title of main supervisor:	Professor Marlena Kruger
In which chapter is the manuscript/published work?	Chapter 3 Literature Review

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

Conception and design: JOD Lead Author, PhD Candidate
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1

Doctoral Research Committee
May 2023

3.5 Publication: Use of an Index to Predict NHF Outcomes

O'Donnell, J., Pirret, A., & Hoare, K. (2021a). How do nurses better predict outcomes for adult COVID-19 patients receiving nasal high-flow therapy in the emergency care setting? *International Emergency Nursing*, *p. 57*, 101011. https://doi.org/https://doi.org/10.1016/j.ienj.2021.101011

The adoption of nasal high-flow therapy (NHF) as a form of respiratory support (RS) has steadily increased, particularly since the emergence of COVID-19 (Calligaro et al., 2020). Formally, RS of the spontaneously breathing adult patient was achieved using non-invasive ventilation (NIV) or conventional oxygen therapy (COT). Today, RS includes the option of NHF therapy. Nasal high-flow therapy is used in various clinical settings, including busy emergency care (EC), where it is regarded as a feasible RS option. In patients with acute respiratory failure, reliable evidence credits NHF use with a possibly lower mortality rate (HR 2.50; 95% CI, 1.31 to 4.78) non-invasive ventilation vs NHF (p = 0.006) (Frat et al., 2015) this evidence has driven changes to patient care (Mauri et al., 2017a). Whereby, based on the degree of hypoxaemia: mild acute respiratory failure is (200 mm Hg < $PaO_2/FiO_2 \leq 300$ mm Hg), moderate (100 mm Hg < $PaO_2/FiO_2 \leq 200$ mm Hg), and severe ($PaO_2/FiO_2 \leq 100$ mm Hg) (Ranieri et al., 2012). Emergency Care Nurses are motivated to improve the prediction of outcomes for those receiving NHF therapy. Nurses in EC appreciate that any delay in care escalation is associated with an increase in poor outcomes such as mortality, increased length of hospital stay, and cost (Huang et al., 2020). Unstable EC patients require close monitoring and assessment to ensure timely escalation and possible intubation, including those receiving NHF therapy. Additionally, EC nurses should be aware of NHF therapy's potential to mask symptoms such as unstable oxygen saturation and blurring the diagnostic process.

Nasal high flow (NHF) therapy delivers humidified gas (air and oxygen) to the upper airway via a specialist nasal cannula. A humidifier (within the NHF system) warms (up to 37 °C) and adds water to the gas, ready for inspiration. This therapy replicates the natural balance of heat and moisture seen in healthy lungs. The NHF system can deliver humidified gas to adult patients at a flow rate between 10 and 60 litres per minute and a fraction of inspired oxygen (FiO_2) between 0.21 (21% oxygen) and 1.0 (100% oxygen). The flow rate and the FiO_2 level can be independently adjusted (Mauri et al., 2017a).

The benefits of NHF therapy in acute respiratory failure are attributed to:

- Gas flow rates that a) do prevent the patient from entraining room air, thereby reducing the FiO_2 available to them, and b) reduce airway dead space by washing out expired CO_2 from the upper airway. Both of these factors reduce the patient's work of breathing.
- Delivery of a level of dynamic, positive airway pressure that increases functional residual capacity; this pressure is often referred to as a positive end-expiratory pressure (PEEP) in the NHF therapy literature.
- Airway humidification that is comfortable for the patient and aids sputum clearance (Mauri et al., 2017a).

The most common COVID-19 complication is acute respiratory failure, secondary to interstitial pneumonia. This acute respiratory failure (due to interstitial pneumonia) is primarily characterised by fever, cough, dyspnea, bilateral infiltrates on x-rays, and a 10% prevalence of hypoxaemia (Pascarella et al., 2020).

Patients may present to the EC with atypical symptoms, such as a moderate increase in respiratory rate and severe hypoxia (Wu & McGoogan, 2020). These patients can suddenly deteriorate, with 15 to 30% progressing within one to two days to severe respiratory failure due to acute respiratory distress syndrome (ARDS) (Xia et al., 2020). Patient care strategies for COVID-19 ARF align with the generic patient care strategies for ARF. However, this alignment has not yet been formally established by way of a controlled study.

Previously, the NHF therapy benefits such as comfort, improved oxygenation, and decreased work of breathing have been reported for patients with ARF (Mauri et al., 2017a). It has been assumed that these benefits may also apply to those with COVID-19 ARF. However, while NHF therapy has been described as beneficial for COVID-19 patients with mild to moderate ARF, the mortality rate is high in severe respiratory failure, and NHF therapy should be cautiously used (Xia et al., 2020). Clinicians must be aware that these patients may suddenly deteriorate and require urgent escalation of care.

An evidence-based approach to EC nursing is now even more essential during the COVID-19 pandemic, where consequences are high, and resources constrained. Nurses must navigate the swiftly less rigorous and ubiquitous evidence alongside evidence that is reliable and valid. Any changes to patient care should not rely only on unreliable evidence sources, e.g., case series, case reports, and anecdotes. An evidence-based strategy is required to consider the relative disadvantages and advantages that RS therapies provide for patients and healthcare practitioners. For example, non-invasive RS may reduce the infectious risk to clinicians by avoiding the need for invasive intubation, a procedure known to be highly infectious. However, all forms of RS generate aerosols, and seemingly, any risk of aerosol-based infection is more influenced by the mechanics of breathing individuals rather than specific therapies applied (Gaeckle et al., 2020).

An evidence-based approach to nursing care is informed by bedside physiology and supported by clinically significant outcome data. An index that uses bedside physiology is the ROX (Respiratory rate-OXygenation) index. This index also considers the clinically significant outcome, which is the need to escalate care for patients receiving NHF therapy.

The ROX index was founded on the premise that sicker patients have higher oxygen needs and higher respiratory rates. The index involves three common physiological measurements: FiO_2, oxygen saturation via pulse oximetry (SpO_2), and respiratory rate. The ROX index is the first validated scoring system (SS) used in adults receiving NHF therapy who have ARF due to pneumonia alone (Roca et al., 2019).

Post commencing NHF therapy, the ROX index should be calculated at three specific time points: 2, 6, and 12 hours. The index is validated at these time points. The ROX index is determined by dividing the SpO_2 by the FiO_2 and dividing this result by the respiration rate (SpO_2/FiO_2)/respiratory rate. If the patient has a normal SpO_2 of 96% while breathing room air (FiO_2 0.21) and a respiratory rate of 18, their ROX index would be 25.3 (Table 9). Table 9 also shows the ROX index calculation for a hypoxaemic patient. This patient has a SpO_2 of 90%, with a FiO_2 of.80 and a respiratory rate of 30, which results in a ROX index of 3.75.

Table 9

Respiratory rate-OXygenation (ROX) index explained at 12h after commencing NHF (Roca et al., 2019)

Healthy Adult ROX	Hypoxaemic Adult ROX
Calculated at 12 hours post-NHF commencing	Calculated at 12 hours post-NHF commencing
$\frac{96/0.21}{18} = 25.3$	$\frac{90/0.80}{30} = 3.75$
ROX index is 25.3	ROX index is 3.75
Suggests continuing with NHF	Suggests consideration of escalation of patient care

The hypoxaemic patient presented in Table 9 with a ROX score of 3.75, therefore categorising them as requiring consideration for escalation of care. In contrast, those with an index of ≥4.88 measured after 12 hours of NHF therapy are deemed at a lower risk and suggest continuation of NHF therapy (Roca et al., 2019). Index values ≤ 2.85 at 2 hours, ≤ 3.47 at 6 hours, or ≤ 3.85 at 12 hours of NHF use suggest that the patient may be failing, and escalating care should be considered along with more intensive monitoring (see Table 10).

Table 10

ROX Value Thresholds Suggesting Consideration of Patient Care Required (Roca et al., 2019

ROX Thresholds Suggesting Consideration of Patient Care Required at Three-Time Points	
Calculated at 2 hours post-NHF commencing	≤ 2.85
Calculated at 6 hours post-NHF commencing	≤ 3.47
Calculated at 12 hours post-NHF commencing	≤ 3.85

The ROX index is one of the over 250,000 scoring systems (SS) in use across all clinical domains. EC nurses regularly use scoring systems to inform the safety, diagnosis, treatment, and prognosis of their patients, including those receiving NHF therapy. In addition to informing the early detection of patient deterioration, the ROX index may also help determine which EC patients can be discharged safely. Determining who should be hospitalised is essential when dealing with a rapidly spreading global COVID-19 pandemic that has the potential to overwhelm hospital capacity. Quick and easy tools such as the ROX index may support EC nurses in making these critical clinical decisions.

Since 2016, both the clinical and research communities have both adopted the ROX index. The use of the index has been described in differing patient groups and settings. The index has recently been used to consider patients' success or failure with COVID-19-related ARF receiving NHF therapy. In these patients, a ROX index calculated at 6 hours (ROX-6) of ≥3.7 (ROX-6 ≥3.7) predicted patient success on NHF therapy 80% of the time. Alternatively, a ROX-6 of 2.2 predicted patient failure on NHF therapy 74% of the time (Calligaro et al., 2020).

Researchers have also piloted modifications to the original index. A modified index that incorporates heart rate (HR), known as ROX-HR, was tested (Goh et al., 2020). The ROX-HR index may also be useful for early prediction of patient outcomes in those with acute hypoxic respiratory failure (AHRF) and those following planned extubation. The ROX index is simple to calculate and is easily interpreted by EC nurses in practice in an often chaotic environment with multiple interruptions. Online ROX index calculators have been developed and are now available for clinicians to use: https://www.mdcalc.com/rox-index-intubation-hfnc.

In the busy EC environment now inundated with COVID-19 patients, the ROX index may complement EC nurses' clinical decision-making when delivering NHF therapy. Further study is necessary to demonstrate that the ROX index can improve EC clinical outcomes rather than only predict them.

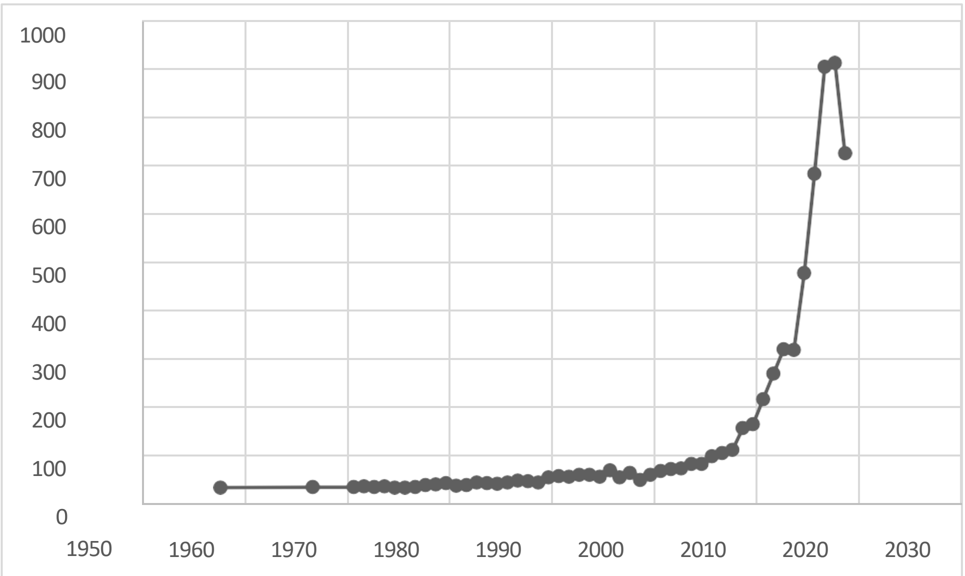
3.6 The Emergency Department Described

As reported, the NHF evidence is emerging from many clinical settings, from the home to the ICU, including the ED. Nasal high-flow therapy studies set in the ED report on a variety of clinical conditions, for example, asthma and heart failure. The outcomes and methods, including changes in respiratory rate and SpO_2, have been considered using controlled study methods (Table 11).

Since the early 2000s, the NHF evidence and application in the adult population has accelerated, with some of this evidence relevant to the unique ED setting (Figure 11). This doctoral research has an ED focus; therefore, the ED setting and NHF evidence pertinent to this setting are now described.

Figure 11

Nasal High Flow Publications Indexed on PubMed by Number Over Time (Current December 2023).



Note. This figure describes the increasing number of publications for nasal high-flow therapy in the vertical axis over time in the horizontal axis.

Table 11

Summary of Emergency Department Nasal High Flow Therapy Studies by Condition, Outcomes, Methods and Supporting Evidence

Conditions	Outcomes	Methods	Evidence
Asthma	Therapy response	RCT [a]: NHF [b] vs COT[c]	Geng et al., 2020
Heart Failure	Respiratory Rate	RCT: NHF vs COT	Makdee et al., 2017b
Pulmonary Oedema	Improved physiology	RCT: NHF vs COT	Ko et al., 2020
Carbon Monoxide Poisoning	Intubation	NHF vs NRM[d]	Kim et al., 2020
COVID-19	Intubation rate	RCT: NHF vs COT	Ospina-Tascon et al., 2021
Pulmonary Fibrosis ARF [e]	Mortality	Retrosp. Observational study NHF vs INV	Lee et al., 2020
Peri intubation	Hypoxaemia	Retrospective observational NHF	Mitsuyama et al., 2022
Rapid sequence intubation	Lowest SpO_2	RCT: NHF vs NRM or NP	Chua et al., 2022
Dyspnoea	Escalation	RCT: NHF vs COT	Bell et al., 2015
Respiratory Distress	Escalation	RCT: NHF vs COT and NIV[f]	Jones et al., 2016
Respiratory Failure	Intubation	Before and After	Macé et al., 2019
Respiratory Failure	Feasibility	Prospective observational NHF	Lenglet et al., 2012

Note. Randomised Controlled Trial= RCT [a]; Nasal High Flow= NHF [b]; Conventional Oxygen Therapy= COT[c]; Nonrebreather Mask= NRM [d;] Acute Respiratory Failure = ARF [e]; Non-invasive ventilation =NIV

Globally, the delivery of ED care varies (Fleischmann & Fulde, 2007). Most commonly, the ED is central to a system that provides comprehensive and coordinated support to those with acute illness or injury (FitzGerald et al., 2009). This system usually includes hospital EDs, primary healthcare providers, first aid, and paramedic services (FitzGerald et al., 2009). In the New Zealand (NZ) ED setting, care is delivered for patients presenting independently, by a community referral system, or by ambulance (New Zealand Government, Ministry of Health, 2015). In many countries, the ED provides vital access to care for those patients without other financial means (Razzak & Kellermann, 2002). In New Zealand, primary healthcare providers deliver routine and urgent health care.

In contrast, NZ EDs provide intermittent 'crisis' care for those needing acute care, including hospital admission. Occasionally, in New Zealand, there is an overlap between primary care and ED care (New Zealand Government Ministry of Health, 2015).

The ED patient demonstrates a wide-ranging series of presentations, with some necessitating urgent intervention (New Zealand Government, Ministry of Health, 2015). Consequently, the ED clinician and their patients must navigate complex and diverse ED clinical pathways. Complexity is derived from multifaceted symptomology, emerging diagnoses, and probable outcomes requiring consideration (New Zealand Government Ministry of Health, 2015).

The needs of the ED patient population are increasing, and so is the complexity of their care (Augustine, 2020). As a result, a significant percentage of those presenting to the ED require some form of RS. Historically, high-needs ED patients with ARF have received RS with either, or a combination of, COT, NIV, or INV. However, NIV and INV have known complications, which can increase mortality and morbidity (Davidson et al., 2016; Fan et al., 2017). Additionally, for these acute respiratory failure patients, COT using non-fixed performance devices has been associated with unintentional alveolar damage due to hypoxaemia (Sarkar et al., 2017). Additionally, the delivery of NIV or INV is resource-draining, as some patients require admission to a specialist ward or an ICU. In contrast, NZ and Australia require a 1:1 nurse-patient ratio (Rose et al., 2009) for patients receiving INV in ICU. However, regardless of the RS provided, patients need careful monitoring.

Improving patient care involves EBP; however, the ED challenge is the availability of reliable and valid evidence to inform this care delivery (Kelly & Horsely, 1999). Compared to many other specialities, emergency medicine is a relative newcomer. Different specialities, such as cardiology, benefit from recognised scopes of practice, knowledge, research, and training (Williams, 2018). As such, professional specialisation supports EBP and improved patient outcomes (Williams, 2018). Additionally, the ED has other interrelated challenges which indirectly compromise EBP. These challenges include overcrowding (Savioli et al., 2022), workplace violence (Mitra et al., 2018), staff shortages (Vaughan & Edwards, 2023) and burnout (Petrino et al., 2022). These challenges are well described locally in New Zealand and globally (Vaughan & Edwards, 2023). These issues have compelled many ED clinicians and their professional societies to advocate for political change (Rixon et al., 2023).

3.7 Nasal High Flow Clinical and Safety Outcomes in the Emergency Department

In January 2024, a literature search of the primary research outputs located a subset of the ED-specific evidence. This search revealed 78 publications, including three guidelines, 52 clinical trials, 46 RCTs, and 23 reviews with or without MA.

The efficacy of NHF use in the ED may be assumed for the previously discussed clinical and safety outcomes; however, several ED outcomes require further consideration. The clinical and safety outcomes for heart failure, chronic obstructive pulmonary disease, hypercapnic respiratory failure, asthma, respiratory failure, and carbon monoxide poisoning have all been considered for the ED. Many studies have noted improvements in physiology, such as reduced respiratory rate, but no difference in outcomes of clinical significance, such as mortality (Table 11).

In the ED, RS is provided using NHF therapy to adults with various needs (Marjanovic et al., 2020). Over recent years and in many settings, NHF has been introduced as an option for non-invasive RS for those with acute respiratory failure. In this acute respiratory failure cohort, NHF use was associated with a statistically significant reduction in the need for INV and admission to the ICU for those with a PaO_2/FiO_2 ratio ≤ 200, $p = 0.01$ (Frat et al., 2015).

While research has confirmed the effectiveness of NHF for adults in the ICU, limited research is available in the ED, where patients first present to a hospital (New Zealand Government, Ministry of Health, 2015). One study has confirmed the feasibility of NHF delivery, an essential consideration in the ED setting (Lenglet et al., 2012). However, evidence to support the efficacy of NHF in the ED is still emerging. Hence, ED clinicians using NHF must primarily refer to the evidence from the ICU setting and/or their own experience of the therapy (Marjanovic et al., 2020).

The lack of robust evidence for RS in the ED has been demonstrated in the current COVID-19 pandemic. Respiratory support therapies may be indicated for those with acute respiratory failure secondary to COVID-19 infection (Forrest et al., 2021; Jarou et al., 2021). During this pandemic, evidence of varying quality emerged, as did contrasting opinions and resource constraints, which paralysed care delivery in many countries (Roy et al., 2021). The need to inform practice with reliable, valid, and applicable evidence on RS in the ED is obvious, pandemic notwithstanding. One Colombian multicentre RCT compared NHF to COT in 220 ED and ICU patients with severe acute respiratory failure due to COVID-19. This study demonstrated the superiority of NHF over COT for avoiding escalation to INV (hazard ratio, 0.62; 95% CI, 0.39 to 0.96; $p = 0.03$) (Ospina-Tascon et al., 2021).

The first ED-controlled studies demonstrated that NHF therapy could resolve dyspnoea and reduce the mean respiratory rate from 28 to 25 breaths per minute ($p \leq 0.001$) (Lenglet et al., 2012). Two subsequent studies have confirmed Lenglets' findings (Bell et al., 2015; Makdee et al., 2017b). This evidence suggests that NHF is efficacious and feasible in ED patients with dyspnoea. Jones and colleagues (2016) conducted the largest and most-cited NHF RCT in New Zealand. However, following the loss of equipoise, the study terminated early, with the researchers recruiting 322 participants out of the required 800 (determined a priori by power calculation). The researchers concluded that NHF use was not associated with a reduced need for INV in the ED compared with COT, despite the study being underpowered (NHF 5.5%; 95% CI, 2.8 to 10.2 vs COT 11.6%; 95% CI, 7.2 to 18.1; $p = 0.053$).

In 2017, a multicentre point observational prevalence study (Kelly et al., 2017) was published. The study described the epidemiology of 3044 patients presenting with dyspnoea at EDs in the Asia-Pacific region. The authors concluded that dyspnoea is a common symptom in those presenting to the ED and that these patients contribute significantly to the overall ED, ICU, and hospital burden. This epidemiological method has research utility to inform the generation of hypotheses for future testing and has influenced the choice of the PPS method for this thesis.

According to the EBP hierarchy of evidence, a valid SR with MA is regarded as the *best evidence* (Burns et al., 2011). In response to this and despite a lack of ED evidence from RCTs, seven NHF ED systematic reviews have been published (Huang et al., 2019; Li et al., 2023; Lin et al., 2017; Marjanovic et al., 2020; Tinelli et al., 2019; Wang et al., 2020; Zhu et al., 2017) (Table 12). The minority of these SRs exclusively included RCTs set in the ED (Huang et al., 2019; Tinelli et al., 2019). However, these SRs are over two years old, and a new or updated SR is required. The five remaining SRs have methodological limitations as they incorporated a variety of study types, including cohort studies, across a variety of study settings, including the ICU (Li et al., 2023; Lin et al., 2017; Marjanovic et al., 2020; Wang et al., 2020; Zhu et al., 2017).

On this basis and in keeping with the EBP theoretical foundation of this doctoral research, an SR with an MA, including the most current ED RCTs, was justified and completed as the first method in this multi-method thesis. The published protocol for the SR is reported in Chapter Four *Methodology* (O'Donnell et al., 2021b), and the published SR is reported in Chapter Five *Results* (O'Donnell et al., 2024).

Table 12

Summary of Findings of Seven ED NHF Systematic Reviews

Review	PICOT[a]	Included studies	Conclusions as quoted
Huang et al., 2019	ARF[b] COT[c] vs NHF[d] INTUBATION RATE	5	"NHF therapy in ARF patients in EDs might decrease the intubation rate compared with COT. In addition, it can decrease the need for escalation, and patient's dyspnoea level, and increase the patient's comfort level compared with COT" (Huang et al., 2019, p.1). (RR, 0.41; 95% CI, 0.22-0.78; p = 0.006; I^2 = 0%)
Lin et al., 2017	AHRF[e] NHF vs COT or NIV[f] INTUBATION RATE	8	"The use of NHF showed a trend toward reduction in the intubation rate, which did not meet statistical significance, in patients with acute respiratory failure compared with COT and NIV. Moreover, no difference in mortality. So, large, well-designed, randomized, multicentre trials are needed to confirm the effects of NHF in acute hypoxemic respiratory failure patients" (Lin, 2019, p. 58). (OR = 0.79; 95% CI, 0.60-1.04; p = 0.09; I^2 = 36%).
Marjanovic et al., 2020	RF NHF vs COT INTUBATION RATE	5	"The early use of NHF in patients admitted to an ED for acute respiratory failure did not reduce the need for mechanical ventilation as compared to COT. However, NHF decreased respiratory rate" (Marjanovic et al., 2020, p. 1508). (RR = 0.75; 95% CI, 0.41-1.35; p = 0.31; I^2 = 16%).
Tinelli et al., 2019	NHF vs COT or NIV INTUBATION RATE	4	"No benefit for NHF compared with COT and NIV in terms of intubation requirement, treatment failure, hospitalisation, and mortality; COT was better tolerated" (Tinelli et al., 2019, p.322). (MA no difference)

Table 12 cont.

Review	PICOTa	Included studies	Conclusions as quoted
Wang et al., 2020	IMMUNOCOMP NHF vs COT or NIV INTUBATION RATE	8	"There was no significant difference in short-term mortality with NHF compared with COT or NIV for immunocompromised patients with ARF. A lower intubation rate than COT and a shorter length of ICU stay than NIV were observed in the NHF group" (Wang et al., 2020, p.413). (COT) (RR 0.89; 95% CI, 0.73-1.09; p = 0.25, I^2 = 47%), (NIV) (RR 0.66; 95% CI, 0.37-1.18; p = 0.16, I^2 = 58%).
Zhu et al., 2017	ARF NHF vs COT INTUBATION RATE	4	"NHF therapy was similar to COT in ARF patients. The subgroup analysis showed that NHF therapy may decrease the escalation of respiratory support and the intubation rate when ARF patients were treated with NHF for ≥24 h compared with COT. Further high-quality, large-scale studies are needed to confirm our results" (Zhu et al., 2017, p.1). (RR, 0.74; 95% CI, 0.55-1.00; z = 1.95, p = 0.05), mortality (RR, 0.82; 95% CI, 0.36-1.88; z =0.47, p = 0.64)
Li et al., 2023	ARF COVID NHF vs COT INTUBATION RATE	9	"HFNC may reduce intubation rate and 28-day ICU mortality and improve 28-day VFDs in patients with ARF due to COVID-19 compared with COT". (Li et al., 2023, p.1) (OR 0.44; 95% CI, 0.28 -0.71, p = 0.0007)

Note. The word PICOT is a mnemonic derived from the elements of a clinical research question – patient, intervention, comparison, outcome, and (sometimes) time = PICOT [a]; Acute Respiratory Failure = ARF [b]; Conventional Oxygen Therapy=COT [c]; Nasal high Flow=NHF [d]; Acute Hypoxaemic Respiratory Failure= AHRF [e]; Non-invasive ventilation= NIV, RR=relative risk, OR=odds ratio; CI =confidence

3.8 Implications for Evidence-Based Practice and Research for Nasal High-Flow in the Emergency Department

Establishing research priorities in settings, including the ED, aligns research and genuine needs, justifies the allocation of research funding, and reduces duplication and resource waste (Crilly et al., 2022). As of January 2024, 837 adult NHF clinical trials are registered on the International Clinical Trials Registry Platform (ICTRP) (World Health Organisation, 2024). Only 38 of the 837 trials are set in ED, suggesting either a low ED research engagement or a failure to register trials prospectively. It is acknowledged that the COVID-19 pandemic severely impacted research activity. The registered ED trials are either repeating methods or considering novel applications of NHF. The novel applications include automated titration of NHF therapy (ACTRN12622000423718) and a single-bore nasal cannula (NCT05829083). It is difficult to know whether these pursuits have legitimate clinical foundations or potential patient risk.

The literature review has exposed the gaps in the NHF evidence. Some gaps are novel, some not, and some research warrants repetition. For example, even though many RCTs have considered NHF in those with acute respiratory failure, further robust, well-powered studies are needed to optimise the combined strength of their findings with meta-analysis. Further ED studies are required to evaluate NHF compared with other forms of RS and for clinically significant outcomes, such as mortality, and additional RCTs are needed for conditions other than hypoxaemic respiratory failure.

3.9 Chapter Three Conclusion

In this third Chapter, *Literature Review*, the evidence describing the mechanisms and benefits of action, physiological effects, and clinical and safety outcomes for NHF in adults in the ED have been described. The mechanisms and benefits described include: dead space clearance, generation of positive pressure, heating and humidification of gases, accurate FiO_2, and comfort. Collectively, these mechanisms and benefits may trigger a series of physiological responses that support improved patient outcomes.

Improved clinical outcomes have been reported in ED patients with acute hypoxaemic respiratory failure, heart failure, pneumonia, asthma, and, most recently, those with acute respiratory distress syndrome secondary to COVID-19. The efficacy of NHF for Type II respiratory failure remains unclear, with limited benefit noted for those with mild-moderate Type II respiratory failure.

It must be acknowledged that the validity and applicability of much of the evidence reviewed were limited; for example, most studies were underpowered, and many involved heterogeneous non-ED populations, including the ICU and the ward. Overall, the literature review findings are consistent with many published SR reviews that report a lack of reliable and valid NHF evidence applicable to ED. These SRs typically conclude that 'more research is required.' Ironically, imprecision and pooling of heterogeneous methodologies, outcomes, and populations are often also demonstrated in these SRs (Rochwerg et al., 2020). However, regardless of these issues and, ironically, in pursuit of EBP, this evidence has been incorporated into practice guidelines. Currently, these guidelines propose recommendations for practice for acute respiratory failure, post-extubation, peri-intubation, and postoperative care (Chaudhuri et al., 2020; Oczkowski et al., 2022; Rochwerg et al., 2020). Despite the supporting evidence, which is often ICU-focused, these guidelines are proposed to be applicable across many clinical settings, including the ED. This apparent scarcity of valid and reliable evidence may be due to NHF being used in ED practice before controlled studies positioned high on the EBP hierarchy of evidence.

However, a conundrum exists: despite gaps in such evidence, a perceived superiority of NHF over COT now prevails over the potential randomisation of study participants to an intervention perceived as inferior (Alnajada et al., 2023; Ricard et al., 2020). Additionally, and regardless, the published epidemiological platform for ED research is limited (Alnajada et al., 2023).

This Chapter, *Literature Review*, has provided a narrative summary of ED-relevant literature reporting on RS with NHF. The rationale and purpose of this narrative literature review was to provide a conceptual frame for the thesis and to define the scope of this doctoral research. Here, the objectives included confirming the novelty of the study; however, it has exposed the ED NHF evidence grey zone. This review has established the significance of this doctoral research and ratified use of the EBP framework and methodology as described in the next chapter.

The fourth and subsequent Chapter *Methodology* collectively describes the philosophical paradigm, the research approach and strategy, the research design and time horizon, and the two methods used to ethically and reliably answer the six thesis questions, which all relate to the nature of the RS provided to adults in the ED. This fourth Chapter includes three publications: two are study protocols (O'Donnell et al., 2021b; O'Donnell et al., 2022), and one is an audit of published NHF systematic reviews (O'Donnell et al., 2023).

Chapter Four

Methodology

The previous third Chapter, *Literature Review,* provided a narrative summary of ED-relevant literature reporting on RS with NHF. This review focused particularly on NHF RS. Three NHF themes emerged from the review: mechanisms and benefits of action, physiological and clinical outcomes, and safety outcomes. This review exposed evidence and scholarship gaps for NHF in ED, confirming the significance of this doctoral research and ratifying its EBP framework and methodology.

The purpose of this fourth Chapter, *Methodology,* is to collectively describe the philosophical paradigm, the theoretical framework, research approach and strategy, the research design and the two methods used to ethically and reliably answer the six thesis questions.

The two overarching thesis questions were:

1. What is the nature of the NHF delivered to adults in the ED?
2. What influence does the delivery of NHF have on adult ED patient outcomes?

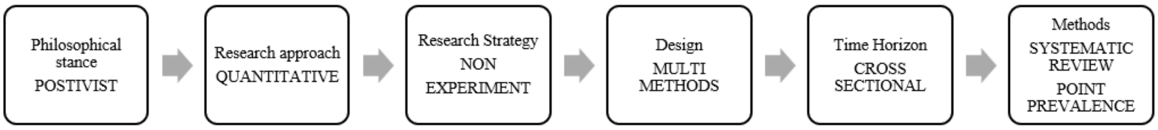
The four core thesis questions were:

1. Who receives NHF in the ED?
2. How is NHF therapy delivered in the ED?
3. Which patients receiving NHF require escalation of therapy in the ED?
4. What are the effects seen with NHF therapy on physiological and patient-centred outcomes?

These thesis questions informed decisions around the methodology. In this thesis, the philosophical paradigm was positivist, the research approach was quantitative, the research strategy was nonexperimental, the research design was multi-method, and the time horizon was cross-sectional. The two methods used were 1) a systematic review (SR) with meta-analysis (MA) and 2) a point prevalence study (PPS) (Figure 2).

Figure 2 (From Chapter One)

Thesis Research Methodology: An Overview of Methodological Components of the Thesis



Note. This figure demonstrates the six interlinked methodological components of the thesis

This fourth chapter has eight sections, with three included publications (O'Donnell et al., 2021b; O'Donnell et al., 2022; O'Donnell et al., 2023):

- Defining Elements: Epistemology, Ontology, and Axiology
- Research Theoretical Framework
- Research Design
- Research Methods
- Research Method One: The Systematic Review with Meta-Analyses. Including Publications: Protocol for Method One, SR (O'Donnell et al., 2021b), and Audit of Systematic Reviews (O'Donnell et al., 2023)
- Research Method Two: The Point Prevalence Study. Including Publication: Protocol for Method Two, PPS (O'Donnell et al., 2022)
- The Soundness of the Doctoral Research Methods
- Chapter Four Conclusion.

The methodological structure of the thesis comprises a series of interconnected elements (Figure 12). This structure reflects a framework first proposed by Crotty (1998) and is adapted here for this thesis. This chapter introduces these elements and contextualises the methodology.

Figure 12

Considerations and Elements Demonstrated in the Doctoral Research (adapted from Crotty, 1998)

Considerations	Elements Demonstrated
Epistemology	Objectivism
Ontology	Realism
Axiology	Beneficence
Philosophy	Positivist
Theoretical Framework	Evidence-Based

Note. This figure describes how the methodological considerations translate and are demonstrated within the thesis.

4.1 Defining Elements: Epistemology, Ontology, and Axiology

Paradigms are the philosophies of science guiding research through its ontological, axiological, and epistemological elements (Park et al., 2020). Ontology is the theory that concerns the nature of reality and what exists. Ontology reflects either *relativism* or, as in this research, *realism.* Here, reality can be understood; the questions are objective and ask who, how, what, and why. This research asked who receives NHF, how NHF is delivered, and what patient outcomes are seen. While ontology considers the nature of reality, epistemology considers how knowledge is conceived and the often value-laden relationship between the researcher, their research, and what is known (Denzin & Lincoln, 2008). However, knowledge acquisition for this research does not rely on the interpretation of values or moral content, which is more prone to be value-laden.

The epistemological acquisition of knowledge here is objectivist; as such, the researcher has no relationship with the research participants, who are ED patients. The final element, axiology, prescribes what is valued. The axiological position for this research, consistent with all ethical research methodologies, is beneficence. This protects research participants and their data from exploitation or harm (Barrow, 2023). Ensuring beneficence in this research setting is challenging, given that the ED patient population is inherently vulnerable. However, this research was entirely observational and was granted full ethical and multi-site locality approval (Appendices D & E). Collectively, the ontological, epistemological, and axiological elements of this objectivist doctoral research dictate its theoretical perspective or philosophy. The theoretical perspective shall now be presented.

4.2 Research Theoretical Framework

In research, the philosophical assumptions and theoretical framework provide the methodological foundations to legitimise the research questions, research design and methods (Holden & Lynch, 2004). A theoretical perspective or philosophy informs understanding, defines viewpoints, and promotes self-awareness for knowledge acquisition through research. Consequently, these founding philosophies must align with divergent researcher assumptions about truth and knowledge acquisition (Hitchcock & Hughes, 1995).

As explained in Chapter One, *Introduction*, the researcher's varied clinical, academic, and research background aligns with her positivist research philosophy for exploring cause and effect. This collective experience qualifies her understanding of issues of genuine clinical significance to the ED. The researcher has thoroughly considered the personal factors that shape her philosophical stance and, at times, felt self-conscious about her positivist philosophical paradigm, which is less common among nurse researchers (Corry et al., 2019). However, she recognises that the resolution of any research question depends on aligning the research methodology with its questions.

The evidence-based theoretical framework of this doctoral research is founded on positivism (Després, 2017). This framework informs clinical decisions to improve outcomes through the collective use of *best evidence, professional expertise*, and *consumer values*. The positivist paradigm has discernible links to ancient philosophical works, including the Sophist Protagoras (5th century BCE), the classical sceptic Septus Empiricus (3rd century CE), and Pierre Bayle (17th century), his reviver. William of

Ockham, a medieval nominalist, also exhibited parallels to contemporary positivism. In the 18th century, the German philosopher Georg Lichtenberg and his contemporaries emerged as a modern precursor to positivistic antimetaphysics. The associations between positivism and the French Enlightenment (‘Age of Reason,’ ‘Aufklärung,"siècle de Lumières’) are evident. The Enlightenment movement emphasised the clear light of reason and 18th-century British empiricism, with the works of David Hume and Bishop George Berkeley emphasising the significance of sensory perception.

Auguste Comte (1798–1857) was attributed as the first philosopher of science and the first to describe the positivist paradigm, founded within the scientific method of investigation. Comte was impacted by the Enlightenment Encyclopaedists’ (including Jean d’Alembert and Dennis Diderot) and, particularly, by Claude-Henri, Comte de Saint-Simon, the forefather of French socialism. Comte had been a disciple of Saint-Simon since his youth, and it is from him that the term “positivism” originates. The scientific method has been used to consider cause-and-effect associations and reflect gaining clinical knowledge; this method of enquiry has been in use since the 17th century.

Positivism refers to an evidence-based reality that is numerically described, thus reflecting the theoretical foundations of this study's EBP framework. The positivist rhetoric is precise, scientific, and presented objectively with unbiased and generalisable results (Macionis & Gerber, 2010). This positivist paradigm involves careful testing, examination, and questioning of what is observed, along with an appreciation of the impact of bias. In contrast, clinicians (including ED clinicians) have historically depended on expertise gained from traditionally handed-down experience, likely leading to poor patient outcomes (Kelly & Horsley, 1999). Increasingly, the scientific stance has become valued and motivated by the adoption of EBP (Titler, 2008). The positivist paradigm was selected because it aligns with the EBP theoretical foundation demonstrated throughout this thesis, particularly concerning the EBP component's *best evidence,* and *professional expertise*.

The positivist paradigm was the conceptual lens used by the researcher to underpin both the study's design and data analysis. Based on these assumptions, the positivist paradigm promoted applying two quantitative research methods. The positivist paradigm required precision in data collection, analysis, and interpretation. In addition, this paradigm provided an opportunity to define the relationships embedded within the data drawn from two methods reporting on RS with NHF in adult ED patients.

Positivism, however, has been critiqued. Opponents of the positivist paradigm suggest that study participants are controlled, dehumanised, and reduced to numerical data (Park et al., 2020). The opponents also agree that other ways of knowing exist, prompting the emergence of post-positivism and different paradigms. It likely reinforces the contribution of EBP frameworks, which reflect *consumer values* in conjunction with the *best evidence*.

The assumptions drawn from the positivist paradigm have validated the thesis methodology, where the positivist assumptions legitimised the processes and components of both studies and aligned them with the EBP framework (Park et al., 2020). For example, the choice of methods for both studies was defined by the type of questions considered. The study research design will now be presented.

4.3 Research Design

The research design refers to the practical means by which research achieves its aims to answer its research questions. Here, a multi-method method was selected. The multi-method design involves "the practice of employing two or more different methods or styles of research within the same study or research rather than confining the research to the use of a single method" (Hunter, A., & Brewer, J. D. 2015, p.185). Notably, there is a clear distinction between mixed methods, where both quantitative and qualitative methods are used, and multi-methods. The multi-method methodology allowed the researcher to *cast a wider net* and thus achieve diverse and comprehensive research findings (Kasirye, 2021). This required the researcher to be open to serendipity and aware of the strengths and weaknesses of the quantitative methods used.

The quantitative and qualitative methodologies have deductive or inductive diametric considerations, which inherently illustrate the reciprocity of the theory and research relationship. The typically inductive qualitative method collects data to inform theory development, whereas the deductive quantitative approach starts with theory and tests emergent hypotheses (Kim, 2021). The aims of this doctoral study and its thesis questions were mandated using a deductive multi-method research design using two quantitative methods. Deduction is rudimentary reasoning that begins with a statement or hypothesis and, through examination, reaches logical conclusions. Although the researcher did not test any hypothesis, all other aspects employed a two-step deductive approach completed in parallel. Quantitative data were reported from each method and then integrated to enable conclusions, thus reflecting a multi-method design. The perceived benefits of this research design for this thesis were an opportunity to complement a real-world method with a non-real-world method and a better chance to strengthen the applicability of the overall thesis conclusion. These two methods will now be presented.

4.4 Research Methods

The research method, or strategy, is how the researcher intends to perform the research. Two quantitative methods used in parallel in this doctoral research were a SR with MA and a PPS, which reported epidemiological patient data. The choice of these methods reflects the principles of EBP, whereby the SR of randomised controlled trials (RCTs) is acknowledged as the *best evidence*, and the PPS reports on real-world findings that may reflect the use of EBP, professional expertise and consumer values. Whilst these methods sit opposites in the EBP pyramid, they were deemed complementary and appropriate for co-investigating the patient-focused outcome—escalation of RS in the ED.

The research methods used here were nonexperimental and observational. Experimental and non-experimental methods differ in terms of researcher control and manipulation. In experimental techniques, the setting is prescribed, and variables of interest are controlled. The randomised RCT involves an experimental method; however, experimentation may sometimes be unnecessary, impossible, or inappropriate (Capili, 2021). The researcher deemed that a conventional 'head-to-head' RCT of NHF vs another form of RS is now likely unethical to many clinicians with demonstrated efficacy in related settings (Nishimura, 2015). In contrast to this PPS and other non-experimental observational studies, the ED is a real-world setting; variables are not controlled and are only observed. These features do limit the ability of nonexperimental and observational methods to demonstrate causality (Capili, 2021). However, the researcher and the Australian College of Emergency Medicine (ACEM) understand the contribution epidemiological studies may have. The ACEM has established an ED Epidemiology Network (EDEN) (ACEM), 2024). Real-world, real-time snapshots of truth gleaned from observational studies such as this PPS may inform future hypotheses that may be best tested using controlled methods (Eltorai et al., 2023).

The two methods supporting this doctoral study's methodology were formalised and published as individual research protocols (O'Donnell et al., 2021b; O'Donnell et al., 2023). Publishing these protocols preserves the novelty and transparency of the methods and provides an opportunity for peer review. The two study multi-method design methods, the SR with MA and PPS, will now be presented.

4.5 Research Method One: The Systematic Review with Meta-Analyses

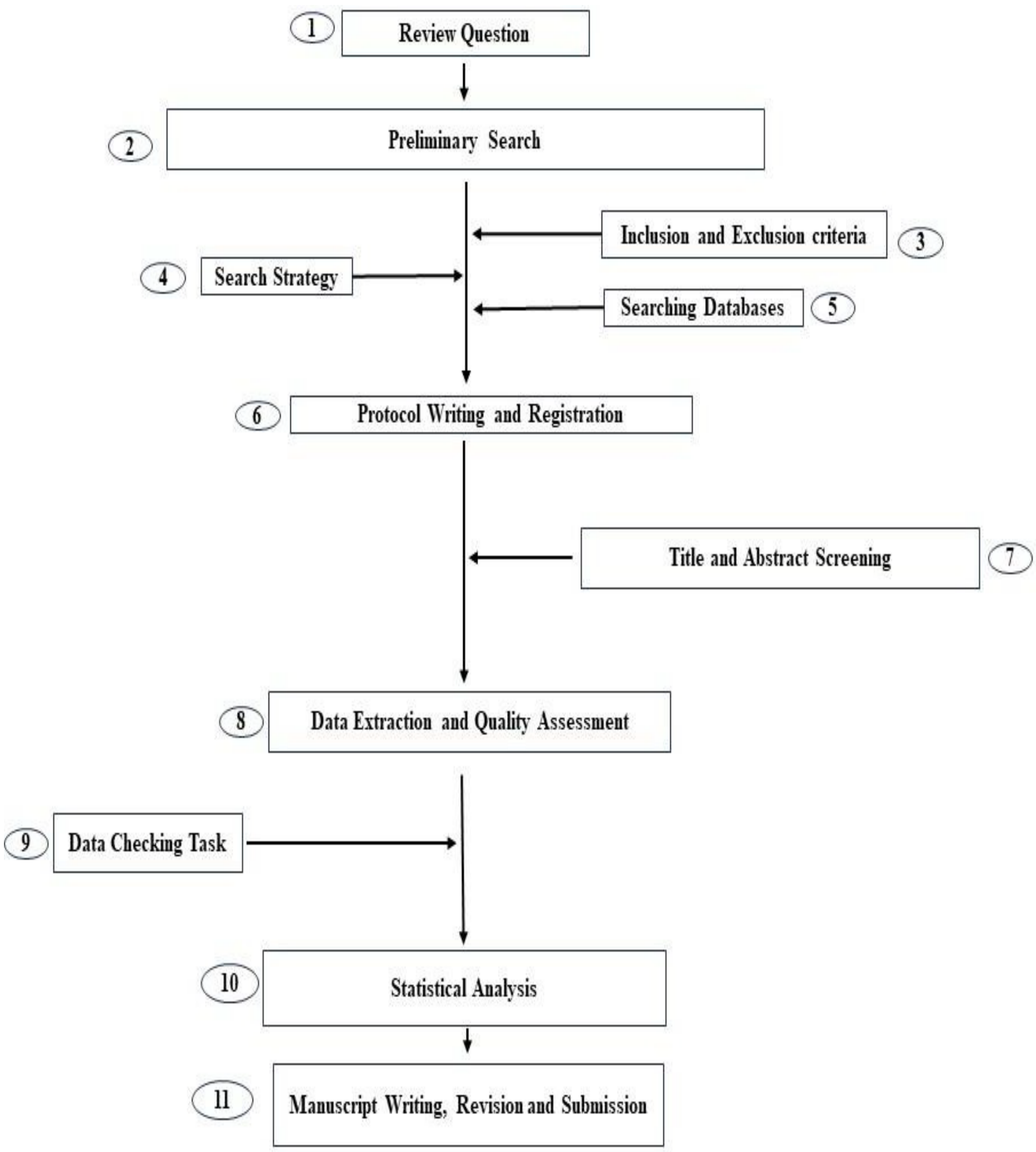
As previously said, the theoretical foundations of the SR with the MA method align with the EBP framework. This framework proposes that practice should encompass the most *current reliable evidence*, *professional expertise*, and *consumer values* (Melnyk & Fineout-Overholt, 2019). The framework EBP also proposes a hierarchy of evidence with the most reliable evidence; the SR with MA sits atop the hierarchy (Higgins, 2023). The SR is distinct from a narrative review. In contrast to the SR, the narrative review is not protocolised and does not synthesise primary data using meta-analyses (Jahan et al., 2016).

As with most primary quantitative research, SR methods are protocolised and reproducible. The SR authors follow a series of steps, beginning with developing a research question, then locating, appraising, and completing narrative synthesises of included evidence, all to answer the initial question (Tawfik et al., 2019). The time horizon for SRs was cross-sectional and reflects the evidence's availability at a given time; consequently, SRs must be updated as new evidence emerges. Some SRs include a MA when numerical data (sourced from the included evidence) are combined to report a treatment effect. Examples of treatment effects include the odds ratio (OR) and the relative risk (RR). The SR and the treatment effects they may report are often incorporated within guidelines and policies and may justify further primary research. Figure 13 provides an algorithm describing 11 SR steps; this algorithm and the 17-item PRISMA P checklist (Appendix F) were used to prospectively structure the SR protocol for this doctoral research (O'Donnell et al., 2021b). The PRISMA P checklist was introduced to improve transparency and accurate reporting in SRs, ultimately supporting evidence-based decision-making with the *best evidence*.

The aim of the SR protocol was to describe how the SR will be conducted, including the objective(s), design, methodology, statistical considerations and organisation of the SR to ensure the integrity of the data collected. The objective of the publication was to prospectively write and register the SR protocol on PROSPERO CRD42021222517. PROSPERO is an international database of prospectively registered SRs, mainly where health-related outcomes are reported. The rationale for this publication was to ensure the SR protocol had a permanent record. PROSPERO helps avoid duplication of SRs and minimises reporting bias by enabling peer review of the completed SR, primarily as described in the registered protocol. This publication was justified as it aligns with the doctoral research and its first method, the SR. Utilising the PRISMA checklist also better enabled the overall reporting quality of the SR. The protocol for the SR is now presented as published (O'Donnell et al., 2021b).

Figure 13

Eleven Systematic Review Steps (Adapted from (Tawfik et al., 2019))



Note. This figure depicts the typical steps undertaken to complete a systematic review.

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GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Jane O'Donnell
Name and title of main supervisor:	Professor Marlena Kruger
In which chapter is the manuscript/published work?	Chapter 4 Methodology SR & MA Protcocol

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

Conception and design: JOD Lead Author, PhD Candidate
Draft manuscript preparation: JOD
Review manuscript drafts : JOD, AP, EM, KH, RF.
All authors reviewed the results and approved the final version of the manuscript.

Please select one of the following three options:

(●) **The manuscript/published work is published or in press**

Please provide the full reference of the research output:

O'Donnell J, Pirret A, Hoare K, McDonald E, Fenn R. (2021b). Respiratory support strategies for adult emergency care patients: a systematic review and meta-analysis. PROSPERO PROTOCOL 2021 CRD42021222517 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD420212225

( ) **The manuscript is currently under review for publication**

Please provide the name of the journal:

( ) **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	Jane O'Donnell — Digitally signed by Jane O'Donnell Date: 2024.03.28 13:34:03 +13'00'	Main supervisor's signature:	Marlena Kruger — Digitally signed by Marlena Kruger DN: cn=Marlena Kruger, c=NZ, o=Massey University, ou=School of Health Sciences, email=m.c.kruger@massey.ac.nz Date: 2024.03.28 14:17:36 +13'00'

This form should be placed at the beginning of each relevant thesis chapter.

[1] Refer to the Massey University Publishing and Authorship guidelines (OneMassey for staff, Stream for students) and/ or Contributor Roles Taxonomy (CRediT) guidelines for guidance.

4.5.1 The Published Protocol for Method One: The Systematic Review with Meta-Analysis.

O'Donnell J, Pirret A, Hoare K, McDonald E, Fenn R. (2021b). Respiratory support strategies for adult emergency care patients: a systematic review and meta-analysis. PROSPERO PROTOCOL 2021 CRD4202122.

https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42021222517

Review Questions

- How does respiratory support with nasal high flow impact the need to escalate care compared to other forms of respiratory support in adult Emergency Care patients with or without COVID-19?
- How does respiratory support with nasal high flow impact mortality compared to other forms of respiratory support in adult Emergency Care patients with or without COVID-19?
- How does respiratory support with nasal high flow impact adverse events in adult Emergency Care patients compared to other forms of respiratory support with or without COVID-19?

Searches

The search strategies developed to search for evidence will use Medical Subject Headings and free-text words related to the keywords embedded within the SR PICO.

Population: Adult; Emergency Care

Intervention: High Flow Oxygen Nasal Cannula; Humidified Oxygen Therapy; Nasal

Comparisons: Continuous Positive Airway Pressure Ventilation; BiPAP; Oxygen Therapy

Outcomes: Escalation, Adverse Event, Mortality.

The search start dates will be restricted from January 2000 because, before 2000, NHF was not widely used in this cohort. Trials reported in English only shall be included.

The review authors shall search for evidence using customised strategies in five databases

- Cochrane Central Register of Controlled Trials (CENTRAL) in The Cochrane Library, including the Cochrane COVID-19 Register
- Ovid MEDLINE
- CINAHL, EBSCO host
- EMBASE, OvidSP
- ISI Web of Science (Appendix G).

The search strategy will incorporate the highly sensitive Cochrane search strategy for identifying RCTs (Randomized Controlled Trials) in CENTRAL, as described in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins, 2023).

Searches for other sources of evidence, including gray evidence or unpublished evidence. Examples of gray evidence include theses, research and committee reports, government reports, conference papers, and incomplete research. Gray literature may reduce publication bias and increase the SR's validity and reliability (Paez, 2017). Two electronic databases listing higher-degree theses shall be searched for relevant unpublished trials: Index to Theses (2000 to date) and ProQuest Digital Dissertations (2000 to date).

The following three conference proceedings shall be searched for unpublished evidence:

- European Society of Emergency Medicine (EUSEM)
- American College of Emergency Practice (ACEP)
- Australasian College of Emergency Medicine (ACEM).

Two clinical trial registries shall be searched for trials that are in progress:

- US National Library of Medicine. ClinicalTrials.gov
- International Clinical Trials Registry Platform (ICTRP) International Clinical Trials Registry Platform (ICTRP) (who. int).

Types of Study to be Included

Due to the current scarcity of RCTs conducted in the EC setting, a variety of evidence types will be included (Corbett et al., 2016). The eligible evidence for inclusion will be randomized controlled trials (RCTs), parallel, quasi-randomised trials and crossover RCTs. Quasi- randomization is regarded as non-true randomisation and allocation of trial participants into trial arms.

The eligible evidence must consider NHF and any combination of other nominated RS therapies: COT, CPAP, and BiPAP for the six primary and secondary outcome measures (need for escalation of care due to therapy failure in EC, rate of mortality in hospital, rate of AEs in EC, duration of RS in EC, hospital and EC length of stay, EC discharge destination).

Ineligible evidence types are:

- cluster-randomised trials
- retrospective studies
- prospective cohort
- observational studies
- case-control studies
- systematic reviews
- any evidence where there is ambiguity regarding the type of intervention or comparator.
- non-English studies
- animal or bench studies
- published before 2000
- reporting on neonates or paediatrics.

Condition or Domain Being Studied

Respiratory support (RS) is an umbrella term for a continuum of therapies provided to improve patients' outcomes with differing clinical acuities and in different settings, including emergency care (EC).

There are many varied RS therapies available. Respiratory support can be provided either in an invasive or non-invasive manner. Invasive ventilation RS. is not within the scope of this SR. Non-invasive methods of delivering RS include both variable-performance and fixed-performance therapies.

The need for RS is a leading cause for patients to present to EC. This requirement for RS may be due to a range of aetiologies, such as COPD (Chronic Obstructive Pulmonary Disease) or trauma. Patients receive RS to counteract the inadequacies of their oxygenation, ventilation, and work of breathing and to avoid lung injury. In addition, the COVID-19 pandemic sees patients present to the EC with a requirement for RS secondary to COVID-19 infection. There is an additional urgent need to complete this review to consider and compare the efficacy of the various RS provided to the adult EC population. The nature of the patients' presentation typically dictates the RS applied. Each form of RS has benefits and drawbacks, which determine their respective clinical efficacy.

Participants/Population

Spontaneously breathing adults with or without COVID-19 (>16 years) in EC who require respiratory support.

Participants:

- Age ≥ 18 years
- Acute respiratory failure without COVID-19
- Acute respiratory failure with COVID-19
- Respiratory rate < 15
- Respiratory rate > 30
- Intervention(s):
- NHF flow rates < 40L/min
- NHF flow rate > 40L/min
- NHF FiO_2 < 50%
- NHF FiO_2 > 50%.

Intervention(s), Exposure(s)

Nasal High-Flow Therapy (NHF) is a form of RS. It can deliver up to 60L/min of warmed and humidified air and oxygen blends via a bespoke nasal cannula. The gas flow rate (10 to 60 L/min), oxygen concentration (21-100%), and temperature (34-37°C) can each be independently titrated.

The four proposed means of action of NHF therapy are:

- Reduction of anatomical airway dead space (Moller et al., 2017)
- Delivery of dynamic, positive airway pressure (Corley et al., 2011)
- Airway hydration/humidification (Plotnikow et al., 2021)
- Accurate delivery of supplemental oxygen (Masclans et al., 2015).

The demonstrated physiological effects and clinical efficacy can be attributed to the mechanisms and benefits of action of this therapy. The improved physiological parameters include oxygenation, work of breathing, minute volume, respiratory rate and lung volume, dynamic lung compliance, transpulmonary pressure, and lung homogeneity (Mauri et al., 2017). It can be assumed that these physiological benefits positively impact clinical outcomes, such as a reduced need to escalate care. This therapy has been provided to EC patients with or without COVID-19.

Comparator(s)/Control

The comparators are other forms of respiratory support (i.e., either one or a combination of)

- conventional oxygen via nasal cannula or facemask 15 L/ min O_2 (COT),
- or continuous positive airway pressure (CPAP),
- or bilevel positive airway pressure (BiPAP)).

Both CPAP and BiPAP are both forms of non-invasive ventilation (NIV). These comparator interventions have been provided to EC patients with or without COVID-19.

Context

The context for this review is the spontaneously breathing adult patient (patients with or without COVID-19) in EC. These patients will require or receive NHF and one or a combination of the following forms of respiratory support: COT, CPAP, or BiPAP while in the EC. The term EC is regarded as synonymous with Accident and Emergency, Emergency Department, Emergency Room, and Casualty.

Main Outcome(s)

The three primary and three secondary outcomes for this review are both surrogate and clinical outcomes. By default, a need for RS may be indirectly associated with either an adverse event or a need to escalate care (Kelly et al., 2017). An adverse event (AE) is characterised here as unintentional harm arising from the care or services provided to the patient (Canadian Institute for Patient Safety, 2022). Escalation of care involves strategies to avoid clinical deterioration and possible death. In this SR, escalation is classified as the requirement to accelerate the RS delivered, such as from NHF to NIV or intubation. The clinical outcome failure of treatment is one of this SR's primary outcome measures.

The three primary outcomes for this SR are***:***

- A need for escalation of care due to therapy failure in EC
- Rate of mortality in hospital (up to 90 days)
- Rate of AEs in EC.

Three secondary outcomes for this SR are:

- Duration of RS in EC (hours)
- Hospital and EC length of stay (days)
- Emergency Care discharge destination (ward, home, ICU).

Measures of Effect

There is a need for escalation of care due to therapy failure in the EC. Categorical data shall be extracted for each intervention group, and relative risks (RRs) calculated. Rate of mortality in hospital (up to 90 days)

- Categorical data shall be extracted for each intervention group, and RRs calculated
- The rate of AEs in EC Categorical data shall be extracted for each intervention group, and the RRs will be calculated.
- For statistically significant RRs, the number needed to treat (NNT).
- For statistically significant RRs, the number needed to harm (NNH).

The 95% confidence interval (CI) shall be reported for all estimates. For all statistical analyses, a threshold of $p < .05$ shall be deemed a statistically significant threshold.

Additional Outcome(s)

- Duration of respiratory support
- Hospital and EC length of stay
- Emergency Care Discharge Destination.

Measures of Effect

Duration of RS in EC in hours Mean and standard deviation (SD) shall be calculated, and further analysis completed using weighted mean differences (WMDs). The mean and SD for hospital and EC length of stay in days will be calculated, and further analysis will be completed using WMDs. Emergency Care discharge destination: Categorical data shall be extracted for each intervention group, and risk differences (RDs) will be calculated. If different scales are used to measure the same continuous data across SMDs, will be calculated.

Data Extraction (Selection and Coding)

The review authors will extract and confirm relevant data from the evidence included on the Covidence platform. Any disagreement will be resolved through discussion. The subsequent trial and outcome data will be extracted and loaded onto the Covidence platform:

- Trial data
- First author
- Year of publication
- Trial design
- Trial region or country
- Trial population
- Patient baseline characteristics COVID-19 or not
- Intervention
- Comparisons
- Sample size.

Outcome data

Primary outcomes:

1. A need for escalation of care in EC;
2. Rate of mortality in hospital (up to 90 days);
3. Rate of AEs in EC.

Secondary outcomes:

1. Duration of RS in EC (hours);
2. Hospital and EC length of stay (days);
3. Emergency Care discharge destination (ward, home, ICU).

Risk of Bias (Quality) Assessment

Risk of bias assessment will involve five domains, which reflect the Cochrane risk of bias tool (Higgins, 2023).

- Random sequence generation (selection bias);
- Allocation concealment (selection bias);
- Blinding of outcome assessors (performance and detection bias);
- Incomplete outcome data, intention to treat (attrition bias);
- Selective reporting.

Trials would be assessed as having a low risk of bias if all of these areas were deemed to be adequate. Conversely, trials will be assessed as having a high risk of bias if one or more of these areas were deemed inadequate or unclear. Two review authors shall complete this process at the trial level; disagreements will be resolved by discussion. If more than ten trials are included, a funnel plot shall be constructed to check for publication bias. The results of the assessment will inform data synthesis.

Strategy for Data Synthesis

Where possible, per-patient data may be synthesised using pairwise MA. The MAs shall be completed using Rev Man 5.4.1. Grouping for MAs shall be according to the SR primary outcomes (the clinically significant outcomes). MA shall be conducted with >two or more trials available with equivalent populations and interventions. Data will be synthesised, including outcomes and summary effect measures. Risk ratios shall be used in the forest plots as the point estimate for dichotomous outcomes and WMD as the point estimate for continuous outcomes. The quality of the evidence shall be classified as low or high ROB. Low ROB evidence is adequate for all domains; otherwise, evidence shall be classified as high ROB.

Three forms of heterogeneity will be assessed:

1. Clinical heterogeneity (of participants, interventions, and outcomes) assessed by the authors and their clinical judgement;
2. Methodological heterogeneity assessed during the ROB evaluations and visual examination of MA forest plots;
3. Statistical heterogeneity with I^2 statistic, χ^2 test, p values, and CI intervals.

The χ^2 test for homogeneity has low power when the number of trials included in MA is small; probability shall be set at a 10% significance level. Heterogeneity shall be classified with an I^2 statistic: 0% to 40%, not important; 30% to 60%, moderately important; 50% to 90%, substantially important; and > 90%, considerably important (Higgins, 2023). The I2 statistic shall be used to determine if the pooling of data is valid.

Both fixed-effect (FE) and random-effects (RE) models for MA shall be used, the most conservative results being regarded as the main results. The treatment effect across studies will be estimated using the FE or RE model, and the FE model will be used if it is reasonable to assume that studies estimate the same underlying treatment effect. Statistical significance shall be assumed at an alpha of $p < 0.05$.

Analysis of Subgroups or Subsets

Clear definitions of which types of study or individual will be included in each group (e.g., study design such as randomised/non-randomised trial, intervention type such as high flow/low flow gas, participant characteristics such as male/female)

Details of the planned analytic approach (e.g., meta-regression, tests of interaction between groups, logistic regression using individual-level data). Where applicable, this should include details of statistical models to be used. Where sufficient data permits, a subgroup analysis of the participant and intervention data shall be completed. Subgroup analyses shall be used to assess the potential impact of bias on the review findings.

Patients who require escalation of care are known to require more oxygen and have a higher respiratory rate, which justifies investigating these elements in a subgroup analysis (Roca et al., 2019).

Contact details for further information: Jane ODonnell j.f.odonnell@massey.ac.nz

Organisational affiliation of the review: Massey University https://www.massey.ac.nz/

Review Team Members and Their Organisational Affiliations

- Mrs Jane O'Donnell. Massey University
- Dr Alison Pirret. Massey University
- Professor Karen Hoare. Massey University
- Assistant/Associate Professor Elissa McDonald. Massey University
- Rebecca Fenn. Middlemore Hospital

Type and Method of Review

Intervention, Systematic Review. The anticipated start date is 19 March 2021, and the anticipated completion date is 30 April 2022.

Funding Sources/Sponsors None Conflicts of Interest

The lead author was once employed by a company that manufactures NHF, and the second author has received speaking fees and expenses from a company that manufactures NHF.

Language: English

Country: New Zealand

4.5.2 Systematic Review with Meta-Analysis - Quality Considerations

Like all forms of research, the quality of some published SRs may be questionable. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist was developed in 2009 to guide authors in optimising SR reporting quality (Page et al., 2021) (Appendix F). The PRISMA checklist provides reporting guidance for SR methods that best locate, choose, appraise, and synthesise studies; this checklist was used to optimise the quality of the SR completed in the first method of this doctoral research (Appendix F).

For SRs of ED evidence, the lack of robust RCTs and the homogeneous ED patient population likely impact their reliability. Compelled to consider this further, the researcher audited the quality of reporting of a subset of ED SRs (O'Donnell et al., 2023). Two blinded authors retrospectively appraised the reporting quality of 17 ED SRs published until 2022. The scoring involved using the PRISMA 2020 27-point checklist (Page et al., 2021) (Appendix F). Each SR's reporting quality (adherence to the checklist) was scored out of 27 (Appendix F). No cut-off score was used to define adherence to the checklist. The results were presented in a narrative format with frequency data (*n* and %); continuous score data was presented as means with standard deviations. The results of this audit were as published (O'Donnell et al., 2023).

The aim of the publication was to use the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist to evaluate the reporting quality of selected ED NHF SRs (Appendix F). The objective was to present the findings of an audit of published SRs at the American College of Emergency Medicine (ACEM) annual conference in the USA in 2023 and to support the improved quality of SR reporting and EBP. The rationale for this audit was consistent with the EBP theoretical framework supporting this thesis, with an informal appraisal of the *best evidence* and a prospective aim to raise awareness around reporting quality for the new evidence generated from this first method of this doctoral research. This publication aligns with the first method of this doctoral research, the SR. This publication demonstrates the application and utility of the PRISMA 2020 27-point checklist both in this audit and for the SR completed in this thesis. The audit is now presented as published (O'Donnell et al., 2023).

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STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Jane O'Donnell
Name and title of main supervisor:	Professor Marlena Kruger
In which chapter is the manuscript/published work?	Chapter 4 Methodology

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

Conception and design: JOD Lead Author, PhD Candidate
Draft manuscript preparation: JOD
Review manuscript drafts : JOD, AP, EM, KH
All authors reviewed the results and approved the final version of the manuscript.

Please select one of the following three options:

- (●) **The manuscript/published work is published or in press**

  Please provide the full reference of the research output:

  O'Donnell, J., Pirret, A., Hoare, K., & McDonald, E. (2023). An Evaluation of the Reporting Quality of Emergency Room Systematic Reviews. ACEP Research Forum. Annals of Emergency Medicine, 82(4), A1-A2. https://doi.org/10.1016/s0196-0644(23)01217-9

- ( ) **The manuscript is currently under review for publication**

  Please provide the name of the journal:

- ( ) **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	Jane O'Donnell — Digitally signed by Jane O'Donnell Date: 2024.03.28 13:34:03 +13'00'	Main supervisor's signature:	Marlena Kruger — Digitally signed by Marlena Kruger DN: cn=Marlena Kruger, c=NZ, o=Massey University, ou=School of Health Sciences, email=m.c.kruger@massey.ac.nz Date: 2024.03.28 14:17:38 +13'00'

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1

Doctoral Research Committee
May 2023

4.5.3 The Published Audit of Systematic Reviews.

O'Donnell, J., Pirret, A., Hoare, K., & McDonald, E. (2023). ACEP Research Forum. *Annals of Emergency Medicine*, *82*(4), A1-A2. https://doi.org/10.1016/s0196-0644(23)01217-9

Objectives

Numerous studies have demonstrated the efficacy of nasal high-flow (NHF) therapy in many settings, including the emergency room (ER). Systematic reviews (SR) and meta-analyses (MA) of these studies have now emerged, particularly since the arrival of COVID-19. Accurately reported SRs and MAs can influence ER patient-centred outcomes.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist was developed in 2009 to guide SR reporting quality (Page et al., 2021). This evaluation used the PRISMA checklist to assess the reporting quality of selected ER SRs (Appendix F).

Methods

A search for SRs comparing NHF to other forms of respiratory support in adults was completed. A low-sensitivity search strategy was employed to capture the subset of these SRs reporting on ER patient-centred outcomes across the wide-ranging ER context. Three databases, PubMed, the Cochrane Database of Systematic Reviews, and SCOPUS were searched from NHF inception to April 2023. The evaluation of reporting quality was completed by two authors using the PRISMA 2020 27-point checklist (Page et al., 2021) (Appendix F). The reporting quality (adherence to the checklist) of each SR was scored out of 27 (Appendix F). The continuous score data were presented as means with standard deviations.

Results

The search revealed 113 SRs. Based on the individual SR inclusion criteria, 17 of the 113 were assessed as ER-relevant; notably, three of these 17 had an exclusive ER focus (Bocchile et al., 2018; Cabrini et al., 2018; Huang et al., 2019; Huang et al., 2020; Lee et al., 2016; Leeies et al., 2017; Lin et al., 2017; Maitra et al., 2016; Marjanovic, Guénézan, et al., 2020; Peng et al., 2022; Rochwerg et al., 2019; Sklar et al., 2018; Tinelli et al., 2019; Wang et al., 2020; Yue et al., 2017; Zhao et al., 2017; Zhu et al., 2017). The reporting quality of these 17 SRs was evaluated.

The 17 included SRs were published between 2016 and 2022. The majority of these (*n* = 5, 29 %) were published in 2017. Sixteen were SRs with MA. Ten SRs (*n* = 10, 58 %) exclusively included RCTs. It was unclear whether a statistician had been involved in most SRs. The SRs were authored in seven countries. The primary outcomes considered were care escalation, intubation and reintubation rates, and mortality. The patient profiles were all forms of respiratory failure, peri-intubation, immunological compromise, and COVID-19. All SRs proposed further research is required.

Adherence to the PRISMA checklist was implied in 11 (64%) SRs, with one fulfilling all elements of the checklist. The overall mean PRISMA checklist elements achieved was 23 ± 3.31. However, the mean elements achieved for SRs adhering to the PRISMA checklist were 24 ± 1.84 versus 2 ± 4.19 not adhering; 95% CI, -6.08 to 0.08; *p* = 0.06. While better reporting was not demonstrated with checklist adherence, the data describing individual checklist items warranted attention.

Reporting quality was lowest for:

- Data availability (*n* = 3, 17%)
- Data items (*n* = 5, 29%)
- Support (*n* = 7, 41%)
- SR protocol (*n* = 8, 47%)
- Search strategy (*n* = 7, 41%)

In contrast, the reporting quality was highest for the abstracts, information sources, study characteristics and their conclusions, interpretation of results, and summary of evidence (*n* = 17, 100%).

Conclusions

This evaluation considered reporting quality alone. Nonetheless, adherence to the PRISMA checklist indirectly improves study quality. The quality of reporting of ER SRs and MAs was previously evaluated before the 2020 update of the PRISMA checklist (Page et al., 2021) (Appendix F).

These findings again suggest that the quality of reporting of ER SRs and MAs must be improved. Evaluations of reporting inform the interpretation of the quality of all types of evidence. These findings may help inform research prioritisation in the ER.

4.6 Research Method Two: The Point Prevalence Study

As per the multi-method design, the second method was the Point Prevalence Study (PPS). A PPS describes the real-world prevalence of characteristics within a defined population and point in time (Eltorai et al., 2023). Researchers study a sample deemed representative of an entire population, a prevalence snapshot (Black, 1996). These epidemiological studies are scientific, systematic, and observational (Capili, 2021). Before the COVID-19 pandemic, epidemiological methods had been trivialised (Nature Communications, 2018). The utility of this method was demonstrated when epidemiological data were used to inform strategies designed to minimise the COVID-19 impact (Nature Communications, 2018).

The PPS was the second quantitative method undertaken to understand and estimate the prevalence of escalation of RS in the ED. Because escalation of RS may relate to clinician *professional expertise* or *consumer values*, reporting on the second method also reflects the EBP framework of this thesis as described in Figure 1, Chapter One.

Figure 1 (From Chapter One)

The Evidence-Based Practice Framework and its Component Parts.

Note. The EBP framework describes the conscientious use of current best evidence in conjunction with professional expertise and consumer values to inform clinical decisions. The EBP Framework and its Component Parts (adapted from Sackett, 2000).

The PPS method used cross-sectional time horizons where epidemiological data were obtained at a specific time. The prospective time horizon for the PPS was two 12-hour intervals, each separated by four weeks. Based on NZ Government reports, the days (Mondays and Sundays) and the time intervals were predicted to provide the best opportunity to capture a representative sample while causing the least disruption to the four participating EDs (MOH, 2015).

Considerable logistical hurdles were overcome before the conduct of the study; these included:

- Consultation with numerous stakeholders, including senior ED clinicians, hospital management, and local iwi;
- Development and piloting of all study materials, including training material with senior ED clinicians (Appendices H & I);
- Human resourcing, funding, and induction of the data collectors, e.g., REDCap, ISO, and GCP (Appendices A, B, & J);
- Gaining all the required approvals and credentials, e.g., ethics, hospital IT, hospital policy, locality approval (Appendices D & E);
- Contingency planning.

The aim of this publication was to describe the protocol, which details how the PPS was going to be conducted to ensure the integrity of the data collected and the protection of the study participants. The objective was to prospectively register the PPS on a clinical trial database registration number ACTRN12621001167853 (O’Donnell et al., 2021c) and prospectively formalise and publish the protocol in a peer-reviewed journal (O'Donnell et al., 2022). As study protocols, when published, are permanent records, the rationale for the publication was to help avoid duplication of study methods and minimise reporting bias by enabling peer review of the completed study, as described in the registered and published protocol. This publication aligns with the second method of doctoral research, the PPS. Publication of this protocol is consistent with good clinical research practice (GCP). The protocol for the PPS is now presented as published (O’Donnell et al., 2022).

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STATEMENT OF CONTRIBUTION
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We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Jane O'Donnell
Name and title of main supervisor:	Professor Marlena Kruger
In which chapter is the manuscript/published work?	Chapter 4 Methodology Point Prevalence Study Protocol

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

Conception and design: JOD Lead Author, PhD Candidate
Draft manuscript preparation: JOD
Review manuscript drafts : JOD, AP, EM & KH.
All authors reviewed the results and approved the final version of the manuscript.

Please select one of the following three options:

(●) **The manuscript/published work is published or in press**

Please provide the full reference of the research output:

O'Donnell, J., Pirret, A., Hoare, K., & McDonald, E. (2022). Respiratory support of adults in the emergency department: A protocol for a prospective, observational, multicenter point prevalence study. Health Science Reports, 6(1), e966. https://doi.org/10.1002/hsr2.966

( ) **The manuscript is currently under review for publication**

Please provide the name of the journal:

( ) **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	Jane O'Donnell Digitally signed by Jane O'Donnell Date: 2024.03.28 13:34:03 +13'00'	Main supervisor's signature:	Marlena Kruger Digitally signed by Marlena Kruger Date: 2024.03.28 14:17:38 +13'00'

This form should be placed at the beginning of each relevant thesis chapter.

[1] Refer to the Massey University Publishing and Authorship guidelines (OneMassey for staff, Stream for students) and/ or Contributor Roles Taxonomy (CRediT) guidelines for guidance.

4.6.1 The Published Protocol for Method Two: The Point Prevalence Study.

O'Donnell, J., Pirret, A., Hoare, K., & McDonald, E. (2022). Respiratory support of adults in the emergency department: A protocol for a prospective, observational, multicenter point prevalence study. *Health Sci Rep*, *6*(1), e966. https://doi.org/10.1002/hsr2.966

Abstract

Background and Aims.

Providing respiratory support (RS) to patients may improve their oxygenation and ventilation, reducing the work of breathing. Emergency department (ED) patients often need RS; COVID-19 has heightened this need. Patients receiving RS may need escalation of their treatment; hence, studies considering the prevalence of escalation are warranted.

Method.

This is a protocol for a prospective, observational, multicenter point prevalence study (PPS). Researchers will collect data over two days. All participants are adult ED patients needing RS. The setting is four EDs in New Zealand. The primary research question asks, "*Which patients receiving RS require escalation of therapy in the ED?*"

For example, transitioning from conventional oxygen therapy (COT) to intubation is deemed an escalation of therapy. To resolve the primary research question, a sample size of 80 participants is required.

Secondary research questions:

1) Which patients receive nasal high flow (NHF) in the ED?
2) How is NHF therapy delivered in the ED?
3) What are the effects of NHF therapy on physiological and patient-centered outcomes?

Research Electronic Data Capture (REDCap) will be used for data organization. Data will be imported for analysis from REDCap to IBM SPSS software (Statistics for Windows, Version 27.0). Data reporting on the primary outcome shall be considered by analysis of variance, regression modelling, and determination of two treatment effects: odds ratio (OR) and number needed to treat (NNT). Statistical significance for inferential statistics shall use a two-sided α with *p*-values fixed at ≤ 0.05 level of

significance and 95% confidence intervals. This protocol has ethical approval from Massey University, New Zealand (22/18).

Conclusion.

This novel PPS may reduce the evidence and clinical practice gap on RS delivery and ED patient outcomes, as evidenced by the emergence of COVID-19.

Keywords.

COVID-19, emergency, nasal high flow, point prevalence, respiratory support.

Introduction Background

Many emergency department (ED) patients require respiratory support (RS) to optimize their oxygenation and limit the likelihood of requiring escalation of their care. However, the effects of escalating care include an increase in morbidity and mortality risk. The limited availability of evidence focusing on RS delivery in the ED justifies an investigation. This protocol has been developed to facilitate an observational multicentre point prevalence study (PPS).

Patients reporting to the ED often need RS (Marjanovic, Guénézan et al., 2020). These RS therapies can decrease the work of breathing (Raven et al., 2013). Many of these presenting patients also have chronic respiratory disease (Kelly et al., 2017); however, acute ED patients may also need RS, such as patients with trauma, infection, or those experiencing side effects of other interventions (Marjanovic, Guénézan, et al., 2020).

RS is an umbrella term for a collection of therapies. The collection includes conventional oxygen therapy (COT), also referred to as standard oxygen therapy (using traditional masks and cannulae); nasal high flow (NHF); non-invasive (NIV); and invasive ventilation (INV). Clinicians provide RS therapies either in an invasive or NIV manner. Invasive RS involves intubation and mechanical ventilation. NIV RS includes COT, NHF, and two forms of NIV: bilevel positive airway pressure and continuous positive airway pressure.

Several of these RS therapies are in use in the ED. The most novel of these RS therapies is NHF, which is the focus of this study (Ischaki et al., 2017). NHF RS provides high flows of warmed, humidified gas (at up to 60 L/min) (Ischaki et al., 2017). Gas temperature (31-37°C), gas flow (2-60 L/min), and the inspired oxygen fraction (FiO_2) (21%-100%) are independently titrated. The delivery of gases to spontaneously breathing patients is via specialized nasal cannulae (Mauri et al., 2017). Despite the lack of reliable and valid evidence, the use of this RS therapy in the ED is widespread (Rochwerg et al., 2019).

Clinicians accept that improved patient outcomes rely on evidence-based care (Titler, 2008). However, since 2000, the adult NHF evidence and NHF use have accelerated disproportionally. To date, PubMed has indexed more than 3900 NHF publications. Yet, most of these NHF publications are case reports or observational studies with an intensive care focus (Rochwerg et al., 2019). Hence, ED clinicians have limited NHF-controlled studies to inform their clinical practice (Ruiz et al., 2016). The limited availability of reliable and valid evidence provides the rationale for this study.

The first NHF-controlled study reported that NHF could reduce respiratory rates of ED patients (21 -28 breaths/min) (p < 0.001) (Lenglet et al., 2012). Two later studies confirmed Lenglet's findings, suggesting the efficacy and feasibility of NHF in the ED (Bell et al., 2015; Makdee et al., 2017). These controlled studies have motivated completing a New Zealand randomized controlled trial (RCT).

The New Zealand study was the first large ED RCT that compared NHF to COT (Jones et al., 2016). The primary study outcome was a need for escalation to NIV or INV. The study identified no difference in the need for escalation between NHF (3.6%, 95% CI, 1.5 to 7.9) and COT (7.3%, 95% CI, 3.8 to 13) (p = 0.16).

Nevertheless, this study was underpowered, with 40% of the target sample recruited. Even so, the researchers concluded that NHF did not reduce the need for escalation to NIV or INV compared to COT. Researchers involved in this initial RCT have subsequently completed a multicenter ED PPS based in the Asia-Pacific region. The PPS described the epidemiology of 3044 patients experiencing dyspnea (Kelly et al., 2017). The authors of this PPS confirmed that ED patients often present with dyspnea in this region. However, despite these efforts, large gaps remain in the evidence describing RS delivery and patient outcomes.

Despite the lack of high-quality primary ED evidence, several NHF systematic reviews have now been published (Huang et al., 2019; Marjanovic, Guénézan et al., 2020). But, the lack of valid and reliable evidence has then impacted the validity and reliability of these reviews, limiting their applicability in clinical practice and research (Huang et al., 2019). This proposed PPS is novel and may reduce the evidence and clinical practice gap regarding RS delivery and ED patient outcomes, as evidenced by the emergence of COVID-19 (Liu & Cheng, 2022).

Study Objectives and Aims

All research should look to inform clinicians and improve patient outcomes. To achieve this, researchers must explore outcomes of clinical significance (Heneghan et al., 2017). This proposed research aims to examine the nature of RS delivered in the ED and its influence on the escalation of therapy in the ED. As such, the outcomes of this study will have clinical significance.

The primary research question is:

- Which patients receiving RS require escalation of therapy in the ED?
- Also, three secondary research questions focus on the RS NHF:
- Which patients receive NHF in the ED?
- How is NHF therapy delivered in the ED?
- What are the effects of NHF therapy on physiological parameters and escalation of therapy?

Methods

Study Design.

This study design is a prospective, observational multicenter PPS. Of note, the researchers acknowledge that the RCT is the gold standard when considering the efficacy of any therapy, including NHF therapy (Akobeng, 2005). But, as NHF therapy has become ubiquitous, undermining the ethics of conducting RCTs involving NHF (Ricard et al., 2020), the researchers are convinced that an observational research design selection is now ethically validated (Faraoni & Schaefer, 2016). Furthermore, this observational PPS design enables rapid and reliable data collection from a large ED patient cohort (Creswell & Creswell, 2017). Finally, this protocol describes the planned observational multicenter PPS.

Study Setting.

This study is set in New Zealand EDs. The researchers are aware of the importance of study selection. Poor site selection can undermine the reliability of a study and even threaten its completion (Hurtado-Chong et al., 2017). Therefore, the researchers selected four New Zealand EDs. Two participating sites are tertiary referral EDs in a large metropolitan city, and two are regional EDs in smaller cities. Data collection is due to be completed by December 2022.

Study Conditions.

This is an observational multicenter PPS. There are no study controls. Experimental conditions are not applied in this study.

Study Participants.

Establishing an appropriate target population must align with the study outcomes under consideration (Heneghan et al., 2017). Therefore, the target population is ED patients 18 years of age or older who require RS. These patients may have respiratory insufficiencies or have side effects related to other interventions (Marjanovic, Flacher et al., 2020). This population aligns with the study outcomes.

Study Participant Recruitment.

The methods used in this study mean that participants do not need active management postinclusion, unlike in the RCT (Faraoni & Schaefer, 2016). Instead, the data collectors shall use predetermined inclusion criteria to screen potential participants for inclusion (Table 13). The data collectors shall document the screening process in a screening log.

Table 13

Point Prevalence Study: Screening Criteria

Inclusion criteria	Exclusion criteria
ED[a] patients aged ≥ 18 years needing any form or combination of RS[b] (via COT[c], NIV[d], NHF[e], BiPAP[f], CPAP[g], and or INV[h]) during one of the two study intervals	ED[a] patients aged ≥ 18 years not needing any form or combination of RS[b] (via COT[c], NIV[d], NHF[e], BiPAP[f], CPAP[g], and or INV[h]) during one of the two study intervals

Note. [a] ED = emergency department; [b] RS = respiratory department; [c] COT = conventional oxygen therapy; [d] NIV = non-invasive ventilation; [e]NHF = nasal high flow; [f]BiPAP = bilevel positive airway pressure; [g]CPAP = continuous positive airway pressure; [h] INV = invasive ventilation.

Researchers shall collect data for every ED patient meeting the criteria for inclusion during two prespecified 12-hour data collection periods, each separated by four weeks (Table 14).

Table 14

Point Prevalence Study: Study Data Categories

Categories of data captured in the Screening Log	Categories of data captured eCRFa part A	Categories of data captured eCRF part B.
Screening log number	Comorbidities	NHF[b]-related AE[c] in ED[d]
NHI[e]	Medications (usual)	Duration of NHF in ED
Name (surname first)	Mode of arrival to ED	Requirement for escalation of RS[f] in ED
Age (Years) Gender	Prehospital treatment by ambulance Initial	Rationale for escalation of RS Type
M, F, Other	treatment in the ED	of escalation of RS
Date screened for inclusion DD/MM/YY Ethnicity	Initial ED assessment	NHF data (physiological outcomes, therapy delivery)
Time screened for inclusion. Included Y	Treatment in ED after 1st assessment ED	
or N	diagnosis	
Reason excluded A or B Participating	Cause of RS requirement in ED ED	
hospital	discharge destination	
ED & 30-day data collection complete COVID-19	Final hospital discharge date (LOS)[g] Final	
status	hospital discharge diagnosis	
COVID 19 vaccination status		

Note. [a] eCRF = electronic case report form; [b] NHF = nasal high flow; [c] AE = adverse event; [d] ED = emergency department; [e] NHI = national health index number; [f] RS = respiratory support; [g] LOS= length of stay.

Protection of Study Participants.

All participants in clinical research need to be protected. The International Council for Harmonization guideline (International Conference on Harmonisation of technical requirements for registration of pharmaceuticals for humans, 2001) "Technical Requirements for Pharmaceuticals for Human Use" proposes that the risks and benefits of a study must be evaluated and justified before a study begins. The researchers have assessed the risks and benefits of this study. This PPS observes ED standard clinical practice. The study has no experimental intervention or additional data collection. Therefore, the researchers have determined that this study poses no additional risk or benefit to the participants. As this study observes standard practice, researchers or data collectors shall not seek participant informed consent. The data collected shall be deidentified, kept confidential, and not used in ancillary studies.

The proposed study has gained full ethical approval (reference number: NOR 22/18) from the Massey University New Zealand Ethics Committee (Appendix E). In addition, the researchers shall procure the appropriate hospital site-specific locality approvals.

The researchers will uphold transparency. The research protocol is available on a clinical trial registry (ACTRN12621001167853p U1111-1262-086) (Appendix K). Furthermore, the researchers shall present the findings of this study at national and international conferences. Also, the researchers shall publish the study findings in peer-reviewed quartile one journals. The researchers listed in this protocol are responsible and eligible for authorship. Finally, the researchers shall report the study findings to hospital representatives.

Study Procedures.

Appraisals of observational studies often question their validity and reliability based on the usual lack of available detail regarding study procedures (Vandenbroucke et al., 2007).

In contrast, peer review and publication of this study protocol shall provide the details for the proposed PPS procedures. This peer-reviewed published protocol will support the appraisal of the PPS when completed.

This study has three procedural phases. The first phase is prestudy, the second is data collection, and the final phase is analysis and completion. Each study phase has five procedural steps (Figure 14). The researchers shall complete the study phases and steps in sequence. The guidelines provided by Assel et al. (2019) and Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) (Vandenbroucke et al., 2007) were both used by the researchers while developing this protocol (Appendix M).

Figure 14

Point Prevalence Study: Three Study Procedural Phases

Phase	Procedure
1. Pre-Study	Study protocol developed and approved eCRF[a] developed and piloted Study sites confirmed Ethics and locality approvals gained Funding confirmed Data collectors recruited and trained
2. In Study Data Collection	ED patients screened Participants recruited Data collection day one Data cleaning Data collection day two Data cleaning
3. Study Completion & Data Analysis	eCRF data checked, cleaned and anonymised Data queries resolved Data analysed Research findings reported

Note. [a]eCRF = electronic case report form

Study Data Collection.

Inaccurate data collection may invalidate the findings of a study (Yang et al., 2012). The researchers are responsible for all aspects of data collection and management. To ensure the rigor of the data collection, dedicated data collectors shall be trained and resourced at each site.

During each data collection period, data collectors must screen and include study participants using the inclusion criteria (Table 13). Also, data collectors shall allocate a unique study number (USN) to each included study participant.

These USNs shall help protect the participants' anonymity. In addition, data collectors shall document the screening process and the allocated USN in an electronic screening log. Also, data collectors shall complete one (Parts A and B) electronic case report form (eCRF) per

study participant. The eCRF is purpose-built and piloted to capture all study data (Appendix H). The researchers have no plans for external data monitoring or interim analyses. Thus, guidelines for the early termination of the study due to safety concerns are not required for this study.

Handling of Missing Study Data

Missing study data can undermine a study's findings (Heneghan et al., 2017). The PPS design maximizes an opportunity for data collection while reducing the risk of missing data. The descriptive analysis shall also identify any missing data. The strategy for dealing with missing data will be to use a process of regression imputation (Jakobsen et al., 2017). This strategy involves the replacement of missing data with estimated values. This strategy shall ensure the maintenance of the study sample (Kang, 2013).

Study Data Security Procedures.

The researchers and data collectors must maintain the security of all study data (International Conference on Harmonisation of technical requirements for registration of pharmaceuticals for human, 2001). The security measures meet the requirements of the approving ethics committee and the participating hospitals. The secure internet-based application Research Electronic Data Capture (REDCap; project-redcap.org) shall host the screening logs and the eCRFs. Researchers shall have access to the eCRFs data alone. All electronic devices that collect and send data will be password protected and shall have additional firewall security.

Study Variables.

Establishing the appropriate outcome variables requires alignment with the study objectives and questions (Heneghan et al., 2017). The study considers one primary and three secondary questions. The study outcome variables support the four research questions (Vetter & Mascha, 2017).

Each research question involves composite variables comprising several normally correlated outcome variables (Vetter & Mascha, 2017). Table 15 positions each research question with the respective outcome variables, data types, and data collection time points.

Table 15

Point Prevalence Study: Research Questions, Outcome Variables, Data Types, and Data Collection Time Points

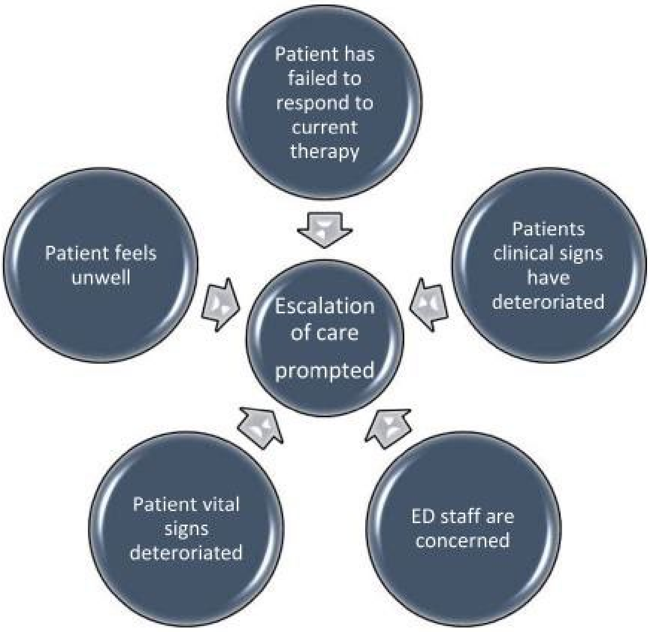
Research Question(s)	Outcome Variables	Data Types	Data Collection Time Points
Primary	Requirement for escalation of care[c]	Dichotomous	While in ED
Which patients in ED[a] receiving RS[b] require escalation of care	ED Diagnostic category	Categorical	
Secondary	ED Diagnostic category	Categorical	While in ED
Which patients in ED receive NHF[d] RS	Duration of RS in hrs	Continuous	
	Type of RS	Categorical	
What are the effects seen with NHF delivery?	Hospital mortality	Dichotomous	This hospitalisation
	ED mortality	Dichotomous	While in ED
	AE[e] in ED	Dichotomous	While in ED
	Hospital LOS[f]	Continuous	This hospitalisation
	ED LOS hours	Continuous	While in ED
	ED discharge destination	Categorical	While in ED
	Physiology SpO_2[g]	Continuous	While in ED
	Physiology BR[h]	Continuous	While in ED
	Physiology PR[i]	Continuous	While in ED
How is NHF delivered in the ED?	Duration	Continuous	While in ED
	Flow rate	Continuous	
	FiO_2[i]	Continuous	

Note. [a]ED= emergency department; [b]RS= respiratory support; [c]escalation of care, see figure 16; [d]NHF= nasal high flow; [e]AE= adverse event, an event in which care resulted in an undesirable clinical outcome or outcome not caused by underlying disease that prolonged the patient stay, caused permanent patient harm, required life-saving intervention, or contributed to death; [f]LOS=length of stay; [g]SpO2=oxygen saturation; [h]BR=breath rate; [i]PR=pulse rate.

The primary research question is, *"Which patients receiving RS require escalation of therapy in the ED?"* Often, in ED, one or more escalation triggers indicate a need for escalation of patient care. So, the primary question considers whether a patient meets the threshold for escalation by meeting one or more of the nominated triggers for escalation (Figure 15).

Figure 15

Triggers for Escalation of Care in the Emergency Department



The three secondary questions lend supporting evidence to the primary question. The three questions are:

1. Which patients receive NHF in the ED?
2. How is NHF therapy delivered in the ED
3. What are the effects of NHF therapy on physiological and patient-centered outcomes?

Study Sample Size.

Study design involves establishing a representative sample of the study population. Without this, no reliable study conclusions can be made. Modelling can determine the appropriate sample size (Andrade, 2020).

This study involves ED patients receiving RS as a representative sample from the entire ED population presenting during the two data collection periods. A 95% confidence interval (CI) with a 5% margin of error (α = 0.05) will be applied. Sample size modelling for this study provided a sample size of 80 participants (Table 16). This modelling computes the minimum number of necessary samples to meet the desired statistical constraints. It incorporates the mean incidence of escalation to INV or NIV of 5.45%, as reported by Jones (Jones et al., 2016). Any reduction in this INV or NIV incidence was deemed clinically significant.

Table 16

Point Prevalence Study: Sample Size Model

	Model
Incidence of escalation to INV[a] or NIV[b] in the population	5.45%
Alpha	0.05
Power	80%
Sample size target	80

Note. [a] INV= invasive ventilation; [b] NIV=non-invasive ventilation.

Study Analytical Methods.

Following data collection, the researchers must review the eCRFs for data discrepancies. Any discrepancies must be resolved in REDCap before data exportation to IBM SPSS (Statistics for Windows, Version 27.0) for statistical analysis.

The researchers shall perform two-phased analyses of the study data. Phase one shall involve a descriptive analysis of the data. This description shall include a narrative overview and analysis using central tendency and percentage measures. Normally distributed continuous data shall be described with means and standard deviations, and nonnormally distributed continuous data shall be described with medians and interquartile ranges. In addition, both categorical and dichotomous data will be reported as frequencies and percentages.

The completion of inferential analysis of data shall occur in the second phase. The inferential analysis plan was developed for each data type (categorical, continuous, and dichotomous).33 The inferential study analysis will be completed using IBM SPSS software (Statistics for Windows, Version 27.0).

Study Statistical Methods.

Selecting the most appropriate statistical test to analyze study data is vital (Kim et al., 2017). Therefore, the researchers consulted with a statistician when developing this study protocol. The statistical significance for all inferential analyzes shall use a two-sided α with *p*-values fixed at a ≤0.05 level of significance and CI set at 95%. Also, the Bonferroni method shall adjust the overall significance level for the three secondary outcomes (Armstrong, 2014).

The inferential analysis methods shall include analysis of variance (ANOVA), regression modelling, and determination of treatment effects. First, the one-way ANOVA shall compare primary outcome data for escalation between the four RS therapies.

Then, regression modelling will estimate the relationships between the dependent and selected independent variables. Finally, the dependent variable for the logistic regression modelling shall be a requirement for escalation while in the ED, and the covariates, such as age, shall be the independent variables. The dichotomous and categorical outcome data analysis shall be done with logistic regression. In addition, continuous data (such as ED length of stay) shall be analyzed using linear regression. These analyzes shall test the suitability and fitness of the models.

If available, survival using the time-to-event data (i.e., mortality) shall be analyzed using the Cox proportional hazards regression model. Finally, two treatment effects, odds ratio and number needed to treat, shall be reported for the primary outcome. These treatment effects may describe the respective causal effects of the RS therapies.

Discussion

Providing high-quality ED care is essential to lowering the global health burden and better safeguarding public health in emergencies and epidemics. For example, the global COVID-19 pandemic drove a significant influx of seriously ill patients to the ED, quickly overwhelming them. NIV RS has been commonplace during the pandemic because of the scarcity of ventilators, the high mortality of intubated patients, and the high infection risk among healthcare professionals involved in intubation. In addition to the unique physiological effects of NHF, individuals with COVID-19 could comfortably receive high fractions of humidified FiO_2 (Liu & Cheng, 2022). However, the evidence reporting on the use of NHF in ED patients is still yet to fully emerge. Of note, there are methodological and practical difficulties when doing research in the ED setting. Therefore, as a first step, research priorities for ED research must be established using epidemiological studies such as this.

Conclusion

This is a description of a protocol for a prospective multicenter observational PPS. This study is to be conducted in four New Zealand EDs. The protocol has been confirmed, the trial registered, and ethical approval obtained. The study and its reporting reflect the guidance, and the standards as described by STROBE (Vandenbroucke et al., 2007) and ICH (International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals for Humans, 2001) (Appendix M). The delivery of RS may improve patient outcomes in the ED. This observational research may contribute to the evidence required to help better those who need it and those who provide RS in this setting.

All authors have read and approved the final version of the manuscript. Jane O'Donnell has full access to this proposed study's data. She takes complete responsibility for the data's integrity and the data analysis's accuracy. The data contributing to the final study's findings may be available from Jane O'Donnell following a reasonable request.

Author Contributions

Jane O'Donnell: Conceptualization, methodology, project administration, resources, visualization, writing original draft, writing review, and editing. Alison Pirret: Methodology, supervision, writing review, and editing. Karen Hoare: Supervision, writing review, and editing. Elissa McDonald:

Supervision, writing review, and editing.

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Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

This manuscript describes a protocol for a study yet to be completed. As such, there are no data yet generated. When completed, data supporting the study's findings may be made available on request from the corresponding author. The data from the proposed study are not publicly available due to privacy or ethical restrictions.

Transparency Statement

The lead author, Jane O'Donnell, affirms that this manuscript is an honest, accurate, and transparent account of the study being reported, that no important aspects of the study have been omitted, and that any discrepancies from the study as planned (and if relevant, registered) have been explained. **ORCID**
Jane O'Donnell https://orcid.org/0000-0002-9554-5497.

4.7 The Soundness of the Doctoral Research Methods

This doctoral research employed a multi-method design, which included using two discreet quantitative methods, the SR with MA and the PPS. As described previously in this chapter, the selection of the multi-method design allowed the researcher to '*cast the net wider'*.

Ultimately, quantitative researchers seek to establish an association between dependent and independent variables. Establishing associations enables researchers to extrapolate their findings to broader populations, although a lack of validity limits extrapolation. It must be acknowledged that all research has limitations. Some limitations cannot be ameliorated and are reflected in the execution, interpretation, and reporting of findings (Resnik & Shampoo, 2017). Two categories of validity are usually described: external and internal. External validity concerns the potential generalisability of the research findings, whereas internal validity concerns the ability of the methods to determine genuine association, namely cause and effect (Patino & Ferreira, 2018).

The researcher acknowledges the limitations of the methods employed, with the limitations of both the SR (Owens, 2021; Uttley et al., 2023) and PPS (Wang & Cheng, 2020) methods well described. The threats to this research's external and internal validity were fully considered (Table 17). The researcher developed the study protocols and subsequent reporting to reflect the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols (PRISMA-P) (Page et al., 2021) and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklists (Vandenbroucke et al., 2007) (Appendix F & M). Before the commencement of both studies, the two protocols were developed and then published (O'Donnell et al., 2021b; O'Donnell et al., 2022).

The PPS cross-sectional method was appropriate for determining the real-world prevalence of outcomes in this ED cohort. This method enabled the relatively quick description of the study sample and the exploration of potential associations among more than 700 recorded study variables, increasing the study's external validity to inform future ED studies (Patino & Ferreira, 2018). The PPS's validity considerations were consistent with cross-sectional time horizons, especially concerning concurrent validity (Wang & Cheng, 2020). This method had strengths and weaknesses; the researcher mitigated them with careful planning and execution designed to increase its internal construct and content validity (Clark-Carter, 2018; Patino & Ferreira, 2018). Internal validity concerns bias in study design, conduct, and analysis and the ability of the study to answer the research questions (Andrade, 2018). The external validity of a study reflects its ability to generalise its findings in other settings (Andrade, 2018). Construct validity was addressed in several ways. After the study protocol was established, the researcher then developed bespoke electronic case report forms (eCRFs) (Appendix H) and six web-based training modules for data collectors (Appendix J). The protocol for the study and all logistical aspects, including the eCRF, underwent rigorous peer review and piloting with senior ED clinicians and researchers at two of the study sites and also with two of the data collectors. Throughout this process, the researcher actively consulted senior ED clinician-researchers.

Following application to the Massey University Ethics Committee, approval to proceed was granted (Appendix E). Each of the four study sites required individual locality approval. Locality approval was gained following a complete evaluation of the proposed study's potential cultural, financial, and service delivery impacts (Appendix D). Cultural sensitivity was a priority, and consultations were undertaken with the respective Māori Iwi and Pacifica representatives (Appendix D). After this approval process, the researcher recruited, contracted, and trained 18 data-collection clinicians. The researcher sought and gained unrestricted funding for the data collectors. The strategies undertaken by the researcher are outlined in Table 17.

Table 17

Research Validity Strategies Undertaken by the Researcher

Validity Strategy	Source
External Validity	
PPS is multicentre that increases generalisability through replication	
Participant selection was not random; the PPS is an epidemiological study.	
Internal Validity	
PPS prospective registration on the Australasian Clinical Trial Registry	(Appendix K)
Full ethical approval for PPS[a] obtained	(Appendix E)
Full locality approvals for PPS obtained	(Appendix D)
Piloting and appraisal of research procedures for SR[b] and PPS	
Induction of data collectors for SR and PPS	(Appendix J & L)
PPS mainly completed as per a priori published protocol	(O'Donnell et al., 2022)
PPS data capture in eCRF[c] on REDCap[d] software	(Appendix H)
PPS lead investigator blinded for data collection	
PPS data analysis blinded and duplicated	
SR mainly completed as per a priori published protocol	(O'Donnell et al.,2021b)
Duplicate SR data capture on COVIDENCE[e] software	
STROBE checklist used (Vandenbroucke et al., 2007)	(Appendix M)
PRISMA[f] & PRISMA-P[g] checklists used (Page et al., 2021)	(Appendix F)

Note. PPS[a] = Point Prevalence Study, SR[b] = Systematic Review, eCRF[c] = electronic case report form, REDCap[d]= Research Electronic Data Capture, COVIDENCE[e] = Covidence Systematic Review Software, PRISMA[f] = Preferred Reporting Items for

Systematic Reviews and Meta-Analyses, PRISMA P [g]= Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols.

Secure purpose-built web instruments, Covidence (Version 2.0) and Review Manager (RevMan, Version 5.4) for the SR, and Research Electronic Data Capture (REDCap) (Harris et al., 2009) for the PPS, increased the internal validity of both studies for data collection, management, and analysis. All SR data collection was blind, and duplicate data were entered into Covidence. Data were exported from Covidence to RevMan for analysis. The internal validity of the SR method was further upheld with the use of Cochrane methods (Higgins, 2023). All PPS data were double entered for consistency onto REDCap, with the researcher blinded to the original data source. All PPS data were anonymised and exported from REDCap to IBM SPSS software for analysis (Statistics for Windows, Version 27.0). The SR with MA and the PPS were designed and completed according to the good clinical research (GCP) standards described by the International Council for Harmonization (International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals for Humans, 2001).

4.8 Chapter Four Conclusion

This fourth chapter has presented the methodology underpinning the doctoral research. The purpose of this Chapter, *Methodology,* was to collectively describe the philosophical paradigm, the research approach and strategy, the research design and time horizon, and the two methods used to ethically and reliably answer the six thesis questions.

The methodological aspects discussed were the objectivist epistemology, the positivist philosophical paradigm, the EBP theoretical framework, and the multi-method design with its two quantitative methods: a SR with MAs and the PPS. The protocols for the SR with MA and the PPS were presented as published, and their aims, objectives, rationale and justification were described (O'Donnell et al., 2021b; O'Donnell et al., 2022).

The fifth and sixth subsequent chapters present the doctoral research findings, the data analysis, and finally substantiate the integrated findings. Chapter Five *Results* presents the systematic review with meta-analyses as published (O'Donnell et al., 2024), and Chapter Six *Results* presents the point prevalence study in two parts. Part one introduces the epidemiology of patients who have been provided RS in the ED; this part is presented as submitted for publication (O'Donnell et al., 2024). Part two presents the subset of the PPS data reporting on NHF RS alone.

Chapter Five

Results – Systematic Review with Meta-Analyses

The previous, fourth Chapter, *Methodology,* presented the methodology underpinning the doctoral research. The methodological aspects discussed were the objectivist epistemology, the positivist paradigm, the evidence-based theoretical framework, and the multi-method design with its two quantitative methods: a SR with MAs and a PPS. The fourth chapter presented protocols as published for the SR with MAs and the PPS (O'Donnell et al., 2021b; O'Donnell et al., 2022).

Chapter Five, *Results-Systematic Review with Meta-Analyses*, presents the published SR with MA findings (O'Donnell et al., 2024), which was the first method of the multi-method design. This SR with MA was completed primarily per its published protocol (O'Donnell et al., 2021b). The data analysis, the interpretation of results, and the substantiation of findings are presented as published. This chapter has nine sections, seven of which are components of the SR publication (O'Donnell et al., 2024):

- Abstract
- Introduction
- Method
- Results
- Discussion
- Limitations
- Areas for Potential Research
- The SR and MAs contribution to Evidence- Based Practice
- Chapter Five Conclusion.

The SR and MAs publication aimed to compare NHF to conventional oxygen therapy (COT) or non-invasive ventilation (NIV) in adult ED patients. The objective was to provide evidence for clinical decision-making regarding the delivery of RS in the ED. The rationale for the publication was that SRs are viewed as the most reliable form of evidence and broadly supports all aspects of EBP (Stevens, 2001). The publication aligned with the doctoral research and its first method, the SR. The SR with MA as published (O'Donnell et al., 2024) will now be presented, followed by an erratum for the SR publication.

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GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Jane O'Donnell
Name and title of main supervisor:	Professor Marlena Kruger
In which chapter is the manuscript/published work?	Chapter 5 Results SR & MA

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

Conception and design: JOD Lead Author, PhD Candidate
Draft manuscript preparation: JOD
Review manuscript drafts : JOD, AP, EM, KH, RF.
All authors reviewed the results and approved the final version of the manuscript.

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O'Donnell, J., Pirret, A., Hoare, K., Fenn, R., & McDonald, E. (2024). Respiratory support in the emergency department a systematic review and meta-analysis. Worldviews on Evidence-Based Nursing, 10.1111/wvn.12718. Advance online publication. https://doi.org/10.1111/wvn.12718

( ) **The manuscript is currently under review for publication**

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Student's signature:	Jane O'Donnell — Digitally signed by Jane O'Donnell Date: 2024.03.28 13:34:03 +13'00'	Main supervisor's signature:	Marlena Kruger — Digitally signed by Marlena Kruger DN: cn=Marlena Kruger, c=NZ, o=Massey University, ou=School of Health Sciences, email=m.c.kruger@massey.ac.nz Date: 2024.03.28 14:17:36 +13'00'

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5.1The Published Systematic Review with Meta-Analyses

O'Donnell, J., Pirret, A., Hoare, K., Fenn, R., & McDonald, E. (2024). Respiratory support in the emergency department: a systematic review and meta-analysis. ***Worldviews on Evidence-Based Nursing,*** **10.1111/wvn.12718. . https://doi.org/10.1111/wvn.12718**

5.1.1 Abstract

Background.

An estimated 20% of emergency department (ED) patients require respiratory support (RS). Evidence suggests nasal high flow (NHF) reduces RS need.

Aims.

This review compared NHF to conventional oxygen therapy (COT) or non-invasive ventilation (NIV) in adult ED patients.

Method.

The systematic review (SR) and meta-analysis (MA) methods reflect the Cochrane Collaboration methodology. Six databases were searched for randomised controlled trials (RCTs) comparing NHF to COT or NIV use in the ED. Three summary estimates were reported: need to escalate care, mortality, and adverse events (AE).

Results.

This SR and MA included 18 RCTs (n = 1874 participants). Two of the five MA conclusions were statistically significant. Compared with COT, NHF reduced the risk of escalation by 45% (RR 0.55; 95% CI = 0.33 to 0.92, p = 0.02, NNT = 32); however, no statistically significant differences in risk of mortality (RR 1.02; 95% CI = 0.68 to 1.54; $p = 0.91$) and AE (RR 0.98; 95% CI = 0.61 to 1.59; $p = 0.94$) outcomes were found. Compared with NIV, NHF increased the risk of escalation by 60% (RR 1.60; 95% CI = 1.10 to 2.33; $p = 0.01$); the risk of mortality was not statistically significant (RR 1.23, 95% CI = 0.78 to 1.95; $p = 0.37$).

Linking Evidence to Action

- Evidence-based decision-making regarding RS in the ED is challenging.
- ED clinicians have, at times, had to rely on non-ED evidence to support their practice.
- Compared with COT, NHF was seen to be superior and reduced the risk of escalation.
- Conversely, for this same outcome, NIV was superior to NHF. However, substantial clinical heterogeneity was seen in the NIV delivered.
- Research considering NHF versus NIV is needed.
- COVID-19 has exposed the research gaps and slowed the progress of ED research.

Keywords

systematic review; respiratory; oxygenation; emergency; COVID-19, nasal high flow, meta-analysis; high flow nasal cannula

5.1.2 Introduction

Clinicians in the emergency department (ED) use a variety of therapies to deliver respiratory support (RS) to their spontaneously breathing patients. Historically, RS has been provided with non-invasive ventilation (NIV) or conventional oxygen therapy (COT). Nasal high flow (NHF) therapy presents clinicians with another option when making decisions about the RS of ED patients. All forms of RS have advantages and disadvantages that should be clinical decision-making considerations (Hardavella et al., 2019; Popowicz & Leonard, 2022) (Table 18). Clinical decision-making theories describe the dynamic nature of decision-making and the requirement for adaptability when identifying factors influencing patient care and outcomes. The patient outcome considered by this systematic review is a requirement for RS or the escalation of RS. Recognizing a requirement for RS or its escalation corresponds with the model of hypothetico-deductive reasoning and normative theory (Pearson, 2013). This SR of NHF ED evidence has been completed to provide an evidence base for clinical decision making around the delivery of RS in the ED.

The Review Intervention.

Nasal high-flow therapy is the intervention considered in this systematic review (SR). This intervention is compared to non-invasive ventilation (NIV) or conventional oxygen therapy (COT). The terminology describing NHF is globally inconsistent with > 20 terms and > ten abbreviations in current use; some of the common examples include high-flow nasal cannula (HFNC) and high-flow oxygen (HFO) (Heikkila et al., 2019). Whilst the abbreviation NHF is used in this SR, the search incorporates the other available equivalent terms. Nasal high-flow therapy provides humidified medical gas to the upper respiratory tract through a specialised nasal cannula (the interface). The NHF humidifier conditions the inspiratory gases (up to 37°C and 100% relative humidity) and provides the same balance of warmth and humidity, just like the healthy lungs. For adults, NHF therapy can deliver humidified medical gas at flow rates of between 10 and 70 L/min with a fraction of inspired oxygen (FiO_2) between 0.21 (21% oxygen) and 1.0 (100% oxygen). Flow rate and FiO_2 level can be modified independently (Mauri, Turrini, et al., 2017). Evidence confirms that NHF can optimise patient oxygenation and reduce their work of breathing (WOB) by 1) limiting entrainment of room air, which decreases available FiO_2; 2) reducing physiological airway dead space; 3) flushing expired carbon dioxide (CO_2) from the upper airway; 4) providing a dynamic, positive airway pressure that augments functional residual capacity (FRC); and 5) airway humidification for improved comfort and sputum clearance (Mauri, Turrini, et al., 2017). Despite evidence describing these benefits, NHF use and delivery are inconsistent in the ED, and evidence-based guidance is limited (Mitsuyama et al., 2022).

The Review Comparators.

This SR involves two RS comparators, the so-called non-invasive ventilation (NIV) and conventional oxygen therapy (COT). Non-invasive ventilation (NIV) RS provides pressurised gas flows to spontaneously breathing patients. The options for RS pressure include continuous positive airway pressure (CPAP), where the pressure delivered is constant, or bi-level positive airway pressure (BiPAP). The term BiPAP is sometimes used in practice to mean NIV. During BiPAP, there are two pressure settings: on inhalation (IPAP) and exhalation (EPAP). Bi-level positive airway pressure RS respects the pressure differential across the breathing cycle. Various NIV interfaces are positioned on the face or nose; these include helmets, full FM, and nasal masks. Non-invasive RS requires a reliable interface seal. Non-invasive ventilation is challenging to tolerate and requires expertise to deliver (Popowicz & Leonard, 2022). Conventional oxygen therapy RS includes nasal cannula (NC), face masks (FM), and non-rebreathing masks (NRM). Typically, low flows of < 15L/ min of O_2 is provided it is not heated or humidified; it is dry and cool. These interfaces are common; they are relatively inexpensive and easy to use (Popowicz & Leonard, 2022).

Table 18

Systematic Review: Advantages and Disadvantages of Respiratory Support Therapies/ Interfaces Compared (Hardavella et al., 2019; Popowicz & Leonard, 2022)

[a]RS therapy	[b]Flow L/min	[c]FiO_2%	Indications	Advantages	Disadvantages
Nasal Cannula*	1-6	24 – 40 Varies with entrainment	Spontaneous breathing Domiciliary O_2	Low cost Easy to use Mouth not obstructed	Gas not heated & humidified Unknown FiO_2 Cannot reduce [d]WOB No dead space washout
Face Mask*	5-10	35 – 60 Varies with entrainment	Spontaneous breathing Nebulisation	Low cost Easy to use	Gas not heated & humidified Unknown FiO_2 Claustrophobic Limited therapy Mouth obstructed Cannot reduce WOB No dead space washout
Venturi Mask*	2-15	24 – 50 Varies with entrainment	Spontaneous breathing	Low cost Easy to use	Gas not heated & humidified Variable FiO_2 Claustrophobic Mouth obstructed Cannot reduce WOB No dead space washout
Nonrebreather Mask *	10-15	24 -50 Varies with entrainment	Spontaneous breathing	Low cost Easy to use	Gas not heated & humidified Variable FiO_2 Claustrophobic Mouth obstructed Cannot reduce WOB No dead space washout

Table 18 cont.

[a]RS therapy	[b]Flow L/min	[c]FiO_2%	Indications	Advantages	Disadvantages
Nasal High Flow	10-70	21-100	Spontaneous breathing Respiratory failure	Fixed FiO_2 Open system Gas heated & humidified Improves mucous clearance Mouth not obstructed Meets insp flow demand [e]PEEP Flushes dead space Can reduce WOB	Complex Noise High cost
Non-invasive Ventilation	10-60	21-100	Spontaneous breathing Respiratory Failure	High costs Fixed FiO_2 Closed system Gas heated & humidified May improve mucous clearance Meets insp flow demand [g] IPAP [h] EPAP Can reduce WOB	Known [f]AE High-cost Complex Claustrophobic Uncomfortable Increases dead space Mouth obstructed Many contraindications: Facial trauma ± deformity Upper airway obstruction or bleed Reduced GCS[k] </10 Inability to protect the airway

Note. [a] Respiratory Support= RS; [b] Flow of gas liters per minute=Flow L/minFiO2 ;[c] Fraction of Inspired Oxygen Percentage= FiO2 ; [d] Work of Breathing= WOB;[e] Positive End Expiratory Pressure= PEEP; [f] Adverse Event= AE; [g] Inspiratory Positive Airway Pressure= IPAP; [h] EPAP= Expiratory Positive Airway Pressure .* Conventional Oxygen Therapy .

The Review Patient Population.

The diverse ED patient population presents many complex life-threatening conditions that require emergency care; respiratory failure is an example. Dyspnoea, increased WOB, and poor oxygenation are common in respiratory failure. Typically, those with respiratory failure present with either an arterial oxygen tension (PaO2) of <60 mmHg or an arterial carbon dioxide tension (PaCO2) of >45 mmHg or both (Roussos & Koutsoukou, 2003). Spontaneously breathing ED patients who require RS are the population of interest for this SR.

The Review Outcomes.

Respiratory support may reduce the need to escalate care. Escalating care may include one or a combination of RS therapies: COT, NHF, NIV (Table 18), or invasive ventilation (INV).

This SR will compare the intervention NHF with either NIV or COT for three SR outcomes:

1) the 'need to escalate care,' defined as the need to progress to NHF, NIV, or INV;

2) mortality; and

3) adverse event (AE) rates.

Delayed RS escalation of respiratory failure patients is associated with increased mortality and morbidity (Roca et al., 2019; Slutsky & Ranieri, 2013).

5.1.3 Methods

The PICO(S) theoretical framework was used to abstract and structure the SR question (Clephas & Heesen, 2022). The question asked in this SR was: In adult ED patients requiring RS, what is the effect of RS with NHF compared to other forms of RS on patient outcomes?

The SR was completed as per its registered protocol (O'Donnell et al., 2021b) and the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist (Page et al., 2021) (Appendix F). **Study**

Literature Search and Inclusion Criteria.

The scope and methods of this review precluded the inclusion of qualitative studies or non- randomized trials, much like Cochrane SR of interventions (Higgins, 2022). The SR inclusion criteria were: 1) RCT set in ED, 2) reporting on adults >18 years, and 3) comparing NHF versus COT or NIV. The exclusion criteria were 1) non-English, 2) non-RCT, and 3) grey literature due to its high risk of bias (RoB) (Adams et al., 2016). The sensitivity of the search for NHF evidence was low, given all the numerous names and acronyms for NHF (Heikkila et al., 2019). In consultation with two subject librarians, a search strategy was designed to locate RCTs for potential inclusion. The strategy included keywords and Medical Subject Headings (Appendix G). The search was executed in six databases, two conference proceedings, and two clinical trial registries (Appendix G).

Study Data Extraction.

A data extraction form was developed to collect data comparing NHF, NIV (either continuous positive airway pressure (CPAP) or bilevel positive airway pressure (BiPAP), and all types of COT reporting on the three SR primary outcomes. Two reviewers used the data collection form to capture three categories of data: 1) study characteristics, 2) study outcomes, and 3) data for the risk of bias (RoB) assessment. One SR reviewer verified these extracted data prior to their synthesis and analysis. Covidence and RevMan platforms were used to support data extraction and RoB assessment. Two SR reviewers completed critical appraisals of the included studies, including the RoB assessments. The RoB assessment used the Cochrane 'Risk of Bias' tool (Higgins, 2022). Six domains of bias were considered: random sequence generation, allocation concealment, outcome assessment blinding, incomplete outcome data, selective reporting, and 'other' biases. Any RoB assessment for 'blinding' was limited to outcome assessments as RS interventions cannot be blinded. The same Cochrane tool was used to classify RoB as "low," "unclear," or "high" for each domain. Evidence was classified as low RoB only if all bias domains were deemed low risk. The final RoB rating was the highest risk assigned to any risk domain

Study Data Analysis.

This SR analysis included a series of meta-analyses (MA) and a narrative synthesis (NS). The NS provided a descriptive summary of the review findings (Popay, 2005). In contrast, the MAs used numerical data to describe the overall or 'absolute' treatment effects, where independent study data were able to be extracted and systematically merged. Study data were entered into RevMan Web (Cochrane Collaboration, 2020) for analysis. The reviewers employed well-established, systematic methods to manage differences in sample size and heterogeneity in the study approaches and reported treatment effects. These methods determined the sensitivity of SR findings and tested the methods' reliability (Higgins, 2022). Two estimates of treatment effect were completed: 1) risk ratio (RR) for dichotomous outcomes and 2) number needed to treat (NNT). The 95% confidence interval (95% CI) was used to describe the precision of effect for these two estimates. The threshold for statistical significance of the estimates was $p < 0.05$. As is now convention, both p values and z scores were reported. The z score reflects the magnitude of the treatment effect irrespective of sample size (Clephas &

Heesen, 2022).

The standard unit of analysis for all outcomes was 'per participant' as opposed to a 'treatment period.' For example, pair-wise comparisons were completed for multiple intervention studies, and multiple interventions were combined for analysis into a single intervention group. As per Cochrane methods, when multiple time points were reported in a single study, the most relevant time points pre-intervention, baseline, and first recorded time point post-intervention were used (Higgins, 2022). The recorded first-time points after implementation of the interventions were inconsistent across the included studies.

As it is not uncommon for RCTs to have missing outcome data (Wood et al., 2004), therefore every included study was appraised for missing data. If there had been a study with > 20% of their primary outcome data missing, then its impact upon the MA would have been considered by sensitivity analysis.

The fixed-effect Mantel-Haenszel model was used to estimate the pooled overall adjusted RR and applied to MAs with no significant heterogeneity (Higgins, 2022). For completeness, the random-effects model was also used to test whether the effects seen were consistent across both models.

Three forms of heterogeneity were explored. First, reviewers used their clinical judgment to examine sources of clinical heterogeneity. Second, methodological heterogeneity was explored during the RoB appraisal and the visual examination of the MA forest plots. Finally, the I-squared (I^2) statistic, chi-square ($\chi 2$) test, with associated p values collectively considered statistical heterogeneity. The degree of heterogeneity was categorised using the I2 statistic: 0% to 40%, not important; 30% to 60%, moderately important; 50% to 90%, substantially important; and > 90%, considerably important (Higgins, 2022). The I^2 statistic and their reported CIs helped determine if the data pooling was valid in MA with small numbers of included studies (von Hippel, 2015). The power of the $\chi 2$ test for homogeneity is low if the number of studies within a MA is small, so a 10% significance level was set for probability in this SR (Higgins, 2022).

The Recommendations, Assessment, Development, and Evaluations (GRADE) method informed MA certainty by considering within-study methodological bias, directness, heterogeneity, precision of effect estimates, and publication bias (Schünemann et al., 2008). The summary of findings (SOF) table (Table 20) presents pooled estimates and certainty of SR findings for the three primary outcomes (Schünemann et al., 2008).

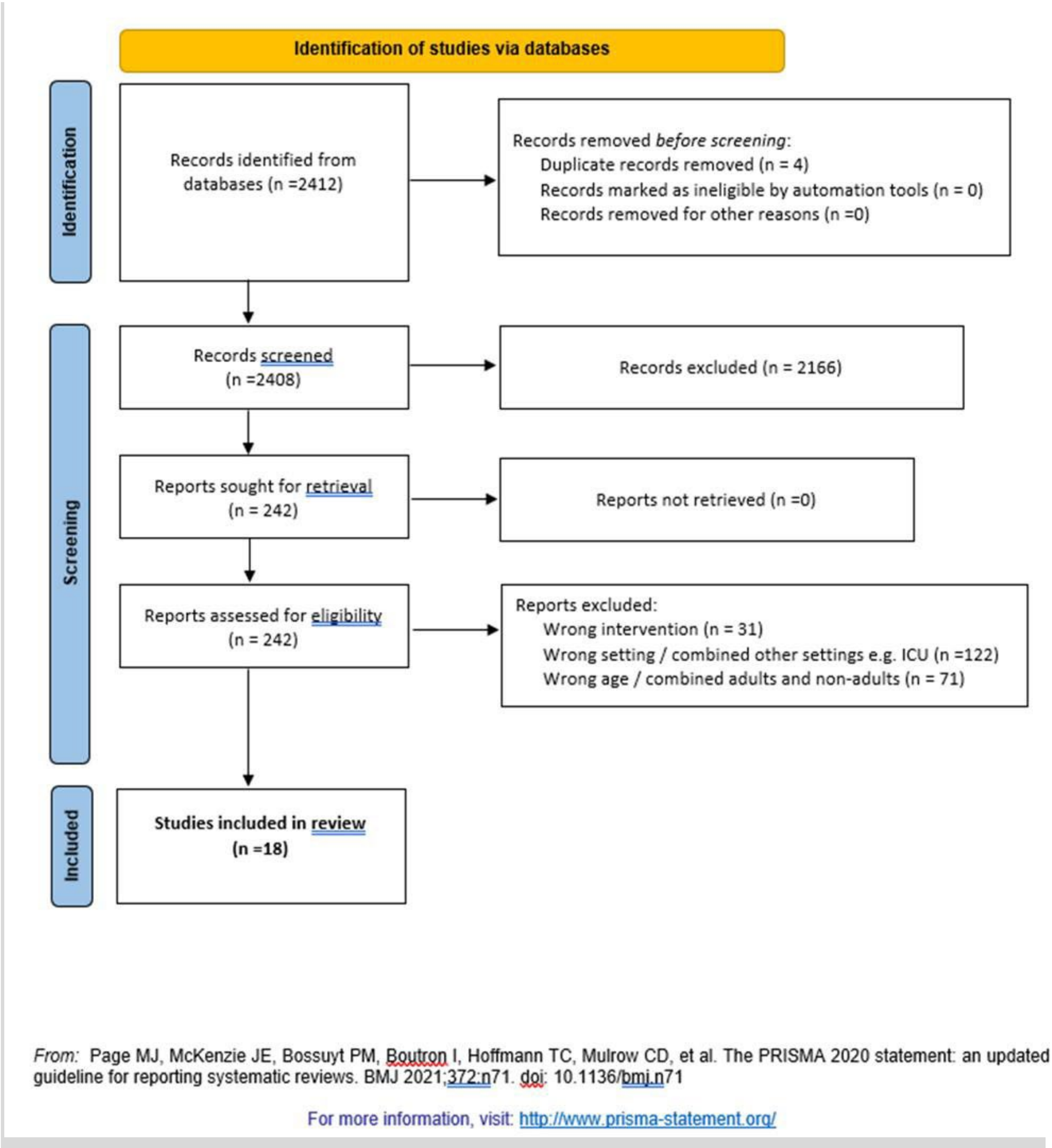
5.1.4 Results

Study Selection and Characteristics.

The final search on July 15, 2023, yielded *n* = 2,412 citations. The abstracts and titles were screened, and *n* = 242 full manuscripts were considered. Eighteen of these *n* = 242 studies met the SR per protocol inclusion criteria applied by two reviewers (Figure 16) (Attia et al., 2017; Bell et al., 2015; Chua et al., 2022; Cortegiani et al., 2020; Doshi et al., 2018, 2020; Geng et al., 2020; Haywood et al., 2019; Hsu et al., 2020; Jones et al., 2016; Kim et al., 2020; Ko et al., 2020; Makdee et al., 2017; Osman et al., 2021; Raeisi et al., 2019; Rittayamai et al., 2015; Ruangsomboon et al., 2020, 2021).

Figure 16

Systematic Review: PRISMA Flow Chart Describing Identification of Studies



All included study characteristics are detailed in the SR section 'Results' and 'Characteristics of Included Studies' Table (Appendix N). Table 19 provides a narrative summary of the included studies

Table 19

Systematic Review: Narrative Summary of the Included Studies

Study Methods
Two of the 18 studies (Doshi et al., 2020; Haywood et al., 2019) were secondary data analyses from an earlier study (Doshi et al., 2018).Fifteen studies used a standard parallel RCT design (Attia et al., 2017; Bell et al., 2015; Chua et al., 2022; Doshi et al., 2018; Doshi et al., 2020; Geng et al., 2020; Haywood et al., 2019; Jones et al., 2016; Kim et al., 2020; Ko et al., 2020; Makdee et al., 2017; Osman et al., 2021; Raeisi et al., 2019; Rittayamai et al., 2015; Ruangsomboon et al., 2021);Two used a non-inferiority design (Cortegiani et al., 2020; Doshi et al., 2018),One used a crossover design (Ruangsomboon et al., 2020). The second treatment period's outcome data were excluded from the SR analysis for the crossover study.Eleven studies were single centre (Attia et al., 2017; Geng et al., 2020; Hsu et al., 2020; Jones et al., 2016; Kim et al., 2021; Makdee et al., 2017; Osman et al., 2021; Raeisi et al., 2019; Rittayamai et al., 2015; Ruangsomboon et al., 2020; Ruangsomboon et al., 2021). The study sample size ranged between 22 and 303 (mean = 64). The sample size was not powered a priori in four studies (Attia et al., 2017; Doshi et al., 2020; Haywood et al., 2019; Raeisi et al., 2019). All included studies were conducted in an ED setting in n = 11 countries: Australia (Bell et al., 2015; Hsu et al., 2020), China (Geng et al., 2020), Egypt (Attia et al., 2017), Italy (Andrea Cortegiani et al., 2020), Iran (Raeisi et al., 2019), Korea (Kim et al., 2020; Ko et al., 2020), Malaysia (Osman et al., 2021), New Zealand (Jones et al., 2016), Singapore (Chua et al., 2022), Thailand (Rittayamai et al., 2015; Ruangsomboon et al., 2020; Ruangsomboon et al., 2021) and USA (Doshi et al., 2018; Doshi et al., 2020; Haywood et al., 2019). Fourteen studies were sponsored in some way (Bell et al., 2015; Chang et al., 2021; Cortegiani et al., 2020; Doshi et al., 2018; Doshi et al., 2020; Haywood et al., 2019; Hsu et al., 2020; Jones et al., 2016; Kim et al., 2020; Ko et al., 2020; Raeisi et al., 2019; Rittayamai et al., 2015; Ruangsomboon et al., 2021; Ruangsomboon et al., 2022). Most studies declared that the sponsors had not influenced the study findings. Two studies neither commented on nor declared sponsorship (Attia et al., 2017; Osman et al., 2021). Fifteen studies were prospectively registered; the remaining three did not declare any prospective trial registration (Geng et al., 2020; Hsu et al., 2020; Kim et al., 2021).

Table 19 cont .

Study Populations
All included study populations involved adult participants with various conditions requiring RS. Three studies considered RS in ARF (Attia et al., 2017; Doshi et al., 2018; Jones et al., 2016); three studies in asthma (Geng et al., 2020; Raeisi et al., 2019; Ruangsomboon et al., 2021); two studies in heart failure (Haywood et al., 2019; Ko et al., 2020); two studies in hypoxaemia with dyspnoea (Bell et al., 2015; Rittayamai et al., 2015) and two studies in cardiogenic pulmonary oedema (Makdee et al., 2017; Osman et al., 2021). Finally, in single studies, the RS of six additional conditions were considered: acute exacerbation of COPD (Cortegiani et al., 2020), hypercapnic respiratory failure (Doshi et al., 2020), carbon monoxide gas poisoning (Kim et al., 2020), rib fractures (Hsu et al., 2020), patients requiring rapid sequence intubation (Chua et al., 2022) and palliative care (Ruangsomboon et al., 2020).
Study Interventions
Respiratory Support Used All included study interventions involved randomising participants to receive NHF. Oxygen was delivered using one or a mixture of conventional face masks (Bell et al., 2015; Jones et al., 2016; Ko et al., 2020), nasal cannulae (Attia et al., 2017; Bell et al., 2015; Geng et al., 2020; Jones et al., 2016; Ko et al., 2020; Makdee et al., 2017; Raeisi et al., 2019; Rittayamai et al., 2015; Ruangsomboon et al., 2020; Ruangsomboon et al., 2021), a non-rebreather mask and or venturi mask (Bell et al., 2015; Geng et al., 2020; Hsu et al., 2020; Kim et al., 2020; Makdee et al., 2017; Rittayamai et al., 2015; Ruangsomboon et al., 2020; Ruangsomboon et al., 2021). One study used a non-rebreather mask and nasal cannulae (Chua et al., 2022). *Respiratory Support Flow Rates* Non-invasive ventilation was the comparator in five studies (Cortegiani et al., 2020; Doshi et al., 2018; Doshi et al., 2020; Haywood et al., 2019; Osman et al., 2021). All NIV comparator group participants received bi-level positive airway pressure (BiPAP). The BiPAP was administered using an oronasal mask (Doshi et al., 2018; Doshi et al., 2020; Haywood et al., 2019); either an oronasal mask or full-face mask (Cortegiani et al., 2020); or a helmet (Osman et al., 2021). Various NHF gas flow rates were reported. Some studies specified a range of flow rates between 35 and 60 L/min (Chua et al., 2022; Makdee et al., 2017; Ruangsomboon et al., 2020; Ruangsomboon et al., 2021); in single studies, the range was 15 to 35 L/min (Raeisi et al.,2019), and 30 to 40L/min (Geng et al., 2020). Other studies specified an initial flow rate of 35L/min with subsequent increases (Doshi et al., 2018; Doshi et al., 2020; Haywood et al., 2019; Makdee et al., 2017; Ruangsomboon et al., 2020; Ruangsomboon et al., 2021) or respective decreases from 60 L/min (Cortegiani et al., 2020; Hsu et al., 2020), 50 L/min (Osman et al., 2021), 45 L/min (Ko et al.,2020), or 40 L/min (Attia et al., 2017). Single studies specified the respective set flows of 35 L/min Rittayamai et al., 2015), 40 L/min (Jones et al., 2016), 50 L/min (Bell et al., 2015), or 60 L/min (Chua et al., 2022; Kim et al., 2020). Conventional oxygen therapy was the comparator in 13 studies (Attia et al., 2017; Bell et al., 2015; Chua et al., 2022; Geng et al., 2020; Hsu et al., 2020; Jones et al., 2016; Kim et al., 2020; Ko et al., 2020; Makdee et al., 2017; Raeisi et al., 2019; Rittayamai et al., 2015; Ruangsomboon et al., 2020; Ruangsomboon et al., 2021).

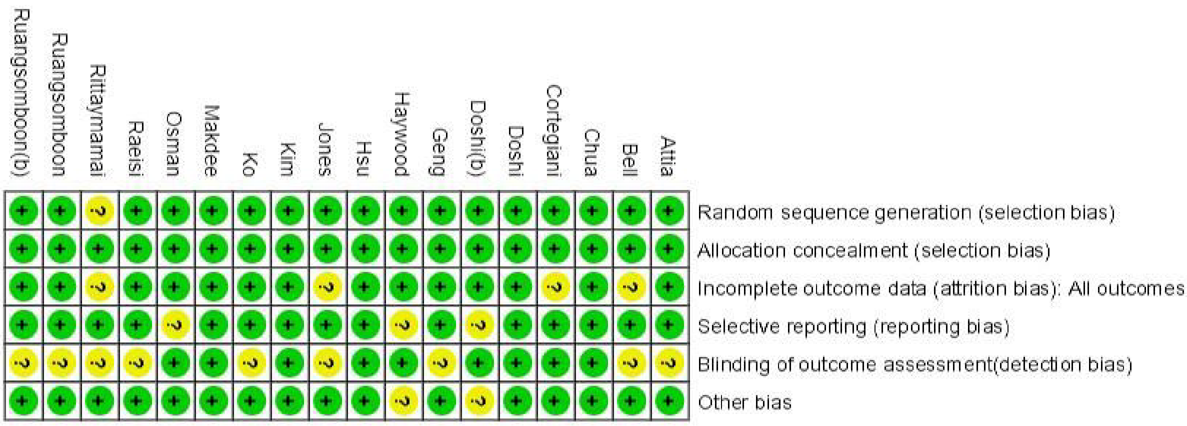
Table 19 cont .

Study Outcomes
The studies included in this SR reported on a variety of outcomes. Seventeen studies reported on the requirement to escalate care, 17 reported on mortality and seven on AEs.

None of the included studies was deemed to have high RoB, whereby the bias was such that the results may be invalidated (Figure 17).

Figure 17

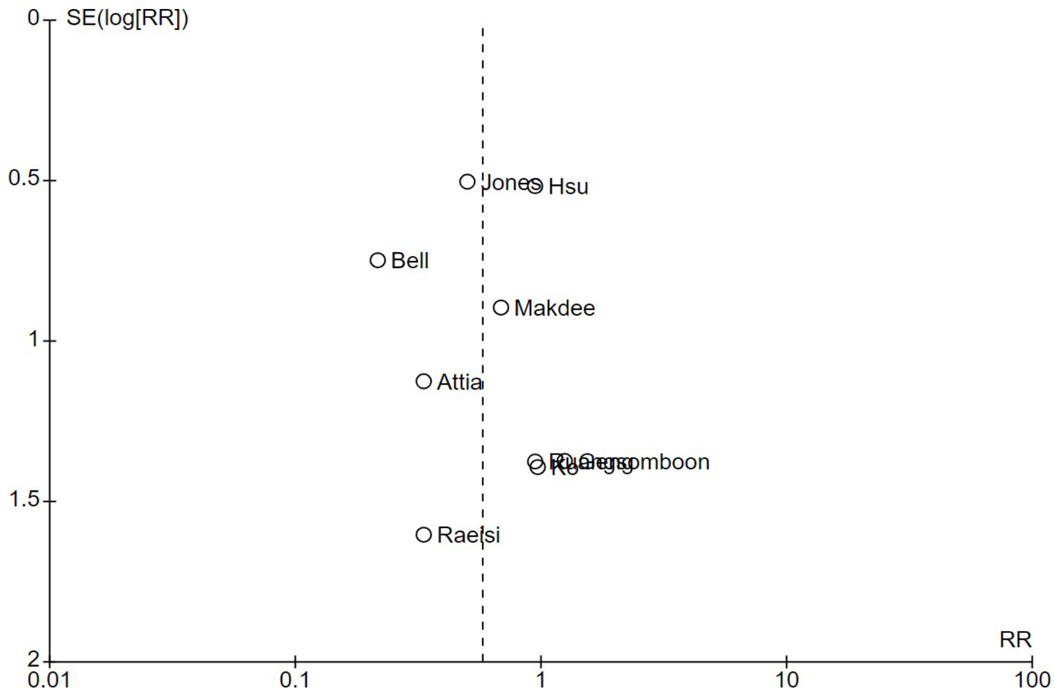
Systematic Review: Overall Risk of Bias of Included Studies



Because more than ten studies were included in the MA (NHF versus COT), an assessment of publication bias was performed by visually inspecting the symmetry within the funnel plot for the escalation outcome; publication bias was not evident (Figure 18).

Figure 18

Systematic Review: Funnel Plot Considering Publication Bias



Meta-analysis Findings.

The SR involved pooling *n* = 1874 participant data sets within five MA. All MA compared NHF to either COT or NIV. However, the reported mix of NIV interfaces and ventilator settings dictates that all MA findings (NHF versus NIV) must be cautiously viewed.

Requirement to escalate care in ED patients -NHF versus COT.

For the comparison NHF versus COT and the outcome need for escalation, the MA confirmed that NHF reduces the need for escalation by 45% (RR 0.55; 95%; CI = 0.33 to 0.92; $z = 2.26$, $p = 0.02$; $I^2 = 0\%$; 9 RCTs, $n = 991$, NNT = 32) (Figure 19). An absolute effect of 3% (95% CI = 1 to 5) fewer NHF ED patients will need escalation of care if they receive NHF versus COT. For completeness, the random-effects model demonstrated consistency in the effects seen (RR 0.58; 95% CI = 0.34 to 0.99; $z = 2.00$, $p = 0.05$; $I^2 = 0\%$) (Figure 20).

Figure 19

Systematic Review: Forest Plot Requirement to Escalate Care In ED Patients -NHF Versus COT, Fixed Effect

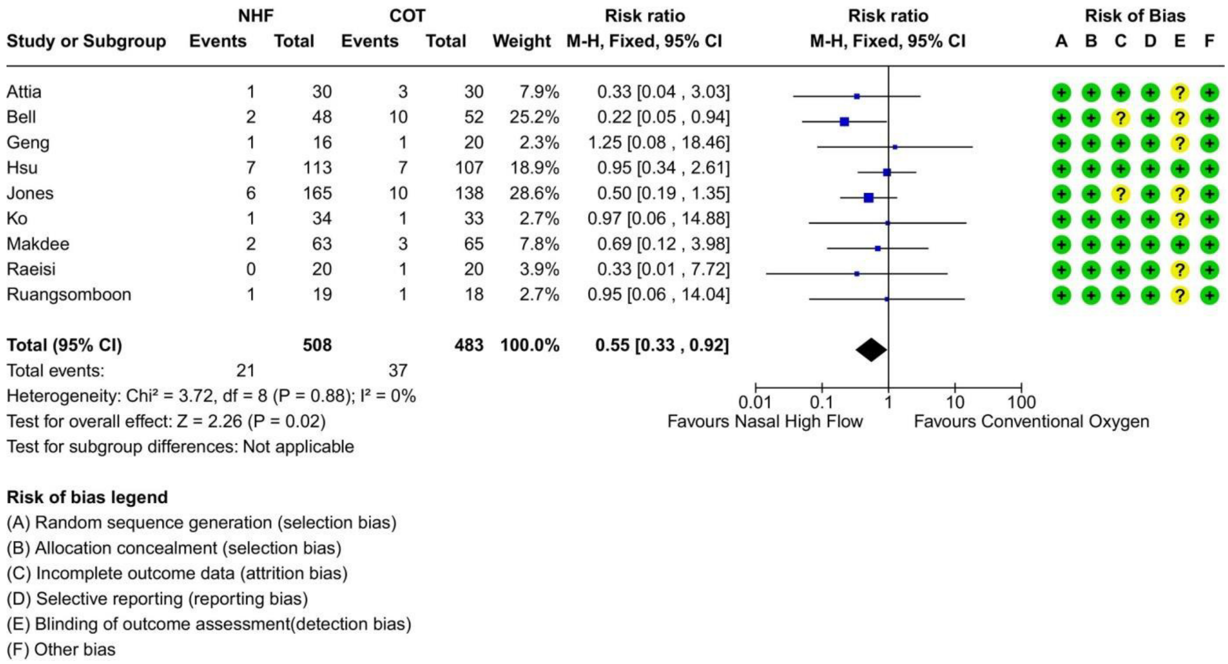
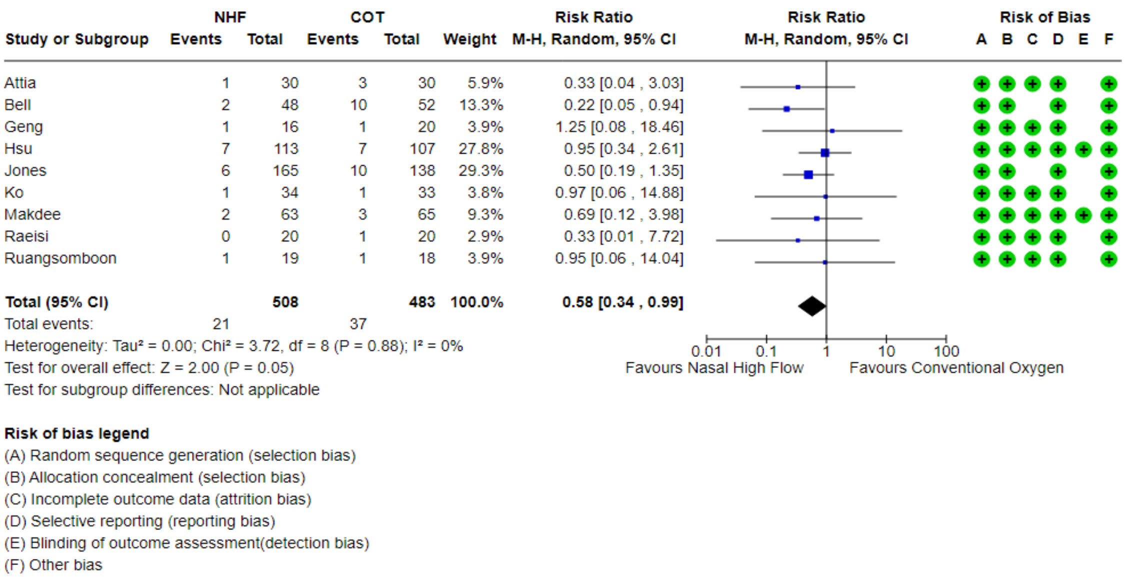


Figure 20

Systematic Review: Forest Plot Requirement to Escalate Care In ED Patients -NHF Versus COT, Random Effect

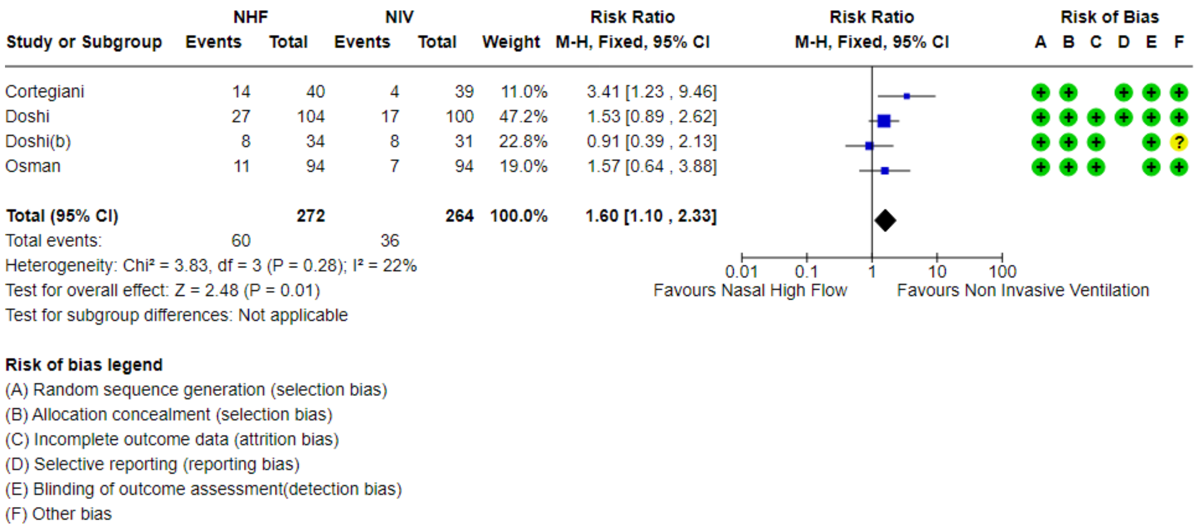


Requirement to Escalate Care in ED Patients -NHF versus NIV.

For the comparison NHF versus NIV and the outcome need for escalation, the MA confirms that NHF increases the need for escalation by 60% (RR 1.60; 95% CI = 1.10 to 2.33; $z = 2.48$, $p = 0.01$; $I^2 = 22\%$; 4 RCTs, $n = 536$, NNT = 13) (Figure 21). The absolute effect reported suggests that 8% (95% CI = 1 to 17) more ED patients may require escalation if they receive NHF versus NIV. The I^2 of 22% suggests that heterogeneity was not important.

Figure 21

Systematic Review: Forrest Plot Requirement to Escalate Care in ED Patient – NHF versus NIV

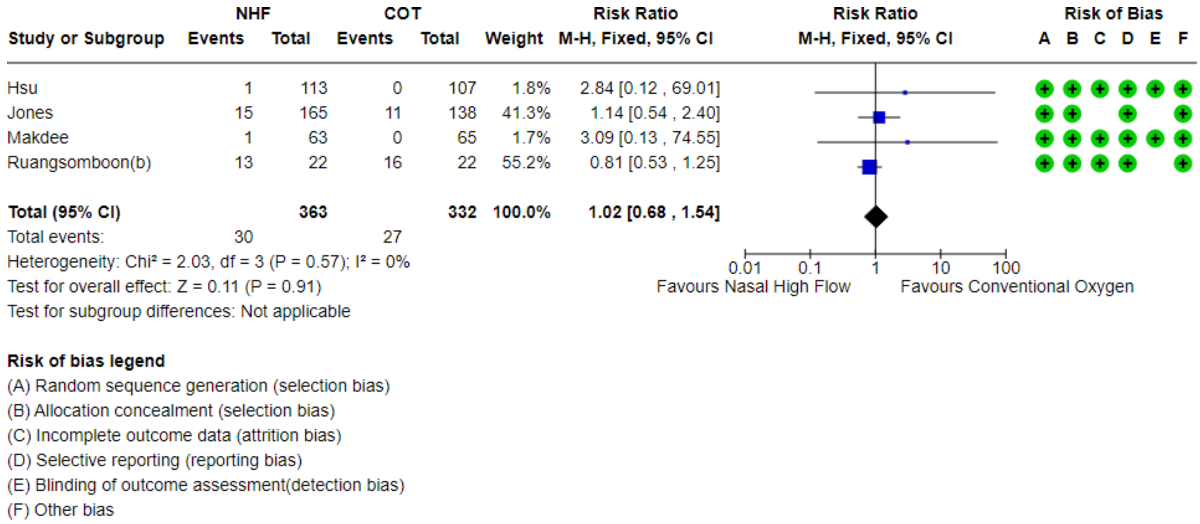


Mortality of ED Patients -NHF versus COT.

For the comparison NHF versus COT and the outcome mortality, the MA findings were not statistically significantly different (RR 1.02; 95% CI = 0.68 to 1.54; $z = 0.11$ $p = 0.91$, $I^2 = 0\%$; 4 RCTs, $n = 695$) (Figure 22). The absolute effect reported suggests that 1% (95% CI = 2 to 4) more ED patients may have increased mortality rates with NHF versus COT.

Figure 22

Systematic Review: Forrest Plot Mortality Rate In-Hospital (Up to 90 Days) NHF versus COT

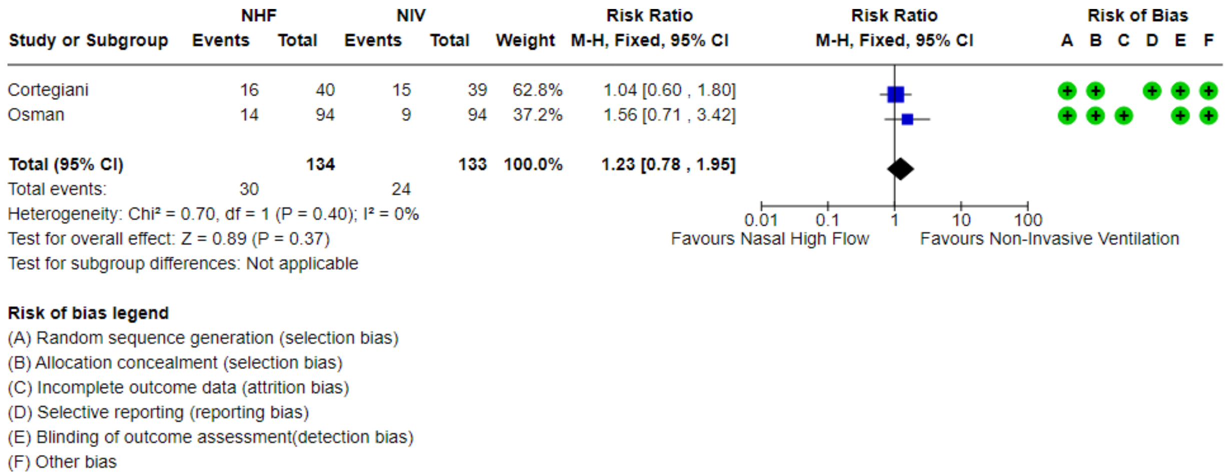


Mortality of ED Patients – NHF versus NIV.

For the comparison NHF versus NIV and the outcome mortality, the MA findings were not significantly different (RR 1.23, 95% CI = 0.78 to 1.95; $z = 0.89$, $p = 0.37$; $I^2 = 0\%$; 2 RCTs, 267 patients) (Figure 23).

Figure 23

Systematic Review: Forrest Plot Mortality Rate in Hospital (Up To 90 Days) NHF versus NIV

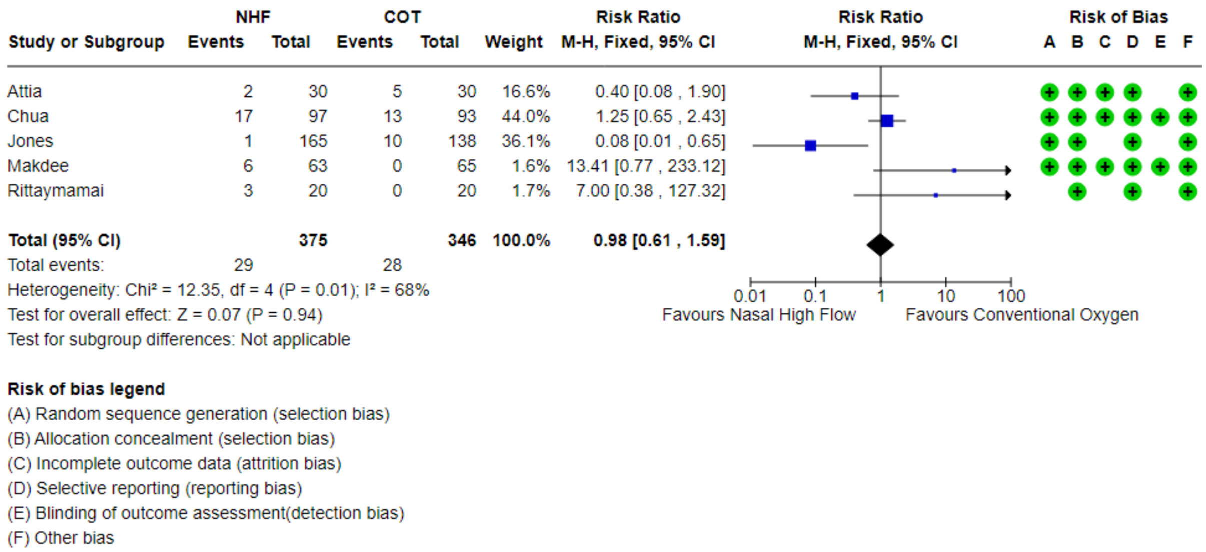


Rate of Adverse Events in ED.

The inconsistent and poor reporting of AEs was reflected in measures of heterogeneity (such as I^2). The reported AEs for NHF versus COT included thoracic and cervical discomfort, feeling hot, apnoea, reduction in Glasgow Coma Scale (GCS) score of two or more points, reduction in GCS with CO_2 retention, unpleasant smell, temperature too warm, and chest discomfort (Attia et al., 2017; Chua et al., 2022; Jones et al., 2016; Makdee et al., 2017; Rittayamai et al.,2015). For this comparison of NHF versus COT, the MA findings were not statistically significantly different for AEs (RR 0.98; 95% CI = 0.61 to 1.59; z = 0.07, p = 0.94, I^2 = 68%; 5 RCTs, n = 721) (Figure 24). The I^2 of 68% was deemed substantially important and anticipated due to its inherent clinical heterogeneity. A single study reported no difference in AEs for the NHF versus NIV; this study described discomfort and poor tolerance (Cortegiani et al., 2020).

Figure 24

Systematic Review: Forrest Plot Adverse Events in ED NHF versus COT



The GRADE certainty assessment and summary of findings for the included studies for three primary outcomes relating to the two comparisons NHF versus COT and NHF versus NIV are outlined in Table 20.

Table 20

Systematic Review: Summary of Findings GRADE Assessment of Certainty

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Nasal High Flow	Conventional Oxygen	Relative (95% CI)	Absolute (95% CI)		
Escalation of care NHF v COT												
12	randomised trials	serious	not serious	not serious	serious	none	21/560 (3.8%)	37/537 (6.9%)	**RR 0.55** (0.33 to 0.92)	**3 fewer per 100** (from 5 fewer to 1 fewer)	⊕⊕⊕◯ Moderate	CRITICAL
Mortality NHF v COT												
12	randomised trials	serious	not serious	not serious	serious	none	30/560 (5.4%)	27/537 (5.0%)	**RR 1.11** (0.79 to 1.56)	**1 more per 100** (from 1 fewer to 3 more)	⊕⊕⊕◯ Moderate	CRITICAL
Adverse event NHF v COT												
6	randomised trials	serious	not serious	not serious	serious	none	29/423 (6.9%)	28/398 (7.0%)	**RR 0.98** (0.61 to 1.59)	**0 fewer per 100** (from 3 fewer to 4 more)	⊕⊕◯ low	CRITICAL

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Nasal High Flow	Non Invasive Ventilation	Relative (95% CI)	Absolute (95% CI)		
Escalation of care NHF v NIV												
5	randomised trials	serious	not serious	not serious	serious	none	60/292 (20.5%)	36/284 (12.7%)	**RR 1.60** (1.10 to 2.33)	**8 more per 100** (from 1 more to 17 more)	⊕⊕⊕◯ Moderate	CRITICAL
Mortality NHF v NIV												
5	randomised trials	serious	not serious	not serious	serious	none	30/292 (10.3%)	24/284 (8.5%)	not estimable		⊕⊕⊕◯ Moderate	CRITICAL

Note. CI = confidence interval; RR = risk ratio.

5.1.5 Discussion

Key Results.

This SR included 18 RCTs (n = 1752 patients) and reported on three outcomes when NHF was compared to NIV or COT. Two of the five MAs were conclusive (Figures 20 and 21). Compared with COT, NHF reduces the risk of escalation by 45%; however, its effect on the risk of mortality or AEs remains unclear. Compared with NIV, NHF increased the risk of escalation by 60% but not mortality.

Interpretation.

This SR demonstrates the requirement for adaptability when identifying decision-making factors which influence patient care and outcomes, such as the need to escalate care (Pearson, 2013). It is important to remember that ED patients requiring RS are at high risk of needing escalation of care, and NHF may disguise their deterioration, and ED clinicians should be cognisant of this when making clinical decisions (Ricard et al., 2019). Patients in the ED receiving NHF must be carefully monitored to avoid delays in care escalation. However, these SR conclusions for RS contrast, when NHF is compared to COT, the need to escalate patient care is reduced, this is of high clinical significance. However, the advantage of NIV over NHF remains unclear. The variation in patient clinical conditions, age, respiratory rate, intervention interfaces, flow rates, and FiO2 could account for these findings, and there were less available data to analyse some of the outcomes in this SR. Subgroup analyses based on patient clinical conditions, age, respiratory rate, NHF flow rates, and FiO_2., were proposed; however, very few RCTs reported separate outcome data for these subgroups. Additionally, no RCTs reported cost-benefit outcomes such as reduced ED length of stay. These factors limit the generalisability of the current SR of ED RCTs findings to ED practice.

Generalisability.

Evidence-based practice (EBP) theory incorporates the best research evidence, patient preference and clinician expertise (Sackett, 1997). Initially, patient preference and clinician expertise informed NHF use; recently, the rapid emergence of NHF evidence has been influential; however, its generalisability is questionable. Establishing the efficacy of NHF in practice has demonstrated a legitimate EBP step wise process. This process now refers to evidence from across the evidence hierarchy and across the gamut of quantitative and qualitative methodologies. The NHF evidence describing the clinical outcomes seen is rapidly emerging and highly cited. As of January 2024, the top 48 NHF publications have been cited 8670 times (mean 180), with the most cited study (n= 2371) considering acute respiratory failure (Frat et al., 2015). Some of these emergent publications have included much-cited NHF SRs and Clinical guidelines (Rochwerg et al., 2020). Many of the published ED SRs include evidence from outside the ED, which limits their genuine generalisability in this setting. The common themes considered were coronavirus disease 2019 62%, acute respiratory failure 19%, post-extubation care 6%, prediction outcomes 4%, supporting intubation 4%, delaying escalation 2% and post-operative support 2%. Evidence sourced using a variety of methods suggests that NHF RS provides favourable clinical outcomes to spontaneously breathing patients with various respiratory conditions in many settings, including for adults in the ICU (Table 21).

Table 21

Systematic Review: Described Conditions / Applications of Nasal High Flow Therapy-A Summary

Condition	Evidence	Evidence Type	Setting
Acute Hypoxemic Respiratory Failure	(Mauri et al., 2017)	Cross Over RCT[a]	ICU[b]
Acute Hypoxemic Respiratory Failure	(Colombo et al., 2022)	Observational Study	Ward
Acute Hypoxemic Respiratory Failure	(Rochwerg et al., 2020)	Clinical Guideline	All
Acute Hypoxemic Respiratory Failure	(Pitre et al., 2023)	Network Meta-Analysis	All
Acute Hypercapnic Respiratory Failure	(Pilcher et al., 2017)	Cross Over RCT	Ward
Acute Hypercapnic Respiratory Failure	(Ovtcharenko et al., 2022)	SR with MA	All
Acute Respiratory Distress Syndrome	(Messika et al., 2015)	Observational Study	ICU
Postsurgical / Postoperative	(Stéphan et al., 2017)	Noninferiority RCT	ICU
Postextubation	(Hernandez et al., 2016)	RCT	ICU
Postextubation	(Rochwerg et al., 2020)	Clinical Guideline	All
Peri intubation (RSI)[c]	(Patel & Nouraei, 2015)	Controlled Trial	OT[d]
Peri Intubation	(Rochwerg et al., 2020)	Clinical Guideline	All
Immunocompromised	(Azoulay et al., 2018)	RCT	ICU
Immunocompromised	(Wang et al., 2020)	SR	All
Dyspnoea / Breathlessness	(Bell et al., 2015)	RCT	ED[e]
Chronic Obstructive Pulmonary Disease	(Bräunlich et al., 2019)	RCT	Ward
Cariogenic Pulmonary Oedema	(Makdee et al., 2017)	RCT	ED
Heart Failure	(Makdee et al., 2017)	RCT	ED

Table 21 cont.

Condition	Evidence	Evidence Type	Setting
Cystic Fibrosis	(Sklar et al., 2018)	Cross Over RCT	Ward
Trauma	(Mu et al., 2020)	Retrospective Study	Hospital
Carbon Monoxide Poisoning	(Tomruk et al., 2019)	Observational Study	ED
Interstitial Lung Disease	(Al Chikhanie et al., 2021)	Controlled Trial	Non-Hospital
Asthma	(Ruangsomboon et al., 2021)	RCT	ED
As an alternative to NIV	(Doshi et al., 2018)	RCT	ED
Conscious Sedation	(Ayuse et al., 2020)	RCT	For ERCP [f]
Postoperative	(Rochwerg et al., 2020)	Clinical Guideline	Postoperative
Dyspnea in cancer pts	(Hui et al., 2021)	RCT	All
Endoscopy	(Nay et al., 2021)	RCT	Outpatients
Bronchoscopy COPD	(Sharma et al., 2023)	RCT	Outpatients
Bronchoscopy	(Lucangelo et al., 2012)	Prospective Controlled Study	ICU

Note. Randomized Controlled Trial = RCT [a]; Intensive Care Unit = ICU [b]; Rapid Sequence Intubation = RSI [c]; Operating Theatre = OT[d] ; Emergency Department = ED[e]; Endoscopic Retrograde Cholangio Pancreatography= = ERCP[f].

The COVID-19 pandemic has recently impacted all ED research and healthcare delivery (Khanna et al., 2023). The lack of robust evidence for RS in the ED was demonstrated during the pandemic when RS therapies are often indicated for those with respiratory failure secondary to COVID- 19 infection (Jarou et al., 2021). During this pandemic, evidence of varying quality emerged, some NHF studies could not be sustained, and contrasting opinions and resource constraints paralysed care delivery in many countries (Roy et al., 2021). The need to inform practice with reliable, valid, and applicable evidence on RS in the ED is obvious, pandemic notwithstanding. One Colombian multicentre RCT compared NHF to COT in 220 ED and ICU patients with severe acute respiratory failure due to COVID-19. This study demonstrated the superiority of NHF over COT for avoiding escalation to INV (hazard ratio, 0.62; 95% CI= 0.39-0.96; p = 0.03) (Ospina-Tascón et al., 2021).

As demonstrated, limited research is available in the ED, where patients first present to the hospital; however, it must be acknowledged that conducting research in the ED is challenging (Graham, 2019). Consequently, ED clinicians using NHF often rely on evidence drawn from other settings, such as the ICU, and/or their own experience of the therapy (Marjanovic et al., 2020).

5.1.6 Limitations

This SR and its protocol have followed the Cochrane methodology to minimise its bias and limitations (Higgins, 2022). The reviewers acknowledge the scope of the review with, which precluded inclusion of non-RCTs and qualitative evidence, which may have added further dimensions to the review findings. Systematic reviews are required to be iterative as they require updating as new evidence emerges, however secondary to COVID-19 ED evidence has been slow to emerge. As such, this SR includes the most recent data on ED patients and from RCTs based in ED.

The limitations of this SR include 1) insufficient data to consider subgroups; 2) use of outcome data impacted by imprecision for all outcomes; 3) including studies only published in English, and 4) use of data that had unavoidable RoB linked to the inability to fully blind participants, clinicians, and researchers.

5.1.7 Areas for Potential Research

While the reviewers acknowledge that conducting RCTs in the ED is challenging (Price et al., 2020), ED researchers are compelled to conduct rigorous, adequately powered ED RCTs that qualify for inclusion in future SRs. These studies should explore NHF cost-benefit and NHF use in different patient clinical conditions, age, respiratory rate, differing NHF flow rates, and FiO_2.

5.1.8 Conclusions

This SR and MA's findings inform both clinical research and patient care by providing clinicians and researchers with an appraisal and synthesis of the collective RCT evidence of adults requiring RS in the ED. The RCTs included could be pooled using MA techniques, which increased the certainty of the findings and condensed the vast amount of data. However, only one SR comparison (NHF versus COT) could be fully resolved, thus confirming the evidence gaps.

PROSPERO Protocol Registration Number: CRD42021222517

DATA AVAILABILITY STATEMENT

Data sharing does not apply to this manuscript as no new data were created in this SR.

CONFLICT OF INTEREST STATEMENT

Prior to 2020, JOD was an employee of Fisher & Paykel Healthcare. All other authors have no conflicts to declare.

5.1.9 The SR and MAs contribution to Evidence Based Practice

The main results reported in the SR and MAs were a lower risk of RS escalation for NHF compared to COT, and in contrast, a lower risk of RS escalation was seen for NIV compared to NHF. The Cochrane approach, PRISMA-P, and the PRISMA standards guided the completion of SR and MA (Appendix F). The SR authors worked independently in screening, data collection, and ROB assessment, and two authors entered, analysed, and checked the analysis of data. The manuscript was constructed to meet the requirements of the quartile one journal where it was published.

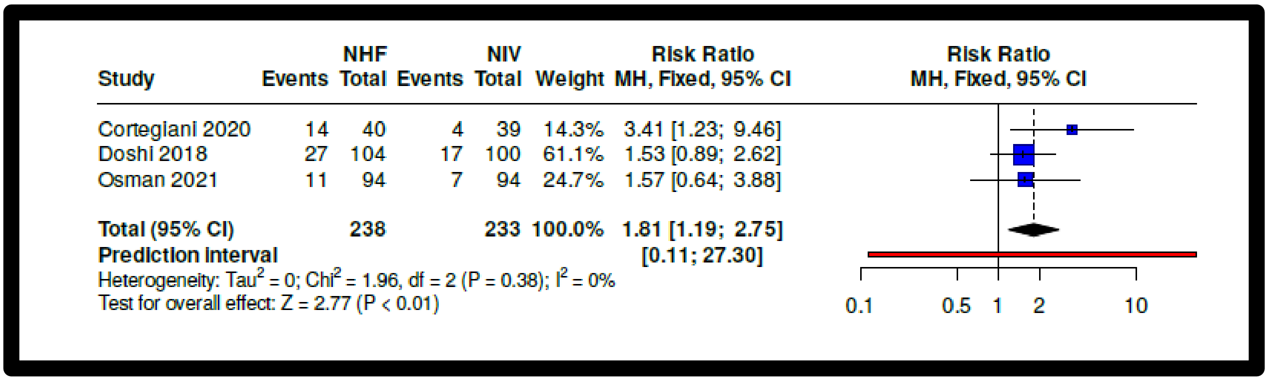
The two deviations from the SR protocol were made:

1. Secondary outcomes were not able to be reported.
2. 'Other' domain was added to the ROB assessment.

Notably, errors have been identified since the publication of the SR manuscript (O'Donnell et al., 2024). The error involved a MA of studies for the comparison of NIV to NHF (Figure 21). One study was incorrectly included in this MA (Doshi et al., 2020). The Doshi study (2020) was a secondary analysis of data drawn from previously published research (Doshi et al., 2018). The MA (Figure 21) was re-executed, and the MA conclusions were reconsidered (Figure 25). The overall SR findings remain unchanged, with a lower risk of RS escalation seen for NIV compared to NHF (RR 1.81; 95% CI, 1.19 to 2.75; $p < 0.01$). An erratum will be published in the journal.

Figure 25

Systematic Review: Corrected Forrest Plot RS Escalation Seen for NIV Compared To NHF



Note. This figure describes the meta-analysis of three studies in a forest plot.

The completion of a SR in this thesis clearly demonstrates the EBP theoretical framework within this doctoral research (Figure 1). As per the multi-method research design, the results of the SR with MAs are integrated with the second PPS method in the following chapter to inform the final thesis findings (Chapter Six [6.3]).

Figure 1 (From Chapter One)

The Evidence-Based Practice Framework and its Component Parts (adapted from Sackett, 2000).

Note. The EBP framework describes the conscientious use of current best evidence in conjunction with professional expertise and consumer values to inform clinical decisions.

5.2 Chapter Five Conclusion

This fifth Chapter*, Results,* has presented the results from the first method SR with MA, as published (O'Donnell et al., 2024). The aims, objectives, rationale and justification of the publication describing the SR have been described. The SR with MA exemplifies the *best evidence* described by EBP proponents, demonstrating the linkage between the methods, multi-methods research design, EBP theoretical framework, and its positivist paradigm. As already stated, in keeping with the multi-method design, the results of the SR with MAs will be integrated to inform the final thesis findings following the reporting of the results from the second method, the PPS, in the next chapter (Chapter Six [6.3]).

Having presented the published results of the first method, SR with MA, the results of the second method, the PPS, are presented in the sixth subsequent chapter, *Results – Point Prevalence Study.* The aim of the PPS (O'Donnell et al., 2024) was to provide a real-time, real-world epidemiological characterisation of adults receiving RS and their outcomes in four NZ EDs. The objective was to answer questions on the nature of RS provided in the ED and how this RS should be provided to achieve the best ED patient outcomes. These questions include: what form of RS should be provided, when should RS be provided, and to whom, and when is it appropriate to escalate RS provided along the complex continuum of care? The rationale for this publication was to fill a genuine gap in the ED RS evidence; this PPS method is novel, and so is its focus on interventions rather than diseas

Chapter Six

Results – Point Prevalence Study

The previous chapter, Chapter Five, *Results - Systematic Review with Meta-Analyses*, presented the findings of the published SR with MA (O'Donnell et al., 2024), the first of the two methods of the multi-method design.

The purpose of Chapter Six, *Results - Point Prevalence Study*, is to present the point prevalence study (PPS) results. This study is the second of the two methods of the multi-method design. Here, the analysis of PPS data, interpretation of results, and substantiation of findings are presented in two parts. Part one introduces the epidemiology of patients who have been provided RS in the ED; this part is presented as submitted for publication (O'Donnell et al., 2024). Part two presents the subset of the PPS data reporting on NHF. Here, the four core thesis questions are answered:

- Who receives NHF in the ED?
- How is NHF therapy delivered in the ED?
- Which patients receiving NHF require escalation of RS in the ED?
- What are the effects seen with NHF therapy on physiological and patient-centred outcomes?

This chapter comprises four sections, including a manuscript submitted for publication (O'Donnell et al., 2024) and a Chapter Conclusion.

- Part One Publication: The Epidemiology of Respiratory Support in the Emergency Department: A Prospective Point Prevalence Study
- Part Two: Nasal High Flow in the Emergency Department- A Subgroup of Prospective Point Prevalence Study Data
- Multi-method Design – Integration of the SR and PPS Results
- Chapter Six Conclusion

The aims, objectives, rationale and justification of the publication describing the PPS are as follows (O’Donnell et al., 2024):

Publication Aims: To use a PPS method to provide a real-time, real-world epidemiological characterisation of adults receiving RS in four NZ EDs.

Publication Objective: To answer questions that persist over the provision of RS in the ED and how RS should be provided to achieve the best ED patient outcomes. These questions include: what form of RS should be provided, when should RS be provided, and to whom, and when is it appropriate to escalate RS provided along the complex continuum of care?

Publication Rationale: A genuine gap in the ED RS evidence exists; this PPS method is novel, and so is its focus on interventions rather than disease.

Publication Justification: This publication aligns with the program of doctoral research and its second method, the PPS.

This chapter now begins with the presentation of the PPS as submitted for publication (O’Donnell et al., 2024).

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STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Jane O'Donnell
Name and title of main supervisor:	Professor Marlena Kruger
In which chapter is the manuscript/published work?	Chapter 6 Results Point Prevalence Study

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

Conception and design: JOD Lead Author, PhD Candidate
Draft manuscript preparation: JOD
Review manuscript drafts : JOD, AP, EM, KH, MK
All authors reviewed the results and approved the final version of the manuscript.

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The Epidemiology of Respiratory Support in the Emergency Department- A Prospective Point Prevalence Study
Submitted to Australasian Emergency Care

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6.1 Part One Manuscript for Publication: The Epidemiology of Respiratory Support in the Emergency Department: A Prospective Point Prevalence Study

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Keywords: Emergency; Casualty; Respiratory; Escalation; Oxygenation; Pulmonary.

6.1.1 Abstract

Background:

Adult Emergency Department (ED) patients often require respiratory support (RS). This real-time, real-world study characterised the epidemiology of ED patients receiving RS. The primary study outcome was RS escalation prevalence.

Methods:

This prospective, observational, multisite point prevalence study (PPS) included n = 76 adults provided RS, representing 8.4% of all presentations (N = 898). In autumn 2023, data were collected as the relaxation of COVID-19 public health measures began.

Results:

The PPS was underpowered and unable to support all planned analyses. The mean age of the participants was 67.38 years (SD ± 17.41); 52% were male, 48.6% had >3 comorbidities, and 44% had respiratory diagnoses. The prevalence of escalation of RS was 28.9%. Differences were seen for those escalated vs not for mean admission breath rate (p = 0.02), GCS (p = 0.04), hospitalisation rates were

22% higher (RR 1.22, 95% CI 0.99-1.5, $p = 0.05$), and hospital length of stay (LOS) was 42% longer (seven (IQR = 4 to 12) vs three days (IQR = 1 to 7)). Māori demonstrated a 5.8% higher risk of requiring escalation of care on an absolute scale ($n = 6$ [33.3%] vs $n = 16$ [27.5%]) and a 22% increased risk on a relative scale (RR 1.22; 95% CI 0.56 to 2.67; $p = 0.60$) than non-Māori.

Conclusions:

The minority required RS, and a high incidence of RS escalation was seen, as were subsequent increases in hospital admission and LOS. These findings are especially apparent for NZ Māori. These epidemiological data may inform prospective research.

6.1.2 Introduction

The Emergency Department (ED) typically provides the first point of care for those with chronic conditions, trauma, infection, or complications of interventions, with many providing some form of respiratory support (RS) (WHO, 2024; Kelly et al., 2017). This ED research focuses on the RS provided in the ED.

The collective term respiratory support describes a continuum of therapies provided across clinical settings, including ED. Respiratory support delivery in ED is complex; some patients require RS escalation to reduce rates of avoidable morbidity and mortality (Hacker Peper et al., 2022). Respiratory support therapies include conventional oxygen therapy (COT), also known as standard oxygen therapy (with a simple mask or cannula); nasal high flow (NHF); non-invasive (NIV); and invasive ventilation (INV). The delivery of RS may involve either invasive or non-invasive approaches. Invasive RS requires intubation and mechanical ventilation (MV). Non-invasive RS includes COT, NHF, and two forms of NIV: bilevel positive airway pressure (BiPAP) and continuous positive airway pressure (CPAP).

Historically, high-need ED patients are provided RS with either a combination of COT, NIV, or INV. Conventional O_2 therapy using non-fixed performance devices may be associated with unintentional alveolar damage due to hyperoxia (Mach et al., 2011). Non-invasive ventilation and INV have known complications, including increased mortality and morbidity (Resnick, 2008; Davidson et al., 2016). Additionally, the delivery of NIV or INV is also resource-draining and usually requires admission to a specialist ward or an ICU. In contrast, NHF use in ED is increasing; compared to NIV, NHF is less burdensome to deliver and better tolerated by patients (Stéphan et al., 2017); for these reasons, NHF use may have increased in ED despite a limited evidence base (Marjanovic et al., 2020).

A paucity of robust prospective ED RS research forces clinicians to practice in an 'evidence grey zone' (Kelly & Horsley, 1999). Questions persist over the provision of RS in the ED and how RS should be provided to achieve the best ED patient outcomes. These questions include: what form of RS should be provided, when should RS be provided, and to whom, and when is it appropriate to escalate RS provided along the complex continuum of care?

In March 2020, the coronavirus disease 2019 (COVID-19) pandemic was declared. During this pandemic, up to 30% of COVID-19 patients developed secondary acute hypoxaemic respiratory failure (AHRF) (Xia et al., 2019), amplifying the need to provide forms of RS in ED (Alhazzani et al., 2019; Burnim et al., 2022). Clinicians looked for evidence to guide practice. However, the gaps in the ED RS evidence were clear, and subsequently, nonpeer-reviewed evidence emerged. The lack of robust evidence, combined with contrasting opinions, panic, and resource constraints, paralysed care delivery in many countries (Leonie et al., 2021). The need to inform ED practice with reliable, valid, and applicable RS evidence is obvious, pandemic notwithstanding.

Additionally, given the evolution of the ED high-needs population, it is likely that ED patients will increasingly require targeted efficacious RS. Failure to promptly and appropriately provide RS will likely impact patient outcomes and increase healthcare burdens, such as increased hospital length of stay (LOS). These issues have genuine clinical significance for ED practice and research (Fan et al., 2017). Clinical significance here refers to meaningful ED patient outcomes.

One of the fundamental problems is that the epidemiological profile of the heterogeneous patients provided RS in the ED needs to be better characterised and then understood by clinicians and researchers. Evidence-based practice (EBP) requires a reliable epidemiological foundation to contextualise interventions such as RS and provide a platform for robust prospective research (Rasmussen & Goodman, 2019). Investigations such as randomised controlled trials (RCT) rely on epidemiological data as a baseline to inform their methods (Rasmussen & Goodman, 2019). While the RCT is regarded as methodologically superior to other trials, it can be problematic, as it is unethical to deny participants an efficacious therapy (Resnik, 2008). Many RS therapies reported here have demonstrated efficacy in settings such as the ICU (Nishimura, 2015).

The method used here was a point prevalence study (PPS). The PPS is an epidemiological study capable of reporting liability within a population and informing healthcare and research strategies (Harder, 2014). There is a shortage of large-scale epidemiologic studies reporting data specific to the ED patient population (Kelly et al., 2017; Alnajada et al., 2023; Mockel et al., 2013).

As said, a genuine gap in the ED RS evidence exists; this PPS method is novel, and so is its focus on interventions rather than disease. Therefore, this PPS aimed to provide a real-time, real-world epidemiological characterisation of adults receiving RS in four NZ EDs.

6.1.3 Method

Design.

A prospective, observational PPS method was used to characterise the real-world, real-time epidemiology of adults receiving RS in four NZ EDs.

Outcomes.

Aside from the data collected to characterise the epidemiology of the study participants, data were also collected to report on the primary study outcome: escalation of RS in the ED. The secondary study outcomes related to ED disposition. The dichotomous primary outcome RS escalation is defined as a patient requiring at least one transition along the RS continuum. Here, patients transition from one form of RS to another, for example, COT to NHF or NHF to INV. De-escalation was defined as the reverse of escalation, for instance, NHF to COT.

Additionally, the available records of escalated participants were explored to better understand the rationale prompting escalation; here, there was no intent to attribute cause or effect. In this exploration, the rationale for escalation was classified accordingly:

1) failure to respond to current therapy,

2) feels unwell,

3) clinical signs deteriorated,

4) vital signs deteriorated, or

5) ED staff are concerned.

The exploration of escalation involved both subjective and objective interpretation; for example, 'ED staff are concerned'. Notably, 'ED staff are concerned' is a validated Modified Early Warning Score (MEWS) consideration. The MEWS is an example of an EWS used in ED practice to identify those at risk of deterioration (Burch et al., 2018). In contrast, exploration of clinical signs of deterioration, such as dyspnoea and cyanosis, was objective, as were the data reporting vital signs of deterioration defined as per the MEWS criteria, including body temperature, pulse rate (PR), breath rate (BR), systolic blood pressure (SBP), Glasgow Coma Score (GCS), and peripheral oxygen saturation (SpO_2) (Burch et al., 2018).

Setting.

The study setting was the ED, also known as an accident and emergency department (A&E), emergency room (ER), emergency ward (EW), or casualty department. The study involved four EDs in NZ. Two participating EDs were in tertiary referral hospitals (Hospitals A & B) in one large metropolitan city, and two were within regional hospitals in smaller cities (Hospitals C & D). In the year before this study and ending December 2022, the total census of those aged >18 years presenting at the participating EDs was n = 169,929 (mean 465.5 per day). Each hospital's respective census for this period was: Hospital A 85,436; Hospital B 43,776; Hospital C 27,467; and Hospital D 13,250 (Table 22). Table 22 reports the presentation data for all ED patients (and by Māori Ethnicity) for the year ended December 2022, which was the year before the PPS was conducted.

Table 22

Point Prevalence Study: All ED Patients (and by Māori Ethnicity) Presentations for The Year Ended December 2022 – The Year Before the PPS

	All Ethnicities *n*	All Ethnicities mean per 24hrs	Māori[1] *n* (%)	
Hospital A	85,436	234.0	16,210	(19.0)
Hospital B	43,776	119.9	3838	(8.8)
Hospital C	27,467	75.2	7776	(23.3)
Hospital D	13,250	36.3	7614	(57.4)
Total	169,929	465.5	35,438	(20.8)

Note. Data are reported as *n*, %

Each participating ED is staffed by Registered Nurses, Nurse Practitioners, House Officers, Registrars and ED Consultants. Three of these EDs are university-affiliated. By profession, the responsibility for clinical decision-making (CDM) around the provision of RS varies, with some EDs relying on established clinical pathways.

Each participating ED has a designated Short Stay Unit (SSU); these also vary significantly. In New Zealand, the SSU is intended to provide short-term management (< 24 hours) for ED patients deemed in need at ED triage or by direct referral from a primary healthcare service such as a General Practitioner (GP). Before the commencement of the PPS, an informal survey of the participating EDs revealed that most SSU patients were direct GP referrals, bypassing the ED and its triage. Three SSUs are managed and supported by EDs, and one is not. On this basis, this PPS did not include patients from any of the respective SSUs.

Participants.

The study sample was ED patients aged ≥18 years and provided RS in the ED; no exclusion criteria were applied. The scope of this study was limited to those provided RS in the ED. Therefore, we must assume that those not provided RS did not need it and vice versa.

Sample size modelling computed the minimum participant number required to meet the desired statistical thresholds. The modelling incorporated a mean incidence of RS escalation to either INV or NIV of 5.45%, as reported by Jones (Jones et al., 2016). This modelling determined that a sample size of 80 participants was needed to determine the primary outcome. However, any change in the incidence of escalation was deemed a clinically significant finding. A clinically significant finding is one that potentially improves patient outcomes. This study characterises the ED patient who requires escalation of RS; the outcome escalation of RS is known to be indirectly associated with increased morbidity and mortality (Hacker Teper et al., 2022).

Data Collection.

All data were collected from the available participant clinical records. During April and May 2023 (Autumn in New Zealand), data were collected by 18 specifically trained data collectors who were either Registered Nurses or nursing and medical students. Data were collected over two twelve-hour intervals (1000–2200), first on a Sunday and then on a Monday, four weeks apart. Sundays and Mondays are typically the busiest days in NZ EDs (MOH, 2015).

On March 11th, 2020, the World Health Organization declared the COVID-19 pandemic a Public Health Emergency (PHE) (Baker et al., 2020). Notably, the first study data collection interval occurred at the end of the PHE period in New Zealand, just as strict COVID-19 elimination and containment strategies were fully relaxed (Augustine, 2020). The study participants were observed, and their de-identified data were extracted from their available clinical records.

The collected data were categorised and are presented as follows:

- Participant Characteristics,
- Participant Emergency Department, and
- Participant Emergency Department Disposition.
- The primary outcome escalation of RS in the ED is reported in the second of these categories.

Ethical considerations.

Ethics and hospital locality approvals were obtained for each participating ED (Appendices D & E). The Massey University Ethics Committee (NOR 22/18) approval included a waiver for individual participant consent because the data collected were de-identified, and the lead investigator was not involved in extracting data from its primary source (Appendix E). Those who were involved in data extraction had signed confidentiality agreements.

Study Data Management and Analysis.

De-identified participant data were entered into a REDCap (Harris et al., 2009) electronic case report form (eCRF) by the 18 trained data collectors. The lead investigator then exported the data from REDCap into SPSS IBM software for analysis (Statistics for Windows, Version 29.0).

A two-phased data analysis was designed and described in the published study protocol (O'Donnell et al., 2022). Phase one involved a descriptive analysis, including a narrative overview and analysis using central tendency and percentage measures. Normally distributed continuous data were described using mean (M) and standard deviation (SD), and nonnormally distributed continuous data were expressed as median (Mdn) and interquartile ranges (IQR). In addition, both categorical and dichotomous data were reported as frequencies and percentages. Given the final sample size limitation, the planned inferential data analyses still needed to be fully executed.

A series of t-tests and inferential data analyses were completed. These analyses explored the differences between the means of those provided RS and those that were escalated vs not escalated, as well as the treatment effects relative risk (RR) and the number needed to treat (NNT). The statistical significance for all analyses used a two-sided alpha ≤ 0.05 and confidence interval (CI) of 95%.

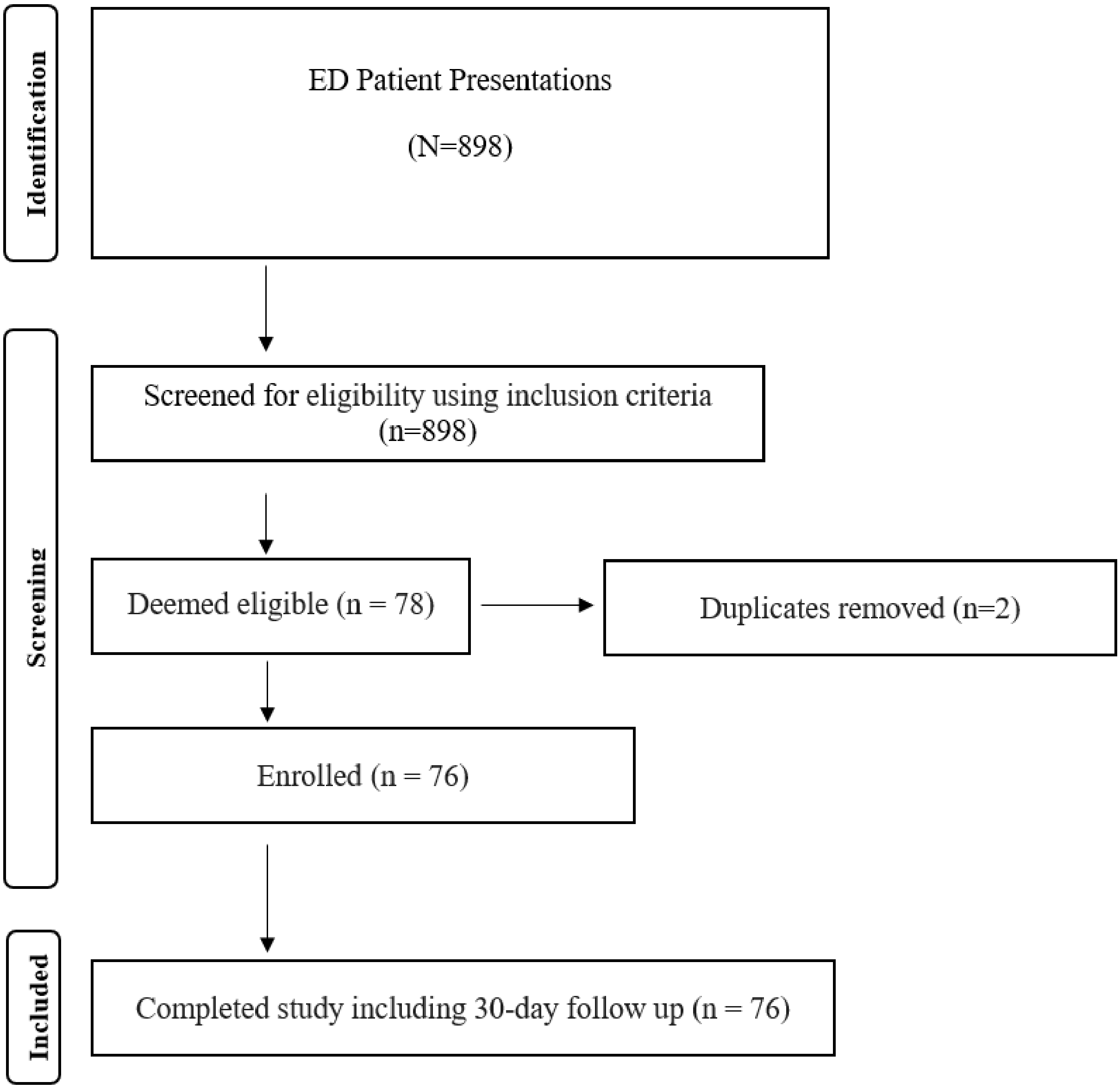
These methods mostly reflect the previously published protocol (O'Donnell et al., 2022) and its prospective trial registration (Appendix K). The study reporting follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations (von Elm et al., 2008) (Appendix M).

6.1.4 Results

During the two 12-hour study intervals, N = 898 patients aged >18 years presented to the four participating EDs; notably, this represented a 51.8% increase in census year on year. All N = 898 patients were screened for inclusion. Finally, *n* = 76 (8.4%) was included in the PPS (Figure 26). Figure 26 is a flowchart which describes the study of patient recruitment. However, the number of included participants was (*n* = 4; 5%) less than the target sample size determined a priori by power calculation. This failure to recruit the target sample size has limited the planned series of inferential analyses outlined in the published protocol (O'Donnell et al., 2022).

Figure 26

Point Prevalence Study: Study Flowchart Showing Study Recruitment



Participant Characteristics.

The demographic characteristics of the included participants are summarised in Table 23. Table 23 reports data on participant demographic characteristics, their arrival mode to ED and the duration of their symptoms before their ED presentation. The mean age was 67.3 (SD ± 17.4) years. The majority identified as male (*n* = 40; 52%), with 47% (*n* = 36) female. Most participants were NZ European (*n* = 31; 40%) or NZ Māori ethnicity (*n* = 18; 23%). The overall NZ Indigenous population comprises 17% Māori (Crengle et al., 2022); therefore, in this study, Māori were overrepresented. The mean duration of symptoms before admission varied considerably, with a median of 24, IQR = 1 to 48 hours. Most (*n* = 58; 76%) arrived by ambulance from home and received some form of O_2 therapy en route (*n* = 46; 60%).

The most prevalent ED diagnostic groups for those receiving RS were respiratory (*n* = 34; 44%), cardiac (*n* = 9; 11.8%), and musculoskeletal (*n* = 6; 7.8%). The remaining 18 diagnostic groups had individual prevalence rates of 6.5% or less. For example, the diagnostic group mental health prevalence was 3.9% (*n* = 3) and less than 6.5%.

Table 23

Point Prevalence Study: Participant Demographic Characteristics, Arrival Mode to ED and Duration of Symptoms

Age, years	M	SD ±
Age, all	67.38	17.41
	n	%
Age > 65	30	39.4
Age < 65	46	60.5
Gender	**n**	**%**
Male	40	52
Female	36	47.4
Ethnicity, Māori vs non-Māori	**n**	**%**
NZ Māori	18	23.7
Non-Māori	58	76.3
Ethnicity, all	**n**	**%**
European	7	9.2
NZ European	31	40.8
Asian	7	9.2
Pacifica	5	6.5
Other	8	10.5
Māori	18	23.7

Table 23 cont.

Arrival Mode	n	%
Ambulance from another hospital	1	1.3
Private vehicle	14	18.4
Ambulance from home	58	76.3
Unknown	3	3.9
Duration of symptoms prior to ED admission in hours	Mdn 24	IQR 1-48

Note. Data are reported as mean (M) with standard deviation (SD), *n*, or %, Median (Mdn) with Inter Quartile Range (IQR).

Study participants presented with a history of a mean of three comorbidities (SD ± 5.2). The cardiac (*n* = 48; 63%), respiratory (*n* = 34; 44%), endocrine (*n* = 32; 42%), renal (*n* = 26; 34%), and neurological (*n* = 24; 31%) comorbidities were the most prevalent (Table 24). Table 24 reports study data on the participant comorbidities.

Table 24

Point Prevalence Study: Participant Comorbidities

Mean Comorbidities	3.3	(5.2)
Comorbidities*	***n***	**(%)**
Alcohol or Drug	4	(5.3)
Blood-related	2	(2.6)
Burns	0	
Cardiac/Circulatory	48	(63.2)
Digestive / Gastrointestinal	11	(14.5)
Ear, nose, throat	3	(3.9)
Endocrine	32	(42.1)
Eye	6	(7.9)
Hepatobiliary	8	(10.5)
Infectious disease	1	(1.3)
Injury, poisoning – due to drugs	0	
Mental health	8	(10.5)
Musculoskeletal	18	(23.7)
Neoplastic disorders	6	(7.9)
Neurological	24	(31.6)
Other	7	(9.2)
Other health service issues	7	(9.2)
Pregnancy-related	0	
Renal/Urinary	26	(34.2)
Reproductive	6	(7.9)
Respiratory	34	(44.7)

Note. Data are reported as *n*, %, or mean (M) with standard deviation (SD)

On arrival, the baseline observations, the mean respective Modified Early Warning Score (MEWS) of 8.60 (SD ± 4.62), and the Australasian ED triage score of 2.58 (SD ± 0.89) suggested a high overall participant acuity. Table 25 reports study data on the participant ED admission triage scores.

Table 25

Point Prevalence Study: On ED Admission Triage Score

On ED Admission Triage Score	*n*,	(%)
Immediately life-threatening, immediate simultaneous triage and treatment	12	(15.6)
Imminently life-threatening or important time-critical	15	(19.5)
Potentially life-threatening, potential adverse outcomes from delay > 30 min	44	(57.2)
Potentially serious or potential adverse outcomes from delay > 60 min, or significant complexity or severity	3	(3.9)
Less urgent or dealing with administrative issues	2	(2.6)

Note. Data are reported as *n*, %

Forty-nine final ED diagnoses were determined across the 76 participants. The most prevalent final ED diagnosis was pneumonia (*n* = 11; 14.3%) and exacerbations of chronic obstructive pulmonary disease (COPD) (*n* = 7; 9.1%). Most of the final hospital or ED discharge group classifications were respiratory (*n* = 35; 46.1%) or renal (*n* = 13; 17.1%) (Table 26). Table 26 reports data on the Final ED Diagnoses of the participants where more than one diagnosis was possible.

Table 26

Point Prevalence Study: Final Primary ED Diagnoses

Diagnosis	*n*	(%)
Acute bronchitis	1	(1.3)
Acute pulmonary oedema	3	(3.9)
Aspiration secondary to dysphagia secondary to oesophageal cancer	1	(1.3)
Bronchiectasis exacerbation	2	(2.6)
Bronchiectasis vs COVID vs pneumonia	2	(2.6)
Cardiac arrest followed by ventricular tachycardia	1	(1.3)
Chest sepsis	1	(1.3)
Collapse	1	(1.3)
Constipation	1	(1.3)
Diabetic keto acidosis	1	(1.3)
Back pain and chest pain of unclear cause	1	(1.3)
Exacerbation chronic obstructive pulmonary disease	7	(9.1)
Exacerbation of congestive heart failure	2	(2.6)
Fluid overload in the context of alcoholic liver disease	1	(1.3)
Hip dislocation	1	(1.3)
Hypertensive intracerebral haemorrhage	1	(1.3)
? Fluid overload causes unknown	1	(1.3)
Infection, source unknown	1	(1.3)
Influenza	3	(3.9)
Intentional overdose	3	(3.9)
Left distal radius fracture	1	(1.3)

Table 26 cont.

Left lower leg cellulitis	1	(1.3)
Urinary tract infection causing hypoactive delirium in dementia	1	(1.3)
Multiple liver lesions	1	(1.3)
Multiple rib fractures, wrist fracture	1	(1.3)
Non-ST-elevation myocardial infarction	1	(1.3)
Palliative, family not coping	1	(1.3)
Pneumonia	11	(14.3)
Chronic lymphoedema, bilateral cellulitis, and sepsis	1	(1.3)
Probable fluid overload +/-acute ischaemia and infection	1	(1.3)
Probable urinary retention	1	(1.3)
Progression of disease	1	(1.3)
Relapsed stage 4a R Middle Zone squamous cell cancer of the lung	1	(1.3)
Renal colic	1	(1.3)
Seizure	2	(2.6)
Sepsis? Cause	2	(2.6)
Sepsis? chest source	1	(1.3)
Sepsis? cause? lower respiratory tract infection	1	(1.3)
Sepsis ruptured appendix	1	(1.3)
Sepsis secondary to obstructive renal stone	1	(1.3)
Septic shock, cerebral abscess from mastoid	1	(1.3)
Shortness of breath	1	(1.3)
Shoulder dislocation following seizure	1	(1.3)
Shoulder dislocation/ fracture	1	(1.3)
Syncope –multifactorial	1	(1.3)
Traumatic sub dural haematoma	1	(1.3)
Unwitnessed fall in anticoagulated elderly patient	1	(1.3)
Urosepsis	1	(1.3)
Viral exacerbation asthma	1	(1.3)
Total	76	

Note. * > One is possible. Data are reported as *n*, %.

Participant Emergency Department Interventions.

The treatments provided pre-hospital are described in Table 27. Table 27 reports study data on the treatment patients received both pre-hospital and pre-ED-admission. The RS received in the ED comprised either a single therapy or a combination of therapies. The most common RS received was COT low flow < 5L/minute via nasal cannula (*n* = 56; 73.7%). The least common RS received was INV, with one participant (*n* = 1;1.3%) requiring intubation. No humified face mask RS was received by any participant (Table 28). Table 28 reports study data on the RS provided to patients in the ED and after their discharge from the ED.

Table 27

Point Prevalence Study: Patient Treatment Pre-Hospital and Pre ED-Admission

Treatment Pre-Hospital*	*n*	(%)
Nebuliser	5	(6.6)
O_2 venturi mask	2	(2.6)
O_2 conventional O_2 mask	37	(48.7)
Non-invasive ventilation	0	
Defibrillation	0	
Cardiopulmonary resuscitation	1	(1.3)
Ambubag	2	(2.6)
Artificial Airway	3	(3.9)
Tracheostomy	0	
Endotracheal tube	0	

Note. Data are reported as *n*, %

Table 28

Point Prevalence Study: Respiratory Support Provided in ED and on ED Discharge

Respiratory Support*	In ED *n* (%)		On ED disch *n* (%)	
Conventional low-flow oxygen nasal cannula	56	(73.7)	25	(32.8)
Conventional low-flow oxygen mask	13	(17.1)	4	(5.2)
Humidified face mask	0		0	
Venturi mask	2	(2.6)	0	
Nebuliser face mask	15	(19.7)	0	
Nasal high-flow therapy	12	(15.6)	3	(3.9)
Non-invasive ventilation	4	(5.2)	1	(1.3)
Invasive Ventilation via endotracheal tube	1	(1.3)	1	(1.3)
Total	103		34	(44.

Note. [1] NZ indigenous population. Data are reported as *n*, %.

In addition to the RS received, participants received an array of adjunctive interventions and investigations to support ongoing monitoring and confirmation of diagnoses (Table 29). Nearly all participants (*n* = 75; 98.7%) had continuous monitoring of their temperature, BP, pulse, and breath rate. Many had SpO_2 monitoring (*n* = 61; 80.3%) and an intravenous cannula inserted (*n* = 47; 61.8%). Most participants had laboratory (*n* = 68; 89.5%) and/or radiological investigations (*n* = 47; 61.8%) (Table 29). Table 29 reports study data on the treatments and investigations patients received in ED both on admission and during their ED stay.

Table 29

Point Prevalence Study: Treatments and Investigations in ED both on Admission and During ED Stay

Treatments, Investigations*	On Admission *n* (%)	During Admission *n* (%)
Monitoring of T, BR, PR, BP	75 (98.7)	66 (86.8)
Monitoring of fluid input and output	8 (10.5)	9 (11.8)
Weight	3 (3.9)	4 (5.3)
Neurologic checks Glasgow Coma Score	35 (46.1)	20 (26)
Vascular checks	3 (3.9)	0
Fingerstick blood glucose	8 (10.5)	0
Pulse oximetry SpO_2	61 (80.3)	44 (33.8)
Electrocardiogram continuous	27 (35.5)	23 (29.9)
Electrocardiogram 12 Lead	35 (46.1)	9 (11.7)
Laboratory testing	68 (89.5)	32 (41.6)
Radiology testing	47 (61.8)	25 (32.5)
Oral medication	11 (14.5)	20 (26)
Intravenous medication	32 (42.1)	46 (59.8)
Intravenous fluids	15 (19.7)	19 (24.7)
Wound care	0	0
Nourishment	0	2 (2.6)
Routine personal care	1 (1.3)	0
Specialty referral	4 (5.3)	4 (5.3)
Cultural Services	0	0

Table 29 cont.

Treatments, Investigations*	On Admission *n* (%)	During Admission *n* (%)
Palliation in ED	1 (1.3)	1 (1.3)
Care limitation in ED	3 (3.9)	3 (3.9)
Withdrawal of care in ED	1 (1.3)	0
Major or minor surgical intervention	0	0
Minor orthopaedic intervention	0	4 (5.3)
Major orthopaedic intervention	0	0
Care coordination	0	4 (5.3)
Education of patient	0	0
CPR, Cardioversion or Defibrillation	0	0
Intubation	0	1 (1.3)
In-dwelling urinary catheter	4 (5.3)	7 (9.1)
Chest drain	0	0
Nebulisation	0	0
Intravenous line insert	44 (57.9)	13 (16.9)
Central venous line insert	0	1 (1.3)
Arterial line	1 (1.3)	0
Naso gastric or Naso jejunal insert	0	0
Reperfusion STEMI	0	0
End-tidal carbon dioxide ($PetCO_2$)	6 (7.9)	5 (6.5)
Therapeutic tap, e.g. pneumothorax	0	0
Dialysis	0	1(1.0)

Note. Data are reported as *n*, % ..T= temperature, BR= breath rate, PR=pulse rate, BP=blood pressure; STEMI=ST-elevation myocardial infarction

Many participants received medications in the ED (Table 30). The most common classes of medication received were antibiotics (n = 36; 47.4%), analgesia (n = 28; 36.8%), and respiratory, including bronchodilators and corticosteroids (n = 17; 22.4%). Some of these medications were part of usual home regimes. The most prevalent usual at-home indications were for endocrine (n = 24; 31.6%), gastrointestinal (n = 36; 47.4%), and cardiovascular (n = 48; 63.2%) conditions. Table 30 reports study data on the usual medications patients take at home and what they were provided whilst in the ED.

Table 30

Point Prevalence Study: Medications Usual 'At Home' or in the Emergency Department

Medication* Type	Pre ED n	(%)	In ED n	(%)
Analgesic	33	(43.4)	28	(36.8)
Antiallergics & Medicines Anaphylaxis	5	(6.6)		0
Anticonvulsants / Antiepileptics	6	(7.9)	5	(6.6)
Antidotes & Other Substances for Poisonings	1	(1.3)		0
Antibiotics/antivirals	17	(22.4)	36	(47.4)
Antimigraine	0			0
Antiparkinson	1	(1.3)		0
Antiseptics And Disinfectants	0		2	(2.6)
Blood Product or Treatment	9	(11.8)	6	(7.9)
Cardiovascular	48	(63.2)	16	(21.1)
Dental Preparations	0			0
Dermatological	10	(13.2)		0
Diagnostic Agents	0		1	(1.3)
Diuretics	21	(27.6)		-
Ear nose throat	2	(2.6)		-
Endocrine Disorders	24	(31.6)	7	(9.2)
Gastrointestinal	36	(47.4)	13	(17.1)
General Anaesthetics	0		2	(2.6)
Homeopathic Herbal Remedies	1	(1.3)		0

Table 30 cont.

Medication* Type	Pre ED n (%)		In ED n (%)	
Mental and Behavioural	18	23.7)	1	(1.3)
Muscle Relaxants / Peripherally Acting and Cholinesterase Inhibitors	1	(1.3)	1	(1.3)
Oncology	5	(6.6)		0
Ophthalmology	5	(6.6)	1	(1.3)
Peritoneal Dialysis Solution	2	(2.6)	1	(1.3)
Reproductive Health and Perinatal Care		0		0
Respiratory	20	(26.3)	17	(22.4)
Sedation	10	(13.2)	9	(11.8)
Solutions for Correcting H_2O Electrolyte, Acid-Base	2	(2.6)	16	(21.1)
Vitamins and Minerals	15	(19.7)	4	(5.3)
Vaccines	1	(1.3)	1	(1.3)
Immunomodulators and Antineoplastics	1	(1.3)		0
Joint Disease	12	(15.8)	2	(2.6)
Local Anaesthetics	0		3	(3.9)
Medical Gases	3	(3.9)	9	(11.8)

Note. Data are reported as *n*, % ..

Participant Primary Study Outcome – Escalation of Respiratory Support.

As anticipated, the overall management of the RS received, including initiation, escalation, and de-escalation, varied. For the primary study outcome, the absolute prevalence of at least one escalation of RS in this cohort was n = 22 (28.9%) (Table 31). Therefore, RS provided to the majority was not escalated (n = 54, 71%). For example, many of those who commenced COT remained on it for the duration of their ED admission. Table 31 reports study data on the rates and type of RS escalation or de-escalation in the ED.

Table 31

Point Prevalence Study: Escalation or De-escalation of Respiratory Support

		Escalated		Non escalated	
		n	%	n	%
Escalation	**76**	**22**	**28.9**	**54**	**71**
1st Escalation of RS	**22**				
COT cannula to NHF		7	9.2		
Venturi mask to NHF		1	1.3		
Venturi mask to NIV		1	1.3		
NHF to CPAP		1	1.3		
COT cannula to COT mask		3	3.9		
COT to nebulisation		9	11.8		
2nd Escalation of RS	**7**				
COT mask to NHF		1	1.3		
NIV to Invasive		1	1.3		
COT to nebulisation		6	7.9		
De-escalation of RS	**8**				
NHF to COT cannula		2	2.6		
CPAP to COT cannula		1	1.3		
CPAP to NHF		1	1.3		
COT mask to COT cannula		4	5.3		

Note Data are reported as n; %. More than one event is possible COT = conventional oxygen therapy; NHF = nasal high flow; NIV = non-invasive ventilation; CPAP = Continuous Positive Airway Pressure; INV = Invasive ventilation.

The most common escalations occurred from COT cannula to NHF (*n* = 7, 9.2%) or to adjunctive nebulisation (*n* = 9, 11.8%). The minority of these (*n* = 8, 36.3%) then required a subsequent escalation and transition across a continuum of RS therapies (Table 31). An exploration of the rationale for the first escalation of RS appeared to be most prompted by deterioration in participants' clinical status (11.8%) or vital signs (15.8%). The difference in mean vital signs on admission between those who escalated and those who did not were statistically significant for GCS (p = 0.04) and breath rate (p = 0.02) alone. In contrast, de-escalation of RS was also seen (n = 8, 36.3%). This appeared to be mostly prompted mainly by the positive response to the RS received (n = 7, 31.8%) and for others due to imposed limits to care (n = 1, 4.5%) (Table 32). Table 32 reports study data on the total rates of escalation of RS, and considered this by age, gender, ethnicity, number of comorbidities, triage and EWS scores and diagnostic groups.

Data were further explored to identify factors influencing the primary outcome. No demographic differences were noted for those who escalated vs those who did not (Table 32). Participants in the respiratory diagnostic category were not statistically at higher risk of escalation than the overall sample (RR 0.91; 95% CI, 0.47 to 1.77; p = 0.79) (Table 33), nor were those aged > 65 years (RR 1.05; 95% CI 0.59 to1.84; p = 0.86), or being male (RR 1.20, 95% CI 0.69 to 2.09; p = 0.49) (Tables 32-33). In contrast to the comparisons described in Table 32, Table 33 reports study data on RS escalation vs non-RS escalation by patient diagnostic group.

Table 32

Point Prevalence Study: Escalation of Respiratory Support by Age, Gender, Ethnicity, Number of Comorbidities, Triage and EWS scores and Diagnostic Group

Total Escalations, *n* (%)	Total **76**		Escalated **22 (28.9)**			Non escalated **54 (71)**		
Rationale Escalation, *n* (%)								
Unknown	3	(3.9)						
Patient feels unwell	2	(2.6)						
ED staff concerned	5	(6.6)						
Failure to respond	5	(6.6)						
Clinical signs deteriorated	9	(11.8)						
Vital signs deteriorated	12	(15.8)						
For a procedure	1	(1.3)						
Rapid sequence intubation	1	(1.3)						
Escalation Approach, *n* (%)								
1st Escalation of RS			**2nd Escalation of RS**			**De-escalation of RS**		
COT cannula to NHF	7	(9.2)	COT mask to NHF	1	(1.3)	NHF to COT cannula	2	(2.6)
Venturi mask to NHF	1	(1.3)	NIV to Invasive	1	(1.3)	NIV to COT cannula	1	(1.3)
Venturi mask to NIV	1	(1.3)	COT to nebulization	6	(7.9)	NIV to NHF	1	(1.3)
NHF to CPAP	1	(1.3)				COT mask to COT cannula	4	(5.3)
COT cannula to COT mask	3	(3.9)						
COT to nebulisation	9	(11.8)						

Table 32 cont.

	Total		Escalated		Non escalated		*p*-value
Age							
Age –M (± SD)	67.38	(17.41)	68.45	(13.84)	66.94	(18.7)	0.34* $p = 0.7341$
Age > 65, *n* (%)	46	(60.5)	14	(30.4)	32	(69.5)	RR 1.05 $p = 0.86$
Age < 65, *n* (%)	30	(39.4)	8	(26.6)	22	(73.3)	
Gender, *n* (%)							
Male	40	(52)	14	(35)	26	(65)	RR 1.2 $p = 0.49$
Female	36	(47.4)	8	(22)	28	(88)	
Ethnicity, *n* (%)							
European	7	(9.2)	0		7	(100)	
NZ European	31	(40.8)	11	(35.5)	20	(64.5)	RR 1.22 $p = 0.56$
Asian	7	(9.2)	2	(28.5)	5	(71.4)	
Pacifica	5	(6.5)	0		5	(100)	
Other	8	(10.5)	3	(37.5)	5	(62.5)	
NZ Māori	18	(23.7)	6	(33.3)	12	(66.7)	RR 1.20 $p = 0.63$
Non-Māori	58	(76.3)	16	(27.6)	42	(72.4)	
Comorbidities							
Comorbidities > 3, *n* (%)	37	(48.6)	14	(37.8)	23	(62.1)	
Comorbidities < 3, *n* (%)	39	(51.3)	8	(20.5)	31	(79.4)	
Comorbidities –M (± SD)	3.34	±1.87	3.18	(2.19)	3.42	(1.71)	0.51* $p = 0.61$
EWS –M (± SD)	8.60	(4.62)	7.55	(4.96)	9.07	(4.46)	-1.30* $p = 0.19$
Triage score –M (± SD)	2.58	(0.89)	2.77	(0.97)	2.5	(0.86)	1.19* $p = 0.23$

Table 33

Point Prevalence Study: Respiratory Support Escalation vs Non-Respiratory Support Escalation by Diagnostic Group

Diagnostic Group, n (%)	Total		Escalated		Non escalated		*p*-value
Alcohol or Drug	0		-		-		
Blood-related	0		-		-		
Burns	0		-		-		
Cardiac/Circulatory	9	(11.8)	4	(44.4)	5	(55.5)	
Digestive / Gastrointestinal	2	(2.6)	1	(50)	1	(50)	
Ear, nose, throat	0		-		-		
Endocrine	1	(1)	1	(100)	0		
Eye	0		-		-		
Hepatobiliary	2	(2.6)	0		2	(100)	
Infectious disease	0		-		-		
Injury, poisoning – drugs	0		-		-		
Mental health	3	(3.9)	0		3	(100)	
Musculoskeletal	6	(7.8)	2	(33.3)	4	(66.6)	
Neoplastic disorders	2	(2.6)	0		2	(100)	
Neurological	5	(6.5)	1	(25)	4	(75)	
Other	3	(3.9)	1	(33.3)	2	(66.6)	
Other health service issues	3	(3.9)	1	(33.3)	2	(66.6)	
Pregnancy-related	0		-		-		
Renal/Urinary	5	(6.5)	1	(20)	4	(80)	
Reproductive	0						
Respiratory	34	(44)	9	(26.4)	25	(73.5)	RR 0.91 $p = 0.79$
Skin, sub-cut tissue, breast	1	(1)	1	(100)	0		

Note. Reported: n (%); mean (M) standard deviation (SD); median (MD) interquartile range (IQR); *= t-test; relative risk= RR COT = conventional oxygen therapy, NHF = nasal high flow, NIV = non-invasive ventilation, CPAP = Continuous Positive Airway Pressure, INV = Invasive ventilation, LOS = length of stay

Participant Emergency Department Disposition.

The secondary study outcomes were related to ED disposition, including respective LOS in the ED and hospital (Table 34). One study participant died in the ED; a further seven (9.2%) died within 30 days of study enrolment. Most participants' ED LOS exceeded six hours (*n* = 46; 60%), Mdn = 7.5 hours, IQR = 3 to 27.

Most participants (*n* = 60; 78.9%) required hospitalisation following their ED admission. The majority required inpatient admission on a ward for > 24 hours (*n* = 47, 61.8%). The median duration of hospital LOS of four days (IQR, days = 1 to 9) was also higher in the 'RS escalated in the ED group' at seven days (IQR, days = 4 to 12). Many (*n* = 16, 21.1%) participants were discharged directly home from the ED, with a number discharged to another care facility or rest home (*n* = 8, 10.5%).

With respect to RS, most of those participants admitted to the hospital from the ED required ongoing RS (*n* = 36, 44.7%). A requirement for hospitalisation was 22% higher for those who required RS escalation in ED compared to those who did not (RR 1.22; CI 0.99 to 1.5; *p* = 0.05; NNT of 5.9 [harm] 95% CI 2.72 to 33.13). Many of those who died within 30 days of enrolment (*n* = 3, 37.5%) had required escalation of RS in ED. Mortality was determined by access to the Mortality Collection (MORT), which classifies the underlying cause of death for all deaths registered in New Zealand. Table 34 reports study data on the ED patient disposition and length of ED stay for those requiring RS escalation vs those not.

Table 34

Point Prevalence Study: Emergency Department Disposition and Length of Stay for Respiratory Support Escalated vs Not Escalated

Variable	All *n*	All %	Escalated *n*	Escalated %	Not escalated *n*	Not escalated %
ED Discharge						
Home	16	21.1	2	12.5	14	87.5
Home via ED SSU	5	6.6	0	0	5	100
In-Patient Ward>24 hrs	47	61.8	16	34	31	65.9
HDU	1	1.3	1	100	0	0
ICU	3	3.9	3	100	0	0
Another Hospital	1	1.3	0	0	1	100
Care Facility/Rest Home	2	2.6	0	0	2	100
Death in ED	1	1.3	0	0	1	100
Length of stay	Mdn	IQR	Mdn	IQR	Mdn	IQR
Hosp. LOS days	4	1-9	7	4-12	3	1-7
ED LOS hrs	7.5	3-27	3.5	2-6	20.5	5-35.5

Note. Data are reported as n; %; or median (Mdn); interquartile range (IQR). HDU = high dependency unit; ICU = intensive care unit; LOS = length of stay; SSU = short stay unit

6.1.5 Discussion

This study has achieved its aim. This study has delivered a real-time, real-world epidemiological characterisation of adult ED patients receiving RS in NZ. This study has four major findings:

- the minority of ED patients are provided RS;
- patients provided RS in ED often require escalation of their RS;
- patients requiring escalation of RS in ED have increased hospitalisation rates and hospital LOS;
- by ethnicity, NZ Māori are more likely to require RS and subsequent escalation of the RS provided.

Provision of Respiratory Support in the Emergency Department.

This study has determined that most adult patients are not provided RS in NZ EDs. This finding is consistent with the limited number of other RS-focused ED studies completed in this region. However, our study was unusual as it did not focus on a single disease, intervention or symptom.

An Australasian PPS involving 3044 ED participants reported a prevalence of dyspnoea symptomology of 5.2% (95% CI, 5.0 to 5.4), with the majority then provided RS 48.8% (95% CI, 47 to 50.6) (Kelly et al., This study has determined that most adult patients are not provided RS in NZ EDs. This finding is consistent with the limited number of other RS-focused ED studies completed in this region. However, our study was unusual as it did not focus on a single disease, intervention, or symptom.

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When we compared our sample to those from a single centre NZ ED RCT, comparing the efficacy of NHF vs COT, our participants were younger in mean years (73 vs 67), had fewer mean comorbidities (6 vs 3.34), were more of Indigenous NZ Māori ethnicity (14.5% vs 23.7%), but had an increased mean hours ED LOS (4.7 vs 6.5) and requirement for escalation (5.4% vs 28.9%), respectively (Jones et al., 2016). This study has determined that most adult patients are not provided RS in NZ EDs. This finding is consistent with the limited number of other RS-focused ED studies completed in this region. However, our study was unusual as it did not focus on a single disease, intervention, or symptom.

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Escalation of Respiratory Support in the Emergency Department.

This study determined that those provided RS in the ED often require subsequent escalation of their RS. The escalation of care in the ED is influenced by environmental, organisational, individual, and interpersonal factors (Hacker Teper et al., 2022). Failure to recognise and provide timely escalation of care may increase avoidable patient mortality and morbidity (Hacker Teper et al., 2022). Notably, the timeliness of escalation was not assessed in this PPS. Escalation of RS involves CDM around the selection of RS and its delivery, for example, the titration of gas flow and FiO_2 and ongoing assessment to avoid further deterioration, especially as some RS therapies may mask deterioration and delay escalation of care (Ricard et al., 2020).

The processes supporting the escalation of care comprise three steps: detection, reporting, and response. Several interrelated factors, both extrinsic and intrinsic to the ED, influence 'clinician-prompted escalation of care' (Bijani et al., 2021). These factors include clinician knowledge, experience, and skill, enabling reliable detection and execution of an appropriate RS escalation response. It is acknowledged here that escalation of care is not always appropriate; increasingly, patients live longer with complex and incurable conditions requiring palliative or limited care (Arendts et al., 2016). Notably, this PPS did not assess the appropriateness of the escalation seen.

Clinicians use a variety of algorithms and scoring tools to detect, report, and respond to escalation requirements of the heterogeneous ED population (Connell et al., 2021). Theoretically, scoring tools such as these can be used to prioritise care delivery and augment ED CDM (Bijani et al., 2021). Data from two common MEWS and the Australasian Triage Scale were reported in this study.

Clinical decision-making in the ED is not solely reliant on these tools; these decisions are complex, and multiple factors and triggers are involved. The escalation triggers may include the patient's failure to respond to current therapy, feeling unwell, clinical and/or vital sign deterioration (Connell et al., 2021), or clinician concerns, all explored here as a potential rationale for escalation of RS (Leonard-Roberts et al., 2020).

Hospitalisation Rates and Hospital Length of Stay.

The study findings suggest that those who require escalation of RS in the ED may be more likely to be admitted to the hospital and, once hospitalised, may then require a longer LOS. Therefore, it is plausible to suggest that these patients are high consumers of healthcare resources. Emergency departments straddle primary and tertiary care, with the ED waiting room being described as a health service barometer, as the consequences of primary and tertiary service stress are often demonstrated in the ED (Kraus, 2020). The so-called ED 'barometer' effect may provide an opportunity to inform health sector strategies and policies.

New Zealand Māori Respiratory Support Needs and Outcomes in the Emergency Department

This study indicates that those of Indigenous NZ Māori ethnicity presenting in NZ EDs have poorer outcomes when compared to non-Māori. Māori represent 17.3% of the total NZ population, and the well-described inequity and high material need (HMN) experienced by Māori negatively impact their age, life expectancy, and amenable mortality (Curtis et al., 2022; Te Waihanga, 2024).

Globally, EDs provide care to susceptible patients with HMN. This HMN may be for food, accommodation, education, or healthcare. In New Zealand, primary healthcare is not free; consequently, some patients may delay presentation and compound the effects of their illness or injury. In contrast, in NZ, ED care is free; therefore, the ED is often the first point of care for those with HMN (Curtis et al., 2022).

As we and others report, many NZ ED patients requiring RS have high rates of comorbid conditions and HMN (Kelly et al., 2017; Telfar-Barnard & Zhang, 2020). Notably, these rates are higher among members of the Indigenous NZ Māori and Pasifika populations and indirectly demonstrate their HMN and health inequity (Telfar-Barnard & Zhang, 2020).

6.1.6 Study Strengths and Limitations

Evidence-based practice improves patient care and outcomes; however, EBP requires a reliable epidemiological foundation. The shortage of large-scale epidemiologic studies reporting on the real-world ED patient population is well described (Alnajada et al., 2023; Kelly et al., 2015; Mockel et al., 2013). Epidemiological studies contextualise interventions such as RS and provide supporting evidence to confirm their appropriate implementation (Rasmussen et al., 2019). This epidemiological study contextualises RS delivery in the ED. This PPS has been completed to inform future RS ED research and clinical practice by improving understanding of the real-world delivery of RS in the ED (Harder, 2014). These epidemical data are anticipated to provide a baseline for future appropriate investigations (Rasmussen et al., 2019). However, this study has strengths and limitations that relate to the PPS method and its execution (Wang & Cheng, 2020).

Conducting clinical research in the ED is known to be challenging. The recent global pandemic has had catastrophic impacts on all aspects of ED healthcare delivery, and demand has also likely compounded the challenges for ED clinical research (Howard et al., 2022; Graham, 2019). Our NZ study was completed in the fall of 2023, coinciding with the relaxation of public health and social measures introduced during the SARS-CoV-2 (COVID-19) pandemic. This prospective observational real-world study was completed in four NZ EDs. The study methods enabled rapid and reliable representative real-world sampling, a snapshot of the wider NZ ED population (Creswell & Creswell, 2017; Faraoni & Schaefer, 2016). However, the researchers acknowledge that this sampling method may not represent the ED patient population in other countries or on another given day; hence, caution is needed in generalizing the findings.

The study was mainly executed per protocolised methods to reduce bias and ensure data reliability (O'Donnell et al., 2023). The PPS reporting reflects the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations (von Elm et al., 2008) (Appendix M). The two usual sources of bias in PPSs are selection and information bias, which may undermine a study's internal and external validity (Buitrago-Garcia et al., 2022).

Selection bias did not exist in this PPS, as all eligible patients were recruited. Misinterpretation and/or observer bias were predicted sources of information bias. Therefore, thorough data collector training and piloting the electronic case report form (eCRF) were undertaken to standardise data collection (Appendix H).

The study has clear limitations. The study's absolute number of participants was 5% less than required by power calculation. Therefore, the study was underpowered and unable to support analyses of association for any variables. Unlike an adequately powered RCT, a study with limited sample size and method cannot establish cause and effect regardless of the outcome or variables considered (Akoberg, 2005). Additionally, determining the incidence of the primary outcome of escalation was reliable. However, the rationale for the escalations seen relied on subjective interpretation alone. Therefore, any additional interpretation of these findings should be limited, and the need to determine predictive factors for the escalation of RS remains.

The scope of this study was limited to a cohort of patients receiving RS and the subset of those who required escalation. We must assume that no patients were inappropriately included or excluded from this cohort.

6.1.7 Implications of the Research

This epidemiological study contextualises the provision of RS in four NZ EDs. This PPS has been completed to inform future RS ED research by providing real-world and real-time data on the delivery of RS in the ED (Harder, 2014). These epidemical data are anticipated to provide a baseline for future ED investigations reporting clinically significant outcomes (Rasmussen & Goodman, 2019).

The suggested avenues for future ED investigations include:

i. a PPS of RS in the ED, including more sites and potentially across countries to improve the generalisability of findings;
ii. a PPS of RS in the ED, with the inclusion of all patients regardless of whether they were provided RS or escalation, to report on the appropriateness of the RS provided;
iii. exploration of clinical decision-making around the provision of RS, for example, gas flow rates and FiO_2;
iv. Validate a tool for predicting a need for escalation of RS.

6.1.8 Conclusion

We acknowledge that the PPS method may not represent the ED patient population in other countries or on another given day; hence, caution is needed in generalising its findings. Whilst no statistically significant findings were seen for the primary outcome, the absolute data presented suggest that age, gender, number of comorbidities, and diagnostic group all impact the risk of escalation. These apparent differences in the incidence of escalation are clinically significant, and as suggested, these clinically significant findings are those that potentially improve patient outcomes.

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Author contributions.

The authors confirm their contribution to the paper: Study conception and design: JOD Author.; data collection: Independent Data Collectors (not authors); analysis and interpretation of results: JOD. Author, AP. Author, CB. Author; draft manuscript preparation: JOD. Author. All authors reviewed the results and approved the final version of the manuscript.

Conflict of Interest Disclosure.

JOD reports grant money from the NZ Government Health Research Council and Fisher and Paykel Healthcare to conduct research conceived and written by JOD at the University of Auckland. AP, CB, EM, KH, and MK all report no conflict of interest.

6.2 Part Two: Respiratory Support with Nasal High Flow in the Emergency Department

Part two of this chapter presents the PPS data reporting only on NHF RS.

6.2.1 Background

The most recent addition to the ED respiratory support (RS) armoury is nasal high flow (NHF). Currently, evidence supporting NHF efficacy in the ED is emerging. In 2023, an international study found that NHF was used in 95% of the hospitals surveyed. Additionally, the ED was identified as the highest area of NHF use (Alnajada et al., 2023).

An ED point prevalence study (PPS) was designed (O'Donnell et al., 2023) and then completed (O'Donnell et al., 2024). The PPS captured comprehensive epidemiological real-world data to profile adults receiving RS in the ED; here, a subset of these data reporting on RS with NHF is presented. These data answer the six doctoral research questions.

6.2.2 Methods

The study methods are described in Chapter Four, *Methodology,* and the published protocol (O'Donnell et al., 2022).

6.2.3 Results

As outlined in the manuscript in Part One of this chapter (6.1), 898 ED adult patients presented to ED during the study periods, of which 76 met inclusion criteria and were enrolled. Of the 76 enrolled, all received some form of RS, and the minority (*n* = 12, 15.7%) received NHF. These descriptive data profiles those receiving NHF RS alone (*n* = 12, 15.7%).

6.2.3.1 Who receives NHF in the ED?

The first core thesis question asked *Who receives NHF in the ED?* Here, data on who receives NHF vs those not receiving NHF were reported by gender, age, ethnicity, NZ Early Warning Score (NZEWS) and Triage scores, comorbidities and primary diagnosis. The characteristics of the ED patients receiving RS with NHF here were heterogeneous. By gender, the majority (*n* = 8, 66%) were male; by ethnicity, the majority were NZ European (*n* = 4, 33%) and had a mean age of 69.91 (SD ± 18.93) years, as described in Table 35.

On presentation to the ED, the mean triage (2.66, SD ± 0.65) and NZEWS (7.58, SD ± 3.32) were high. Of the 21 ED diagnostic categories, the most common was respiratory (*n* = 5, 41.5%), followed by musculoskeletal (*n* = 4, 33.3%) and 'neurological' (*n* = 2, 16.6%). The mean overall number of comorbidities was 3.3. These data were not skewed for NHF 3.3 (SD ± 1.5); the respiratory diagnostic category was the most common comorbidity described in Table 35. The most common reasons prompting NHF delivery were to improve oxygenation (*n* = 4, 33.3%) and/or hypercapnia (*n* = 6, 50%). One patient received NHF as RS during rapid sequence intubation (Table 35). Table 35 also reports study data on who receives NHF vs those who do not receive NHF based on their gender, age, ethnicity, NZ EWS, triage scores, comorbidities, and diagnosis.

Table 35

Point Prevalence Study: Characteristics of Those Receiving NHF vs Those Not Receiving NHF by Gender, Age, Ethnicity, EWS and Triage Scores, Comorbidities and Diagnosis

	Overall		NHF		Non-NHF	
Sample *n* (%)	76		12	(15.7)	64	(84.2)
Gender (male) *n* (%)	40	(52.6)	8	(66)	32	(50)
Age (years) M (± SD)	67.38	(17.41)	69.91	(18.93)	66.90	(17.23)
Age < 65 years n (%)	30	(39.4)	5	(41.6)	25	(37.5)
Age > 65 years n (%)	46	(61.8)	7	(58.3)	39	(60.9)
Ethnicity *n* (%)						
NZ European	31	(40.8)	4	(33.3)	27	(42.1)
NZ Māori	18	(23.7)	1	(8.3)	17	(26.5)
Tongan	2	(2.6)	1	(8.3)	1	(1.5)
Chinese	3	(3.9)	1	(8.3)	2	(3)
Indian	4	(5.3)	2	(16.6)	2	(3)
Other	18	(23.6)	3	(25)	15	(23.4)
EWS M (± SD)	8.60	(4.53)	7.58	(3.32)	8.79	(4.83)
Triage Category M (± SD)	2.58	(0.9)	2.66	(0.65)	2.56	(0.94)
Comorbidities M (± SD)	3.3	(5.2)	1.5	(2.32)	3.4	(5.8)

Table 35 cont.

Primary Diagnostic Category *n* (%)	Overall		NHF		Non-NHF	
Alcohol or Drug	0		0		0	
Blood-related	0		0		0	
Cardiac/Circulatory	9	(11.8)	0		9	(14.0)
Digestive / Gastrointestinal	2	(2.6)	0		2	(3.1)
Ear, nose, throat	0		0		0	
Endocrine	1	(1.3)	0		1	(1.5)
Eye	0		0		0	
Hepatobiliary	2	(2.6)	0		2	(3.1)
Infectious disease	0		0		0	
Injury, poisoning – due to drugs	0		0		0	
Mental health	3	(3.9)	0		3	(4.6)
Musculoskeletal	6	(7.8)	4	(33.3)	2	(3.1)
Neoplastic disorders	2	(2.6)	0		2	(3.1)
Neurological	5	(6.5)	2	(16.6)	3	(4.6)
Other	3	(3.9)	1	(8.3)	2	(3.1)
Other health service issues	3	(3.9)	0		3	(4.6)
Pregnancy-related	0		0		0	
Renal/Urinary	5	(6.5)	0		5	(7.8)
Reproductive	0		0		0	
Respiratory	34	(44)	5	(41.6)	29	(4.5)
Skin, tissue, breast, burns	1	(1.3)	0		1	(1.5)

Note. Data reported as *n*, (%), mean =M, standard deviation (SD), median=Mdn, interquartile range (IQR).

The rationale for delivering or discontinuing NHF varied (Table 36). After one hour, half of those who commenced on NHF had discontinued it (*n* = 6, 50%). The reasons for discontinuation were largely unknown (*n* = 5, 55%) but seemed mainly prompted by patient or clinician preference (*n* = 3, 33.3%). One patient was unable to tolerate NHF and was discontinued. Table 36 reports study data on NHF use, including the rationale for discontinuation and/or continuation post-ED discharge.

Table 36

Point Prevalence Study: Nasal High Flow Therapy Use and Rationale for Discontinuation and or Continuation Post-ED

NHF Use Rationale*	*n*	(%)
Other	0	
RSI	1	(8.3)
Conscious Sedation	0	
Reduce WOB	0	
Improve Oxygenation	4	(33.3)
Improve Hypercapnia	6	(50)
Reduce Respiratory Rate	0	
Airway Humidification	2	(16.6)
NIV Rest Therapy	0	
Other RS Intolerance	0	
Clinician Preference	0	
Resource / Logistical Issues	0	
NHF Discontinuation Rationale*	*n*	(%)
Other / Unknown	5	(55.5)
Other RS required (escalation)	1	(11.1)
Patient preference	2	(22.2)
Clinician preference	1	(11.1)
NHF post ED discharge *n* (%)	3	(25)

Note. *More than one possible. Data reported as *n*, (%).

6.2.3.2 How was NHF Delivered?

The second core thesis question asked *How was NHF Delivered?* Clinicians can independently titrate NHF, FiO_2, gas flow, and temperature to suit patients' individual needs. Data on NHF delivery includes FiO_2, gas flow settings, SpO_2, respiratory, and heart rates captured over four hours at ED discharge. Data on gas temperature were not collected. Subjective assessment data on the reasons for discontinuation or continuation of NHF in ED post-ED discharge was also collected.

Nasal high-flow delivery data were reported in five-time intervals, for a maximum of four hours, and on ED discharge. The maximum flow reported was 55 L/min, with the mean gas flow reducing from 46.25 L/min (SD ± 7.11) to 40 L/min (SD ± 5.0). For the entire period, the mean gas flow was 44.32 L/min (SD ± 2.72) (Table 36).

The maximum FiO_2 reported was 0.5. The mean FiO_2 increased over time from 0.33 (SD ± 0.097) to 40.33% (SD ± 0.167). For the entire period, the mean FiO_2 was 0.37 (SD ± 0.027) (Table 36). No NHF temperature adjustments were reported. Notably, delivered gas temperature is known to influence the humidification level of the inspired gas and, most importantly, patient comfort and tolerance (Mauri et al., 2018).

The range in reported patient SpO_2, respiratory and heart rates were respectively 89 to 95%, 14 to 32 and 52 to 128 per minute (Table 36). Table 36 reports study data on the NHF settings and patient SpO_2 respiratory and heart rates seen over each hour, for four hours, and at ED discharge to either the home or an inpatient setting.

Table 37

Point Prevalence Study: Nasal High Flow Settings Over 4 Hours and at Emergency Department Discharge

1st hour of NHF n = 12	O_2 %	Gas flow L/Min	Respiratory rate	SpO_2	Heart rate
Mean	33.16	46.25	-	92.16	-
Median	-	-	20	-	96
±SD	9.75	7.11		3.45	-
Lower IQR	-	-	14	-	52
Upper IQR	-	-	24	-	114
2nd hour of NHF n = 6					
Mean	37.50	45.83	-	94.00	-
Median	±±-	-	20	-	88
± SD	8.80	4.91	-	2.36	-
Lower IQR	-	-	16	-	65
Upper IQR	-	-	22	-	110
3rd hour of NHF n = 6					
Mean	39.16	45.83	-	93.83	-
Median	-	-	20	-	87
± SD	8.01	4.91	-	2.78	-
Lower IQR	-	-	18	-	67
Upper IQR	-	-	32	-	128

Table 37 cont.

4th hour of NHF $n = 6$	O_2 %	Gas flow L/Min	Respiratory rate	SpO_2	Heart rate
Mean	38.50	43.33	-	92.83	-
Median	-	-	19	-	84
SD	11.37	6.05	-	3.18	-
Lower IQR	-	-	18	-	72
Upper IQR	-	-	24	-	100
NHF ED disch $n = 3$	FiO_2	Gas flow L/Min	Respiratory rate	SpO_2	Heart rate
Mean	40.33	40.00		93.00	-
Median	-	-	24	-	109
± SD	16.74	5.00		3.46	-
Lower IQR	-	-	20	89.00	104
Upper IQR	-	-	28	95.00	124

Note. Percentage of O_2 delivered = O_2 %; Oxygen saturation = SpO_2. Nasal high flow = NHF. Data reported as *n*, (%), mean=M, standard deviation (SD), median=Mdn , interquartile range =IQR

6.2.3.3 Which patients receiving NHF require escalation of therapy in the ED?

The third core thesis question asked, *Which patients receiving NHF require escalation of therapy in the ED?* A failure to appropriately and timely escalate RS is associated with poor patient outcomes. De-escalation and escalation of RS in this study involved transitioning from one form of RS to another. Data on the escalation or de-escalation of patient RS in the ED were compared by patient diagnostic group, escalation rationale and ROX score. The rationale for escalation in this PPS was one or more of the unknown: the patient feels unwell, the ED staff is concerned, the patient failed to respond, the patient's clinical signs deteriorated, the patient's vital signs deteriorated for the procedure, rapid sequence intubation. The rationale for escalation was derived from the available NHF ED evidence. The ROX index was used as it is a validated early predictor of NHF failure (Mauri et al., 2019).

Patients on NHF required less escalation of RS than those on other forms of RS (n = 1, 8.3% vs n = 21, 32.8%); however, the relative risk for escalation with NHF compared to other forms of RS was not significant (RR 0.31, 95% CI, 0.04 to 2.12, p = 0.23, NNT [benefit] 5.87, 95% CI, 2.43 to 14.07 [benefit]). Data on escalation or de-escalation of patients' RS in the ED, patient diagnosis, rationale for escalation, and ROX score were analysed. Table 38 shows respiratory was the largest diagnostic category for the first escalation (n=9, 40.9%). The one patient who was escalated after more than three hours of NHF was escalated to invasive ventilation. The rationale for the escalation appeared to be prompted by concerns from the ED staff and the decline in the clinical and vital status of the patient (33.3% of the time, respectively) (Table 38). This patient was an 80-year-old female with a primary ED diagnosis of pneumonia.

Six participants received NHF for at least two hours, enabling their ROX index calculation. The ROX (Respiratory rate-OXygenation) index predicts a need to escalate care for patients receiving NHF, and it is only validated for calculation at two, six, and twelve hours (Roca et al., 2019). This study did not collect data beyond four hours; therefore, the ROX score was only reported at two hours. The lowest patient ROX score reported at two hours was 8.27, above the established threshold for escalation of 2.85 (Roca et al., 2019). The mean ROX score for these six patients receiving NHF after two hours was 12.51 (SD ± 3.42). The ROX score for the one patient who required RS escalation from NHF to invasive ventilation was 9.62 (Table 38).

Table 38

Point Prevalence Study: Escalation or De-escalation of Respiratory Support in the Emergency Department by Diagnosis, Rationale and ROX score

	Overall *n (%)*		NHF *n (%)*		Non-NHF *n (%)*	
1st Escalation (yes) *n (%)*	22	(28.9)	1	(8.3)	21	(32.8)
2nd or subsequent escalation (yes) *n (%)*	8	(12.5)		0	8	(12.5)
De-escalation any (yes) *n (%)*	8	(12.5)	2	(16.6)	6	(9.3)
1st Escalation by Diagnostic Group *n (%)*	Overall *n (%)*		NHF *n (%)*		Non-NHF *n (%)*	
Alcohol or Drug		0		0		0
Blood-related		0		0		0
Burns		0		0		0
Cardiac/Circulatory	4	(18.8)		0	4	(19)
Digestive / Gastrointestinal	1	(4.5)		0	1	(4.7)
Ear, nose, throat		0		0		0
Endocrine	1	(4.5)		0	1	(4.7)
Eye		0		0		0
Hepatobiliary		0		0		0
Infectious disease		0		0		0
Injury, poisoning – due to drugs		0		0		0
Mental health		0		0		0
Musculoskeletal	2	(9)		0	2	(9.5)
Neoplastic disorders		0		0		0
Neurological	1	(4.5)		0	1	(4.7)
Other	1	(4.5)		0	1	(4.7)
Other health service issues	1	(4.5)		0	1	(4.7)
Pregnancy-related		0		0		0
Renal/Urinary	1	(4.5)		0	1	(4.7)
Reproductive		0		0		0
Respiratory	9	(40.9)		1	8	(38)
Skin, sub-cut tissue, breast	1	(4.5)		0	1	(4.7)

Table 38 cont.

Rationale for Escalation* *n (%)*	Overall *n (%)*	
Unknown	3	(7.8)
Patient feels unwell	2	(5.2)
ED staff concerned	5	(15.6)
Patient failure to respond	5	(15.6)
Patient's clinical signs deteriorated	9	(28.1)
Patient's vital signs deteriorated	12	(31.5)
For procedure	1	(2.6)
Rapid Sequence Intubation	1	(2.6)

ROX Score *calculated at 2 hours	
Patient 1	12.51
Patient 2	16.31
Patient 3	9.62
Patient 4	10.62
Patient 5	14.69
Patient 6	15.60
Patient 7	8.27

Note. Data are reported as *n*, (%), mean=M, and standard deviation (SD). The ROX score is only validated for calculation at 2, 6, and 12 hours. More than one rationale for escalation were possible.

6.2.3.4 What are the effects seen with NHF therapy on physiological and patient outcomes?

The fourth core thesis question asked: *What are the effects of NHF therapy on physiological and patient outcomes?* This question has two considerations: physiology, and other patient outcomes. During the data collection interval, the effects of NHF were reported for three physiological outcomes: respiratory rate, heart rate, and SpO_2, (Table 36). The other patient outcomes reported were hospital LOS, mortality, NHF-related adverse events, and ED discharge destination. The ED discharge destinations included: home, home via ED Short Stay Unit, In-Patient Ward >24 hours, HDU, ICU, another Hospital, or another care facility, e.g. Rest Home. Table 39 reports the comparison of NHF vs non-NHF for the patient outcomes: LOS, mortality, NHF adverse events, and ED discharge destination.

Physiological Outcomes.

The effects of NHF were reported for three physiological outcomes: respiratory rate, heart rate, and SpO_2, as previously reported in Table 36. These outcomes were selected and prioritised based on available NHF ED evidence (Ischaki et al., 2017).

The overall median respiratory rate per minute was 20 (IQR 19.5 to 22), and the median heart rate per minute was 88 (IQR 85.5 to 102.5). The reported respiratory and heart rates appeared to decrease as the FiO_2 increased. The mean SpO_2 was 93.18% (SD ± 0.74). It was apparent that during this time and on ED discharge, no clinically significant deterioration or improvement in physiological outcomes was seen with NHF; this contrasts with the published evidence, which consistently reports improved physiological outcomes with NHF (Mauri et al., 2019). However, the contrast is likely related to the small number of patients receiving NHF and, therefore, the inability to test for significance.

Other Patient Outcomes.

Data comparing NHF vs non-NHF for the patient outcomes included LOS, mortality, NHF adverse events, and ED discharge destination. RS data was drawn from the PPS and included NHF. These outcomes were selected and prioritised based on available NHF ED evidence (Ischaki et al., 2017).

Patients on NHF or having had NHF were all admitted to the hospital (n = 12, 100%), with most being discharged from the ED to general wards (n = 10, 83.3%) and the majority remaining on NHF (n = 9, 75%) (Table 39).

Typically, all participating hospitals manage NHF patients on their wards. For those admitted to the hospital, the median LOS was 8 (IQR 4 to 15) days; this hospital LOS was significantly higher in the NHF group than in those not provided NHF (U = 183, p = 0.004). No patients died while on NHF in the ED. One NHF-related adverse event was reported, prompting the discontinuation of NHF as the patient was unable to tolerate it (Table 39).

Table 39

Point Prevalence Study: NHF vs non-NHF Other Patient Outcomes: LOS[a], Mortality, Adverse Events, ED Discharge Destination

	Overall		NHF		Non-NHF		Test
LOS[a] Hosp Days Mdn IQR	4	(1-9)	8	(4-15)	3	(1-7.5)	U = 183 $P = 0.004$
Mortality *n* (%)	1	(1.3)	0		1	(1.5)	
Adverse event on NHF *n* (%)		-	1	(8.3)		-	-
ED discharge destination *n* (%)	Overall *n* (%)		NHF *n* (%)		Non-NHF *n* (%)		
Home	16	(21.1)	0		16	(29.6)	
Home via ED Short Stay Unit	5	(6.5)	0		5	(9.2)	
In Patient Ward >24 hours	47	(61.8)	10	(83.3)	37	(65.5)	
High Dependency Unit	1	(1.3)	1	(8.3)	0		
Intensive Care Unit	3	(3.9)	1	(8.3)	2	(3)	
Another Hospital	1	(1.3)	0		1	(1.5)	
Another Care Facility, e.g. Rest Home	2	(2.6)	0		2	(3)	

Note. Data reported as *n*, (%), mean =M, standard deviation = SD, median=Mdn, inter quartile range=IQR. Mann-Whitney U Test = U, LOS[a]= Length of Stay.

Summary and Interpretation of Findings Nasal High Flow in Emergency Department- A Subset of PPS Data.

Part two of this sixth chapter presented the subset of PPS data reporting only on RS with nasal high flow (NHF). These descriptive data profiles those receiving NHF RS (*n* = 12, 15.7%) alone and answers the four core thesis questions. These data collectively provided answers to the four core thesis questions:

1. Who receives NHF in the ED?
2. How is NHF delivered in the ED?
3. Which patients receiving NHF require escalation of RS in the ED?
4. What are the effects seen with NHF on physiological and patient-centred outcomes?

The NHF was provided to the minority of ED patients requiring RS *(n* = 12, 15.7%). Firstly, these absolute unadjusted data report that, most typically, NHF was provided to NZ European males with a mean age of 69 years, with many presenting with respiratory-related diagnoses. These patients receiving NHF had high acuities, as suggested by their ROX and NZEWS scores and the mean number of comorbidities.

Secondly, any active titration of NHF was limited and likely limited the efficacy of the therapy. The reason for this is unclear and will be further discussed in the following seventh chapter. However, the reasons for this need to be clarified; could this be due to patient intolerance, lack of patient supervision or support or lack of clinician knowledge and clinical expertise in NHF therapy? This area requires exposure response research to establish any magnitude of the NHF effect seen when the RS is titrated. Notably, respiratory and heart rates did appear to reduce, and these patients may have been receiving concomitant treatments with effects not yet demonstrated.

Thirdly, patients receiving NHF appeared less likely to require escalation of their RS compared to all other forms of RS combined. Finally, the number of NHF patients requiring hospitalisation was high, which suggests this cohort is a high consumer of healthcare resources. The reported NNT has given some indication of the clinical effectiveness of NHF in this setting; however, formal economic studies are required.

6.3 Multi-method Design- Integration of SR and PPS Results

As reported in chapters five and six, the multi-method design dictates the integration results of the SR with MA and PPS. This integration of results establishes the overall thesis findings based on answers to two overarching questions and the four core thesis questions.

1. What is the nature of the NHF delivered to adults in the ED setting?
2. What influence does the delivery of NHF have upon adult ED patient outcomes?
3. Who receives NHF in the ED?
4. How is NHF delivered in the ED?
5. Which patients receiving NHF require escalation of RS in the ED?
6. What are the effects seen with NHF on physiological and patient-centred outcomes?

The SR produced statistically significant findings in two MA reports on the ‘escalation of care’ outcome alone. Therefore, in addition to the characterisation of ED patients receiving RS in NZ, the main thesis finding was that nearly a third of those receiving RS required escalation of their RS, with those receiving NHF requiring less escalation than those receiving all other forms of RS combined. This result partially aligns with the SR, where the MA shows the superiority of NHF over COT for escalation of care but not for NHF over NIV. The integrated thesis findings drawn from the results of the SR and PPS are summarised in Table 40.

Table 40

Thesis Findings: Integrated Results of Systematic Review and Point Prevalence Study

PPS Participant Profile	RS with NHF	Escalation reported: PPS	Escalation reported: SR
Mean Age 67. 3 years	15.7% provided NHF	Overall escalation 28.9%	**Less escalation NHF vs COT**
52% Male	Higher acuity	**Less escalation NHF < All other RS combined**	Less escalation NIV vs NHF
48.6% ≥ 3 Comorbidities	Higher hospitalisation		
44% Resp. Diagnosis	Increased LOS in hospital		
Māori over-represented	Active titration of NHF limited		

6.4 Chapter Six Conclusion

This sixth chapter comprised two parts. The first part presented the PPS manuscript as submitted for publication (O’Donnell et al., 2024). This PPS publication's aims, objectives, rationale, and limitations were described, as well as detailed descriptions and interpretations of the data reported on RS in the ED. In part two of this chapter, the subset of the PPS data was presented, reporting only on NHF.

In part two, the four core thesis questions were answered:

- Who receives NHF in the ED?
- How is NHF therapy delivered in the ED?
- Which patients receiving NHF require escalation of RS in the ED?
- What are the effects seen with NHF therapy on physiological and patient-centred outcomes?

As per the multi-method design, the results from the two methods, the SR with MA reported in Chapter Five and the PPS reported here in Chapter Six, were integrated, and a final thesis finding was reported.

Whilst aspects of the methods used in this doctoral research have been discussed within their respective publications, in the seventh and subsequent Chapter *Discussion and Conclusion,* the integrated thesis findings will now be discussed as a whole. The implications of this thesis for research and EBP in the ED and nursing will also be proposed.

Chapter Seven

Discussion and Conclusion

The results from the two study methods and their integrated findings were presented in the previous two Chapters Five and Six. These integrated results have informed the final thesis findings and conclusions. This seventh-chapter *Discussion and Conclusion a*ims to summarise and interpret the doctoral research in relation to the broader international context. This discussion is organised according to the EBP theoretical framework of this thesis and its three parts: *best evidence, consumer values,* and *professional expertise*. These three elements collectively best inform clinical decision-making. The implications of the thesis findings for nurses, the ED, and patients will be considered using this and the Integrated Promoting Action on Research Implementation in Health Services (i-PARIHS) frameworks (Zhang et al., 2024). The PARHIS framework describes the successful implementation of research into practice as the function of the interplay of three core elements— the context or environment into which the research is utilised, the method or way in which the process is facilitated, and the level and nature of the evidence (Kitson et al., 1998). The thesis findings will be compared to previous research, and the strengths and limitations of the thesis will be declared. Finally, recommendations for avenues for further studies will be proposed, and the conclusions to the thesis will be made. This seventh *Discussion and Conclusion* Chapter has seven sections:

- Summary of the Doctoral Research
- Interpretation and Implications of this Research for ED EBP
- Strengths and Limitations of the Doctoral Research
- Recommendations: Avenues for Further Studies or Analyses
- Thesis Conclusion
- Chapter Seven Conclusion
- Thesis Concluding Statement.

7.1 Summary of the Doctoral Research

The Doctoral research aimed to focus on RS provided in the ED and patient outcomes then seen. This doctoral research was informed by its positivist philosophical stance and a methodology underpinned by an EBP theoretical framework. The doctoral research thesis answered its six research questions using a quantitative research approach, a non-experimental strategy, a multi-method design, and two methods that used cross-sectional time horizons. The two methods were a SR with MA and a PPS. A synthesis of the best available evidence was presented in a SR with MAs, and the epidemiology of patients receiving RS, notably RS with NHF, was described in a PPS. Each method was conducted in parallel, and the findings were then integrated.

The two overarching thesis questions answered were:

- What is the nature of the NHF delivered to adults in the ED setting?
- What influence does the delivery of NHF have upon adult ED patient outcomes?

The four core thesis questions answered were:

- Who receives NHF in the ED?
- How is NHF therapy delivered in the ED?
- Which patients receiving NHF require escalation of RS in the ED?
- What are the effects seen with NHF therapy on physiological and patient-centred outcomes?

In the first method, the SR provided five MAs involving 18 ED RCTs reporting on 1874 participants. A 45% reduction in escalation relative risk (RR) was seen for NHF vs COT with no difference in mortality or adverse event risk. For NHF vs NIV, NHF increased escalation risk by 81%. Mortality risk was not different for NHF vs NIV.

In the second method, the PPS characterised 76 patients receiving RS from 898 ED-presenting patients. The PPS was underpowered and unable to support its planned inferential analyses. The mean age of the participants was 67.38 years (SD ± 17.4); 52% (*n* = 40) were male, 48.6% (*n* = 37) had greater than three comorbidities, and 44% (*n* = 34) had primary respiratory diagnoses.

By ethnicity, the Indigenous New Zealand Māori were overrepresented in the data (n = 18, 23%). Of those receiving RS, the minority (n =12, 15.7%) received NHF; however, all these required subsequent hospitalisations. The absolute prevalence of the requirement for escalation of RS was 22 (28.9%). The hospitalisation rate was 22% higher, and the hospital length of stay was 42% longer for those requiring RS escalation in the ED. Māori demonstrated a 5.8% higher risk of requiring escalation of care on an absolute scale (n = 6, 33.3%) vs non-Māori (n = 16, 27.5%) and a 22% increased risk on a relative scale (RR 1.22; 95% CI 0.56 to 2.67; p = 0.60) than non-Māori.

When the results from the two methods were integrated, the main thesis finding was that nearly a third of those receiving RS required escalation of their RS, with those receiving NHF requiring less escalation than those receiving all other forms of RS combined. This finding aligns with the meta-analysis of studies for the comparison of NHF compared to COT but not the comparison of NHF compared to NIV (O'Donnell et al., 2024).

7.2 Interpretation and Implications of this Research for ED Evidence-Based Practice

The interpretation and implications of the doctoral research findings shall now be contextualised regarding its EBP theoretical framework. This interpretation will describe the implications for ED clinicians, particularly nurses and their patients. The EBP framework is a problem-solving approach that dictates that clinical decision-making is informed by the interplay of *best evidence, professional expertise,* and *consumer values*.

7.2.1 Best Evidence

In EBP, clinical decision-making should be informed by the *best evidence*. The two complementary methods used produced evidence at opposite ends of the EBP evidence pyramid, with the SR and MA an example of the best evidence positioned atop this pyramid. Using a multi-method design, common patient-focused outcomes were investigated, such as escalation of RS in the ED. A requirement for escalation of RS is clinically significant and may be associated with increased adverse events and health sector burden.

The first of the two quantitative methods was a SR with MA considering RS in the ED (O'Donnell et al., 2024). As described compared with COT, NHF reduced the risk of escalation by 45%, although no statistically significant differences were seen in mortality risk or adverse events; these are clinically plausible findings. In contrast, compared with NIV, NHF increased the risk of escalation by 81%; however, the MA had high clinical heterogeneity for this outcome; hence, this is a clinically questionable finding which requires further exploration. The NIV interventions in the included studies varied. For example, the NIV gas flow rate and interfaces were not consistent. Some studies reported that a full-face mask (Cortegia et al., 2020), a helmet (Osman et al., 2021), or a nasal mask provide NIV (Doshi et al., 2018). Collectively, these inconsistencies have likely impacted the SR results. Further subgroup analysis to explore this could not be completed due to the limited number of studies qualifying for inclusion. Three other published ED SRs (Table 12) have compared NHF to NIV and to COT (Lin et al., 2017; Tinelli et al., 2019; Wang et al., 2020). The most up-to-date ED SR results in this doctoral research (O'Donnell et al., 2024) did not fully align with these three comparable SRs.

In contrast, in the second method, the PPS, real-world sampling complemented the non-real world of the SR. Pragmatic studies such as this PPS measure report what happens in everyday clinical practice. This is in direct contrast to MAs of RCTs, which are completed in experimental settings, which are often so divorced from the real world that they cannot fully answer the questions that need to be answered and from which the results have limited applicability to the ED setting. Notably, EBP relies on robust epidemiological foundations. The scarcity of large-scale epidemiologic studies profiling the real-world ED patient population is well described (Alnajada et al., 2023; Kelly et al., 2015; Mockel et al., 2013). Epidemiological studies, such as this PPS, provide context for interventions, as in the case of RS and provide a foundation for the further generation of *best evidence* (Rasmussen & Goodman, 2019).

Applying the multimethod design, the integrated SR and PPS results have strengthened the validity and reliability of the overall thesis findings to provide the *best evidence*, which has enabled a comprehensive understanding of the nature of the RS provided in the ED. This *best evidence* should provide a foundation for clinician *professional expertise.*

7.2.3 Professional Expertise

In EBP, the *professional expertise* of the clinicians informs their clinical decision-making process and their ability to advocate for their patients. Systematic reviews of evidence, such as the SR in this doctoral research, support and enable professional expertise by driving accountability and evidence utilisation. A pragmatic clinical study, such as this PPS, measured and reported real-world data to indirectly demonstrate the clinicians' typical clinical decision-making and professional expertise within four participating EDs. In NZ EDs, the doctor and nurse practitioner are the clinicians most likely responsible for the prescription clinical decision-making on the need for and provision of RS. As such, the answers to the four core thesis questions indirectly reflect the *professional expertise* of the ED clinicians providing NHF to their patients:

- Who receives NHF in the ED?
- How is NHF therapy delivered in the ED?
- Which patients receiving NHF require escalation of RS in the ED?
- What are the effects seen with NHF therapy on physiological and patient-centred outcomes?

7.2.3.1 Who receives NHF in the ED?

The efficacy of NHF relies on the appropriate selection of patients. The ED patient population is known to be heterogeneous, as is the subgroup of patients provided NHF (Marjanovic et al., 2020). Two studies describing NHF epidemiology have been reported from South-East Asian hospital EDs (Durey et al., 2017; Ito et al., 2018). The first was a retrospective observational study of NHF delivery in a single Korean ED; 43 patients with acute respiratory failure receiving NHF were reported over 25 months (Durey et al., 2017). The baseline patient characteristics were comparable to those in this PPS, except for sex, with 79% male participants in the Korean study. These authors also report extraordinary rates of NHF failure requiring intubation (25.5%) and mortality (36.6%). Despite this, significant improvements in physiological and respiratory parameters were claimed.

The second epidemiological study was a retrospective cross-sectional survey of NHF use in 33 Japanese EDs (Ito et al., 2018). All included patients who had also received one or a combination of COT, NIV, or INV RS. The indications for NHF included acute respiratory failure (65.4%), postoperative RS (15.9%), and post-extubation RS (11.2%). The outcomes reported included positive physiological responses to NHF RS. Collectively, these epidemiological studies demonstrate the limitations to the generalisability of findings when using this method.

7.2.3.2 How NHF therapy is delivered in the ED?

In the PPS, data on *how NHF therapy is delivered in the ED* were reported at five-time intervals, for a maximum of four hours, and on ED discharge. The efficacy of NHF also relies on the active, ongoing management of patients and the NHF RS they receive, with an opportunity to independently titrate gas flow and FiO_2. Notably, supplemental O_2 provided during RS is a drug and, hence, should be prescribed, administered, and monitored accordingly (Kane et al., 2013). However historic, misconceptions about O_2 therapy have persisted. For example, for those with chronic obstructive pulmonary disease, O_2 therapy was incorrectly thought to induce hypercapnia by disturbing their 'hypoxic drive', making clinicians reluctant to provide supplemental O_2 to chronic obstructive pulmonary disease hypoxemic patients (Brill & Wedzicha, 2014). However, the potential for hypercapnia due to the Haldane effect remains, along with a worsening VQ matching and ratio in the good parts of the lung caused by O_2-induced vasodilation in the damaged areas of the lung (Brill & Wedzicha, 2014).

Whilst the doctoral research did not directly explore clinical decision-making, the data on '*How was NHF delivered?'* suggest the provision of RS was not optimal, with limited active management or titration of RS to suit individual patient needs. This PPS showed a tendency for a one-size-fits-all approach to gas flow rates and FiO_2, regardless of patient response. The maximum flow reported was consistently less than possible, and minimal adjustments were made to mean gas flows. The maximum FiO_2 reported was half what is possible for this therapy, again with very limited adjustments made over time.

This failure to actively manage RS demonstrated here is also common in practice, with adherence to EBP guidance regarding RS and O_2 delivery known to be poor (L'Her et al., 2017). Whether this phenomenon of limited active management of NHF was driven by workload pressures, clinician skill level, or some unknown factor remains unclear. This finding suggests a failure to demonstrate the implementation of evidence into practice. Clinical decision-making and active management of RS, notably NHF RS, need to be formally explored to inform EBP in ED better.

Finally, data reporting on NHF tolerance were limited, just as for other forms of RS. Patient tolerance is an important consideration that impacts NHF efficacy (Basile et al., 2020). Intolerance of NHF is reported as being related to gas temperature and flow rate along with the level of experience of those clinicians, particularly the nurses who provide the therapy and support patients receiving it (Mauri et al., 2018).

7.2.3.3 Which patients receiving NHF require escalation of RS?

Along with providing support to improve tolerance of RS therapies, ED clinicians make numerous time-sensitive, crucial decisions on behalf of often unstable patients; this justified the question, '*Which patients receiving NHF require escalation of RS?'* Notably, the roles of ED RNs and Nurse Practitioners have expanded due to changes in technology and ED workload demands, and these additional responsibilities broaden the scope of clinical decision-making around aspects of care such as escalation of care (Abu Arra et al., 2023). The failure to appropriately de-escalate or escalate RS, including NHF RS, has consequences for patients and health service resources (Ischaki et al., 2017).

This doctoral research has described the epidemiology of escalation of RS in the ED (O'Donnell et al., 2024) and described the utility of a scoring system that uses physiological parameters to predict a requirement for escalation for patients receiving NHF (O'Donnell et al., 2021a; Roca et al., 2019). The PPS results suggest that those on NHF were escalated appropriately. Whilst the material NHF costs are more than COT, the long-term cost savings related to escalation avoidance are clear (Ischaki et al., 2017). The PPS reports a low benefit NNT of 5.87; this NNT was derived from the non-significant treatment effect calculation. This NNT suggests that nearly six patients must be treated with NHF to avoid one requirement to escalate care. As described, a need for escalation of care may be demonstrated in physiological parameters; therefore, it justified the final question: *What are the effects seen with NHF therapy on physiological and patient-centred outcomes?*

7.2.3.4 What are the effects seen with NHF therapy on physiological and patient-centred outcomes?

In the PPS, changes in physiological outcomes did not always correlate with the therapy provided. It was apparent that during the data collection periods and on ED discharge, no clinically significant deterioration or improvement in physiological outcomes was seen with NHF. These findings contradict the published evidence, which consistently reports improved physiological outcomes with NHF (Mauri et al., 2019).

The other patient-centred outcomes reported in the PPS included data relating to hospitalisation and mortality. In New Zealand, hospital admission rates via the ED are reported to be between 9% and 40% (Jones et al., 2021); in contrast, the PPS reported much higher admission rates for receiving NHF in the

ED then admitted to hospital, with the majority admitted to the general wards. Historically, safety concerns have been raised for patients receiving NHF in the ward setting (Mauri et al., 2019), prompting the development of focused clinical guidelines and protocols (Trump et al., 2022).

Three additional differences in the PPS results were noted compared to a PPS of dyspnoea completed in the Asia Pacific region (Kelly et al., 2017). Firstly, a higher rate of hospital ward admission was seen in the PPS at 83.3% vs 11.4%; secondly, a lower ICU admission rate of 8.3% vs 19.9% (Kelly et al., 2017). Finally, the median hospital LOS was higher at eight (4 to 15) vs five (3 to 8) days. As reported, the PPS data demonstrated that those placed on NHF in ED had significantly higher hospital LOS than those not on NHF. It is likely that These *patient-centred outcomes* are significant and reflect healthcare *consumer values.*

7.2.4 Consumer Values

Consumer-driven healthcare is growing globally, with patients seeking online health information to confirm their healthcare preferences and values. Consequently, healthcare organisations and professionals must prioritise consumer values and preferences in EB care delivery (Melynk & Fineout-Overholt, 2006). Clinicians must respect individual patient circumstances in clinical decision-making, especially in ED settings, as limited opportunity for literacy and prior knowledge can undermine their participation in care decisions (Melynk & Fineout-Overholt, 2006). This has consequences for clinicians, particularly ED doctors and nurses, where patients often must rely on clinicians to advocate on their behalf. Notably, this doctoral research did not consider patients' understanding of the RS provided or whether NHF was adjusted to their comfort level.

Emergency departments across the world provide care to these vulnerable patients. Some of these ED patients present with serious illnesses or injuries requiring immediate attention, while others present due to their inequitable access to healthcare or high material need (HMN). This HMN may be for food, housing, education, or healthcare. For those experiencing HMN and inequity in Aotearoa, New Zealand, their first access to healthcare is often the ED (Curtis et al., 2022). Epidemiological studies, such as this PPS, consider the factors, occurrence, and distribution of health and disease within populations (Brachman, 1996). Consequently, the epidemiological profiles of ED patients provide surrogate indicators of health, disease, and HMN within a population and across the healthcare sectors. The PPS data profiling the ED patient revealed a highly significant finding: the overrepresentation of indigenous NZ Māori in the sample. This was not an unexpected finding for this population and aligns with the published evidence which describes the inequity in health outcomes for Māori and Pacifica in New Zealand (Curtis et al., 2022). Globally, Indigenous peoples are overrepresented in the ED; this is likely due to their significant structural barriers to accessing healthcare and comparative inequity in their healthcare literacy (UN Permanent Forum on Indigenous Issues [UNPFII], 2024). A submitted manuscript discusses the PPS findings demonstrated by ethnicity (Appendix C).

7.3 The Strengths and Limitations of the Doctoral Research

The thesis utilised a multimethod design, a systematic method that integrates results from multiple research methods to overcome the limitations of single-method approaches (Brewer & Hunter, 1989). This design aligns with the theoretical framework of this thesis, enabling the delivery of optimal evidence to guide clinical decisions. This design aligns with the theoretical framework of this thesis, enabling the delivery of the *best evidence* to guide clinical decisions. This design has strengths and limitations inherent to the individual research methods; collectively, these elements dictate the thesis findings and the scope of their applicability.

The strengths of this design included allowing a comprehensive understanding of the nature of RS provided in the ED. Here, a more holistic view was achieved through the cross-validation of results from two methods, enhancing the credibility and reliability of the overall findings. This design has allowed flexibility in the research approach for a more tailored response to the six research questions about the provision of RS in ED. The overall validity of the thesis findings was enhanced when the two results from the methods were combined, mitigating any inherent biases in any single method. The limitations of this design included complexities around the implementation of two methods rather than a single method, and careful planning coordination and adequate resourcing were required. Integration of findings from two methods applied in the complex ED setting can be challenging, particularly if the results are contradictory or if the methods are not well-aligned. The integrated findings of this thesis were not contradictory, and the research conclusions were clear.

7.3.1The Systematic Review and Meta-Analyses- Strengths and Limitations

The SR and MAs have strengths and limitations, summarised in Table 41. The completion of the SR and its protocol reflected the Cochrane methodology to mitigate the SR's bias and limitations (Higgins, 2023). The PRISMA-P and PRISMA checklists informed the reporting quality of the SR and its protocol (Appendix M).

However, all SRs have limitations. Firstly, it is acknowledged that the scope of the SR was purposely restricted to include ED RCTs alone; however, non-ED RCTs and qualitative evidence may have provided further dimensions to the SR findings. However, the generalisation to the ED setting would have been limited.

Secondly, SRs are ‘living documents’; they are iterative as they require updating as new evidence emerges; this review shall, therefore, require regular updating. However, secondary to COVID-19, ED evidence has been slow to materialise. The SR in this doctoral research provided high-level evidence when there is a scarcity of ED evidence for RS in ED, particularly NHF.

Finally, many of the SR limitations are secondary to the limitations of studies included in the SR, including 1) a lack of data to enable subgroup analysis; 2) the corporation of outcome data affected by imprecision for all outcomes; 3) including English-only studies; and 4) the use of data that had unavoidable RoB-related to the inability to fully blind participants, clinicians, and researchers.

7.3.2The Point Prevalence Study- Strengths and Limitations

The PPS has strengths and limitations, which are summarised in Table 41. This epidemiological study has contextualised the provision of RS in the ED. This PPS may support future RS ED research and clinical practice by cultivating insight into the real-world delivery of RS in this complex setting (Harder, 2014). This study has strengths and limitations that relate to the PPS method and its execution (Wang & Cheng, 2020). However, the STROBE checklist informed the PPS's reporting quality (Appendix M).

Conducting clinical research in the ED is known to be challenging. Additionally, much like the polio pandemic, the COVID-19 pandemic has had devastating impacts on all aspects of ED healthcare delivery and demand. As a result, the challenges in conducting ED clinical research increased (Howard et al., 2022; Graham, 2019). Notably, the NZ study was completed in the early autumn of 2023, when the public health and social measures introduced during the COVID-19 were easing. This prospective observational real-world study was accomplished in four NZ EDs. The methods facilitated the swift but reliable representative real-world sampling of a cross-section of the greater NZ ED population (Creswell & Creswell, 2017; Faraoni & Schaefer, 2016). However, this sampling method cannot represent this population in other countries or on another given day; hence, generalising the findings should be qualified. The study was primarily executed according to protocolised methods to reduce bias and ensure data reliability (O'Donnell et al., 2021b). The reporting of the study findings reflected the STROBE recommendations (von Elm et al., 2008) (Appendix M).

Typically, in PPSs, the usual sources of bias are selection and information; these forms can diminish a study's internal and external validity (Buitrago-Garcia et al., 2022). Selection bias was non-existent in this PPS, as all eligible patients were recruited. Misinterpretation and/or observer bias were predicted sources of information bias. Therefore, thorough data collector induction (Appendix J) and piloting the electronic case report form (eCRF) (Appendix H) were carried out to homogenise data collection.

This PPS has clear limitations. First, the study's absolute number of participants was 5% less than required by power calculation for the outcome of the escalation of RS. Therefore, the study was underpowered and unable to support inferential analyses for any variables. Secondly, unlike an adequately powered RCT, a study with a limited sample size and method cannot establish cause and effect regardless of the outcome or variables considered (Akoberg, 2005). Therefore, assumptions were made, for example, around any therapy interruptions and or the incidence determination for the primary outcome of escalation could not be relied upon. Finally, the rationale for the escalations seen relied on subjective interpretation alone. Therefore, any additional interpretation of these findings should also be limited, and the need to determine predictive factors for the escalation of RS persists.

The strengths and limitations of each method have been previously described in Chapter Four, *Methodology*, and Chapters Five and Six, *Results,* and which will now be described.*;* these are now summarised in Table 41

Table 41

Summary of Strengths and Limitations of the Two Individual Methods Used in the Doctoral Research

SR Strengths	SR Limitations	PPS Strengths	PPS Limitations
Methods are protocolised, and a thorough summary of all relevant studies was provided; this minimises bias by following a structured methodology	Time and resource-intensive process	Methods are protocolised	Temporal Limitations: data were collected at a single point in time; it does not provide information on changes over time
Systematic scientific search for studies	Publication bias	Methods are observational	Resource impacts are high.
Predefined criteria were used for study selection and data extraction, enhancing the SR's reproducibility.	The quality and availability of included Studies dictate the SR quality	Adherence to Reporting Guidelines (SRTOBE) promotes transparency	Cannot attribute cause and effect
Critical appraisal of studies – exposes study bias and limitations. Ensuring results drawn from the best evidence	Heterogeneity among studies can complicate the pooling of data and may lead to misleading conclusions and oversimplification of complex relationships, potentially masking important nuances	Validates and complements the SR method, providing a more comprehensive understanding	Generalisability limited
The synthesis of findings through MA provides reliable estimates of effects or associations, which is more precise than individual studies, which increases the overall sample size and statistical power.	Narrow focus and limited scope impact applicability: the SR may be limited by the specific research question asked. There is a potential to overlook other relevant studies	Enabled the observation and measurement of a wide range of variables	Regarded as a lower level of evidence

Table 41 cont.			
This SR has highlighted areas where research is lacking, guiding future studies	Potential for bias and error in the review process	Compared to controlled studies, this PPS was simple and less expensive to execute	There may be biases in how data were collected or in the population sampled, which can affect the validity of the results
Regarded as the highest level of evidence to potentially inform clinical guidelines and policy decisions based on a broader evidence base	Homogeneity must be assumed	The PPS provides a quick snapshot of the health status of the NZ ED population, which can aid planning and resource allocation.	The PPS cannot capture the full context of the issues, such as clinical decision-making around RS or the long-term impacts on ED patients.
This SR may help in making informed EBP decisions by compiling high-quality evidence from multiple studies	Sensitivity to outliers: The results can be heavily influenced by outlier studies, which may skew the overall findings	Large amounts of data can be captured from a population all at once	
Comprehensive coverage ensures a more comprehensive understanding of the subject			
Resource impacts are low compared to some methods			
Author collaboration reduces bias			
Adherence to PRISMA promoted transparency and reproducibility			
Through MA, heterogeneity among study results was confirmed, helping to identify factors that may influence outcomes			

7. 4 Recommendations: Avenues for Further Studies or Education

This thesis highlights the complexity of EBP in the complex, unique ED context. It is recommended that the Integrated Promoting Action on Research Implementation in Health Services (i-PARIHS) framework be used to support EBP in the ED systematically (Zhang et al., 2024).

7.4.1 Context

The ED context is facing rising challenges: these include overcrowding, resource limitations, and increased patient demand. Universal inequity and HMN manifest in the ED and burden the healthcare sector. The overrepresentation of Māori in the PPS data is assumed to be related to inequity and HMN. A never-ending cycle exists of high levels of HMN, and inequity feeds the health sector burden and failure. As described, the ED straddles the primary and tertiary health sectors and acts as a 'barometer' signalling performance, consistently demonstrated in the ED. The ED 'barometer' effect provides an opportunity to inform health sector strategies and policies. For example, the PPS data described apparent delays in a presentation to the ED, with the median duration of symptoms before ED admission of 24 hours. Whilst the PPS did not report the rationale for this phenomenon, published evidence confirms the consequence of delayed ED presentation times as significant and associated with poor health outcomes and increased health sector burden (Rodriguez et al., 2001).

In addition to inequity and HMN, the demographic profile of populations in the Organization for Economic Cooperation and Development (OECD) countries is ageing (OECD Library, 2024). On average, the proportion of those over 65 is predicted to increase in OECD countries, from 17.3% in 2019 to 26.7% by 2050. For NZ, an 8.1% increase is expected by 2050 from a base of 15.3% in 2019 (OECD Library, 2024). Increased mean population age, like inequity and HMN, increases healthcare demand and complexity of care, which all impact available resources and patient outcomes (Haddad et al., 2024; Rixon et al., 2023). The doctoral research findings may be consistent with the evidence suggesting that inequity and HMN drive many challenges in the ED and the wider health sector, for example, overcrowding and a mismatch between supply and demand (Badr et al., 2022).

7.4.1.1 Overcrowding in the Emergency Department.

Ironically, the principal role of the ED is to provide immediate, appropriate care through rapid diagnosis and timely treatment. Primary health sector failure has driven an inappropriate reliance on the ED, especially for the very old or young. Globally, ED overcrowding and its impact on timely and appropriate care have been described for over 40 years (Kenny et al., 2020). As described in Chapter One, ED overcrowding is a serious health problem, as the number of ED facilities is not increasing, and the number of patients presenting to these EDs is increasing. Whilst this doctoral research did not report on overcrowding, a 51.8% increase in the annual census was observed in the participating EDs in 2022 and 2023 (Table 22). These census data were likely impacted by NZ's strict measures for COVID-19 control.

ED overcrowding compromises the ED's performance with roadblocks for those awaiting consultation, diagnosis, treatment, or discharge. Essentially, ED overcrowding demonstrates a supply and demand imbalance. The number of patients admitted to the ED (input), the time to manage these patients (throughput), and the number of patients discharged from the ED (output) all contribute to this ED supply and demand imbalance (Badr et al., 2022).

A disproportionate number of those in the PPS required prolonged ED admission and subsequent hospital admission, suggesting they are a high-need cohort. Much work has been done to quantify ED overcrowding and provide an evidence-based understanding of its repercussions; however, effective solutions are lacking. Patient boarding is the most significant factor impacting ED overcrowding. Boarding commonly results from hospital ward bed blocks: ED boarding and overcrowding compromise ED patients and the clinicians caring for them. These compromises for ED clinicians manifest as staff shortages and burnout (Badr et al., 2022).

7.4.1.3 Staff Shortage and Burnout.

The rate of ED clinician burnout is increasing and is associated with poor staff and patient outcomes. The authors of a NZ multidisciplinary, multi-site study of ED staff wellbeing have called for a solution-focused approach to burnout with a greater understanding of workplace wellbeing (Anderson et al., 2021). These unique ED challenges impact staff shortages in the ED. Nurses comprise the largest ED clinician group by profession, with global shortages in this ageing profession driven by a shortage of educators, increasing staff turnover, and inequity across the profession (Haddah et al., 2023). Collectively, overcrowding and WPV burnout impact the opportunity to provide quality care, which relies on clinical decision-making that is evidence-based.

7.4.2 Facilitation

Facilitation of EBP and research reflects the unique ED context, which poses challenges and opportunities for ED EBP and research. By definition, nurses in the ED play a crucial role in healthcare; increasingly, they are compelled to translate research evidence into practice to improve patient outcomes. Education programmes, reminders, and champions help nurses understand and apply research, but implementing the best evidence is difficult (Zhang et al., 2024). In contrast to consuming or utilising evidence, ED nurses increasingly generate primary evidence through research.

It is acknowledged that conducting any research in the ED is challenging (Price et al., 2020). The scope of clinical practice and research applicable to the ED ranges across health sectors and encompasses most disciplines. Typically, clinical practice and research areas are defined by systems or conditions. In contrast, the ED defies a clear definition that supports its generalisability across populations and health sectors. The quality of ED clinical practice and research and the timeliness of the care provided can impact the vulnerable ED patients' mortality, long-term morbidity, and fiscal healthcare burden. However, the ED is a service described as 'at a breaking point' (Graham, 2019). Firstly, there are limited available ED researchers; secondly, the ED research pathways are not well defined; thirdly, there are few interdisciplinary collaborations or ED research networks; and finally, the typical funding sources are limited (ACEP Research Committee, 2024; Graham, 2019; Olaussen et al., 2017). Notably, the Australasian College of Emergency Medicine has clinical research and an epidemiological network operating within Australasia. However, the novel coronavirus disease of 2019 (COVID-19) pandemic has severely impacted all clinical research, including in the ED (Bratan et al., 2021).

7.4.3 The Nature of the Evidence

Three areas of ED evidence need have been described: basic science, clinical research, and health services research (Aghababian et al., 1996; Becker et al., 2002). The present doctoral research has served some of these needs and exposed avenues for further study. These proposed avenues have been described previously in Chapters Five and Six. For example, the SR reflects the need for further clinical research to compare NIV to NHF. The PPS reflects the need for health service research, focusing on RS clinical decision-making.

Following on from this thesis, further avenues for research include:

- Further consideration of physiological responses to titrations in the respective NHF gas flows and FiO_2
- An exploration of the clinical decision-making of ED doctors, nurse practitioners and nurses concerning the active management of NHF.

This thesis has further described inequity for the NZ indigenous Māori. Further research describing this issue is now not warranted. An EBP Kaupapa Māori approach is required where existing evidence findings are used to inform and drive genuine change and to inform solutions for inequity. The Kaupapa Māori approach relies on genuine collaborations with iwi, Māori asset holders, and other Māori stakeholder groups (Curtis et al., 2022).

Other potential avenues for research identified during the development of this thesis include:

- Exploration of NHF clinical outcomes around escalation of care and safety in apnoeic oxygenation for conscious sedation and intubation. As the PPS was underpowered in determining its primary outcome, it is suggested that further adequately powered research escalation of RS be completed
- The NHF ED subpopulations that require clinical outcome research include those with hypercapnic respiratory failure in chronic obstructive pulmonary disease or those needing end-of-life care
- Given rising care costs, financial data is required to help inform strategic direction. Respiratory support therapies and O_2 are costly and must be used appropriately to preserve health care resources. This research demonstrates an opportunity to explore the cost-benefit of delivering RS in the ED, whether to prevent escalation or to pre-empt admission and readmission to the ED and the wider hospital system.

7.5 Thesis Conclusion

The purpose of this section, *Conclusion,* is to provide a final summation of the doctoral research thesis and its conclusion. The purpose of all clinical research should be to support EBP by producing evidence to inform and, where able, change clinical practice and policy to improve patient outcomes. The researcher recognises a need to better support EBP and research in the ED with respect to the nature of the RS, notably RS with NHF, as provided to adults in the ED. The purpose of all clinical research should be to support EBP by producing evidence to inform and, where able, change clinical practice and policy to improve patient outcomes. The aim of this doctoral research, therefore, was to analyse the nature of ED-based RS and its impact on adult patient outcomes, with a focus on NHF therapy-based RS. The methodology employed in this doctoral research was informed by a positivist philosophical paradigm, and its methodology was underpinned by an evidence-based practice theoretical framework. The research approach was quantitative, the research strategy was non-experimental, the design was multi-method, and the time horizon was cross-sectional, using two methods: 1) a systematic review and meta-analysis and 2) a point prevalence study. Given the doctoral research aims and its methodology, two overarching and four core thesis questions were answered. Using this evidence within the EBP framework, clinical decisions in the ED setting may be better informed and consumer values realised. The issue for clinicians is determining how the new evidence presented in this thesis best translates into practice.

7.6 Chapter Seven Conclusion

This seventh-chapter *Discussion and Conclusion,* not only summarises the doctoral research but also highlights the significance of its findings for EBP in the ED. The doctoral research findings that have emerged from the integration of two methods have been interpreted and discussed, shedding light on the ED, its vulnerable patients, and ED clinical decision-making. The strengths and limitations of the doctoral research have been carefully considered, and recommendations for implementation of EBP and further research using the i-PARIHS framework. The chapter has also provided a final summation of the doctoral research and its thesis. The last section of the thesis now provides the *Concluding Thesis Statement*.

7.7 Concluding Thesis Statement

*The findings in the real-world study demonstrate that nearly a third of those receiving RS required escalation of their RS, with those receiving NHF requiring less escalation than those receiving all other forms of RS combined. This finding aligns with the meta-analysis of studies for the comparison of NHF compared to COT but not the comparison of NHF compared to NIV***.**

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Appendices

Appendix A

Health Research Council Grant Funding (entire contract available)

CONTRACT FOR RESEARCH FUNDING:
HEALTH RESEARCH COUNCIL OF NEW ZEALAND

Contract Number	22/855/A
Contract Type	Research Activation Grant
First Named Investigator	Ms Jane O'Donnell
Title	Delivery of Respiratory Support in the Emergency Department
Research Provider	Massey University
Approved Budget	$ 30,000.00
HRC Contract Manager	Orin Robb

Appendix B

Fisher & Paykel Healthcare Grant Funding (entire contract available).

Fisher & Paykel
HEALTHCARE
Fisher & Paykel Healthcare Limited
15 Maurice Paykel Place
East Tamaki, Auckland 2013
PO Box 14 348
Panmure, Auckland 1741
New Zealand

Tel: +64 9 574 0100
Fax: +64 9 574 0158
Website: www.fphcare.co.nz

January 26th, 2023

Jane O'Donnell
College of Health - School of Nursing Massey University - Albany
Private Bag 102904, North Shore, Auckland 0745
SNW Building, Massey University - Albany,
Albany Expressway (SH17), Albany, Auckland 0632

Dear Jane O'Donnell

Respiratory Support of Adults in the Emergency Department Setting; A Point Prevalence Study

We refer to our recent discussions on the opportunity to assist you in the proposed study of Respiratory Support of Adults in the Emergency Department Setting ("Study") to be undertaken by Jane O'Donnell as part of a doctoral thesis and in her capacity as the Principal Investigator at Massey University ("Institute").

We confirm that we are interested in pursuing this opportunity with the Institute. The purpose of this letter is to record our agreement on Fisher & Paykel Healthcare Limited's ("FPH") contribution to the Study.

Contribution

FPH wishes to contribute to the Study by providing the Institute with NZD 20,000.00 to be paid on or around the dates referred to below, subject in each case to receipt by FPH of a proper invoice from the Institute for the relevant amount and the other requirements set out below:

Date	Milestone Requirements
March 1st 2023	Recruit and induct six RN data collectors
April 1st 2023	Data collection commenced
August 31st 2023	Data collection completed

Appendix C

Manuscript Submitted April 2024

The aims, objectives, rationale and justification for the manuscript are as follows (O'Donnell et al., 2024):

Publication Aims: To report a subset of real-world epidemiological data from the PPS on the Indigenous New Zealand (NZ) Māori ethnicity presenting in NZ EDs

Publication Objective: To describe the epidemiology and RS outcomes of the Indigenous New Zealand (NZ) Māori ethnicity presenting in NZ EDs.

Publication Rationale: Emergency departments (EDs) are straddled between inpatient and primary care sectors; there is a unique opportunity to improve health equity by providing targeted quality care through ED research that reports on equity indicator outcomes by ethnicity.

Publication Justification: This publication aligns with the program of doctoral research and its second method, the PPS.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Jane O'Donnell
Name and title of main supervisor:	Professor Marlena Kruger
In which chapter is the manuscript/published work?	Appendix O

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

Conception and design: JOD Lead Author, PhD Candidate
Draft manuscript preparation: JOD
Review manuscript drafts : JOD, AP, CB, EM, KH, MK
All authors reviewed the results and approved the final version of the manuscript.

Please select one of the following three options:

○ **The manuscript/published work is published or in press**

Please provide the full reference of the research output:

◉ **The manuscript is currently under review for publication**

Please provide the name of the journal:

Knowing How Expensive it is to Be Poor in Aotearoa, New Zealand
Submitted to Journal of Racial and Ethnic Health Disparities

○ **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

Student's signature:	Jane O'Donnell — Digitally signed by Jane O'Donnell Date: 2024.03.28 13:34:03 +13'00'	Main supervisor's signature:	Marlena Kruger — Digitally signed by Marlena Kruger DN: cn=Marlena Kruger, c=NZ, o=Massey University, ou=School of Health Sciences, email=m.c.kruger@massey.ac.nz Date: 2024.03.28 14:17:36 +13'00'

This form should be placed at the beginning of each relevant thesis chapter.

[1] Refer to the Massey University Publishing and Authorship guidelines (OneMassey for staff, Stream for students) and/ or Contributor Roles Taxonomy (CRediT) guidelines for guidance.

Knowing How Expensive it is to Be Poor in Aotearoa, New Zealand

Jane F O'Donnell MN, Ph.D. Cand

The University of Auckland, Auckland, New Zealand. Jane.odonnell@auckland.ac.nz

Alison Pirret PhD[1] Chakra Budhathoki [2] Elissa McDonald PhD[3] Karen Hoare NP, PhD[3] Marlena Kruger PhD[3]

Critical Care Complex, Middlemore Hospital, Auckland, New Zealand

The Johns Hopkins University, Baltimore, Maryland USA

Massey University, Auckland, New Zealand

Abstract

Objectives*:* Emergency departments (EDs) are straddled between inpatient and primary care sectors; there is a unique opportunity to improve health equity by providing targeted quality care through ED research that reports on equity indicator outcomes by ethnicity. The study objective was to describe the epidemiology and respiratory support (RS)outcomes of the Indigenous New Zealand (NZ) Māori ethnicity presenting in NZ EDs.

Design: A point prevalence study (PPS) method captured real-world epidemiological data on ED patients. Our original PPS captured real-world epidemiological data reporting on RS provided to all adult patients at four NZ EDs. The PPS population included those of Indigenous NZ Māori ethnicity; here, the subset of data focusing on ethnicity is reported.

Results*:* Māori presenting to ED were significantly younger, with a mean (± SD) age of 56.8 ± 13.7 compared to non-Māori 70.69 ± 43.0 years (t = 3.11; 95% CI, 4.98 to 22.62; $p < 0.01$). The median difference in the median wait time was 39.5 hours, with Māori waiting longer with symptoms before presenting at the ED (Mdn = 48, IQR 24 to 72 vs non-Māori Mdn = 8.5, IQR 1 to 48); however, the difference was not significant (Mann-Whitney U test, $p = 0.75$). For the primary outcome, Māori demonstrated a 5.8% higher risk of requiring escalation of care on an absolute scale ($n = 6$ [33.3%] vs $n = 16$ [27.5%]), and a 22% increased risk on a relative scale (RR 1.22; 95% CI 0.56 to 2.67; $p = 0.60$) than non-Māori.

***Conclusion**:* Overall, these real-world data suggest that those of Indigenous NZ Māori ethnicity presenting in NZ EDs have poorer outcomes when compared to non-Māori. These data could be used to inform future research and health strategy.

***Keywords**:* inequity, emergency department, high material needs, casualty, indigenous.

Introduction

Globally, Emergency Departments (ED) provide care to vulnerable patients. Some ED patients present with serious illnesses or injuries requiring urgent attention, while others present due to their limited access to healthcare or high material needs (HMN). This HMN may be for food, housing, education, or healthcare. For those experiencing HMN and inequity in Aotearoa, New Zealand (NZ), their first access to healthcare is often the ED (Curtis et al., 2022). In NZ, ED care is free and primary healthcare is not, which likely delays patient presentation and compounds the effects of illness or injury. In 2023, a point prevalence study (PPS) study was completed in four NZ EDs. This paper shares data that relates to HMN and health inequity.

In NZ, many ED patients requiring respiratory support (RS) have chronic respiratory disease (RD) and HMN (Kelly et al., 2017; Telfar-Barnard & Zhang, 2020). Notably, the prevalence of RD is higher within the Indigenous NZ Māori and Pasifika populations and indirectly demonstrates HMN and health inequity (Telfar-Barnard & Zhang, 2020) (Table A).

Māori represent 17.3% of the total NZ population, and the well-described inequity experienced by Māori negatively impacts their age, life expectancy, and amenable mortality (Crengle et al., 2022; Te Waihanga NZIC, 2022). Māori are significantly younger than non- Māori; 30% vs 15%, respectively, are aged < 15 years. The median ages of Māori males and females are 25.3 and 27.3 years, respectively, compared to non-Māori median ages of males and females (36.7 and 38.8 years, respectively). The life expectancy of Māori is, on average, 7.5 years less than non-Māori (males eight years less; females seven years less), with life expectancy related to deprivation (Te Waihanga NZIC, 2022). When compared to non-Māori, Māori have increased avoidable mortality, with standardised incident rates of 2.45 (95% CI, 2.36 to 2.54) in urban areas and 2.34 (95% CI, 2.19 to 2.49) in rural areas (Crengle et al., 2022; Te Waihanga NZIC, 2022).

Table A.

Impacts of Respiratory Disease in New Zealand (Telfar-Barnard & Zhang, 2020; MOH, 2021; MOH, 2014)

- RD is one of the leading causes of presentation to EDs in NZ and the third most common cause of death.
- The cost of RD to NZ is estimated at NZ$ 6.68bn.
- RD accounts for 10% of overnight hospital stays, 1780 per 100,000.
- Since 2000, RD hospitalisations have been increasing at a rate of 17.2 per 100,000 hospitalisations
- Pacific peoples' hospitalisation rates are highest (2.6 higher) across all RD except asthma and COPD with Indigenous Māori rates are 2.2 higher for these conditions across the NZ population.
- Indigenous Māori have the highest RD mortality (rate ratio 1.74).
- Economic deprivation is a significant contributing factor to RD hospitalisation. Those in deprived households are 2.37 times more likely to be admitted to the hospital.

Methods

"Not everything that is faced can be changed, but nothing can be changed until it is faced." (Baldwin, 1972).

However, as Baldwin said, "Not everything that is faced can be changed, but nothing can be changed until it is faced" (Baldwin, 1972). A point prevalence study (PPS) method captured real-world epidemiological data on ED patients. Our original PPS captured real-world epidemiological data reporting on RS provided to all adult patients at four NZ EDs.

The PPS population included those of Indigenous NZ Māori ethnicity; here, the subset of data focusing on ethnicity are reported. The primary outcome reported was a need to escalate RS in the ED, as any requirement for escalation is typically associated with adverse outcomes (Leong et al., 2020). This study received full ethical approval to proceed; the requirement for consent was waived by the approving ethics committee (NOR22/18) (Appendix E).

Results

Table B presents the PPS results. This PPS identified that 8.5% of ED admissions in the presenting population required some form of RS. Most patients were NZ European (40%) or NZ Māori avoidable mortality of 23%, which, adjusted for the overall percentage population of 17.3%, suggested that Māori were overrepresented in this sample. However, testing did not show a significant difference in the sample (χ^2: 2.55: df 1; p = 0.11). The analysis reported no difference between Māori and non-Māori for three secondary outcomes: early warning score (EWS), Australasian triage scale, and mean number of comorbidities. The analysis did report a difference for Māori compared to non-Māori for age and duration of symptoms before ED presentation, both secondary outcomes. Māori were significantly younger, with a mean (M) age of 56.8±13.7 compared to non-Māori 70.69 ± 43.0 years (t = 3.11, 95 % CI, 4.98 to 22.62; p <.01). The median difference in the median wait time was 39.5 hours, with Māori waiting longer with symptoms before presenting at the ED (Mdn=48, IQR 24 to 72 vs non-Māori Mdn=8.5, IQR, hours, 1 to 48) however, the difference was not significant (Mann Whitney U test, p = 0.75). For the primary outcome, Māori demonstrated a 5.8% higher risk of requiring escalation on an absolute scale (n = 6 [33.3%] vs n = 16 [27.5%]) and 22% more risk on a relative scale (RR 1.22, 95% CI, 0.56 to 2.67, p = 0.60) than non-Māori. However, this difference was not significant compared to non-Māori. The non-significant number needed to treat (NNT) to avoid harm for Māori was 16, 3.3 (harm) to ∞ 5.6 (benefit), which is in contrast with published evidence suggesting a requirement to escalate in this population is typically 5.45% (Jones et al., 2016) (Table B). Whilst these findings were not statistically significant, these ED data may be clinically significant and may be suggestive of ethnicity-based health inequity for NZ Māori. The findings related to the primary outcome and other findings for those of Māori ethnicity highlight the impact of HMN and inequity.

Table B.

Point Prevalence Study Study: Comparing Indigenous Māori outcomes to Non-Māori in ED

	Indigenous Māori	**Non-Indigenous, Non-Māori**	**All**	**Test**
Study sample – *n* (%)	18 (23.7)	58 (76.3)	76 (100)	X^2 = 2.55: df 1, *p* = 0.11
Primary outcome				
Escalation – *n* (%)	6 (33.3)	16 (27.5)	22 (28.9)	RR 1.22, CI 0.56 to 2.67, *p* = 0.60
Sample characteristics				
Age (years) –M ± SD	56.8 ± 13.7	70.69 ± 17.13	67.38 ± 17.41	*t* = 3.11, df = 74, CI 4.98 to 22.62, *p* = 0.0026
Age group (years) –*n* (%)				
< 65	13 (72.2)	17 (29.3)	30 (39.4)	
> 65	5 (27.7)	41 (70.6)	46 (60.5)	
EWS –M ±SD	4.56 ± 4.58	4.57 ± 4.56	8.60±4.62	*t* = 0.01, df = 74, CI -2.44 to 2.47, *p* = 0.99
Triage Scale 1-5 –M ± SD	3.22 ± 1.16	2.72 ± 1.24	2.58±0.98	*t* = 1.50, df = 74, CI -1.16 to 0.16, *p* = 0.13,
Comorbidity –M ± SD	3.83 ± 1.9	3.18 ± 1.8	3.34±1.87	*t* = -1.28, df = 74, *p* = 0.10
Comorbidity (M3 Index) M ± SD	1.26 ± 0.51			

Note. X^2= chi-square; df = degrees of freedom; CI = 95 % confidence interval; M mean; p = p-value; SD = standard deviation; t = independent t-test; Man Whitney U test, Median = Mdn, Interquartile range =IQR, RR = relative risk; Triage: Australasian Triage Scale; EWS: Early Warning Score; Comorbidity (M3 Index): The M3 Multimorbidity Index (Stanley & Sarfati, 2017) categorises patients' morbidities based on ICD-10 codes for 61 chronic conditions. ICD-10 codes for diagnoses are a WHO medical classification list.

Discussion

Inequality and inequity are distinct. Inequalities define the distinctions between individuals or groups. In contrast, inequity refers to avoidable differences, usually resulting from discriminatory inequality. Globally, measures of inequity, such as the material well-being index (MWI), have described a wide range of inequity. Across 40 countries, the Netherlands has the highest MWI and Mexico the lowest; New Zealand ranks 20th and, notably, Australia 13th (Grimes et al., 2015). Globally, HMN is a social determinant of poor health outcomes and inequity (Braveman et al., 2014). Achieving health equity relies on trust and the assumption of risk (McHugh et al., 2023). For those with HMN, the ED operates as a potential social safety net (Selby et al., 2018) and allows ED healthcare providers to foster trust with HMN consumers.

"Anyone who has ever struggled with poverty knows how extremely expensive it is to be poor" (Baldwin & Jones, 2012).

As correctly said, "Anyone who has ever struggled with poverty knows how extremely expensive it is to be poor." (Baldwin & Jones, 2012). Trust refers to consumers' confidence in their healthcare providers; this trust enables positive behaviours and outcomes and is fundamental to achieving health equity (McHugh et al., 2023). Healthcare consumers are motivated to assume risk based on personal expectations and their trust level in healthcare providers. However, this trust is vulnerable.

Structural racism can undermine consumers' trust in healthcare providers, particularly health consumers with HMNs. Structural racism occurs when cultural, institutional, and interpersonal forces, which provide advantages to some people over others, are normalised and legitimised. Unique to Aotearoa, New Zealand (NZ), both structural racism and colonialism have severely disadvantaged the NZ Māori population (Crengle et al., 2022) and potentially Pasifika, another minoritised ethnicity. These disadvantages demonstrate inequity and increasingly contribute to chronic adverse health outcomes. The disadvantaged are the social'square pegs' and include those individuals' experiencing poverty, chronic physical or mental health conditions, and HMN.

For the disadvantaged, a lack of trust in healthcare providers is constantly reinforced, both through personal experience and via all forms of media indirectly reporting on inequity. These reports expose the many dimensions of inequity, including access and quality of care, interpersonal treatment, and a lack of patient-centred care. Patient-centred care in healthcare embodies respect, effective communication, partnership, and cultural competence and sensitivity. However, patient-centred care in healthcare can be undermined by ignorance of bias and stereotyping (Curtis et al., 2022).

Inequity in healthcare has been extensively documented; over 1,414,151 related citations are currently indexed on PubMed, indicating a global issue. This evidence suggests that healthcare inequity and its inherent care disparity are more likely attributed to healthcare system failures rather than individual access issues. Research has explored the focus of healthcare systems, whether the focus is on the quality of care, the different social and cultural needs of the population, or the cultural competency of healthcare providers (National Academies of Sciences Engineering and Medicine et al., 2016). A retrospective observational multicentre study involving NZ EDs concluded that the ethnicity-based inequity was most likely due to bias and structural racism, a form of system failure (Curtis et al., 2022). The evidence also described the ubiquitous nature of inequity for conditions, populations, settings, levels, and types of care and how this inequity contributes to disparities and poor health outcomes. Notably, two groups, ethnic minorities and people experiencing HMN, consistently experience the greatest inequity (Te Waihanga NZIC., 2022; Bowker et al., 2023). Since colonisation in 1841, NZ has been promoted as a 'land of milk and honey' a promised land laden with natural riches and infinite opportunity. Currently, this image of NZ is likely not upheld for every ED patient, especially those of Indigenous and racially minoritised groups (Curtis et al., 2022). In addition, the social ideology of health equity is implied in the World Health Organization's (WHO) description of equity.

The WHO describes health equity as a state where every individual has the opportunity to achieve their full health potential, with no individual disadvantaged from realising this potential due to social position or circumstance (Solar & Irwin, 2010). Many complex social factors contribute to health, and understanding these factors and their disparity across groups may resolve health disparity. However, the behavioural choices that people make are often constrained by the choices they have. A complex combination of individual risk behaviours and biological and uncontrollable societal factors drive disparities. Ecological models, such as the Danaher and the Rural Community Health & Well-Being Frameworks, have been used to inform approaches to unpack the complexities of health disparity (National Academies of Sciences Engineering and Medicine et al., 2016). However, despite the modelling and the evidence describing the epidemiology of health disparity, inequity persists. Evidence-based practice is not reliably demonstrated across clinical, public health, or policy real-world settings, including in NZ (Penman-Aguilar et al., 2016).

To conclude, our study's epidemiological findings and others may be used to generate hypotheses for testing in future research with a health burden and inequity foci. As EDs are straddled between inpatient and primary care sectors, there is a unique opportunity to improve health equity by providing targeted quality care through NZ ED research that reports on equity indicator outcomes by ethnicity, comorbidity rate, and age (Curtis et al., 2022). This will better ensure the development of new knowledge and evidence that is generalisable in NZ and potentially improve outcomes in its population.

Acknowledgements

The authors wish to acknowledge the following for their invaluable contributions to facilitating the PPS data collection: Drs. Kate Anson, Chame Blackburn, Andrew Brainard, Troy Brown, Chris Lash, Derek Sage, Eunicia Tan, and Kim Yates.

Jordan Bernard-O'Connor, Ayla Blaxall, JoJo Coleman-Chaiman, Rebecca Clarke, Julie Dela Cruz, Chantelle Dick, Georgia Doyle, Oscar Dane Familiar, Rebecca Fenn, Logan Fenton, Michaela Fletcher, Ana Francia Rachel Hamilton, Eleanor Hoare, Juliana Muller, Sara Olley, Ned Tubac

Declarations

Funding

This study was supported by two unrestricted grants: NZ Health Research Grant and Fisher & Paykel Healthcare, a manufacturer of respiratory devices (Appendices A & B)

Conflicts of interest/Competing interests

The authors have no conflicts of interest or competing interests to declare.

Availability of data and material

Original data may be available on request to the lead author

Code availability

Not applicable

Authors' contributions

The authors confirm their contribution to the paper as follows: study conception and design: JOD Author.; data collection: Independent Data Collectors (not authors); analysis and interpretation of results: JOD. Author, AP. Author, CB. Author; draft manuscript preparation: JOD. Author. All authors reviewed the results and approved the final version of the manuscript.

Ethics approval

Ethics approval gained Massey University New Zealand NOR22/18 (Appendix E) and Clinical Trial Registration ACTRN12621001167853pU1111-1262-086 (Appendix K)

Consent to participate

Waiver of consent awarded by Massey University Ethics Committee (Appendix E)

Consent for publication

Not applicable

Appendix D

Point Prevalence Study Locality Approvals 1 to 5

Te Whatu Ora
Health New Zealand
Counties Manukau

10 February 2023

For the attention of: Jane O'Donnell and Chris Lash

Thank you for the information you have supplied to the Te Whatu Ora Health New Zealand Counties Manukau Research & Evaluation Office regarding the following research project:

Te Whatu Ora Counties Manukau Research Registration Number: 1710
Ethics Approval Reference Number: Massey University NOR 22/18
Project Title: "Respiratory Support of Adults in the Emergency Department – a Point Prevalence Study"

I am pleased to inform you that the Te Whatu Ora Counties Manukau Research & Evaluation Office has received all the required service lead approvals and the Chief Medical Officer's final sign-off for the above research project, which has Jane O'Donnell named as the Principal Investigator and Chris Lash named as the Te Whatu Ora Counties Manukau Facilitator.

This Te Whatu Ora Counties Manukau locality approval is valid until 30-June-2023, which is the Final Report date specified on the study registration information.

All external reporting requirements must be adhered to. Please note that failure to notify us of any amendments, and/or submit copies of annual Progress Reports and annual Ethics renewal letters may result in the withdrawal of ethical and Te Whatu Ora Counties Manukau organisational approval.

FINAL REPORT: It is a requirement of the Te Whatu Ora Counties Manukau Research Policy that all research and audit projects conducted within Te Whatu Ora Counties Manukau should complete a Final Report within three months following completion of the study. The Final Report questionnaire can be found in your study file in the online Research Registry, under the Documents tab. This report will be viewable by all staff with access to the Te Whatu Ora Counties Manukau network. **Please Note** that having an overdue Final Report will impact your application for locality approval of any new studies.

Ngā mihi/Yours sincerely,

A Bennett.

Angela Bennett
Locality Coordinator
Counties Manukau
Under delegated authority from Te Whatu Ora Counties Manukau Research Committee and the Chief Medical Officer

Te Whatu Ora
Health New Zealand
Hauora a Toi Bay of Plenty

Dr Derek Sage
Emergency Department
Tauranga Hospital

10 November 2022 **Study Ref:** 2022-196

Dear Derek

RE: RESPIRATORY SUPPORT OF ADULTS IN THE EMERGENCY DEPARTMENT – A PROTOCOL FOR A POINT PREVALENCE STUDY

I am pleased to advise that this research application has been authorised to be conducted within the Bay of Plenty District Health Board (BOPDHB).

It is your responsibility to ensure that your research is conducted in accordance with the BOPDHB research policy. The Research policy is available under the Controlled Documents section on OnePlace, and can also be accessed via the BOPDHB Research OnePlace page (http://oneplace/Content/Pages/CSC/Research.aspx).

Your project must also be conducted in line with the National Ethical Standards for Health and Disability Research and Quality Improvement.[1]

As a condition of this authorisation you are required to:

(i) inform the Research Office of the start and stop dates of your project;
(ii) contact the Research Office if there are any changes to your study protocol; and
(iii) provide a copy of the final study outcomes or report once your research has been completed.

Please contact the Research Office by email at research@bopdhb.govt.nz. Please don't hesitate to contact the Research Office for further information about your application. We wish you all the best for your study.

Yours sincerely,

Linda Pattison
Clinical School Coordinator

[1] National Ethics Advisory Committee. 2019. National Ethical Standards for Health and Disability Research and Quality Improvement. Wellington: Ministry of Health.[1]

Date: 09/11/2022

Email Address: j.f.odonnell@massey.ac.nz

Te Whatu Ora
Health New Zealand
Hauora a Toi Bay of Plenty

CC: Linda.Chalmers@bopdhb.govt.nz
research@bopdhb.govt.nz

Tēnā koe Jane

Research Approval Letter

Study Title Name: Respiratory Support of Adults in the Emergency Department – a Protocol for a Point Prevalence Study

Request Number: # 3036

Your application has been endorsed by Manukura - Executive Director Toi Ora on behalf of 17 iwi of Mai i Ngā Kuri a Whārei ki Tihirau / Te Whatu Ora Hauora a Toi. All health research conducted in New Zealand and within the Bay of Plenty is of relevance to Māori.

As a Treaty partner and a priority population, Māori involvement in health research is critical because Māori are disproportionately impacted by negative health outcomes and experience. Te Pare ō Toi recommends you utilise the Guidelines for Researchers on Health Research Involving Māori (2010)[1] to assist you in planning and conducting your research project in a culturally sensitive, safe and responsive way.

Please provide a summary of your research findings and recommendations at the completion of your work to Te Pare ō Toi. The summary should include where applicable, your analysis of the data by ethnicity, age and deprivation. Themes or findings from your research with direct relevance or implications for Māori should be highlighted. You may be invited to present your findings in person to Iwi Maori Partnership Boards and Te Amorangi Kahui Kaumatua Kaunihera (Māori Elders Council).

Nāku noa, nā

Dr Linda Chalmers
Pou Haumanu | Clinical Director
Hauora a Toi Bay of Plenty
On behalf of
Marama Tauranga | Maukura – Toi Ora Executive Director
Hauora a Toi Bay of Plenty

Te Pare ō Toi
waea pūkoro: 07 579 8560| īmēra: Maori.Health@bopdhb.govt.nz
Silver Birch House, Hauora ā Toi, 829 Cameron Rd, Tauranga
Private Bag 12024, Tauranga Mail Centre, Tauranga 3143

Te Kāwanatanga o Aotearoa
New Zealand Government

19 December 2022

Te Whatu Ora
Health New Zealand
Te Toka Tumai Auckland

Jane O'Donnell
SNW Building
Massey University – Albany
Albany Expressway (SH17)
Albany
Auckland 0632

Title: Respiratory Support of Adults in the Emergency Department – a Point Prevalence Study

The study setting is based at four Emergency Departments (ED) within Aotearoa New Zealand with Waitematā being one of the sites. The study aims to examine the nature of nasal high flow support delivered in the ED and its influence on patient-centred outcomes. The primary outcome will consider which patients receiving respiratory support will then require an escalation of care. ED clinicians will deliver usual standard of care to participants and data will be collected from their clinical records.

The investigators expect to have 200 participants, of which 70 would be of Māori descent. As this is an observational study, there is no active recruitment of participants. However, ethnicity data will be captured and analysed.

I note in the Information Sheet for Data Collectors and Information Sheet for ED staff there will be contact details for Māori Health support. Another option is to include this statement for Māori cultural support at Te Whatu Ora Waitematā:

> WDHB: If you require Māori cultural support contact the administrator for He Kamaka Waiora (Māori Health Team) by telephoning 09 486 8324 ext 42324. State Title of the study and the name of the primary investigator

We would appreciate a summary of the findings of the research once completed.

On behalf of the Waitematā and Te Toka Tumai Auckland Māori Health Research Committee I would like to thank you for the opportunity to review and approve this study.

Ngā mihi,

Stella Williams
Te Rarawa I Te Aupouri I Ngapuhi
Nurse Consultant
Tino Rangahau I Māori Health Research
Waitematā
waea pūkoro: 021 249 4434
īmēra: Stella.Williams@waitematadhb.govt.nz

Te Whatu Ora
Health New Zealand
Waitematā

8th February 2023

Jane O'Donnell
College of Health - School of Nursing
Massey University - Albany
Albany Expressway (SH17),
Albany
Auckland 0632

Dear Jane,

The Research & Knowledge Centre has now received the relevant approvals for the following study:

Title: Respiratory Support of Adults in the Emergency Department - a Point Prevalence Stud

Registration #: RM15443

This study now has Waitematā Locality Authorisation. Please continue to forward to us copies of all correspondence regarding ongoing ethics approval for this study (if any). All amendments to your study must be submitted to the Research & Knowledge Centre for review. Any substantial amendment (as defined in the Standard Operating Procedures for HECs) must also be submitted to your ethics committee for approval.

Note that all research, audit and related activity must meet ethical standards in relation to the safe storage, retention and disposal of research data.

Good luck with your study.

Regards,

Dr Lorraine Neave, DHSc, MHSc, RGON
Manager Research & Knowledge,
Nurse Consultant - Research
Te Whatu Ora - Waitematā

Appendix E

Point Prevalence Study Massey University Ethics Committee Approval

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

31/05/2022

Dear: Mrs Jane O'Donnell

Re: Ethics Application -NOR 22/18 -Respiratory Support in the Emergency Department a Point Prevalence Study

Thank you for the above application that was considered by the Massey University Human Ethics Committee:

Human Ethics Northern Committee at their meeting held on **Thursday, 31 March 2022**

On behalf of the Committee I am pleased to advise you that the ethics of your application are approved.

Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

Professor Craig Johnson
Chair, Human Ethics Chairs' Committee and Director (Research Ethics)

Research Ethics Office, Research and Enterprise
Massey University, Private Bag 11 222, Palmerston North, 4442, New Zealand T 06 951 6841; 06 95106840 E humanethics@massey.ac.nz; animalethics@massey.ac.nz; gtc@massey.ac.nz

Appendix F

PRISMA-P & PRISMA Checklists Completed for SR Protocol, SR manuscript and Audit of SRs.

PRISMA-P (Preferred Reporting Items for Systematic review and Meta-Analysis Protocols) 2015 checklist: recommended items to address in a systematic review protocol*

Section and topic		Item No	Checklist item
ADMINISTRATIVE INFORMATION			
Title:			
Identification	√	1a	Identify the report as a protocol of a systematic review
Update	NA	1b	If the protocol is for an update of a previous systematic review, identify as such
Registration	√	2	If registered, provide the name of the registry (such as PROSPERO) and registration number
Authors:	√		
Contact	√	3a	Provide name, institutional affiliation, e-mail address of all protocol authors; provide physical mailing address of corresponding author
Contributions	√	3b	Describe contributions of protocol authors and identify the guarantor of the review
Amendments	NA	4	If the protocol represents an amendment of a previously completed or published protocol, identify as such and list changes; otherwise, state plan for documenting important protocol amendments
Support:	√		
Sources	√	5a	Indicate sources of financial or other support for the review
Sponsor	√	5b	Provide name for the review funder and/or sponsor
Role of sponsor or funder	√	5c	Describe roles of funder(s), sponsor(s), and/or institution(s), if any, in developing the protocol
INTRODUCTION			
Rationale	√	6	Describe the rationale for the review in the context of what is already known
Objectives	√	7	Provide an explicit statement of the question(s) the review will address with reference to participants, interventions, comparators, and outcomes (PICO)
METHODS			
Eligibility criteria	√	8	Specify the study characteristics (such as PICO, study design, setting, time frame) and report characteristics (such as years considered, language, publication status) to be used as criteria for eligibility for the review
Information sources	√	9	Describe all intended information sources (such as electronic databases, contact with study authors, trial registers or other grey literature sources) with planned dates of coverage
Search strategy	√	10	Present draft of search strategy to be used for at least one electronic database, including planned limits, such that it could be repeated
Study records:	√		
Data management	√	11a	Describe the mechanism(s) that will be used to manage records and data throughout the review
Selection process	√	11b	State the process that will be used for selecting studies (such as two independent reviewers) through each phase of the review (that is, screening, eligibility and inclusion in meta-analysis)
Data collection process	√	11c	Describe planned method of extracting data from reports (such as piloting forms, done independently, in duplicate), any processes for obtaining and confirming data from investigators
Data items	√	12	List and define all variables for which data will be sought (such as PICO items, funding sources), any pre-planned data assumptions and simplifications
Outcomes and prioritization	√	13	List and define all outcomes for which data will be sought, including prioritization of main and additional outcomes, with rationale

Risk of bias in individual studies √	14	Describe anticipated methods for assessing risk of bias of individual studies, including whether this will be done at the outcome or study level, or both; state how this information will be used in data synthesis
Data synthesis √	15a	Describe criteria under which study data will be quantitatively synthesised
	15b	If data are appropriate for quantitative synthesis, describe planned summary measures, methods of handling data and methods of combining data from studies, including any planned exploration of consistency (such as I^2, Kendall's τ)
	15c	Describe any proposed additional analyses (such as sensitivity or subgroup analyses, meta-regression)
	15d	If quantitative synthesis is not appropriate, describe the type of summary planned
Meta-bias(es) √	16	Specify any planned assessment of meta-bias(es) (such as publication bias across studies, selective reporting within studies)
Confidence in cumulative evidence √	17	Describe how the strength of the body of evidence will be assessed (such as GRADE)

* It is strongly recommended that this checklist be read in conjunction with the PRISMA-P Explanation and Elaboration (cite when available) for important clarification on the items. Amendments to a review protocol should be tracked and dated.

√ = COMPLETED

Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart L, PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2015 Jan 2;349(jan02 1):g7647.

PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) checklist: recommended items to address in a systematic review

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	√ 1	Identify the report as a systematic review	
ABSTRACT			
Abstract	√2	See the PRISMA 2020 for Abstracts checklist.	
INTRODUCTION			
Rationale	√3	Describe the rationale for the review in the context of existing knowledge.	
Objectives	√4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	
METHODS			
Eligibility criteria	√5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	
Information sources	√6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	
Search strategy	√7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	
Selection process	√8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	
Data collection process	√9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	
Data items	√10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	
	√10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	
Study risk of bias assessment	√11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	
Effect measures	√12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	
Synthesis methods	√13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	
	√13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	
	√13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	
	√13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	
	√13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	
	√13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	
Reporting bias assessment	√14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	
Certainty assessment	√15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	
RESULTS			
Study selection	√16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	

Section and Topic	Item #	Checklist item	Location where item is reported
	√16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	
Study characteristics	√17	Cite each included study and present its characteristics.	
Risk of bias in studies	√18	Present assessments of risk of bias for each included study.	
Results of individual studies	√19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	
Results of syntheses	√20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	
	√20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	
	√20c	Present results of all investigations of possible causes of heterogeneity among study results.	
	√20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	
Reporting biases	√21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	√22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	
DISCUSSION			
Discussion	√23a	Provide a general interpretation of the results in the context of other evidence.	
	√23b	Discuss any limitations of the evidence included in the review.	
	√23c	Discuss any limitations of the review processes used.	
	√23d	Discuss implications of the results for practice, policy, and future research.	
OTHER INFORMATION			
Registration and protocol	√24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	
	√24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	√24c	Describe and explain any amendments to information provided at registration or in the protocol.	
Support	√25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	
Competing interests	√26	Declare any competing interests of review authors.	
Availability of data, code and other materials	√27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

√ = COMPLETED

Appendix G

Systematic Review Search Strategies and KeyWords

Keywords	Databases searched 15^{th} July 2023	Conference Proceedings searched	Clinical trial registries searched.
Nasal high flow High flow Heated high flow High flow nasal cannula High flow oxygen Optiflow HVNI High velocity nasal High flow nasal cannula High flow nasal therapy High flow nasal oxygen NHF TNI Transnasal insufflation	CENTRAL in *The Cochrane Library* MEDLINE, OvidSP CINHAL, EBSCOhost EMBASE, OvidSP ISI Web of Science PubMed	European Society of Emergency Medicine (EUSEM) American College of Emergency Practice (ACEP)	US National Library of Medicine International Clinical Trials Registry Platform (ICTRP)

Note. HVNI= high velocity nasal insufflation; NHF= nasal high flow; TNI= trans nasal inflation.

Search strategy applied across six databases:

- CENTRAL
- MEDLINE (Ovid)
- EMBASE
- CINAHL
- ISI WEB OF SCIENCE
- PubMed

CENTRAL & ISI WEB OF SCIENCE

(nasal high flow OR high flow OR heated high flow OR high flow nasal cannula OR high flow oxygen OR optiflow OR HVNI OR high velocity nasal OR high flow nasal cannula OR high flow nasal therapy or high flow nasal oxygen OR AIRVO OR NHF OR TNI OR trans nasal insufflation)

PubMed

("Oxygen Inhalation Therapy"[Mh] OR "nasal high flow" [tiab:~2] OR "nasal insufflation" [tiab:~2]) AND ("Emergency Service, Hospital"[Mesh] OR "emergency room" [tiab:~2] OR "emergency rooms" [tiab:~2] OR "emergency department" [tiab:~2] OR "ED"[tiab] OR "emergency department"[tiab:~2] OR "emergency departments"[tiab:~2] OR "emergency room"[tiab:~2] OR "ER"[tiab] OR "emergency rooms"[tiab:~2] OR "emergency services"[tiab:~2] OR "emergency service"[tiab:~2] OR "emergency hospital service"[tiab:~2] OR "emergency hospital services"[tiab:~2] OR "emergency hospital department"[tiab:~2] OR "emergency hospital departments"[tiab:~2] OR "emergency unit"[tiab:~2] OR "emergency units"[tiab:~2] OR "emergency ward"[tiab:~2] OR "emergency wards"[tiab:~2] OR "accident and emergency" [tiab:~2] OR "accident & emergency" [tiab:~2] OR "A & E" [tiab])

Embase and Medline

exp (exp "oxygen inhalation therapy"/ or "nasal high flow" [tiab:~2] or "nasal insufflation" [tiab:~2]) and (exp "emergency service, hospital"/ or "emergency room" [tiab:~2] or "emergency rooms" [tiab:~2] or "emergency department" [tiab:~2] or "ed".ti,ab,cl,oa,kw,kf. or "emergency department"[tiab:~2] or "emergency departments"[tiab:~2] or "emergency room"[tiab:~2] or "er".ti,ab,cl,oa,kw,kf. or "emergency rooms"[tiab:~2] or "emergency services"[tiab:~2] or "emergency service"[tiab:~2] or "emergency hospital service"[tiab:~2] or "emergency hospital services"[tiab:~2] or "emergency hospital department"[tiab:~2] or "emergency hospital departments"[tiab:~2] or "emergency unit"[tiab:~2] or "emergency units"[tiab:~2] or "emergency ward"[tiab:~2] or "emergency wards"[tiab:~2] or "accident and emergency" [tiab:~2] or "accident & emergency" [tiab:~2] or "a & e" .ti,ab,cl,oa,kw,kf.)

CINHAL Scopus

(Oxygen Inhalation Therapy) OR (nasal high flow) OR (nasal insufflation)AND (Emergency Service, Hospital)[Mesh] OR (emergency room) OR (emergency rooms) OR (emergency department) OR (ED) OR (emergency department) OR (emergency departments) OR (emergency room) OR (ER) OR (emergency rooms) OR (emergency services) OR (emergency service) OR (emergency hospital service) OR (emergency hospital services) OR (emergency hospital department) OR (emergency hospital departments) OR (emergency unit) OR (emergency units) OR (emergency ward) OR (emergency wards) OR (accident and emergency) OR (accident & emergency) OR (A & E)

2. Filters applied for each database: 'Adult', 'RCT', English, and search dates 2000 to August 2023.

3. For trials not yet completed

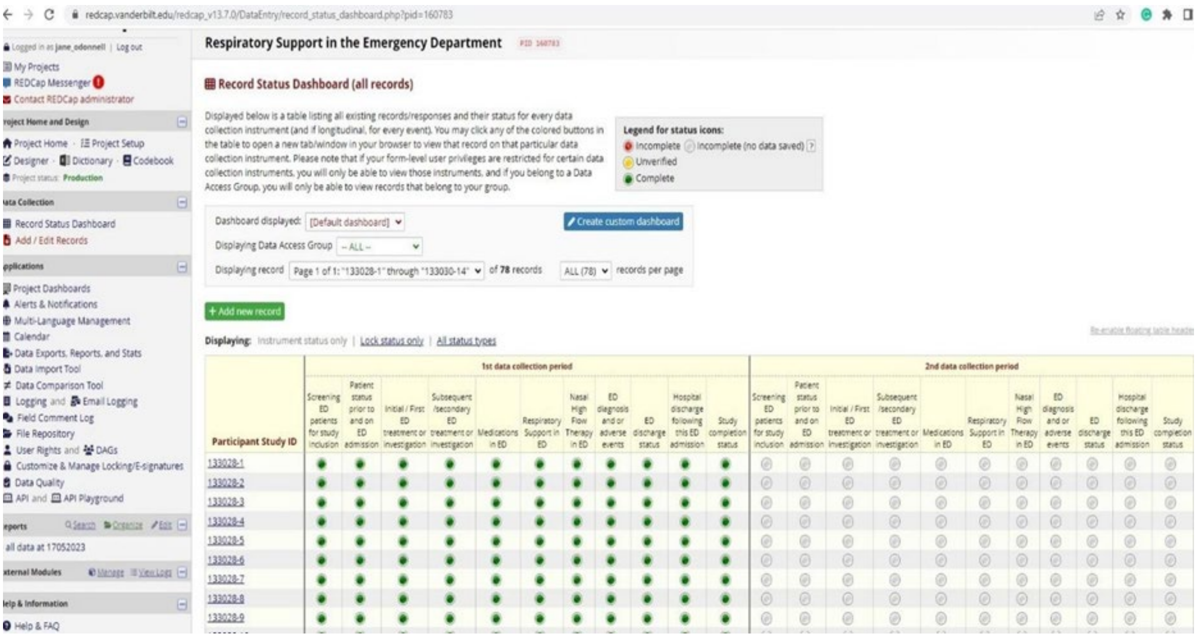
- https://clinicaltrials.gov/
- https://trialsearch.who.int/

4. Conference proceedings: ACEP https://www.acep.org/ EUSEM https://eusem.org/

Appendix H

Point Prevalence Study REDCap CRF

eCRF Screen Shot



Screening ED patients for study inclusion

Participant Study ID	__________________________________
Patient study ID #	__________________________________
Respiratory Support Research	
Screening ED patients for inclusion	
NHI	__________________________________
Date of birth	__________________________________
Age 18 or over	◯ Yes ◯ No
Requirement for respiratory support whilst in ED	◯ Yes ◯ No (Any RS at any time in ED)

Patient status prior to and on ED admission

Respiratory Support Research

Patient status prior to or at ED admission

Gender	◯ Male ◯ Female ◯ X-gender ◯ Unknown
Ethnicity	◯ European ◯ NZ European ◯ NZ Maori ◯ Pacific Island ◯ Samoan ◯ Cook Island Maori ◯ Tongan ◯ Niuean ◯ Tokelauan ◯ Fijian ◯ Other Pacific Island ◯ Asian ◯ Southeast Asian ◯ Chinese ◯ Indian ◯ Other Asian ◯ Middle Eastern ◯ Latin American / Hispanic ◯ African ◯ Other ethnicity
Ethnicity other	______________ (name 'other' or 'unknown')
GP / Primary Care Referral to ED	◯ Yes ◯ No ◯ Unknown
Duration of symptoms before ED admission (H:M)	______________ (If unknown enter 00:00)
Pre ED admission treatment	◯ Yes ◯ No ◯ Unknown
Pre ED admission treatment	☐ Other ☐ Nebuliser ☐ O2 venturi or similar ☐ O2 standard mask or cannula (low flow) ☐ NIV ☐ Defibrillation ☐ CPR ☐ Ambu bag or similar ☐ Airway ☐ INV Trach ☐ INV Endotrach ☐ ETT and Mechanical Ventilation (select all that apply)

Medications before this ED admission

Does the patient have any usual medications OR been medications given within 72 hours before this ED admission?	◯ Yes ◯ No ◯ Unknown
ANTIALLERGICS AND MEDICINES USED IN ANAPHYLAXIS	◯ Yes ◯ No
ANTICONVULSANTS / ANTIEPILEPTICS	◯ Yes ◯ No
ANTIDOTES AND OTHER SUBSTANCES FOR POISONINGS	◯ Yes ◯ No
ANTI-INFECTIVE	◯ Yes ◯ No

- ☐ Anthelmintics
- ☐ Antibacterials
- ☐ Antifungal medicines
- ☐ Antiviral medicines
- ☐ Antiprotozoal medicines
- ☐ Medicines for ectoparasitic infections
- ☐ Other

ANTIMIGRAINE	◯ Yes ◯ No
ANTIPARKINSONISM	◯ Yes ◯ No
ANTISEPTICS AND DISINFECTANTS	◯ Yes ◯ No

- ☐ Antiseptics
- ☐ Disinfectants
- ☐ Other

BLOOD PRODUCT OR TREATMENT	◯ Yes ◯ No

- ☐ Blood and blood components
- ☐ Plasma-derived
- ☐ Plasma substitutes
- ☐ Antianaemia medicines
- ☐ Medicines affecting coagulation
- ☐ Other

CARDIOVASCULAR	◯ Yes ◯ No

COMMENT: Pre ED admission treatment

____

Means of transportation to ED is known	◯ Yes ◯ No
Transportation to ED	◯ Private vehicle ◯ Ambulance ◯ Ambulance from another hospital ◯ Helicopter ◯ Helicopter from another hospital ◯ Public transport ◯ Unknown ◯ Other

Known comorbidities

Does the patient have any known comorbidities (diseases or disorders) ?	◯ Yes ◯ No ◯ Unknown
Comorbidities (diseases or disorders)	☐ Other ☐ Neurological ☐ Eye ☐ Ear, nose, mouth and throat ☐ Respiratory ☐ Circulatory / cardiac ☐ Digestive / gastro intestinal ☐ Hepatobiliary or pancreas ☐ Musculoskeletal system or connective tissue ☐ Skin, subcutaneous tissue and breast ☐ Endocrine, nutritional or metabolic ☐ Renal, kidney, or urinary tract ☐ Reproductive ☐ Pregnancy, childbirth or puerperium ☐ Blood, blood-forming organs and immunological disorders ☐ Neoplastic disorders (haematological and solid neoplasm's) ☐ Infectious and parasitic diseases (systemic or unspecified sites) ☐ Mental health ☐ Alcohol/drug use and alcohol/drug-induced organic mental conditions ☐ Injuries, poisoning and toxic effects of drugs ☐ Burns ☐ Factors influencing health status and other contacts with health services (select all that apply)

COMMENT: Comorbidities (diseases or disorders)

____

☐ Antianginal
☐ Antiarrhythmic
☐ Antihypertensive
☐ Heart failure
☐ Antithrombotic medicines
☐ Lipid-lowering agents
☐ Other

DENTAL PREPARATIONS	◯ Yes ◯ No
DERMATOLOGICAL PREPARATIONS	◯ Yes ◯ No

☐ Antifungal
☐ Anti-infective
☐ Anti-inflammatory and antipruritic
☐ Medicines affecting skin differentiation and proliferation
☐ Other

DIAGNOSTIC AGENTS	◯ Yes ◯ No

☐ Ophthalmic
☐ Radiocontrast media
☐ Other

DIURETICS	◯ Yes ◯ No
ENT	◯ Yes ◯ No
ENDOCRINE DISORDERS	◯ Yes ◯ No

☐ Adrenal hormones and synthetic substitutes
☐ Androgens
☐ Oestrogens
☐ Progestogens
☐ Diabetes
☐ Thyroid hormones and antithyroid medicines
☐ Other

GASTROINTESTINAL	◯ Yes ◯ No

☐ Antiulcer
☐ Antiemetic
☐ Anti-inflammatory
☐ Laxatives
☐ Diarrhoea
☐ Other

GENERAL ANAESTHETICS	☐ Yes	☐ No
HOMEOPATHICS HERBAL REMEDIES	○ Yes	○ No
IMMUNIODULATORS AND ANTINEOPLASTICS	○ Yes	○ No

☐ Immunomodulators for non-malignant disease
☐ Antineoplastics and supportive medicines

JOINT DISEASE	○ Yes	○ No

☐ Gout
☐ Rheumatoid disorders
☐ Juvenile joint diseases

LOCAL ANAESTHETICS	○ Yes	○ No
MEDICAL GASES	○ Yes	○ No
PAIN AND PALLIATIVE CARE	○ Yes	○ No

☐ Non-opioids and non-steroidal anti-inflammatory medicines (NSAIMs)
☐ Opioid analgesics
☐ Medicines for other common symptoms in palliative care
☐ Other

MENTAL AND BEHAVIOURAL	○ Yes	○ No

☐ Psychotic disorders
☐ Mood disorders
☐ Anxiety disorders
☐ Obsessive compulsive disorders
☐ Psychoactive substance use

MUSCLE RELAXANTS peripherally-acting and cholinesterase inhibitors	○ Yes	○ No
ONCOLOGY	○ Yes	○ No
OPHTHALMOLOGY	○ Yes	○ No
PERITONEAL DIALYSIS SOLUTION	○ Yes	○ No
REPRODUCTIVE HEALTH AND PERINATAL CARE	○ Yes	○ No

☐ Contraceptives
☐ Ovulation inducers
☐ Uterotonics
☐ Antioxytocics (tocolytics)

RESPIRATORY	◯ Yes ◯ No

☐ antiasthmatic combinations
☐ antihistamines
☐ antitussives
☐ bronchodilators
☐ decongestants
☐ expectorants
☐ leukotriene modifiers
☐ lung surfactants
☐ miscellaneous respiratory agents
☐ mucolytics
☐ respiratory inhalant products
☐ selective phosphodiesterase-4 inhibitors
☐ upper respiratory combinations
☐ Other

SEDATION	◯ Yes ◯ No
SOLUTIONS FOR CORRECTING WATER ELECTROLYTE AND ACID BASE DISTURBANCE	◯ Yes ◯ No

☐ Oral
☐ Parenteral
☐ IV
☐ Miscellaneous

VITAMINS AND MINERALS	◯ Yes ◯ No
VACCINES	__________________
COMMENT: Usual medications OR medications given within 72 hours before this ED admission	______________________

On ED admission

Eligible for inclusion in this study?	◯ Yes ◯ No
Date and time of ED admission	__________________

Admitting ED	◯ Middlemore - Te Whatu Ora Counties Manukau ◯ Tauranga -Te Whatu Ora Hauora a Toi Bay of Plenty ◯ North Shore -Te Whatu Ora Waitematā ◯ Whakatāne -Te Whatu Ora Hauora a Toi Bay of Plenty
COVID-19 status current	◯ Negative ◯ Positive ◯ Previously Positive ◯ Unknown
COVID-19 vaccination status	◯ Fully Vaccinated ◯ Partial Vaccinated ◯ Un-vaccinated ◯ Unknown
EWS recorded on ED admission	__________________ (If unknown enter 0)
EWS calculated by REDCAP on ED admission	__________________ (Do not calculate)
Australiasian ED triage score on ED admission	◯ Immediately life-threatening, immediate simultaneous triage and treatment ◯ Imminently life-threatening, or important time-critical ◯ Potentially life-threatening, potential adverse outcomes from delay > 30 min ◯ Potentially serious, or potential adverse outcomes from delay > 60 min, or significant complexity or severit ◯ Less urgent, or dealing with administrative issues only ◯ Unknown
GCS at baseline on ED admission	__________________ (If unknown enter 0)
New altered conscious state on ED admission	◯ Yes ◯ No ◯ Unknown (Altered conscious state not known to be chronic or onset < 7 days)
Ability to speak on ED admission	◯ None ◯ Phrases ◯ Sentences ◯ Normal ◯ Unknown
Cyanosis on ED admission	◯ Yes ◯ No ◯ Unknown
Distended jugular veins on ED admission	◯ Yes ◯ No ◯ Unknown
Peripheral oedema on ED admission	◯ Yes ◯ No ◯ Unknown

Oedema other on ED admission	◯ Yes ◯ No ◯ Unknown
Chest auscultation on ED admission	◯ Yes ◯ No ◯ Unknown
Chest auscultation on ED admission	☐ Normal ☐ Bilateral crepitations ☐ Wheeze ☐ Localized rhonchi/bronchial breathing ☐ Widespread rhonchi ☐ Other abnormal (e.g., signs of pneumothorax)
Respiratory rate on ED admission	__________________ (If unknown enter 0)
Systolic BP on ED admission	__________________ (If unknown enter 0)
Diastolic BP on ED admission	__________________ (If unknown enter 0)
Temperature on ED admission	__________________ (If unknown enter 0)
Heart rate on ED admission	__________________ (If unknown enter 0)
SpO2 on air on ED admission	__________________ (If unknown enter 0)
SpO2 on O2 on ED admission	__________________ (If unknown enter 0)
ECG on ED admission	◯ Normal ◯ Abnormal ◯ Unknown
Peak flow on ED admission	__________________ (If unknown enter 0)
Headache on ED admission	◯ Yes ◯ No ◯ Unknown
Pain unspecified at baseline	◯ Yes ◯ No ◯ Unknown
Malaise on ED admission	◯ Yes ◯ No ◯ Unknown
Syncope and collapse on ED admission	◯ Yes ◯ No ◯ Unknown

Febrile convulsion on ED admission	◯ Yes ◯ No ◯ Unknown
Other and unspecified convulsions on ED admission	◯ Yes ◯ No ◯ Unknown
Enlarged lymph nodes, unspecified on ED admission	◯ Yes ◯ No ◯ Unknown
Diarr & vomiting on ED admission	◯ Yes ◯ No ◯ Unknown
COMMENT: Unknown and unspecified causes of morbidity / symptoms on ED admission not listed above	______________________

Initial / First ED treatment or investigation

Respiratory Support Research

Initial (first) ED Treatment or Investigation

First ED treatment or investigation

- ☐ None
- ☐ Other
- ☐ Respiratory support
- ☐ Monitoring of T, RR, HR, BP
- ☐ Monitoring of fluid input and output
- ☐ Weight
- ☐ Neurologic checks GCS
- ☐ Vascular checks
- ☐ Fingerstick blood glucose
- ☐ Pulse oximetry
- ☐ ECG continuous
- ☐ ECG 12 Lead
- ☐ Laboratory investigation
- ☐ Radiological investigation or treatment
- ☐ Oxygen supplementation
- ☐ Oral medications
- ☐ IV medications
- ☐ Intravenous fluids
- ☐ Wound care
- ☐ Nourishment
- ☐ Routine personal care
- ☐ Specialty referral
- ☐ Social Service intervention
- ☐ Cultural Service intervention
- ☐ Palliation in ED
- ☐ Care limitation in ED
- ☐ Withdrawal of care in ED
- ☐ Minor surgical intervention
- ☐ Major surgical intervention
- ☐ Minor orthopaedic intervention
- ☐ Major orthopaedic intervention
- ☐ Care coordination
- ☐ Education of patients
- ☐ CPR
- ☐ Cardioversion
- ☐ Defibrillation
- ☐ Intubation
- ☐ ID Urinary Cath
- ☐ Chest drain
- ☐ Nebulisation
- ☐ IV insert
- ☐ CVL insert
- ☐ Art line insert
- ☐ NG or NJ insert
- ☐ Reperfusion STEMI
- ☐ End-tidal carbon dioxide (PetCO2)
- ☐ Therapeutic tap e.g. pneumothorax
- ☐ Dialysis

(Select all that apply)

Initial 'Laboratory' investigations in ED (any body fluid or tissue)	☐ None ☐ Other ☐ Biochem ☐ Haem ☐ ABG ☐ Pregnancy ☐ Toxicology ☐ Drug Assay ☐ Microbiology ☐ Cytology ( )
Initial ABNORMAL 'laboratory' investigations in ED	☐ None ☐ Other ☐ Bio chem ☐ Haem ☐ ABG ☐ Pregnancy ☐ Toxicology ☐ Drug Assay ☐ Microbiology ☐ Cytology
Initial radiological investigations or treatments in ED	☐ None ☐ Other ☐ Trauma panel ☐ Chest xray ☐ Chest ultrasound ☐ Chest MRI ☐ Chest CT ☐ Abdo xray ☐ Abdo ultrasound ☐ Abdo MRI ☐ Abdo CT ☐ Head xray ☐ Head MRI ☐ Head CT ☐ Interventional radiology
Initial ABNORMAL radiological investigations in ED	☐ None ☐ Other ☐ Trauma panel ☐ Chest xray ☐ Chest ultrasound ☐ Chest MRI ☐ Chest CT ☐ Abdo xray ☐ Abdo ultrasound ☐ Abdo MRI ☐ Abdo CT ☐ Head xray ☐ Head MRI ☐ Head CT ☐ Interventional radiology
COMMENT: Initial first ED treatments or investigations	______________________________

Subsequent /secondary ED treatment or investigation

Respiratory Support Research

Subsequent or ongoing ED treatments or investigations

Subsequent or ongoing ED treatments or investigations ◯ Yes ◯ No

Subsequent or ongoing ED treatments or investigations	☐ None ☐ Other ☐ Respiratory support ☐ Monitoring of T, RR, HR, BP ☐ Monitoring of fluid input and output ☐ Weight ☐ Neurologic checks GCS ☐ Vascular checks ☐ Fingerstick blood glucose ☐ Pulse oximetry ☐ ECG continuous ☐ ECG 12 Lead ☐ Laboratory investigations ☐ Radiological investigations or treatments ☐ Oxygen supplementation ☐ Oral medications ☐ IV medications ☐ Intravenous fluids ☐ Wound care ☐ Nourishment ☐ Routine personal care ☐ Specialty referral ☐ Social Service intervention ☐ Cultural Service intervention ☐ Palliation in ED ☐ Care limitation in ED ☐ Withdrawal of care in ED ☐ Minor surgical intervention ☐ Major surgical intervention ☐ Minor orthopaedic intervention ☐ Major orthopaedic intervention ☐ Care coordination ☐ Education of patients ☐ CPR ☐ Cardioversion ☐ Defibrillation ☐ Intubation ☐ ID Urinary Cath ☐ Chest drain ☐ Nebulisation ☐ IV insert ☐ CVL insert ☐ Art line insert ☐ NG or NJ insert ☐ Reperfusion STEMI ☐ End-tidal carbon dioxide (PetCO2) ☐ Therapeutic tap e.g. pneumothorax ☐ Dialysis (Select all that apply)
Subsequent laboratory investigations in ED (any body fluid or tissue)	☐ None ☐ Other ☐ Biochem ☐ Haem ☐ ABG ☐ Pregnancy ☐ Toxicology ☐ Drug Assay ☐ Microbiology ☐ Cytology (select all that apply)

Subsequent ABNORMAL 'laboratory' investigations in ED	☐ None ☐ Other ☐ Bio chem ☐ Haem ☐ ABG ☐ Pregnancy ☐ Toxicology ☐ Drug Assay ☐ Microbiology ☐ Cytology (select all that apply)
Worst ABG result in ED	◯ On air ◯ On oxygen ◯ Unknown
Worst ABG pH in ED	__________________________
Worst ABG PaCO2 kPa in ED	__________________________
Worst ABG PaO2 kPa in ED	__________________________
Worst ABG HCO3 mEq/L in ED	__________________________
Worst ABG base excess mmol/L in ED	__________________________
Best or only ABG result in ED	◯ On air ◯ On oxygen ◯ Unknown
Best or only ABG pH in ED	__________________________
Best or only ABG PaCO2 kPa in ED	__________________________
Best or only ABG PaO2 kPa in ED	__________________________
Best or only ABG HCO3 mEq/L in ED	__________________________
Best or only ABG base excess mmol/L in ED	__________________________

Subsequent radiological investigations or treatments in ED	☐ None ☐ Other ☐ Trauma panel ☐ Chest xray ☐ Chest ultrasound ☐ Chest MRI ☐ Chest CT ☐ Abdo xray ☐ Abdo ultrasound ☐ Abdo MRI ☐ Abdo CT ☐ Head xray ☐ Head MRI ☐ Head CT ☐ Interventional radiology (select all that apply)
Subsequent abnormal radiological investigations in ED	☐ None ☐ Other ☐ Trauma panel ☐ Chest xray ☐ Chest ultrasound ☐ Chest MRI ☐ Chest CT ☐ Abdo xray ☐ Abdo ultrasound ☐ Abdo MRI ☐ Abdo CT ☐ Head xray ☐ Head MRI ☐ Head CT ☐ Interventional radiology (select all that apply)
COMMENT: Subsequent or ongoing ED treatments or investigations	____________________________

Medications in ED

Respiratory Support Research

Medications in ED

Medications provided in ED?	◯ Yes ◯ No
ANTIALLERGICS AND MEDICINES USED IN ANAPHYLAXIS	◯ Yes ◯ No
ANTICONVULSANTS / ANTIEPILEPTICS	◯ Yes ◯ No
ANTIDOTES AND OTHER SUBSTANCES FOR POISONINGS	◯ Yes ◯ No
ANTI-INFECTIVE	◯ Yes ◯ No

☐ Anthelmintics
☐ Antibacterials
☐ Antifungal medicines
☐ Antiviral medicines
☐ Antiprotozoal medicines
☐ Medicines for ectoparasitic infections
☐ Other

ANTIMIGRAINE	◯ Yes ◯ No

☐ For treatment of acute attack
☐ For prophylaxis
☐ Other

ANTIPARKINSONISM	◯ Yes ◯ No
ANTISEPTICS AND DISINFECTANTS	◯ Yes ◯ No

☐ Antiseptics
☐ Disinfectants
☐ Other

BLOOD PRODUCT OR TREATMENT	◯ Yes ◯ No

☐ Blood and blood components
☐ Plasma-derived
☐ Plasma substitutes
☐ Antianaemia medicines
☐ Medicines affecting coagulation
☐ Other

CARDIOVASCULAR	◯ Yes ◯ No

☐ Antianginal
☐ Antiarrhythmic
☐ Antihypertensive
☐ Heart failure
☐ Antithrombotic medicines
☐ Inotropes eg adrenaline
☐ Lipid-lowering agents
☐ Other

DENTAL PREPARATIONS	◯ Yes ◯ No
DERMATOLOGICAL	◯ Yes ◯ No

☐ Antifungal
☐ Anti-infective
☐ Anti-inflammatory and antipruritic
☐ Medicines affecting skin differentiation and proliferation
☐ Other

DIAGNOSTIC AGENTS	◯ Yes ◯ No
ENDOCRINE DISORDERS	◯ Yes ◯ No

☐ Adrenal hormones and synthetic substitutes
☐ Androgens
☐ Oestrogens
☐ Progestogens
☐ Diabetes
☐ Thyroid hormones and antithyroid medicines
☐ Other

GASTROINTESTINAL	◯ Yes ◯ No

☐ Antiulcer
☐ Antiemetic
☐ Anti-inflammatory
☐ Laxatives
☐ Diarrhoea
☐ Other

GENERAL ANAESTHETICS	◯ Yes ◯ No
HOMEOPATHICS HERBAL REMEDIES	◯ Yes ◯ No
IMMUNIODULATORS AND ANTINEOPLASTICS	◯ Yes ◯ No

☐ Immunomodulators for non-malignant disease
☐ Antineoplastics and supportive medicines

JOINT DISEASE	◯ Yes	◯ No

☐ Gout
☐ Rheumatoid disorders
☐ Juvenile joint diseases

LOCAL ANAESTHETICS	◯ Yes	◯ No
MEDICAL GASES	◯ Yes	◯ No
PAIN AND PALLIATIVE CARE	◯ Yes	◯ No

☐ Non-opioids and non-steroidal anti-inflammatory medicines (NSAIMs)
☐ Opioid analgesics
☐ Medicines for other common symptoms in palliative care
☐ Other

MENTAL AND BEHAVIOURAL	◯ Yes	◯ No

☐ Psychotic disorders
☐ Mood disorders
☐ Anxiety disorders
☐ Obsessive compulsive disorders
☐ Psychoactive substance use

MUSCLE RELAXANTS peripherally-acting and cholinesterase inhibitors	◯ Yes	◯ No
ONCOLOGY	◯ Yes	◯ No
OPHTHALMOLOGY	◯ Yes	◯ No
PERITONEAL DIALYSIS SOLUTION	◯ Yes	◯ No
REPRODUCTIVE HEALTH AND PERINATAL CARE	◯ Yes	◯ No

☐ Contraceptives
☐ Ovulation inducers
☐ Uterotonics
☐ Antioxytocics (tocolytics)

RESPIRATORY	◯ Yes	◯ No

☐ antiasthmatic combinations
☐ antihistamines
☐ antitussives
☐ bronchodilators
☐ decongestants
☐ expectorants
☐ leukotriene modifiers
☐ lung surfactants
☐ miscellaneous respiratory agents
☐ mucolytics
☐ respiratory inhalant products
☐ selective phosphodiesterase-4 inhibitors
☐ upper respiratory combinations
☐ Other

SEDATION	◯ Yes ◯ No
SOLUTIONS FOR CORRECTING WATER ELECTROLYTE AND ACID BASE DISTURBANCE	◯ Yes ◯ No

☐ Oral
☐ Parenteral
☐ IV
☐ Miscellaneous

VACCINES	______________________
VITAMINS AND MINERALS	◯ Yes ◯ No

OTHER MEDICATIONS NOT LISTED

____

Respiratory Support in ED

Respiratory Support Research

Respiratory Support In ED

Respiratory support provided in ED	☐ Other ☐ Venturi mask or similar ☐ Standard low flow oxygen mask < 15 Lmin ☐ Standard low flow oxygen prongs < 15 Lmin ☐ NIV ☐ NHF ☐ Humidified Face mask ☐ INV Endotrach ☐ INV Trach (select all that apply)
Underlying cause of respiratory support requirement whilst in ED	☐ Other ☐ Cardiac ☐ Respiratory ☐ Combined Cardiac and Respiratory ☐ Chronic use (domiciliary) ☐ Procedural ☐ Rapid sequence intubation ☐ Unknown (select all that apply)

Escalation of respiratory support in ED

Escalation of respiratory support required in ED	○ Yes ○ No
Reason for escalation of respiratory support required in ED	☐ None ☐ Other ☐ Unknown ☐ Patient feels unwell ☐ ED staff concerned ☐ Patient failed to respond to current therapy ☐ Patient clinical signs have deteriorated ☐ Patient vital signs have deteriorated ☐ Procedural ☐ Rapid sequence intubation (select all those that apply)

First type of escalation of respiratory support in ED	◯ None ◯ Other ◯ Standard O2 mask to nebuliser ◯ Standard O2 mask to **NHF** ◯ Standard O2 mask to **NIV** ◯ Standard O2 mask to **BiPAP** ◯ Standard O2 mask to **INV** or Trach ◯ Standard O2 cannula to standard mask ◯ Standard O2 cannula to nebuliser ◯ Standard O2 cannula to **NHF** ◯ Standard O2 cannula to **NIV** ◯ Standard O2 cannula to **BiPAP** ◯ Standard O2 cannula to **CPAP** ◯ Standard O2 cannula to **INV** or Trach ◯ Venturi mask to nebuliser ◯ Venturi mask to **NHF** ◯ Venturi mask to **NIV** ◯ Venturi mask to **BiPAP** ◯ Venturi mask to **CPAP** ◯ Venturi mask to **INV** or Trach ◯ **NHF** to **NIV** ◯ **NHF** to **BiPAP** ◯ **NHF** to **CPAP** ◯ **NHF** to **INV** or Trach ◯ **NIV** to **INV** or Trach (select one)
Second type of escalation of respiratory support in ED	◯ None ◯ Other ◯ Standard O2 mask to nebuliser ◯ Standard O2 mask to **NHF** ◯ Standard O2 mask to **NIV** ◯ Standard O2 mask to **BiPAP** ◯ Standard O2 mask to **INV** or Trach ◯ Standard O2 cannula to nebuliser ◯ Standard O2 cannula to **NHF** ◯ Standard O2 cannula to **NIV** ◯ Standard O2 cannula to **BiPAP** ◯ Standard O2 cannula to **CPAP** ◯ Standard O2 cannula to **INV** or Trach ◯ Venturi mask to nebuliser ◯ Venturi mask to **NHF** ◯ Venturi mask to **NIV** ◯ Venturi mask to **BiPAP** ◯ Venturi mask to **CPAP** ◯ Venturi mask to **INV** or Trach ◯ **NHF** to **NIV** ◯ **NHF** to **BiPAP** ◯ **NHF** to **CPAP** ◯ **NHF** to **INV** or Trach ◯ **NIV** to **INV** or Trach (select one)

Deescalation of respiratory support in ED

Deescalation of respiratory support in ED	◯ Yes ◯ No
Type of deescalation of respiratory support in ED	◯ None ◯ Other ◯ Nebuliser to Standard O2 mask ◯ NHF to Standard O2 mask ◯ NIV to Standard O2 mask ◯ BiPAP to Standard O2 mask ◯ INV or Trach Standard O2 mask ◯ Nebuliser to Standard O2 cannula ◯ Standard O2 mask to Standard O2 cannula ◯ NHF to Standard O2 cannula ◯ NIV to Standard O2 cannula ◯ BiPAP to Standard O2 cannula ◯ CPAP to Standard O2 cannula ◯ INV to Trach Standard O2 cannula ◯ Nebuliser to Venturi mask ◯ NHF to Venturi mask ◯ NIV to Venturi mask ◯ BiPAP to Venturi mask ◯ CPAP to Venturi mask ◯ INV or Trach to Venturi mask ◯ NIV to NHF ◯ BiPAP to NHF ◯ CPAP to NHF ◯ INV or Trach to NHF ◯ INV or Trach to NHF NHF (select one)

Respiratory support on ED discharge

Respiratory support required on ED discharge	◯ Yes ◯ No
Respiratory support on ED discharge	◯ None ◯ Other ◯ Venturi mask or similar ◯ Standard low flow oxygen mask < 15 Lmin ◯ Standard low flow oxygen prongs < 15 Lmin ◯ NIV ◯ NHF ◯ Humidified Face mask ◯ INV Endotrach ◯ INV Trach (select one)

Nasal High Flow Therapy in ED

Respiratory Support Research

Nasal High Flow (NHF) Therapy In ED

Received NHF in ED	◯ Yes ◯ No
Rationale for NHF use	☐ None ☐ Other ☐ Rapid sequence intubation ☐ Conscious / procedural sedation ☐ Reduce work of breathing ☐ Improve oxygenation ☐ Improve hypercapnea ☐ Reduce respiratory rate ☐ Airway humidification ☐ CPAP effect ☐ Comfort ☐ NIV rest therapy ☐ Other RS therapy intolerance ☐ Clinician preference ☐ Patient preference ☐ Logistical / resource issues (select all that apply)
Was NHF discontinued in ED	◯ Yes ◯ No
Rationale for NHF discontinuation	☐ None ☐ Other ☐ Not discontinued ☐ Escalation of RS required to another RS e.g. NIV ☐ RSI ☐ Conscious / procedural sedation ☐ Reduce work of breathing ☐ Improve oxygenation ☐ Improve hypercapnea ☐ Reduce RR ☐ Airway humidification ☐ CPAP effect ☐ Comfort ☐ NIV rest therapy ☐ NHF intolerance ☐ Clinician preference ☐ Patient preference ☐ Logistical / resource issues (select all those that apply)
NHF related adverse effects	◯ None ◯ Yes minor, NHF continued ◯ Major, NHF discontinued
COMMENT adverse events associated with NHF	____________________

When was NHF commenced during ED admission?	◯ within 1st hour of ED admission ◯ within 2nd hour of ED admission ◯ within 3rd hour of ED admission ◯ within 4th hour of ED admission ◯ after more than four hours post ED admission (select one)

NHF delivery 1st hour

1st hour of NHF delivery	◯ Yes ◯ No
FiO2 delivered during 1st hour of NHF	______________________ (0.21 TO 1.0 average)
Gas flow delivered during 1st hour of NHF	______________________ (L/ Min, average)
Highest RR during 1st hour of NHF	______________________
Lowest RR during 1st hour of NHF	______________________
Lowest SpO2 during 1st hour of NHF	______________________ (%)
Highest SpO2 during 1st hour of NHF	______________________ (%)
Highest HR during 1st hour of NHF	______________________
Lowest HR during 1st hour of NHF	______________________

NHF delivery 2nd hour

2nd hour of NHF delivery	◯ Yes ◯ No
FiO2 delivered during 2nd hour of NHF	______________________ (0.21-1.0 average)
Gas flow delivered during 2nd hour of NHF	______________________ (L/min , average)
Highest RR during 2nd hour of NHF	______________________
Lowest RR during 2nd hour of NHF	______________________

Highest SpO2 during 2nd hour of NHF	______________ (%)
Lowest SpO2 during 2nd hour of NHF	______________ (%)
Highest HR during 2nd hour of NHF	______________
Lowest HR during 2nd hour of NHF	______________
ROX score calculated at 2 hours of NHF (REDCAP calculation)	______________ (NO NOT CALCULATE)

NHF delivery 3rd hour

3rd hour of NHF delivery	◯ Yes ◯ No
FiO2 delivered during 3rd hour of NHF	______________ (0.21-1.0 average)
Gas flow delivered during 3rd hour of NHF	______________ (L/min, average)
Highest RR during 3rd hour of NHF	______________
Lowest RR during 3rd hour of NHF	______________
Highest SpO2 during 3rd hour of NHF	______________ (%)
Lowest SpO2 during 3rd hour of NHF	______________ (%)
Highest HR during 3rd hour of NHF	______________
Lowest HR during 3rd hour of NHF	______________

NHF delivery 4th hour

4th hour of NHF delivery	◯ Yes ◯ No
FiO2 delivered during 4th hour of NHF	________ (0.21-1.0 average)
Gas flow delivered during 4th hour of NHF	________ (L/min , average)
Highest RR during hour 4 of NHF	________
Lowest RR during hour 4 of NHF	________
Highest SpO2 during hour 4 of NHF	________ (%)
Lowest SpO2 during hour 4 of NHF	________ (%)
Highest HR during hour 4 of NHF	________
Lowest HR during hour 4 of NHF	________

NHF delivery on ED discharge

Total duration of NHF delivery whilst in ED	◯ Less than 30mins ◯ Up to I hour ◯ 1-2 hours ◯ 2-3 hours ◯ 3-4 hours ◯ More than 4 hours
NHF delivered on ED discharge	◯ Yes ◯ No
FiO2 delivered on NHF at ED discharge	________ (0.21-1.0)
Gas flow delivered on NHF at ED discharge	________ (L/min)
RR on NHF at ED discharge	________
SpO2 on NHF at ED discharge	________ (%)

HR on NHF at ED discharge

____
( )

Comments on NHF delivery in ED

____

Appendix I

Point Prevalence Study REDCap Data Dictionary

Data Dictionary Codebook 30/08/2023 11:24am

#	Variable / Field Name	Field Label *Field Note*	Field Attributes (Field Type, Validation, Choices, Calculations, etc.)
Instrument: **Screening ED patients for study inclusion** (screening_ed_patients_for_study_inclusion)			
1	[study_id]	Participant Study ID	text
2	[record_id]	Patient study ID #	text
3	[p0]	Respiratory Support Research	descriptive
4	[p00]	Screening ED patients for inclusion	descriptive
5	[nhi]	NHI	text, Required, Identifier
6	[date_of_birth]	Date of birth	text (date_dmy), Required, Identifier
7	[age_18_or_over]	Age 18 or over	yesno, Required 1 Yes 0 No
8	[rs_in_ed]	Requirement for respiratory support whilst in ED *Any RS at any time in ED*	yesno, Required 1 Yes 0 No Custom alignment: RH
9	[screening_ed_patients_for_study_inclusion_complete]	Section Header: *Form Status* Complete?	dropdown 0 Incomplete 1 Unverified 2 Complete
Instrument: **Patient status prior to and on ED admission** (patient_status_prior_to_and_on_ed_admission)			
10	[p10]	Respiratory Support Research	descriptive
11	[gender]	Section Header: *Patient status prior to or at ED admission* Gender	radio, Required M Male F Female O X-gender U Unknown Custom alignment: RH
12	[ethnicity]	Ethnicity	radio, Required 1 European 2 NZ European 3 NZ Maori 4 Pacific Island 5 Samoan 6 Cook Island Maori 7 Tongan 8 Niuean 9 Tokelauan 10 Fijian 11 Other Pacific Island 12 Asian 13 Southeast Asian 14 Chinese 15 Indian 16 Other Asian 17 Middle Eastern 18 Latin American / Hispanic 19 African 20 Other ethnicity

13	[ethnicity_others] Show the field ONLY if: [ethnicity] = '20' or [ethnicity] = 'XX'	Ethnicity other *name 'other' or 'unknown'*	text
14	[gp_primary_care_referral]	GP / Primary Care Referral to ED	radio, Required Y Yes N No UK Unknown Custom alignment: RH
15	[duration_of_symptoms_before_ed_presentation]	Duration of symptoms before ED admission (H:M) *If unknown enter 00:00*	text (number), Required
16	[pre_ed_treatment]	Pre ED admission treatment	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
17	[pre_ed_treatment_options] Show the field ONLY if: [pre_ed_treatment] = '1'	Pre ED admission treatment *select all that apply*	checkbox, Required 25 pre_ed_treatment_options___25 Other 23 pre_ed_treatment_options___23 Nebuliser 3 pre_ed_treatment_options___3 O2 venturi or similar 4 pre_ed_treatment_options___4 O2 standard mask or cannula (low flow) 5 pre_ed_treatment_options___5 NIV 6 pre_ed_treatment_options___6 Defbrillation 7 pre_ed_treatment_options___7 CPR 8 pre_ed_treatment_options___8 Ambu bag or similar 9 pre_ed_treatment_options___9 Airway 10 pre_ed_treatment_options___10 INV Trach 11 pre_ed_treatment_options___11 INV Endotrach 12 pre_ed_treatment_options___12 ETT and Mechanical Ventilation
18	[pre_ed_treatment_comment]	COMMENT: Pre ED admission treatment	notes
19	[transport_to_ed]	Means of transportation to ED is known	yesno, Required 1 Yes 0 No
20	[transport_to_ed_2] Show the field ONLY if: [transport_to_ed] = '1'	Transportation to ED	radio, Required A Private vehicle B Ambulance 2 Ambulance from another hospital H Helicopter 3 Helicopter from another hospital 1 Public transport NR Unknown 4 Other
21	[does_patient_have_comorbid]	Section Header: *Known comorbidities* Does the patient have any known comorbidities (diseases or disorders) ?	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH

22	[comorbidities_list] Show the field ONLY if: [does_patient_have_comorbid] = '1'	Comorbidities (diseases or disorders) *select all that apply*	checkbox 66 comorbidities_list___66 Other 67 comorbidities_list___67 Neurological 4 comorbidities_list___4 Eye 5 comorbidities_list___5 Ear, nose, mouth and throat 6 comorbidities_list___6 Respiratory 47 comorbidities_list___47 Circulatory / cardiac 48 comorbidities_list___48 Digestive / gastro intestinal 49 comorbidities_list___49 Hepatobiliary or pancreas 50 comorbidities_list___50 Musculoskeletal system or connective tissue 51 comorbidities_list___51 Skin, subcutaneous tissue and breast 52 comorbidities_list___52 Endocrine, nutritional or metabolic 53 comorbidities_list___53 Renal, kidney, or urinary tract 54 comorbidities_list___54 Reproductive 56 comorbidities_list___56 Pregnancy, childbirth or puerperium 58 comorbidities_list___58 Blood, blood-forming organs and immunological disorders 59 comorbidities_list___59 Neoplastic disorders (haematological and solid neoplasm's) 60 comorbidities_list___60 Infectious and parasitic diseases (systemic or unspecified sites) 61 comorbidities_list___61 Mental health 62 comorbidities_list___62 Alcohol/drug use and alcohol/drug-induced organic mental conditions 63 comorbidities_list___63 Injuries, poisoning and toxic effects of drugs 64 comorbidities_list___64 Burns 65 comorbidities_list___65 Factors influencing health status and other contacts with health services
23	[comorbidities_comments]	COMMENT: Comorbidities (diseases or disorders)	notes
24	[patient_usual_med]	Section Header: *Medications before this ED admission* Does the patient have any usual medications OR been medications given within 72 hours before this ED admission?	radio, Required Y Yes N No UK Unknown Custom alignment: RH
25	[allergy_med] Show the field ONLY if: [patient_usual_med] = 'Y'	ANTIALLERGICS AND MEDICINES USED IN ANAPHYLAXIS	yesno 1 Yes 0 No Custom alignment: RH
26	[anticonvul_med] Show the field ONLY if: [patient_usual_med] = 'Y'	ANTICONVULSANTS / ANTIEPILEPTICS	yesno 1 Yes 0 No Custom alignment: RH

27	[antidote_poison_med] Show the field ONLY if: [patient_usual_med] = 'Y'	ANTIDOTES AND OTHER SUBSTANCES FOR POISONINGS	yesno 1 Yes 0 No Custom alignment: RH
28	[anti_infect_med_3] Show the field ONLY if: [patient_usual_med] = 'Y'	ANTI-INFECTIVE	yesno 1 Yes 0 No Custom alignment: RH
29	[anti_infect_med_4] Show the field ONLY if: [anti_infect_med_3] = '1'		checkbox 247 anti_infect_med_4___247 Anthelmintics 248 anti_infect_med_4___248 Antibacterials 249 anti_infect_med_4___249 Antifungal medicines 250 anti_infect_med_4___250 Antiviral medicines 251 anti_infect_med_4___251 Antiprotozoal medicines 252 anti_infect_med_4___252 Medicines for ectoparasitic infections 253 anti_infect_med_4___253 Other Custom alignment: LV
30	[antimigrane_med_3] Show the field ONLY if: [patient_usual_med] = 'Y'	ANTIMIGRAINE	yesno 1 Yes 0 No Custom alignment: RH
31	[antiparkin_med_2] Show the field ONLY if: [patient_usual_med] = 'Y'	ANTIPARKINSONISM	yesno 1 Yes 0 No Custom alignment: RH
32	[antisept_med_3] Show the field ONLY if: [patient_usual_med] = 'Y'	ANTISEPTICS AND DISINFECTANTS	yesno 1 Yes 0 No Custom alignment: RH
33	[antisept_med_5] Show the field ONLY if: [antisept_med_3] = '1'		checkbox 284 antisept_med_5___284 Antiseptics 285 antisept_med_5___285 Disinfectants 286 antisept_med_5___286 Other Custom alignment: LV
34	[blood_med_3] Show the field ONLY if: [patient_usual_med] = 'Y'	BLOOD PRODUCT OR TREATMENT	yesno 1 Yes 0 No Custom alignment: RH
35	[blood_med_4] Show the field ONLY if: [blood_med_3] = '1'		checkbox 1 blood_med_4___1 Blood and blood components 2 blood_med_4___2 Plasma-derived 3 blood_med_4___3 Plasma substitutes 5 blood_med_4___5 Antianaemia medicines 6 blood_med_4___6 Medicines affecting coagulation 4 blood_med_4___4 Other Custom alignment: LV

36	[cardiovascular_med_3] Show the field ONLY if: [patient_usual_med] = 'Y'	CARDIOVASCULAR	yesno 1 Yes 0 No Custom alignment: RH
37	[cardiovascular_med_4] Show the field ONLY if: [cardiovascular_med_3] = '1'		checkbox 1 cardiovascular_med_4___1 Antianginal 2 cardiovascular_med_4___2 Antiarrhythmic 3 cardiovascular_med_4___3 Antihypertensive 4 cardiovascular_med_4___4 Heart failure 5 cardiovascular_med_4___5 Antithrombotic medicines 6 cardiovascular_med_4___6 Lipid-lowering agents 7 cardiovascular_med_4___7 Other Custom alignment: LV
38	[dental_med_2] Show the field ONLY if: [patient_usual_med] = 'Y'	DENTAL PREPARATIONS	yesno 1 Yes 0 No Custom alignment: RH
39	[derm_med_3] Show the field ONLY if: [patient_usual_med] = 'Y'	DERMATOLOGICAL PREPARATIONS	yesno 1 Yes 0 No Custom alignment: RH
40	[dermatological_med_2] Show the field ONLY if: [derm_med_3] = '1'		checkbox 1 dermatological_med_2___1 Antifungal 2 dermatological_med_2___2 Anti-infective 3 dermatological_med_2___3 Anti-inflammatory and antipruritic 4 dermatological_med_2___4 Medicines affecting skin differentiation and proliferation 5 dermatological_med_2___5 Other Custom alignment: LV
41	[diagnost_med_3] Show the field ONLY if: [patient_usual_med] = 'Y'	DIAGNOSTIC AGENTS	yesno 1 Yes 0 No Custom alignment: RH
42	[diagnost_med_2] Show the field ONLY if: [diagnost_med_3] = '1'		checkbox 281 diagnost_med_2___281 Ophthalmic 282 diagnost_med_2___282 Radiocontrast media 303 diagnost_med_2___303 Other Custom alignment: LV
43	[diuretic_med] Show the field ONLY if: [patient_usual_med] = 'Y'	DIURETICS	yesno 1 Yes 0 No Custom alignment: RH
44	[ent_med] Show the field ONLY if: [patient_usual_med] = 'Y'	ENT	yesno 1 Yes 0 No Custom alignment: RH

45	[endocrine_disorders] Show the field ONLY if: [patient_usual_med] = 'Y'	ENDOCRINE DISORDERS	yesno 1 Yes 0 No Custom alignment: RH
46	[endocrine_disorders_2] Show the field ONLY if: [endocrine_disorders] = '1'		checkbox 1 endocrine_disorders_2___1 Adrenal hormones and synthetic substitutes 2 endocrine_disorders_2___2 Androgens 3 endocrine_disorders_2___3 Oestrogens 4 endocrine_disorders_2___4 Progestogens 5 endocrine_disorders_2___5 Diabetes 6 endocrine_disorders_2___6 Thyroid hormones and antithyroid medicines 7 endocrine_disorders_2___7 Other Custom alignment: LV
47	[gastrointestinal_medicines_3] Show the field ONLY if: [patient_usual_med] = 'Y'	GASTROINTESTINAL	yesno 1 Yes 0 No Custom alignment: RH
48	[gastrointestinal_medicines_4] Show the field ONLY if: [gastrointestinal_medicines_3] = '1'		checkbox 1 gastrointestinal_medicines_4___1 Antiulcer 2 gastrointestinal_medicines_4___2 Antiemetic 3 gastrointestinal_medicines_4___3 Anti-inflammatory 4 gastrointestinal_medicines_4___4 Laxatives 5 gastrointestinal_medicines_4___5 Diarrhoea 6 gastrointestinal_medicines_4___6 Other Custom alignment: LV
49	[ga_med] Show the field ONLY if: [patient_usual_med] = 'Y'	GENERAL ANAESTHETICS	checkbox 1 ga_med___1 Yes 2 ga_med___2 No Custom alignment: RH
50	[homeo_med_2] Show the field ONLY if: [patient_usual_med] = 'Y'	HOMEOPATHICS HERBAL REMEDIES	yesno 1 Yes 0 No Custom alignment: RH
51	[immune_med_3] Show the field ONLY if: [patient_usual_med] = 'Y'	IMMUNIODULATORS AND ANTINEOPLASTICS	yesno 1 Yes 0 No Custom alignment: RH
52	[immunology_med_3] Show the field ONLY if: [immune_med_3] = '1'		checkbox 257 immunology_med_3___257 Immunomodulators for non-malignant disease 258 immunology_med_3___258 Antineoplastics and supportive medicines Custom alignment: LV
53	[joint_dis_med_3] Show the field ONLY if: [patient_usual_med] = 'Y'	JOINT DISEASE	yesno 1 Yes 0 No Custom alignment: RH

54	[joint_dis_med_4] Show the field ONLY if: [joint_dis_med_3] = '1'		checkbox 229 joint_dis_med_4___229 Gout 230 joint_dis_med_4___230 Rheumatoid disorders 231 joint_dis_med_4___231 Juvenile joint diseases Custom alignment: LV
55	[local_anaeth_med_2] Show the field ONLY if: [patient_usual_med] = 'Y'	LOCAL ANAESTHETICS	yesno 1 Yes 0 No Custom alignment: RH
56	[medical_gas_med] Show the field ONLY if: [patient_usual_med] = 'Y'	MEDICAL GASES	yesno 1 Yes 0 No Custom alignment: RH
57	[pain_palliat_med_3] Show the field ONLY if: [patient_usual_med] = 'Y'	PAIN AND PALLIATIVE CARE	yesno 1 Yes 0 No Custom alignment: RH
58	[pain_palliat_med_4] Show the field ONLY if: [pain_palliat_med_3] = '1'		checkbox 238 pain_palliat_med_4___238 Non-opioids and non-steroidal anti-inflammatory medicines (NSAIMs) 239 pain_palliat_med_4___239 Opioid analgesics 240 pain_palliat_med_4___240 Medicines for other common symptoms in palliative care 241 pain_palliat_med_4___241 Other Custom alignment: LV
59	[mental_behav_med_3] Show the field ONLY if: [patient_usual_med] = 'Y'	MENTAL AND BEHAVIOURAL	yesno 1 Yes 0 No Custom alignment: RH
60	[mental_behav_med_4] Show the field ONLY if: [mental_behav_med_3] = '1'		checkbox 312 mental_behav_med_4___312 Psychotic disorders 313 mental_behav_med_4___313 Mood disorders 314 mental_behav_med_4___314 Anxiety disorders 315 mental_behav_med_4___315 Obsessive compulsive disorders 316 mental_behav_med_4___316 Psychoactive substance use Custom alignment: LV
61	[mus_relax_med_2] Show the field ONLY if: [patient_usual_med] = 'Y'	MUSCLE RELAXANTS peripherally-acting and cholinesterase inhibitors	yesno 1 Yes 0 No Custom alignment: RH
62	[oncology_2] Show the field ONLY if: [patient_usual_med] = 'Y'	ONCOLOGY	yesno 1 Yes 0 No Custom alignment: RH

63	[ophthal_med_2] Show the field ONLY if: [patient_usual_med] = 'Y'	OPHTHALMOLOGY	yesno 1 Yes 0 No Custom alignment: RH
64	[dialysis_med_2] Show the field ONLY if: [patient_usual_med] = 'Y'	PERITONEAL DIALYSIS SOLUTION	yesno 1 Yes 0 No Custom alignment: RH
65	[reproduct_med_4] Show the field ONLY if: [patient_usual_med] = 'Y'	REPRODUCTIVE HEALTH AND PERINATAL CARE	yesno 1 Yes 0 No Custom alignment: RH
66	[reproduct_med_3] Show the field ONLY if: [reproduct_med_4] = '1'		checkbox 306 reproduct_med_3___306 Contraceptives 307 reproduct_med_3___307 Ovulation inducers 308 reproduct_med_3___308 Uterotonics 309 reproduct_med_3___309 Antioxytocics (tocolytics) Custom alignment: LV
67	[resp_med] Show the field ONLY if: [patient_usual_med] = 'Y'	RESPIRATORY	yesno 1 Yes 0 No Custom alignment: RH
68	[resp_med_3] Show the field ONLY if: [resp_med] = '1'		checkbox 323 resp_med_3___323 antiasthmatic combinations 324 resp_med_3___324 antihistamines 325 resp_med_3___325 antitussives 326 resp_med_3___326 bronchodilators 331 resp_med_3___331 decongestants 332 resp_med_3___332 expectorants 333 resp_med_3___333 leukotriene modifiers 334 resp_med_3___334 lung surfactants 335 resp_med_3___335 miscellaneous respiratory agents 336 resp_med_3___336 mucolytics 337 resp_med_3___337 respiratory inhalant products 341 resp_med_3___341 selective phosphodiesterase-4 inhibitors 342 resp_med_3___342 upper respiratory combinations 321 resp_med_3___321 Other Custom alignment: LV
69	[sedation_med]	SEDATION	yesno 1 Yes 0 No Custom alignment: RH
70	[solutions_med_2] Show the field ONLY if: [patient_usual_med] = 'Y'	SOLUTIONS FOR CORRECTING WATER ELECTROLYTE AND ACID BASE DISTURBANCE	yesno 1 Yes 0 No Custom alignment: RH

71	[solutions_med_4] Show the field ONLY if: [solutions_med_2] = '1'		checkbox 211 solutions_med_4___211 Oral 212 solutions_med_4___212 Parenteral 328 solutions_med_4___328 IV 213 solutions_med_4___213 Miscellaneous Custom alignment: LV
72	[vitamins_med_2] Show the field ONLY if: [patient_usual_med] = 'Y'	VITAMINS AND MINERALS	yesno 1 Yes 0 No Custom alignment: RH
73	[vaccine_med_2] Show the field ONLY if: [patient_usual_med] = 'Y'	VACCINES	text Custom alignment: RH
74	[medications_usual_coments]	COMMENT: Usual medications OR medications given within 72 hours before this ED admission	notes
75	[eligible] Show the field ONLY if: [age_18_or_over] = '1' and [rs_in_ed] = '1'	Section Header: *On ED admission* Eligible for inclusion in this study?	yesno, Required 1 Yes 0 No
76	[date_and_time_admission]	Date and time of ED admission	text (datetime_dmy), Required Field Annotation: @NOW
77	[admitting_ed]	Admitting ED	radio, Required M Middlemore - Te Whatu Ora Counties Manukau T Tauranga -Te Whatu Ora Hauora a Toi Bay of Plenty N North Shore -Te Whatu Ora Waitematā W Whakatāne -Te Whatu Ora Hauora a Toi Bay of Plenty
78	[covid_19_status]	COVID-19 status current	radio N Negative P Positive PP Previously Positive U Unknown
79	[covid_19_vaccination_statu]	COVID-19 vaccination status	radio FV Fully Vaccinated PV Partial Vaccinated UV Un-vaccinated UN Unknown
80	[ews]	EWS recorded on ED admission *If unknown enter 0*	text (number, Min: 0, Max: 20)
81	[ews_rc_cal]	EWS calculated by REDCAP on ED admission *Do not calculate*	calc
82	[australiasian_ed_triage_score]	Australiasian ED triage score on ED admission	radio, Required 1 Immediately life-threatening, immediate simultaneous triage and treatment 2 Imminently life-threatening, or important time-critical 3 Potentially life-threatening, potential adverse outcomes from delay > 30 min 4 Potentially serious, or potential adverse outcomes from delay > 60 min, or significant complexity or severit 5 Less urgent, or dealing with administrative issues only 6 Unknown
83	[gcs]	GCS at baseline on ED admission *If unknown enter 0*	text (number, Min: 0, Max: 15), Required

97	(spo2_air]	SpO2 on air on ED admission *If unknCJNn enterO*	text (number, Min: 0. Max: 105), Required
98	(spo2_o2]	SpO2 on 02 on ED admission *IfunknONn enterO*	text (number, Min: 0. Max: 105), Required
99	(ecg]	ECG on ED admission	radio. Reauired 1 Normal 2 Abnormal 3 Unknown Custom alignment; RH
100	(pf]	Peak flow on ED admission *Ifunknwm enterO*	text {number, Min: 0, Max: 2000). Required
101	(headache)	Headache on ED admission	radio, Reauired 1 Yes 2 No 3 Unknown Custom alignment: RH
102	(pain]	Pain unspecified at baseline	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
103	(malaise]	Malaise on ED admission	radio, Reauired 1 Yes 2 No 3 Unknown Custom alignment: RH
104	(syncope]	Syncope and collapse on ED admission	radio, Required 1 Yes L2 jNo

84	[alt_cons_state]	New altered conscious state on ED admission *Altered conscious state not known to be chronic or onset < 7 days*	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
85	[speech]	Ability to speak on ED admission	radio, Required 1 None 2 Phrases 3 Sentences 4 Normal 5 Unknown
86	[cynaosis]	Cyanosis on ED admission	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
87	[dist_jug_vein]	Distended jugular veins on ED admission	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
88	[perp_oed]	Peripheral oedema on ED admission	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
89	[oed_unsp]	Oedema other on ED admission	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
90	[chest_ausc]	Chest auscultation on ED admission	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
91	[chest_ausc_2] Show the field ONLY if: [chest_ausc] = '1'	Chest auscultation on ED admission	checkbox, Required 4 chest_ausc_2___4 Normal 5 chest_ausc_2___5 Bilateral crepitations 6 chest_ausc_2___6 Wheeze 7 chest_ausc_2___7 Localized rhonchi/bronchial breathing 8 chest_ausc_2___8 Widespread rhonchi 9 chest_ausc_2___9 Other abnormal (e.g., signs of pneumothorax)
92	[rr]	Respiratory rate on ED admission *If unknown enter 0*	text (number, Min: 0, Max: 60), Required
93	[sbp]	Systolic BP on ED admission *If unknown enter 0*	text (number, Min: 0, Max: 300), Required
94	[dbp]	Diastolic BP on ED admission *If unknown enter 0*	text (number, Min: 0, Max: 300), Required
95	[temp]	Temperature on ED admission *If unknown enter 0*	text (number, Min: 0, Max: 45), Required
96	[hr]	Heart rate on ED admission *If unknown enter 0*	text (number, Min: 0, Max: 300), Required

97	[spo2_air]	SpO2 on air on ED admission *If unknown enter 0*	text (number, Min: 0, Max: 105), Required
98	[spo2_o2]	SpO2 on O2 on ED admission *If unknown enter 0*	text (number, Min: 0, Max: 105), Required
99	[ecg]	ECG on ED admission	radio, Required 1 Normal 2 Abnormal 3 Unknown Custom alignment: RH
100	[pf]	Peak flow on ED admission *If unknown enter 0*	text (number, Min: 0, Max: 2000), Required
101	[headache]	Headache on ED admission	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
102	[pain]	Pain unspecified at baseline	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
103	[malaise]	Malaise on ED admission	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
104	[syncope]	Syncope and collapse on ED admission	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
105	[febrile_convulsion]	Febrile convulsion on ED admission	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
106	[other_convulsion]	Other and unspecified convulsions on ED admission	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
107	[lymn]	Enlarged lymph nodes, unspecified on ED admission	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
108	[dia_vom]	Diarr & vomiting on ED admission	radio, Required 1 Yes 2 No 3 Unknown Custom alignment: RH
109	[unknw]	COMMENT: Unknown and unspecified causes of morbidity / symptoms on ED admission not listed above	notes

110	[patient_status_prior_to_and_on_ed_admission_complete]	Section Header: *Form Status* Complete?	dropdown 0 Incomplete 1 Unverified 2 Complete
Instrument: **Initial / First ED treatment or investigation** (initial_first_ed_treatment_or_investigation)			
111	[p13]	Respiratory Support Research	descriptive

112	[first_ed_procedures_2]	Section Header: *Initial (first) ED Treatment or Investigation* First ED treatment or investigation *Select all that apply*	checkbox

1	first_ed_procedures_2___1	None
50	first_ed_procedures_2___50	Other
51	first_ed_procedures_2___51	Respiratory support
49	first_ed_procedures_2___49	Monitoring of T, RR, HR, BP
2	first_ed_procedures_2___2	Monitoring of fluid input and output
37	first_ed_procedures_2___37	Weight
3	first_ed_procedures_2___3	Neurologic checks GCS
23	first_ed_procedures_2___23	Vascular checks
4	first_ed_procedures_2___4	Fingerstick blood glucose
5	first_ed_procedures_2___5	Pulse oximetry
6	first_ed_procedures_2___6	ECG continuous
38	first_ed_procedures_2___38	ECG 12 Lead
7	first_ed_procedures_2___7	Laboratory investigation
8	first_ed_procedures_2___8	Radiological investigation or treatment
9	first_ed_procedures_2___9	Oxygen supplementation
10	first_ed_procedures_2___10	Oral medications
24	first_ed_procedures_2___24	IV medications
11	first_ed_procedures_2___11	Intravenous fluids
13	first_ed_procedures_2___13	Wound care
14	first_ed_procedures_2___14	Nourishment
15	first_ed_procedures_2___15	Routine personal care
16	first_ed_procedures_2___16	Specialty referral
17	first_ed_procedures_2___17	Social Service intervention
19	first_ed_procedures_2___19	Cultural Service intervention
20	first_ed_procedures_2___20	Palliation in ED
39	first_ed_procedures_2___39	Care limitation in ED
40	first_ed_procedures_2___40	Withdrawal of care in ED
21	first_ed_procedures_2___21	Minor surgical intervention
35	first_ed_procedures_2___35	Major surgical intervention
22	first_ed_procedures_2___22	Minor orthopaedic intervention
36	first_ed_procedures_2___36	Major orthopaedic intervention
18	first_ed_procedures_2___18	Care coordination
25	first_ed_procedures_2___25	Education of patients
27	first_ed_procedures_2___27	CPR
28	first_ed_procedures_2___28	Cardioversion
29	first_ed_procedures_2___29	Defibrillation
30	first_ed_procedures_2___30	Intubation
31	first_ed_procedures_2___31	ID Urinary Cath
46	first_ed_procedures_2___46	Chest drain
32	first_ed_procedures_2___32	Nebulisation
33	first_ed_procedures_2___33	IV insert
34	first_ed_procedures_2___34	CVL insert

			41 | first_ed_procedures_2___41 | Art line insert 47 | first_ed_procedures_2___47 | NG or NJ insert 42 | first_ed_procedures_2___42 | Reperfusion STEMI 43 | first_ed_procedures_2___43 | End-tidal carbon dioxide (PetCO2) 44 | first_ed_procedures_2___44 | Therapeutic tap e.g. pneumothorax 45 | first_ed_procedures_2___45 | Dialysis
113	[lab_test_in_ed_3] Show the field ONLY if: [first_ed_procedures_2(7)] = '1'	Initial 'Laboratory' investigations in ED (any body fluid or tissue)	checkbox 1 | lab_test_in_ed_3___1 | None 11 | lab_test_in_ed_3___11 | Other 12 | lab_test_in_ed_3___12 | Biochem 2 | lab_test_in_ed_3___2 | Haem 3 | lab_test_in_ed_3___3 | ABG 5 | lab_test_in_ed_3___5 | Pregnancy 6 | lab_test_in_ed_3___6 | Toxicology 8 | lab_test_in_ed_3___8 | Drug Assay 9 | lab_test_in_ed_3___9 | Microbiology 10 | lab_test_in_ed_3___10 | Cytology
114	[abnom_lab_test_in_ed_2] Show the field ONLY if: [first_ed_procedures_2(7)] = '1'	Initial ABNORMAL 'laboratory' investigations in ED	checkbox 1 | abnom_lab_test_in_ed_2___1 | None 11 | abnom_lab_test_in_ed_2___11 | Other 12 | abnom_lab_test_in_ed_2___12 | Bio chem 2 | abnom_lab_test_in_ed_2___2 | Haem 3 | abnom_lab_test_in_ed_2___3 | ABG 5 | abnom_lab_test_in_ed_2___5 | Pregnancy 6 | abnom_lab_test_in_ed_2___6 | Toxicology 8 | abnom_lab_test_in_ed_2___8 | Drug Assay 9 | abnom_lab_test_in_ed_2___9 | Microbiology 10 | abnom_lab_test_in_ed_2___10 | Cytology
115	[radio_test_in_ed_2] Show the field ONLY if: [first_ed_procedures_2(8)] = '1'	Initial radiological investigations or treatments in ED	checkbox 22 | radio_test_in_ed_2___22 | None 23 | radio_test_in_ed_2___23 | Other 8 | radio_test_in_ed_2___8 | Trauma panel 21 | radio_test_in_ed_2___21 | Chest xray 9 | radio_test_in_ed_2___9 | Chest ultrasound 10 | radio_test_in_ed_2___10 | Chest MRI 11 | radio_test_in_ed_2___11 | Chest CT 12 | radio_test_in_ed_2___12 | Abdo xray 13 | radio_test_in_ed_2___13 | Abdo ultrasound 14 | radio_test_in_ed_2___14 | Abdo MRI 15 | radio_test_in_ed_2___15 | Abdo CT 16 | radio_test_in_ed_2___16 | Head xray 17 | radio_test_in_ed_2___17 | Head MRI 18 | radio_test_in_ed_2___18 | Head CT 20 | radio_test_in_ed_2___20 | Interventional radiology

116	[radio_test_in_ed_3] Show the field ONLY if: [first_ed_procedures_2(8)] = '1'	Initial ABNORMAL radiological investigations in ED	checkbox 22 radio_test_in_ed_3___22 None 23 radio_test_in_ed_3___23 Other 8 radio_test_in_ed_3___8 Trauma panel 21 radio_test_in_ed_3___21 Chest xray 9 radio_test_in_ed_3___9 Chest ultrasound 10 radio_test_in_ed_3___10 Chest MRI 11 radio_test_in_ed_3___11 Chest CT 12 radio_test_in_ed_3___12 Abdo xray 13 radio_test_in_ed_3___13 Abdo ultrasound 14 radio_test_in_ed_3___14 Abdo MRI 15 radio_test_in_ed_3___15 Abdo CT 16 radio_test_in_ed_3___16 Head xray 17 radio_test_in_ed_3___17 Head MRI 18 radio_test_in_ed_3___18 Head CT 20 radio_test_in_ed_3___20 Interventional radiology
117	[comment_1st_tx]	COMMENT: Initial first ED treatments or investigations	notes
118	[initial_first_ed_treatment_or_investigation_complete]	Section Header: *Form Status* Complete?	dropdown 0 Incomplete 1 Unverified 2 Complete
Instrument: **Subsequent /secondary ED treatment or investigation** (subsequent_secondary_ed_treatment_or_investigation)			
119	[p20]	Respiratory Support Research	descriptive
120	[subsequent_ed_treatments_o]	Section Header: *Subsequent or ongoing ED treatments or investigations* Subsequent or ongoing ED treatments or investigations	yesno 1 Yes 0 No Custom alignment: RH

121	[procedures] Show the field ONLY if: [subsequent_ed_treatments_o] = '1'	Subsequent or ongoing ED treatments or investigations *Select all that apply*	checkbox		
			1	procedures___1	None
			50	procedures___50	Other
			51	procedures___51	Respiratory support
			49	procedures___49	Monitoring of T, RR, HR, BP
			2	procedures___2	Monitoring of fluid input and output
			37	procedures___37	Weight
			3	procedures___3	Neurologic checks GCS
			23	procedures___23	Vascular checks
			4	procedures___4	Fingerstick blood glucose
			5	procedures___5	Pulse oximetry
			6	procedures___6	ECG continuous
			38	procedures___38	ECG 12 Lead
			7	procedures___7	Laboratory investigations
			8	procedures___8	Radiological investigations or treatments
			9	procedures___9	Oxygen supplementation
			10	procedures___10	Oral medications
			24	procedures___24	IV medications
			11	procedures___11	Intravenous fluids
			13	procedures___13	Wound care
			14	procedures___14	Nourishment
			15	procedures___15	Routine personal care
			16	procedures___16	Specialty referral
			17	procedures___17	Social Service intervention
			19	procedures___19	Cultural Service intervention
			20	procedures___20	Palliation in ED
			39	procedures___39	Care limitation in ED
			40	procedures___40	Withdrawal of care in ED
			21	procedures___21	Minor surgical intervention
			35	procedures___35	Major surgical intervention
			22	procedures___22	Minor orthopaedic intervention
			36	procedures___36	Major orthopaedic intervention
			18	procedures___18	Care coordination
			25	procedures___25	Education of patients
			27	procedures___27	CPR
			28	procedures___28	Cardioversion
			29	procedures___29	Defibrillation
			30	procedures___30	Intubation
			31	procedures___31	ID Urinary Cath
			46	procedures___46	Chest drain
			32	procedures___32	Nebulisation
			33	procedures___33	IV insert
			34	procedures___34	CVL insert
			41	procedures___41	Art line insert
			47	procedures___47	NG or NJ insert
			42	procedures___42	Reperfusion STEMI
			43	procedures___43	End-tidal carbon dioxide (PetCO2)
			44	procedures___44	Therapeutic tap e.g. pneumothorax
			45	procedures___45	Dialysis

122	[lab_test_in_ed_2] Show the field ONLY if: [subsequent_ed_treatments_o] = '1' and [procedures(7)] = '1'	Subsequent laboratory investigations in ED (any body fluid or tissue) *select all that apply*	checkbox 1 lab_test_in_ed_2___1 None 11 lab_test_in_ed_2___11 Other 12 lab_test_in_ed_2___12 Biochem 2 lab_test_in_ed_2___2 Haem 3 lab_test_in_ed_2___3 ABG 5 lab_test_in_ed_2___5 Pregnancy 6 lab_test_in_ed_2___6 Toxicology 8 lab_test_in_ed_2___8 Drug Assay 9 lab_test_in_ed_2___9 Microbiology 10 lab_test_in_ed_2___10 Cytology
123	[abnom_lab_test_in_ed_3] Show the field ONLY if: [procedures(7)] = '1' and [subsequent_ed_treatments_o] = '1'	Subsequent ABNORMAL 'laboratory' investigations in ED *select all that apply*	checkbox 1 abnom_lab_test_in_ed_3___1 None 11 abnom_lab_test_in_ed_3___11 Other 12 abnom_lab_test_in_ed_3___12 Bio chem 2 abnom_lab_test_in_ed_3___2 Haem 3 abnom_lab_test_in_ed_3___3 ABG 5 abnom_lab_test_in_ed_3___5 Pregnancy 6 abnom_lab_test_in_ed_3___6 Toxicology 8 abnom_lab_test_in_ed_3___8 Drug Assay 9 abnom_lab_test_in_ed_3___9 Microbiology 10 abnom_lab_test_in_ed_3___10 Cytology
124	[abg_worst] Show the field ONLY if: [procedures(7)] = '1' and [lab_test_in_ed_2(3)] = '1' and [subsequent_ed_treatments_o] = '1'	Worst ABG result in ED	dropdown 1 On air 2 On oxygen 3 Unknown
125	[worst_abg_ph] Show the field ONLY if: [subsequent_ed_treatments_o] = '1' and [procedures(7)] = '1' and [lab_test_in_ed_2(3)] = '1' and [abg_worst] = '1' or [abg_worst] = '2' or [abg_worst] = '3'	Worst ABG pH in ED	text (number, Min: 6, Max: 9) Custom alignment: RH
126	[worst_paco2_ph_2] Show the field ONLY if: [subsequent_ed_treatments_o] = '1' and [procedures(7)] = '1' and [lab_test_in_ed_2(3)] = '1' and [abg_worst] = '1' or [abg_worst] = '2' or [abg_worst] = '3'	Worst ABG PaCO2 kPa in ED	text (number, Min: 4, Max: 7) Custom alignment: RH
127	[worst_pao2_ph_3] Show the field ONLY if: [subsequent_ed_treatments_o] = '1' and [procedures(7)] = '1' and [lab_test_in_ed_2(3)] = '1' and [abg_worst] = '1' or [abg_worst] = '2' or [abg_worst] = '3'	Worst ABG PaO2 kPa in ED	text (number, Min: 10, Max: 14) Custom alignment: RH
128	[worst_hco3_4] Show the field ONLY if: [subsequent_ed_treatments_o] = '1' and [procedures(7)] = '1' and [lab_test_in_ed_2(3)] = '1' and [abg_worst] = '1' or [abg_worst] = '2' or [abg_worst] = '3'	Worst ABG HCO3 mEq/L in ED	text (number, Min: 20, Max: 28) Custom alignment: RH

129	[worst_be_6] Show the field ONLY if: [subsequent_ed_treatments_o] = '1' and [procedures(7)] = '1' and [lab_test_in_ed_2(3)] = '1' and [abg_worst] = '1' or [abg_worst] = '2' or [abg_worst] = '3'	Worst ABG base excess mmol/L in ED	text (number, Min: -3, Max: 3) Custom alignment: RH
130	[abg_best_2] Show the field ONLY if: [procedures(7)] = '1' and [lab_test_in_ed_2(3)] = '1' and [subsequent_ed_treatments_o] = '1'	Best or only ABG result in ED	dropdown 1 On air 2 On oxygen 3 Unknown
131	[best_abg_ph_2] Show the field ONLY if: [subsequent_ed_treatments_o] = '1' and [procedures(7)] = '1' and [lab_test_in_ed_2(3)] = '1' and [abg_best_2] = '1' and [abg_best_2] = '2' and [abg_best_2] = '3'	Best or only ABG pH in ED	text (number, Min: 6, Max: 9) Custom alignment: RH
132	[best_paco2_ph_3] Show the field ONLY if: [subsequent_ed_treatments_o] = '1' and [procedures(7)] = '1' and [lab_test_in_ed_2(3)] = '1' and [abg_worst] = '1' or [abg_worst] = '2' or [abg_worst] = '3'	Best or only ABG PaCO2 kPa in ED	text (number, Min: 4, Max: 7) Custom alignment: RH
133	[best_pao2_ph_4] Show the field ONLY if: [subsequent_ed_treatments_o] = '1' and [procedures(7)] = '1' and [lab_test_in_ed_2(3)] = '1' and [abg_worst] = '1' or [abg_worst] = '2' or [abg_worst] = '3'	Best or only ABG PaO2 kPa in ED	text (number, Min: 10, Max: 14) Custom alignment: RH
134	[best_hco3_5] Show the field ONLY if: [subsequent_ed_treatments_o] = '1' and [procedures(7)] = '1' and [lab_test_in_ed_2(3)] = '1' and [abg_worst] = '1' or [abg_worst] = '2' or [abg_worst] = '3'	Best or only ABG HCO3 mEq/L in ED	text (number, Min: 20, Max: 28) Custom alignment: RH
135	[best_be_5] Show the field ONLY if: [subsequent_ed_treatments_o] = '1' and [procedures(7)] = '1' and [lab_test_in_ed_2(3)] = '1' and [abg_worst] = '1' or [abg_worst] = '2' or [abg_worst] = '3'	Best or only ABG base excess mmol/L in ED	text (number, Min: -3, Max: 3) Custom alignment: RH

136	[radio_test_in_ed_6] Show the field ONLY if: [procedures(8)] = '1' and [subsequent_ed_treatments_o] = '1'	Subsequent radiological investigations or treatments in ED *select all that apply*	checkbox 8 radio_test_in_ed_6___8 None 23 radio_test_in_ed_6___23 Other 24 radio_test_in_ed_6___24 Trauma panel 22 radio_test_in_ed_6___22 Chest xray 9 radio_test_in_ed_6___9 Chest ultrasound 10 radio_test_in_ed_6___10 Chest MRI 11 radio_test_in_ed_6___11 Chest CT 12 radio_test_in_ed_6___12 Abdo xray 13 radio_test_in_ed_6___13 Abdo ultrasound 14 radio_test_in_ed_6___14 Abdo MRI 15 radio_test_in_ed_6___15 Abdo CT 16 radio_test_in_ed_6___16 Head xray 17 radio_test_in_ed_6___17 Head MRI 18 radio_test_in_ed_6___18 Head CT 20 radio_test_in_ed_6___20 Interventional radiology
137	[radio_test_in_ed_5] Show the field ONLY if: [procedures(8)] = '1' and [subsequent_ed_treatments_o] = '1'	Subsequent abnormal radiological investigations in ED *select all that apply*	checkbox 22 radio_test_in_ed_5___22 None 23 radio_test_in_ed_5___23 Other 8 radio_test_in_ed_5___8 Trauma panel 21 radio_test_in_ed_5___21 Chest xray 9 radio_test_in_ed_5___9 Chest ultrasound 10 radio_test_in_ed_5___10 Chest MRI 11 radio_test_in_ed_5___11 Chest CT 12 radio_test_in_ed_5___12 Abdo xray 13 radio_test_in_ed_5___13 Abdo ultrasound 14 radio_test_in_ed_5___14 Abdo MRI 15 radio_test_in_ed_5___15 Abdo CT 16 radio_test_in_ed_5___16 Head xray 17 radio_test_in_ed_5___17 Head MRI 18 radio_test_in_ed_5___18 Head CT 20 radio_test_in_ed_5___20 Interventional radiology
138	[subq_treat_comment]	COMMENT: Subsequent or ongoing ED treatments or investigations	text
139	[subsequent_secondary_ed_treatment_or_investigation_complete]	Section Header: *Form Status* Complete?	dropdown 0 Incomplete 1 Unverified 2 Complete
Instrument: Medications in ED (medications_in_ed)			
140	[p23]	Respiratory Support Research	descriptive
141	[patient_received_ed_medi]	Section Header: *Medications in ED* Medications provided in ED?	yesno, Required 1 Yes 0 No Custom alignment: RH
142	[allergy_ed_med_2] Show the field ONLY if: [patient_received_ed_medi] = '1'	ANTIALLERGICS AND MEDICINES USED IN ANAPHYLAXIS	yesno 1 Yes 0 No Custom alignment: RH
143	[anticonvul_ed_med_2] Show the field ONLY if: [patient_received_ed_medi] = '1'	ANTICONVULSANTS / ANTIEPILEPTICS	yesno 1 Yes 0 No Custom alignment: RH

144	[antidote_poison_ed_med_2] Show the field ONLY if: [patient_received_ed_medi] = '1'	ANTIDOTES AND OTHER SUBSTANCES FOR POISONINGS	yesno 1 Yes 0 No Custom alignment: RH
145	[anti_infect_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	ANTI-INFECTIVE	yesno 1 Yes 0 No Custom alignment: RH
146	[anti_infect_ed_med_2] Show the field ONLY if: [anti_infect_ed_med] = '1'		checkbox 247 anti_infect_ed_med_2___247 Anthelmintics 248 anti_infect_ed_med_2___248 Antibacterials 249 anti_infect_ed_med_2___249 Antifungal medicines 250 anti_infect_ed_med_2___250 Antiviral medicines 251 anti_infect_ed_med_2___251 Antiprotozoal medicines 252 anti_infect_ed_med_2___252 Medicines for ectoparasitic infections 253 anti_infect_ed_med_2___253 Other Custom alignment: LV
147	[antimigrane_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	ANTIMIGRAINE	yesno 1 Yes 0 No Custom alignment: RH
148	[antimigrane_ed_med_2] Show the field ONLY if: [antimigrane_ed_med] = '1'		checkbox 254 antimigrane_ed_med_2___254 For treatment of acute attack 255 antimigrane_ed_med_2___255 For prophylaxis 256 antimigrane_ed_med_2___256 Other Custom alignment: LV
149	[antiparkin_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	ANTIPARKINSONISM	yesno 1 Yes 0 No Custom alignment: RH
150	[antisept_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	ANTISEPTICS AND DISINFECTANTS	yesno 1 Yes 0 No Custom alignment: RH
151	[antisept_ed_med_4] Show the field ONLY if: [antisept_ed_med] = '1'		checkbox 284 antisept_ed_med_4___284 Antiseptics 285 antisept_ed_med_4___285 Disinfectants 286 antisept_ed_med_4___286 Other Custom alignment: LV
152	[blood_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	BLOOD PRODUCT OR TREATMENT	yesno 1 Yes 0 No Custom alignment: RH

153	[blood_ed_med_2] Show the field ONLY if: [blood_ed_med] = '1'		checkbox 1 blood_ed_med_2___1 Blood and blood components 2 blood_ed_med_2___2 Plasma-derived 3 blood_ed_med_2___3 Plasma substitutes 5 blood_ed_med_2___5 Antianaemia medicines 6 blood_ed_med_2___6 Medicines affecting coagulation 4 blood_ed_med_2___4 Other Custom alignment: LV
154	[cardiovascular_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	CARDIOVASCULAR	yesno 1 Yes 0 No Custom alignment: RH
155	[cardiovascular_ed_med_2] Show the field ONLY if: [cardiovascular_ed_med] = '1'		checkbox 1 cardiovascular_ed_med_2___1 Antianginal 2 cardiovascular_ed_med_2___2 Antiarrhythmic 3 cardiovascular_ed_med_2___3 Antihypertensive 4 cardiovascular_ed_med_2___4 Heart failure 5 cardiovascular_ed_med_2___5 Antithrombotic medicines 8 cardiovascular_ed_med_2___8 Inotropes eg adrenaline 6 cardiovascular_ed_med_2___6 Lipid-lowering agents 7 cardiovascular_ed_med_2___7 Other Custom alignment: LV
156	[dental_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	DENTAL PREPARATIONS	yesno 1 Yes 0 No Custom alignment: RH
157	[dermatological_ed_med_3] Show the field ONLY if: [patient_received_ed_medi] = '1'	DERMATOLOGICAL	yesno 1 Yes 0 No Custom alignment: RH
158	[dermatological_ed_med_4] Show the field ONLY if: [dermatological_ed_med_3] = '1'		checkbox 1 dermatological_ed_med_4___1 Antifungal 2 dermatological_ed_med_4___2 Anti-infective 3 dermatological_ed_med_4___3 Anti-inflammatory and antipruritic 4 dermatological_ed_med_4___4 Medicines affecting skin differentiation and proliferation 5 dermatological_ed_med_4___5 Other Custom alignment: LV
159	[diagnost_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	DIAGNOSTIC AGENTS	yesno 1 Yes 0 No Custom alignment: RH
160	[endocrine_disorders_ed_3] Show the field ONLY if: [patient_received_ed_medi] = '1'	ENDOCRINE DISORDERS	yesno 1 Yes 0 No Custom alignment: RH

161	[endocr_disorders_ed_med4] Show the field ONLY if: [endocrine_disorders_ed_3] = '1'		checkbox 1 endocr_disorders_ed_med4___1 Adrenal hormones and synthetic substitutes 2 endocr_disorders_ed_med4___2 Androgens 3 endocr_disorders_ed_med4___3 Oestrogens 4 endocr_disorders_ed_med4___4 Progestogens 5 endocr_disorders_ed_med4___5 Diabetes 6 endocr_disorders_ed_med4___6 Thyroid hormones and antithyroid medicines 7 endocr_disorders_ed_med4___7 Other Custom alignment: LV
162	[gastrointest_ed_medicines] Show the field ONLY if: [patient_received_ed_medi] = '1'	GASTROINTESTINAL	yesno 1 Yes 0 No Custom alignment: RH
163	[gastrointest_ed_med_2] Show the field ONLY if: [gastrointest_ed_medicines] = '1'		checkbox 1 gastrointest_ed_med_2___1 Antiulcer 2 gastrointest_ed_med_2___2 Antiemetic 3 gastrointest_ed_med_2___3 Anti-inflammatory 4 gastrointest_ed_med_2___4 Laxatives 5 gastrointest_ed_med_2___5 Diarrhoea 6 gastrointest_ed_med_2___6 Other Custom alignment: LV
164	[ga_ed_med_2] Show the field ONLY if: [patient_received_ed_medi] = '1'	GENERAL ANAESTHETICS	yesno 1 Yes 0 No Custom alignment: RH
165	[homeo_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	HOMEOPATHICS HERBAL REMEDIES	yesno 1 Yes 0 No Custom alignment: RH
166	[immunology_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	IMMUNIODULATORS AND ANTINEOPLASTICS	yesno 1 Yes 0 No Custom alignment: RH
167	[immunology_ed_med_2] Show the field ONLY if: [immunology_ed_med] = '1'		checkbox 257 immunology_ed_med_2___257 Immunomodulators for non-malignant disease 258 immunology_ed_med_2___258 Antineoplastics and supportive medicines Custom alignment: LV
168	[joint_dis_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	JOINT DISEASE	yesno 1 Yes 0 No Custom alignment: RH

169	[joint_dis_ed_med_2] Show the field ONLY if: [joint_dis_ed_med] = '1'		checkbox 229 joint_dis_ed_med_2___229 Gout 230 joint_dis_ed_med_2___230 Rheumatoid disorders 231 joint_dis_ed_med_2___231 Juvenile joint diseases Custom alignment: LV
170	[local_anaeth_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	LOCAL ANAESTHETICS	yesno 1 Yes 0 No Custom alignment: RH
171	[medical_gas_ed_med_2] Show the field ONLY if: [patient_received_ed_medi] = '1'	MEDICAL GASES	yesno 1 Yes 0 No Custom alignment: RH
172	[pain_palliat_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	PAIN AND PALLIATIVE CARE	yesno 1 Yes 0 No Custom alignment: RH
173	[pain_palliat_ed_med_2] Show the field ONLY if: [pain_palliat_ed_med] = '1'		checkbox 238 pain_palliat_ed_med_2___238 Non-opioids and non-steroidal anti-inflammatory medicines (NSAIMs) 239 pain_palliat_ed_med_2___239 Opioid analgesics 240 pain_palliat_ed_med_2___240 Medicines for other common symptoms in palliative care 241 pain_palliat_ed_med_2___241 Other Custom alignment: LV
174	[mental_behav_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	MENTAL AND BEHAVIOURAL	yesno 1 Yes 0 No Custom alignment: RH
175	[mental_behav_ed_med_2] Show the field ONLY if: [mental_behav_ed_med] = '1'		checkbox 312 mental_behav_ed_med_2___312 Psychotic disorders 313 mental_behav_ed_med_2___313 Mood disorders 314 mental_behav_ed_med_2___314 Anxiety disorders 315 mental_behav_ed_med_2___315 Obsessive compulsive disorders 316 mental_behav_ed_med_2___316 Psychoactive substance use Custom alignment: LV
176	[mus_relax_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	MUSCLE RELAXANTS peripherally-acting and cholinesterase inhibitors	yesno 1 Yes 0 No Custom alignment: RH

177	[oncology_ed_med] Show the field ONLY if: [patient_received_ed_med] = '1'	ONCOLOGY	yesno 1 Yes 0 No Custom alignment: RH
178	[ophthal_ed_med] Show the field ONLY if: [patient_received_ed_med] = '1'	OPHTHALMOLOGY	yesno 1 Yes 0 No Custom alignment: RH
179	[dialysis_ed_med] Show the field ONLY if: [patient_received_ed_med] = '1'	PERITONEAL DIALYSIS SOLUTION	yesno 1 Yes 0 No Custom alignment: RH
180	[reproduct_ed_med] Show the field ONLY if: [patient_received_ed_med] = '1'	REPRODUCTIVE HEALTH AND PERINATAL CARE	yesno 1 Yes 0 No Custom alignment: RH
181	[reproduct_ed_med_2] Show the field ONLY if: [reproduct_ed_med] = '1'		checkbox 306 reproduct_ed_med_2___306 Contraceptives 307 reproduct_ed_med_2___307 Ovulation inducers 308 reproduct_ed_med_2___308 Uterotonics 309 reproduct_ed_med_2___309 Antioxytocics (tocolytics) Custom alignment: LV
182	[resp_ed_med_4] Show the field ONLY if: [patient_received_ed_med] = '1'	RESPIRATORY	yesno 1 Yes 0 No Custom alignment: RH
183	[resp_ed_med_2] Show the field ONLY if: [resp_ed_med_4] = '1'		checkbox 323 resp_ed_med_2___323 antiasthmatic combinations 324 resp_ed_med_2___324 antihistamines 325 resp_ed_med_2___325 antitussives 326 resp_ed_med_2___326 bronchodilators 331 resp_ed_med_2___331 decongestants 332 resp_ed_med_2___332 expectorants 333 resp_ed_med_2___333 leukotriene modifiers 334 resp_ed_med_2___334 lung surfactants 335 resp_ed_med_2___335 miscellaneous respiratory agents 336 resp_ed_med_2___336 mucolytics 337 resp_ed_med_2___337 respiratory inhalant products 341 resp_ed_med_2___341 selective phosphodiesterase-4 inhibitors 342 resp_ed_med_2___342 upper respiratory combinations 321 resp_ed_med_2___321 Other Custom alignment: LV
184	[sedation_ed_med] Show the field ONLY if: [patient_received_ed_med] = '1'	SEDATION	yesno 1 Yes 0 No Custom alignment: RH

194	[escalation_rs_in_ed]	Section Header: *Escalation of respiratory support in ED* Escalation of respiratory support required in ED	yesno, Required 1 Yes 0 No Custom alignment: RH
195	[reason_for_rs_escalt_in_ed] Show the field ONLY if: [escalation_rs_in_ed]='1'	Reason for escalation of respiratory support required in ED *select all those that apply*	checkbox, Required 1 reason_for_rs_escalt_in_ed___1 None 10 reason_for_rs_escalt_in_ed___10 Other 11 reason_for_rs_escalt_in_ed___11 Unknown 12 reason_for_rs_escalt_in_ed___12 Patient feels unwell 2 reason_for_rs_escalt_in_ed___2 ED staff concerned 3 reason_for_rs_escalt_in_ed___3 Patient failed to respond to current therapy 4 reason_for_rs_escalt_in_ed___4 Patient clinical signs have deteriorated 5 reason_for_rs_escalt_in_ed___5 Patient vital signs have deteriorated 8 reason_for_rs_escalt_in_ed___8 Procedural 9 reason_for_rs_escalt_in_ed___9 Rapid sequence intubation
196	[first_escal_rs_in_ed_4] Show the field ONLY if: [escalation_rs_in_ed]='1'	First type of escalation of respiratory support in ED *select one*	radio, Required 8 None 33 Other 34 Standard O2 mask to nebuliser 9 Standard O2 mask to NHF 10 Standard O2 mask to NIV 11 Standard O2 mask to BiPAP 12 Standard O2 mask to INV or Trach 32 Standard O2 cannula to standard mask 13 Standard O2 cannula to nebuliser 14 Standard O2 cannula to NHF 15 Standard O2 cannula to NIV 16 Standard O2 cannula to BiPAP 29 Standard O2 cannula to CPAP 17 Standard O2 cannula to INV or Trach 18 Venturi mask to nebuliser 19 Venturi mask to NHF 20 Venturi mask to NIV 21 Venturi mask to BiPAP 30 Venturi mask to CPAP 22 Venturi mask to INV or Trach 23 NHF to NIV 24 NHF to BiPAP 31 NHF to CPAP 25 NHF to INV or Trach 26 NIV to INV or Trach

185	[solutions_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	SOLUTIONS FOR CORRECTING WATER ELECTROLYTE AND ACID BASE DISTURBANCE	yesno 1 Yes 0 No Custom alignment: RH
186	[solutions_ed_med_3] Show the field ONLY if: [solutions_ed_med] = '1'		checkbox 211 solutions_ed_med_3___211 Oral 212 solutions_ed_med_3___212 Parenteral 328 solutions_ed_med_3___328 IV 213 solutions_ed_med_3___213 Miscellaneous Custom alignment: LV
187	[vaccine_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	VACCINES	text
188	[vitamins_ed_med] Show the field ONLY if: [patient_received_ed_medi] = '1'	VITAMINS AND MINERALS	yesno 1 Yes 0 No Custom alignment: RH
189	[other_ed_meds_not_listed] Show the field ONLY if: [patient_received_ed_medi] = '1'	OTHER MEDICATIONS NOT LISTED	text Custom alignment: LV
190	[medications_in_ed_complete]	Section Header: *Form Status* Complete?	dropdown 0 Incomplete 1 Unverified 2 Complete
Instrument: Respiratory Support in ED (respiratory_support_in_ed)			
191	[p24]	Respiratory Support Research	descriptive
192	[type_of_rs_ed_2]	Section Header: *Respiratory Support In ED* Respiratory support provided in ED *select all that apply*	checkbox, Required 11 type_of_rs_ed_2___11 Other 3 type_of_rs_ed_2___3 Venturi mask or similar 4 type_of_rs_ed_2___4 Standard low flow oxygen mask < 15 Lmin 9 type_of_rs_ed_2___9 Standard low flow oxygen prongs < 15 Lmin 5 type_of_rs_ed_2___5 NIV 6 type_of_rs_ed_2___6 NHF 10 type_of_rs_ed_2___10 Humidified Face mask 7 type_of_rs_ed_2___7 INV Endotrach 8 type_of_rs_ed_2___8 INV Trach
193	[cause_of_rs_requirement_whilst_in_ed]	Underlying cause of respiratory support requirement whilst in ED *select all that apply*	checkbox, Required 1 cause_of_rs_requirement_whilst_in_ed___1 Other 9 cause_of_rs_requirement_whilst_in_ed___9 Cardiac 2 cause_of_rs_requirement_whilst_in_ed___2 Respirator 3 cause_of_rs_requirement_whilst_in_ed___3 Combined Cardiac ar Respirator 4 cause_of_rs_requirement_whilst_in_ed___4 Chronic us (domicil ar 7 cause_of_rs_requirement_whilst_in_ed___7 Procedura 8 cause_of_rs_requirement_whilst_in_ed___8 Rapid sequence intubatior 6 cause_of_rs_requirement_whilst_in_ed___6 Unknown

194	[escalation_rs_in_ed]	Section Header: *Escalation of respiratory support in ED* Escalation of respiratory support required in ED	yesno, Required 1 Yes 0 No Custom alignment: RH
195	[reason_for_rs_escalt_in_ed] Show the field ONLY if: [escalation_rs_in_ed]='1'	Reason for escalation of respiratory support required in ED *select all those that apply*	checkbox, Required 1 reason_for_rs_escalt_in_ed___1 None 10 reason_for_rs_escalt_in_ed___10 Other 11 reason_for_rs_escalt_in_ed___11 Unknown 12 reason_for_rs_escalt_in_ed___12 Patient feels unwell 2 reason_for_rs_escalt_in_ed___2 ED staff concerned 3 reason_for_rs_escalt_in_ed___3 Patient failed to respond to current therapy 4 reason_for_rs_escalt_in_ed___4 Patient clinical signs have deteriorated 5 reason_for_rs_escalt_in_ed___5 Patient vital signs have deteriorated 8 reason_for_rs_escalt_in_ed___8 Procedural 9 reason_for_rs_escalt_in_ed___9 Rapid sequence intubation
196	[first_escal_rs_in_ed_4] Show the field ONLY if: [escalation_rs_in_ed]='1'	First type of escalation of respiratory support in ED *select one*	radio, Required 8 None 33 Other 34 Standard O2 mask to nebuliser 9 Standard O2 mask to NHF 10 Standard O2 mask to NIV 11 Standard O2 mask to BiPAP 12 Standard O2 mask to INV or Trach 32 Standard O2 cannula to standard mask 13 Standard O2 cannula to nebuliser 14 Standard O2 cannula to NHF 15 Standard O2 cannula to NIV 16 Standard O2 cannula to BiPAP 29 Standard O2 cannula to CPAP 17 Standard O2 cannula to INV or Trach 18 Venturi mask to nebuliser 19 Venturi mask to NHF 20 Venturi mask to NIV 21 Venturi mask to BiPAP 30 Venturi mask to CPAP 22 Venturi mask to INV or Trach 23 NHF to NIV 24 NHF to BiPAP 31 NHF to CPAP 25 NHF to INV or Trach 26 NIV to INV or Trach

197	[sec_escal_rs_in_ed_6] Show the field ONLY if: [escalation_rs_in_ed]='1'	Second type of escalation of respiratory support in ED *select one*	radio, Required 32 None 33 Other 8 Standard O2 mask to nebuliser 9 Standard O2 mask to NHF 10 Standard O2 mask to NIV 11 Standard O2 mask to BiPAP 12 Standard O2 mask to INV or Trach 13 Standard O2 cannula to nebuliser 14 Standard O2 cannula to NHF 15 Standard O2 cannula to NIV 16 Standard O2 cannula to BiPAP 29 Standard O2 cannula to CPAP 17 Standard O2 cannula to INV or Trach 18 Venturi mask to nebuliser 19 Venturi mask to NHF 20 Venturi mask to NIV 21 Venturi mask to BiPAP 30 Venturi mask to CPAP 22 Venturi mask to INV or Trach 23 NHF to NIV 24 NHF to BiPAP 31 NHF to CPAP 25 NHF to INV or Trach 26 NIV to INV or Trach
198	[deescal_rs_in_ed_5]	Section Header: *Deescalation of respiratory support in ED* Deescalation of respiratory support in ED	yesno, Required 1 Yes 0 No Custom alignment: RH

199	[rs_used_in_desc_ed_7] Show the field ONLY if: [deescal_rs_in_ed_5] = '1'	Type of deescalation of respiratory support in ED *select one*	radio, Required 33 None 34 Other 8 Nebuliser to Standard O2 mask 9 NHF to Standard O2 mask 10 NIV to Standard O2 mask 11 BiPAP to Standard O2 mask 12 INV or Trach Standard O2 mask 13 Nebuliser to Standard O2 cannula 32 Standard O2 mask to Standard O2 cannula 14 NHF to Standard O2 cannula 15 NIV to Standard O2 cannula 16 BiPAP to Standard O2 cannula 29 CPAP to Standard O2 cannula 17 INV to Trach Standard O2 cannula 18 Nebuliser to Venturi mask 19 NHF to Venturi mask 20 NIV to Venturi mask 21 BiPAP to Venturi mask 30 CPAP to Venturi mask 22 INV or Trach to Venturi mask 23 NIV to NHF 24 BiPAP to NHF 31 CPAP to NHF 25 INV or Trach to NHF 26 INV or Trach to NHF NHF
200	[rs_requir_dsch]	Section Header: *Respiratory support on ED discharge* Respiratory support required on ED discharge	yesno, Required 1 Yes 0 No Custom alignment: RH
201	[rs_on_ed_discharge] Show the field ONLY if: [rs_requir_dsch] = '1'	Respiratory support on ED discharge *select one*	radio, Required 2 None 11 Other 3 Venturi mask or similar 4 Standard low flow oxygen mask < 15 Lmin 9 Standard low flow oxygen prongs < 15 Lmin 5 NIV 6 NHF 10 Humidified Face mask 7 INV Endotrach 8 INV Trach
202	[respiratory_support_in_ed_complete]	Section Header: *Form Status* Complete?	dropdown 0 Incomplete 1 Unverified 2 Complete
Instrument: **Nasal High Flow Therapy in ED** (nasal_high_flow_therapy_in_ed)			
203	[p26]	Respiratory Support Research	descriptive
204	[nhf_in_ed_df0a13] Show the field ONLY if: [type_of_rs_ed_2(6)] = '1'	Section Header: *Nasal High Flow (NHF) Therapy in ED* Received NHF in ED	yesno 1 Yes 0 No Custom alignment: RH

205	[nhf_ration_d4ac10] Show the field ONLY if: [nhf_in_ed_df0a13] = '1'	Rationale for NHF use *select all that apply*	checkbox, Required 16 nhf_ration_d4ac10___16 None 17 nhf_ration_d4ac10___17 Other 1 nhf_ration_d4ac10___1 Rapid sequence intubation 2 nhf_ration_d4ac10___2 Conscious / procedural sedation 3 nhf_ration_d4ac10___3 Reduce work of breathing 4 nhf_ration_d4ac10___4 Improve oxygenation 5 nhf_ration_d4ac10___5 Improve hypercapnea 6 nhf_ration_d4ac10___6 Reduce respiratory rate 7 nhf_ration_d4ac10___7 Airway humidification 8 nhf_ration_d4ac10___8 CPAP effect 9 nhf_ration_d4ac10___9 Comfort 10 nhf_ration_d4ac10___10 NIV rest therapy 11 nhf_ration_d4ac10___11 Other RS therapy intolerance 13 nhf_ration_d4ac10___13 Clinician preference 15 nhf_ration_d4ac10___15 Patient preference 14 nhf_ration_d4ac10___14 Logistical / resource issues
206	[nhf_discon_2_5ee697] Show the field ONLY if: [nhf_in_ed_df0a13] = '1'	Was NHF discontinued in ED	yesno, Required 1 Yes 0 No Custom alignment: RH
207	[nhf_discon_3] Show the field ONLY if: [nhf_discon_2_5ee697] = '1' and [nhf_in_ed_df0a13] = '1'	Rationale for NHF discontinuation *select all those that apply*	checkbox, Required 18 nhf_discon_3___18 None 19 nhf_discon_3___19 Other 16 nhf_discon_3___16 Not discontinued 1 nhf_discon_3___1 Escalation of RS required to another RS e.g. NIV 15 nhf_discon_3___15 RSI 2 nhf_discon_3___2 Conscious / procedural sedation 3 nhf_discon_3___3 Reduce work of breathing 4 nhf_discon_3___4 Improve oxygenation 5 nhf_discon_3___5 Improve hypercapnea 6 nhf_discon_3___6 Reduce RR 7 nhf_discon_3___7 Airway humidification 8 nhf_discon_3___8 CPAP effect 9 nhf_discon_3___9 Comfort 10 nhf_discon_3___10 NIV rest therapy 11 nhf_discon_3___11 NHF intolerance 13 nhf_discon_3___13 Clinician preference 17 nhf_discon_3___17 Patient preference 14 nhf_discon_3___14 Logistical / resource issues
208	[nhf_ae_b6a3b1] Show the field ONLY if: [nhf_in_ed_df0a13] = '1'	NHF related adverse effects	radio, Required NHF-related1 None 2 Yes minor, NHF continued 3 Major, NHF discontinued
209	[comment_on_ae_associated_w] Show the field ONLY if: [nhf_ae_b6a3b1] = '3' or [nhf_ae_b6a3b1] = '2' or [nhf_ae_b6a3b1] = '2' or [nhf_ae_b6a3b1] = 'NHF-related1' and [nhf_in_ed_df0a13] = '1'	COMMENT adverse events associated with NHF	notes

210	[when_nhf_commence] Show the field ONLY if: [nhf_in_ed_df0a13] = '1'	When was NHF commenced during ED admission? *select one*	dropdown 1 within 1st hour of ED admission 2 within 2nd hour of ED admission 3 within 3rd hour of ED admission 4 within 4th hour of ED admission 5 after more than four hours post ED admission
211	[first_hour_nhf_delivery] Show the field ONLY if: [nhf_in_ed_df0a13] = '1'	Section Header: *NHF delivery 1st hour* 1st hour of NHF delivery	yesno 1 Yes 0 No Custom alignment: RH
212	[fio2_1hr] Show the field ONLY if: [first_hour_nhf_delivery] = '1' and [nhf_in_ed_df0a13] = '1'	FiO2 delivered during 1st hour of NHF *0.21 TO 1.0 average*	text (number, Min: 0.21, Max: 1.0), Required
213	[gasflow_1hr] Show the field ONLY if: [first_hour_nhf_delivery] = '1' and [nhf_in_ed_df0a13] = '1'	Gas flow delivered during 1st hour of NHF *L/ Min, average*	text (number, Min: 10, Max: 150), Required
214	[highest_rr_1hr] Show the field ONLY if: [first_hour_nhf_delivery] = '1' and [nhf_in_ed_df0a13] = '1'	Highest RR during 1st hour of NHF	text (number, Min: 0, Max: 50), Required
215	[lowest_rr_1hr_2] Show the field ONLY if: [first_hour_nhf_delivery] = '1' and [nhf_in_ed_df0a13] = '1'	Lowest RR during 1st hour of NHF	text (number, Min: 0, Max: 50), Required
216	[spo2_low_1hr] Show the field ONLY if: [first_hour_nhf_delivery] = '1' and [nhf_in_ed_df0a13] = '1'	Lowest SpO2 during 1st hour of NHF *%*	text (number, Min: 20, Max: 100), Required
217	[spo2_high_1hr_2] Show the field ONLY if: [first_hour_nhf_delivery] = '1' and [nhf_in_ed_df0a13] = '1'	Highest SpO2 during 1st hour of NHF *%*	text (number, Min: 20, Max: 100), Required
218	[highest_hr_1hr] Show the field ONLY if: [first_hour_nhf_delivery] = '1' and [nhf_in_ed_df0a13] = '1'	Highest HR during 1st hour of NHF	text (number, Min: 0, Max: 300), Required
219	[lowest_hr_1hr] Show the field ONLY if: [first_hour_nhf_delivery] = '1' and [nhf_in_ed_df0a13] = '1'	Lowest HR during 1st hour of NHF	text (number, Min: 0, Max: 300), Required
220	[secon_hour_nhf_delivery_2] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1'	Section Header: *NHF delivery 2nd hour* 2nd hour of NHF delivery	yesno, Required 1 Yes 0 No Custom alignment: RH
221	[fio2_2hr] Show the field ONLY if: [secon_hour_nhf_delivery_2] = '1' and [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1'	FiO2 delivered during 2nd hour of NHF *0.21-1.0 average*	text (number, Min: 0.21, Max: 1.0)
222	[gasflow_2hr] Show the field ONLY if: [secon_hour_nhf_delivery_2] = '1' and [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1'	Gas flow delivered during 2nd hour of NHF *L/min , average*	text (number, Min: 5, Max: 150)

223	[highest_rr_2hr_3] Show the field ONLY if: [secon_hour_nhf_delivery_2] = '1' and [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1'	Highest RR during 2nd hour of NHF	text (number, Min: 0, Max: 50)
224	[lowest_rr_2hr_4] Show the field ONLY if: [secon_hour_nhf_delivery_2] = '1' and [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1'	Lowest RR during 2nd hour of NHF	text (number, Min: 0, Max: 50)
225	[highest_spo2_2hr] Show the field ONLY if: [secon_hour_nhf_delivery_2] = '1' and [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1'	Highest SpO2 during 2nd hour of NHF *%*	text (number, Min: 0, Max: 100)
226	[lowest_spo2_2hr_2] Show the field ONLY if: [secon_hour_nhf_delivery_2] = '1' and [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1'	Lowest SpO2 during 2nd hour of NHF *%*	text (number, Min: 0, Max: 100)
227	[highest_hr_2hr] Show the field ONLY if: [secon_hour_nhf_delivery_2] = '1' and [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1'	Highest HR during 2nd hour of NHF	text (number, Min: 0, Max: 300)
228	[lowest_hr_2hr_2] Show the field ONLY if: [secon_hour_nhf_delivery_2] = '1' and [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1'	Lowest HR during 2nd hour of NHF	text (number, Min: 0, Max: 300)
229	[rox_score_hr2] Show the field ONLY if: [secon_hour_nhf_delivery_2] = '1'	ROX score calculated at 2 hours of NHF (REDCAP calculation) *NO NOT CALCULATE*	calc
230	[third_hour_nhf_delivery_3] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1'	Section Header: *NHF delivery 3rd hour* 3rd hour of NHF delivery	yesno, Required 1 Yes 0 No Custom alignment: RH
231	[fio2_3hr_16] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1'	FiO2 delivered during 3rd hour of NHF *0.21-1.0 average*	text (number, Min: 0.21, Max: 1.0)
232	[gas_flow_3hr_34] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1'	Gas flow delivered during 3rd hour of NHF *L/min, average*	text (number, Min: 5, Max: 150)
233	[highest_rr_3hr] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1'	Highest RR during 3rd hour of NHF	text (number, Min: 0, Max: 50)

234	[lowest_rr_3hr_10] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1'	Lowest RR during 3rd hour of NHF	text (number, Min: 0, Max: 50)
235	[highest_spo2_3hr] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1'	Highest SpO2 during 3rd hour of NHF *%*	text (number, Min: 0, Max: 100)
236	[lowest_spo2_3hr_25] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1'	Lowest SpO2 during 3rd hour of NHF *%*	text (number, Min: 0, Max: 100)
237	[highest_hr_3hr_25] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1'	Highest HR during 3rd hour of NHF	text (number, Min: 0, Max: 300)
238	[lowest_hr_3hr] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1'	Lowest HR during 3rd hour of NHF	text (number, Min: 0, Max: 300)
239	[fourth_hour_nhf_delivery_4] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1'	Section Header: *NHF delivery 4th hour* 4th hour of NHF delivery	yesno, Required 1 Yes 0 No Custom alignment: RH
240	[fio2_4hr] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1' and [fourth_hour_nhf_delivery_4] = '1'	FiO2 delivered during 4th hour of NHF *0.21-1.0 average*	text (number, Min: 0.21, Max: 1.0)
241	[gasflow_4hr] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1' and [fourth_hour_nhf_delivery_4] = '1'	Gas flow delivered during 4th hour of NHF *L/min , average*	text (number, Min: 10, Max: 150)
242	[highest_rr_hr4] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1' and [fourth_hour_nhf_delivery_4] = '1'	Highest RR during hour 4 of NHF	text (number, Min: 0, Max: 50)

243	[lowest_rr_hr4] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1' and [fourth_hour_nhf_delivery_4] = '1'	Lowest RR during hour 4 of NHF	text (number, Min: 0, Max: 50)
244	[highest_spo2_4hr] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1' and [fourth_hour_nhf_delivery_4] = '1'	Highest SpO2 during hour 4 of NHF *%*	text (number, Min: 0, Max: 100)
245	[lowest_spo2_4hr_2] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1' and [fourth_hour_nhf_delivery_4] = '1'	Lowest SpO2 during hour 4 of NHF *%*	text (number, Min: 0, Max: 100)
246	[highest_hr_hr4] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1' and [fourth_hour_nhf_delivery_4] = '1'	Highest HR during hour 4 of NHF	text (number, Min: 0, Max: 300)
247	[lowest_hr_hr4] Show the field ONLY if: [nhf_in_ed_df0a13] = '1' and [first_hour_nhf_delivery] = '1' and [secon_hour_nhf_delivery_2] = '1' and [third_hour_nhf_delivery_3] = '1' and [fourth_hour_nhf_delivery_4] = '1'	Lowest HR during hour 4 of NHF	text (number, Min: 0, Max: 300)
248	[total_duration_of_nhf_de] Show the field ONLY if: [nhf_in_ed_df0a13] = '1'	Section Header: *NHF delivery on ED discharge* Total duration of NHF delivery whilst in ED	dropdown 1 Less than 30mins 2 Up to I hour 3 1-2 hours 4 2-3 hours 5 3-4 hours 6 More than 4 hours
249	[nhf_delivered_on_ed_discha] Show the field ONLY if: [nhf_in_ed_df0a13] = '1'	NHF delivered on ED discharge	yesno 1 Yes 0 No Custom alignment: RH
250	[fio2_ed_disch] Show the field ONLY if: [nhf_delivered_on_ed_discha] = '1' and [nhf_in_ed_df0a13] = '1'	FiO2 delivered on NHF at ED discharge *0.21-1.0*	text (number, Min: 0.21, Max: 1.0)
251	[gasflow_ed_disch] Show the field ONLY if: [nhf_delivered_on_ed_discha] = '1' and [nhf_in_ed_df0a13] = '1'	Gas flow delivered on NHF at ED discharge *L/min*	text (number, Min: 10, Max: 150)
252	[rr_ed_disch] Show the field ONLY if: [nhf_delivered_on_ed_discha] = '1' and [nhf_in_ed_df0a13] = '1'	RR on NHF at ED discharge	text (number, Min: 0, Max: 50)

253	[spo2_ed_disch] Show the field ONLY if: [nhf_delivered_on_ed_discha] = '1' and [nhf_in_ed_df0a13] = '1'	SpO2 on NHF at ED discharge %	text (number, Min: 0, Max: 100)
254	[hr_ed_disch] Show the field ONLY if: [nhf_delivered_on_ed_discha] = '1' and [nhf_in_ed_df0a13] = '1'	HR on NHF at ED discharge	text (number, Min: 0, Max: 300)
255	[comments_on_nhf_delivery_i] Show the field ONLY if: [nhf_in_ed_df0a13] = '1'	Comments on NHF delivery in ED	notes
256	[nasal_high_flow_therapy_in_ed_complete]	Section Header: *Form Status* Complete?	dropdown 0 Incomplete 1 Unverified 2 Complete
Instrument: ED diagnosis and or adverse events (ed_diagnosis_and_or_adverse_events)			
257	[p31]	Respiratory Support Research	descriptive
258	[sec_ed_diag_2]	Section Header: *ED Diagnosis* Primary ED diagnostic category *select one*	dropdown, Required 26 None 47 Other 48 Neurological 27 Eye 28 Ear, nose, mouth and throat 49 Respiratory 30 Cardiac or circulatory system 31 Digestive or gastrointestinal 32 Hepatobiliary system or pancreas 33 Musculoskeletal system or connective tissue 34 Skin, subcutaneous tissue or breast Endocrine nutritional and metabolic 35 Renal, kidney or urinary tract 37 Reproductive Pregnancy childbirth or puerperium 38 Blood, blood-forming organs or immunological disorders 39 Neoplastic disorders (haematological and solid neoplasm's) 40 Infectious and parasitic diseases (systemic or unspecified sites) 41 Mental health 42 Alcohol/drug use and alcohol/drug-induced organic mental conditions Injuries poisoning and toxic effects of drugs 43 Burns 44 Factors influencing health status and other contacts with health services
259	[prim_dig]	ED primary diagnosis	text, Required

260	[sec_ed_diag_3]	Secondary ED diagnostic categories *select all those that apply*	checkbox 26 sec_ed_diag_3___26 None 47 sec_ed_diag_3___47 Other 48 sec_ed_diag_3___48 Neurological 27 sec_ed_diag_3___27 Eye 28 sec_ed_diag_3___28 Ear, nose, mouth and throat 49 sec_ed_diag_3___49 Respiratory 30 sec_ed_diag_3___30 Cardiac or circulatory system 31 sec_ed_diag_3___31 Digestive or gastrointestinal 32 sec_ed_diag_3___32 Hepatobiliary system or pancreas 33 sec_ed_diag_3___33 Musculoskeletal system or connective tissue 34 sec_ed_diag_3___34 Skin, subcutaneous tissue or breast 50 sec_ed_diag_3___50 Endocrine, nutritional and metabolic 35 sec_ed_diag_3___35 Renal, kidney or urinary tract 37 sec_ed_diag_3___37 Reproductive 38 sec_ed_diag_3___38 Blood, blood-forming organs or immunological disorders 39 sec_ed_diag_3___39 Neoplastic disorders (haematological and solid neoplasm's) 40 sec_ed_diag_3___40 Infectious and parasitic diseases (systemic or unspecified sites) 41 sec_ed_diag_3___41 Mental health 42 sec_ed_diag_3___42 Alcohol/drug use and alcohol/drug-induced organic mental conditions 52 sec_ed_diag_3___52 Injuries or poisoning or toxic effects of drugs 43 sec_ed_diag_3___43 Burns 51 sec_ed_diag_3___51 Pregnancy or childbirth or puerperium 44 sec_ed_diag_3___44 Factors influencing health status and other contacts with health services
261	[prim_dig_2]	ED secondary diagnoses	text
262	[ae_in_ed]	Section Header: *ED Adverse Event* Adverse event in ED	dropdown, Required 1 Yes 2 No 3 Unknown
263	[comment_ae] Show the field ONLY if: [ae_in_ed] = '1'	Comments re ED adverse event	notes
264	[ed_diagnosis_and_or_adverse_events_complete]	Section Header: *Form Status* Complete?	dropdown 0 Incomplete 1 Unverified 2 Complete
Instrument: ED discharge status (ed_discharge_status)			
265	[p32]	Respiratory Support Research	descriptive
266	[did_the_patient_die_in_the]	Section Header: *ED Discharge* Did the patient die in the ED	yesno, Required 1 Yes 0 No

267	[ed_discharge_time_2] Show the field ONLY if: [did_the_patient_die_in_the] = '1'	Date and time of death	text (datetime_dmy), Required
268	[service_dis] Show the field ONLY if: [did_the_patient_die_in_the] = '0'	Speciality (hospital admission)	dropdown, Required 1 None 2 OG 3 ICU 4 Gen Med 5 Resp 6 Gen Sur 7 OT 8 ENT 9 Home 10 Renal 11 CCU 12 HDU 13 Other 14 Older persons health 15 Mental Hlth
269	[ed_discharge_destination] Show the field ONLY if: [did_the_patient_die_in_the] = '0'	ED discharge destination	dropdown, Required 1 Destination Home 2 Destination Home via ED short stay 3 In patient ward >24 hours 4 HDU 5 ICU 6 OT 7 Another hospital 8 Another care facility eg rest home 9 Self discharge against advice 10 Death in ED
270	[ed_discharge_time_3] Show the field ONLY if: [did_the_patient_die_in_the] = '0'	Time and date when declared ready for ED discharge	text (datetime_dmy), Required
271	[ed_discharge_time] Show the field ONLY if: [did_the_patient_die_in_the] = '0'	ED discharge time actual	text (datetime_dmy), Required
272	[ed_discharge_status_complete]	Section Header: *Form Status* Complete?	dropdown 0 Incomplete 1 Unverified 2 Complete
Instrument: **Hospital discharge following this ED admission** (hospital_discharge_following_this_ed_admission)			
273	[p33]	Respiratory Support Research	descriptive
274	[has_the_patient_been_disch]	Section Header: *Hospital discharge status at 30 days post ED admission* Has the patient been discharged from hospital within 30 days of this ED admission?	yesno, Required 1 Yes 0 No Custom alignment: RH
275	[hosp_disch_date] Show the field ONLY if: [has_the_patient_been_disch] = '1'	Hospital discharge date	text (date_dmy), Required
276	[hosp_los] Show the field ONLY if: [has_the_patient_been_disch] = '1'	Hospital length of stay in days (ED & Hosp combined)	text, Required

277	[hosp_dis] Show the field ONLY if: [has_the_patient_been_disch] = '1'	Hosp discharge diagnosis category (disease or disorder) *select all that apply*	checkbox, Required		
			1	hosp_dis___1	None
			24	hosp_dis___24	Other
			25	hosp_dis___25	Neurological
			2	hosp_dis___2	Eye
			3	hosp_dis___3	Ear, nose, mouth or throat
			4	hosp_dis___4	Respiratory
			5	hosp_dis___5	Cardiac or circulatory system
			6	hosp_dis___6	Gastrointestinal or digestive system
			7	hosp_dis___7	Hepatobiliary system or pancreas
			8	hosp_dis___8	Musculoskeletal system or connective tissue
			9	hosp_dis___9	Skin, subcutaneous tissue or breast
			Endocrine	hosp_dis___endocrine	nutritional and metabolic diseases and disorders
			10	hosp_dis___10	Renal , kidney and urinary tract
			26	hosp_dis___26	Reproductive
			Pregnancy	hosp_dis___pregnancy	childbirth and the puerperium
			13	hosp_dis___13	Blood, blood-forming organs and immunological disorders
			14	hosp_dis___14	Neoplastic disorders (haematological and solid neoplasm's)
			15	hosp_dis___15	Infectious and parasitic diseases (systemic or unspecified sites)
			16	hosp_dis___16	Mental health
			17	hosp_dis___17	Alcohol/drug use and alcohol/drug-induced organic mental conditions
			Injuries	hosp_dis___injuries	poisoning or toxic effects of drugs
			18	hosp_dis___18	Burns
			19	hosp_dis___19	Factors influencing health status and other contacts with health service
			22	hosp_dis___22	Dead
			23	hosp_dis___23	Still inpatient at 30 days post ED admission

278	[hosp_disch_diag_comment] Show the field ONLY if: [has_the_patient_been_disch] = '1'	Hospital discharge diagnosis comments	notes
279	[hosp_dish_dest] Show the field ONLY if: [has_the_patient_been_disch] = '1'	Hospital discharge destination	dropdown, Required 1 Destination Home 2 Another hospital 3 Self discharge against advice 4 Death in hospital 5 Another care facility eg rest home 6 Unknown 7 Still inpatient at 30 days post ED admission
280	[hospital_discharge_following_this_ed_admission_complete]	Section Header: *Form Status* Complete?	dropdown 0 Incomplete 1 Unverified 2 Complete
Instrument: Study completion status (study_completion_status)			
281	[p34]	Respiratory Support Research	descriptive
282	[complete_study_auto]	Section Header: *Study Completion Information* complete study (auto)	calc Calculation: if([medications_in_ed_complete]='2' and [preliminary_screening_complete]='2' and [patients_basic_information_pre_diagnosis_complete]='2' and [ed_treatment_or_investigation_complete]='2' and [subsequent_ed_treatment_or_investigation_complete]='2' and [medications_in_ed_complete]='2' and [respiratory_support_in_ed_complete]='2' and [nasal_high_flow_nhf_therapy_in_ed_complete]='2' and [ed_diagnosis_complete]='2' and [ed_adverse_event_complete]='2' and [ed_discharge_complete]='2' and [hospital_discharge_complete]='2',1,0) Field Annotation: @HIDDEN
283	[complete_study_1] Show the field ONLY if: [complete_study_auto]='1'	Patient data entry been completed.	descriptive
284	[complete_study_2] Show the field ONLY if: [complete_study_auto]='0'	Patient data entry incomplete!	descriptive
285	[complete_study]	Has patient data entry been completed?	radio, Required 0 No 1 Yes Field Annotation: @HIDDEN
286	[comment]	Comment	notes
287	[complete_study_date]	Date of study data entry completion	text (date_ymd)
288	[study_comments]	Comments	notes
289	[study_completion_status_complete]	Section Header: *Form Status* Complete?	dropdown 0 Incomplete 1 Unverified 2 Complete

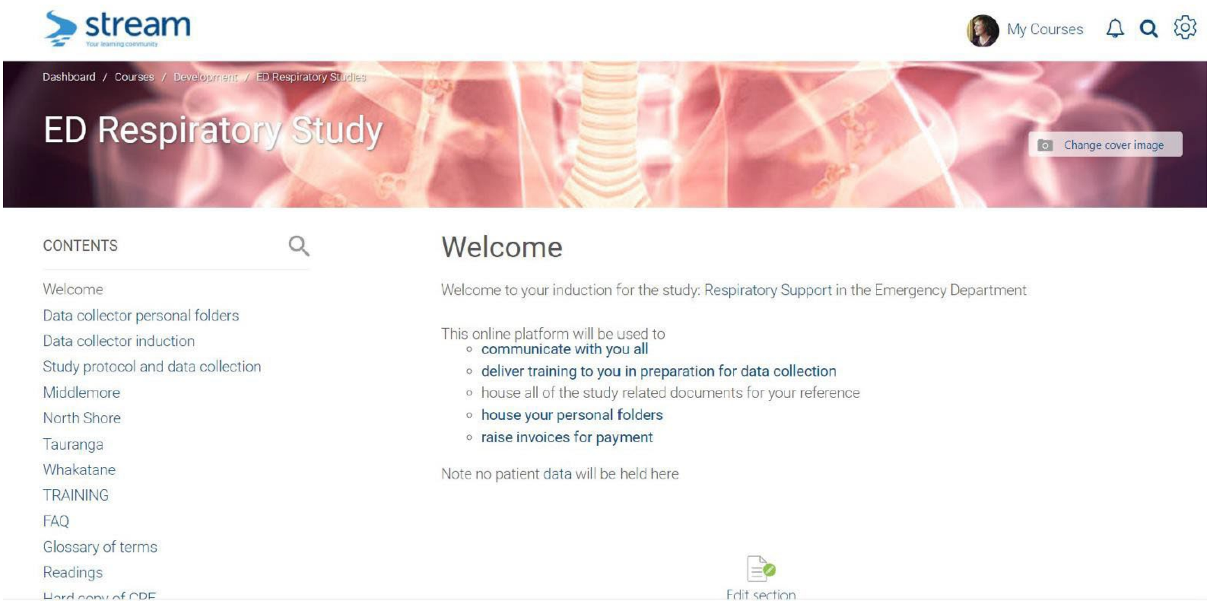
Appendix J

Point Prevalence Study Data Collector Training

This is a screenshot of the bespoke module-based web-based training site for data collectors; this site is password-protected and was hosted by Massey University.

This site facilitated/housed

- Good Clinical Research (GCP) and ISO Training
- Study Induction
- Study Protocol (O'Donnell et al., 2022)
- eCRF on RedCap
- Logistical support
- Contracts
- Resources



Appendix K

Point Prevalence Study Clinical Trial Registration

O'Donnell, J., Pirret, A., & Hoare, K. (2021c). Nasal High Flow Therapy for Respiratory Support in the Emergency Department, a Point Prevalence Study. ANZCTR Trial Registration. Trial Id: ACTRN12621001167853. https://www.anzctr.org.au/Trial/MyTrial.aspx

ANZCTR
Australian New Zealand Clinical Trials Registry

DATA SHARING STATEMENT

Nasal High Flow Therapy for Respiratory Support and the need for escalation of care in the Emergency Department, a Point Prevalence Study

Registration number:	ACTRN12621001167853
Date registered:	27/08/2021
Date this registration last updated:	29/07/2022
Type of registration:	Prospectively registered
Date this document generated:	17/04/2024

Will individual participant data be available?	IPD is not available
Reason	
What additional, related documents will be available?	Study protocol
How or where can supporting documents be obtained?	Study protocol: Email: j.f.odonnell@massey.ac.nz

https://www.anzctr.org.au/Trial/MyTrial.aspx

Update Stage: Re-Submitted	Prospectively registered	Not up to date
Nasal High Flow Therapy for Respiratory Support and the need for escalation of care in the Emergency Department, a Point Prevalence Study		
Trial Id: ACTRN12621001167853	Request Id: 381030	View Trial
Date Registered: 27/08/2021	Start date: 05/12/2022	Last approved: 29/07/2022
	View data sharing statement	

Appendix L

Point Prevalence Study Site Information

Reference folder contents at Each Site:

- Study ethics approval (See also Appendix E)
- Study locality approvals (See also Appendix D)
- Study protocol (O’Donnell et al., 2022)
- Key personnel contact list

Equipment at each site:

- Hard Copy CRFs and Data Dictionary (See also Appendices H & I)
- I Pads for data entry

Appendix M

STROBE Completed checklist-used to structure the PPS manuscript

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract √	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction√		
Background/rationale √	2	Explain the scientific background and rationale for the investigation being reported
Objectives √	3	State specific objectives, including any prespecified hypotheses
Methods √		
Study design √	4	Present key elements of study design early in the paper
Setting √	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection.
Participants √	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants
Variables √	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement √	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias √	9	Describe any efforts to address potential sources of bias
Study size √	10	Explain how the study size was arrived at
Quantitative variables √	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods √	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses
Results √		
Participants √	13*	Report numbers of individuals at each stage of study—e.g. numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram

	Item No	Recommendation
Descriptive data √	14*	(a) Give characteristics of study participants (e.g. demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
Outcome data √	15*	Report numbers of outcome events or summary measures
Main results √	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses √	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses
Discussion √		
Key results √	18	Summarise key results with reference to study objectives
Limitations √	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation √	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability √	21	Discuss the generalisability (external validity) of the study results
Other information √		
Funding √	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org. **√ = COMPLETED**

Appendix N

Systematic Review Summary of Included Studies

Author & Year	Study Design & Aim	Population			Intervention		Comparator	Findings
		Description	N	Setting	Therapy & settings	Time	Therapy & settings	Details
Attia 2017	RCT Single centre Parallel	AHRF (PaO2<60 mmHg room air)	60	ED Egypt	NHF N=30 Initial 6 L/min increased 40 L/min. After 2 hr 30–35 L/min based on response or comfort. FiO_2 started at 0.6 after 2 hrs 0.35 and 0.4. When stabilised, rate (≤20 L/min) for weaning	120mins	COT N=30 NC FiO2 4 to 6 l/ min	BR and PR significantly decreased with NHF. PaO2 and SpO2 increased significantly in the NHF vs NC group (p<0.05). NHF provided rapid SpO2 improvement with fewer side effects and IMV need. Not powered
Bell 2015	RCT Two centre Parallel	Acute undifferentiated SOB	100	ED AUST	NHF N=48 Initial Settings: Flow: 50 L/min FiO_2: 30%	120mins	COT N=52 NP or FM Initial Settings: O2 in both groups was titrated over	NHF reduced BR 2 h (66.7% vs 38.5%, p = 0.005) IMV (4.2% vs 19%, p = 0.02)
Chua 2022	RCT Multi-centre Parallel	Apnoeic oxygenation	190	Singapore	NHF N= 97 60L/min	NS	COT N=93 NRM or NP 15L/min O_2	Median lowest SpO_2 during the 1st intubation attempt was 100% of all participants. Incidence of SpO_2 < 90% was lower NHF (15.5%) vs COT (22.6%) (adjusted RR=0.68, 95% [CI] 0.37-1.25) Compared to usual care, NHF was not superior for SpO_2 for 1st intubation attempt. Possible safe apnoea time prolonged

Author & Year	Study Design & Aim	Population			Intervention		Comparator	Findings
		Description	N	Setting	Therapy & settings	Time	Therapy & settings	Details
Cortegiani 2020	RCT 9 centre Parallel Non inferiority	AECOPD	79	ED ITALY	NHF *N*=34 Initial 60 L/min, 37 °C.	6 HRS	NIV *N*=37 NIV full FM or oro-nasal mask. PSV mode, PEEP 3 -5 cm H2O. Ins press titrated exp TV 6–8 mL kg−1 IBW.	NHF non-inferior to NIV as initial RS reducing $PaCO_2$ after 2 hrs SS. However, 32% receiving NHF req NIV by 6 hrs
Doshi 2018	RCT Multicentre	ARF	204	ED USA	NHF *N*=104 Initial 35 L/min; 35-37°C FiO_2 1.0	72HRS	NIV *N*=100 NIV using an oronasal mask (inspiratory PEEP10 cm H_2O; Exp PEEP 5 cm H_2O)	Tx failure at 72 hours with NHF non-inferior to NIV in adult patients presenting to ED with undifferentiated RF
Doshi 2020	Pre-defined subgroup analysis Doshi 2018 RCT Multicentre	Hypercapnic RF	65	ED USA	NHF HVNI *N*=34 Initial 35 L/min; 35-37°C FiO_2 1.0	72HRS	NIV *N*=31 NIV using an oronasal mask (inspiratory PEEP10 cm H_2O; Exp PEEP 5 cm H_2O)	NHF may deliver RS like NIV in AHCRF PCO_2 and pH are similar in each group. The intubation rate was 5.9% NHF 16.1% IMV in NIV group (p = 0.244). Failure 23.5% NHF group, 25.8% NIV group (p = 1.0) Not powered
Geng 2020	RCT Single Parallel	Bronchial asthma complicated RF	36	ED CHINA	NHF *N*=16 Initial 30–40 L/min; FiO_2 titration to (SpO2) 92%–96%	50 HRS	COT *N*=20 O_2 TITRATED SpO_2 within a range of 92%–96% NC, VM, and storage balloon mask	NHF improved PO_2 NS difference in PCO_2 reduction. HR and RR compared (0 hrs) and at 2, 8, 24, and 48 hrs after admission. Both PR & RR, SS were reduced with time. NS differences in PR and BR at 0, 2, and 8 hrs after admission. SS lower NHF 24 and 48 hrs after admission. NHF improves PO_2 and reduces PR and BR.

Author & Year	Study Design & Aim	Population			Intervention		Comparator	Findings
		Description	N	Setting	Therapy & settings	Time	Therapy & settings	Details
Haywood 2019	Pre-defined subgroup analysis Doshi 2018 RCT Multicentre	DC HF	42	ED USA	NHF *N*=22 Initial 35 L/min; 35-37°C FiO_2 1.0	4HRS	NIV *N*=20 NIV using an oronasal mask (inspiratory PEEP10 cm H_2O; Exp PEEP 5 cm H_2O)	NHF may be non-inferior to NIV. No power NS: intubation rate (p = 1.000), therapy success (p = 1.000) Not powered
Hsu 2020	RCT Single centre Parallel	Trauma: rib fractures	220	ED AUST	NHF *N*= 113 Initial FiO2 0.4.-60 L/min	NS	COT *N*=107 VM Initial FiO_2 0.4.	NS primary outcome comparing NHF and VM (6.2% vs 6.5%, P=1.0). NS in secondary outcomes except for $PaCO_2$ (43.6 vs 45.5, p=0.039) NHF not more effective than VM
Jones 2016	RCT Single centre Parallel	ARF	303	ED NZ	NHF *N*=165 Initial: 40 L/min FiO_2: 28%	Whilst in ED	COT *N*=138 Mask or NP	NHF, 3.6% (95% CI 1.5-7.9%) vs 7.2% (95% CI 3.8-13%) COT required MV (p = .16) 5.5% (95% CI 2.8-10.2%) in NHF vs 11.6% (95% CI 7.2-18.1%) in COT req MV within 24 hrs of admission (p = .053). NS mortality or stay. AE not frequent; & fewer with NHF
Kim 2020	RCT Single centre Parallel	CO poison	22	ED KOREA	NHF *N*=12 Flow 60 L/min	4HRS	COT *N*=10 100% FiO_2 NRM 15 L/min	NHF no reduction fCOHb vs COT May be able to maintain a constant fCOHbt1/2 and reduce fCOHb vs COT
Ko 2020	RCT Multi-centre Parallel	HF	72	ED KOREA	NHF *N*=34 Initial 45 L/min, FiO_2 1.0	1HR	COT *N*=33 NC flow>2 L/min	Improvement with NHF vs COT. Significant changes in ABG within 30 min. NHF therapy could be considered as primary RS

Author & Year	Study Design & Aim	Population			Intervention		Comparator	Findings
		Description	N	Setting	Therapy & settings	Time	Therapy & settings	Details
Makdee 2017	RCT Single centre Parallel	ACPO	128	ED THAI	NHF N=63 35-60 L/min	1HR	COT N=65 NP or NRB Initial: N/A	Mean BR at 60 minutes post int lower NHF (21.8 vs 25.1; difference 3.3; 95% CI 1.9-4.6). NS differences in the admission rate, ED and hospital LOS, NIV, INV or mortality.
Osman 2021	RCT Single centre Parallel	ACPO	188	ED MALY	NHF N=105 50 L/min FiO$_2$ titrated >94% SpO$_2$	1HR	NIV N=101 HELMET CPAP 40 L/min FiO$_2$ 0.6 PEEP 5 cmH$_2$O, titrated 3–5 cm H$_2$O >94%	hCPAP more effective than NHF BR [-12 (95% CI; 11-13) vs -9 (95% CI; 8-10), $p < 0.001$] PR reduction [-20 (95% CI; 17-23) vs -15 (95% CI; 12-18), P = 0.042], P/F ratio improvement [+149 (95% CI; 135-163) vs +120 (95% CI; 107-132), $p = 0.003$]
Raeisi 2019	RCT Single centre Parallel	ASTHMA	40	ED IRAN	NHF N=20 15-35 L/MIN	24HRS	COT N=20 NC 2-5L/MIN	Dyspnea scale decreased 7.58±1.04 to 6.45±0.51 (p=0.0001) and from 7.84±1.7 to 6.89±0.9 (p=0.049) within 2 hrs in NHF and COT. NHF (FEV1) was 1.48 ±0.94 L on admission then increased to 1.61±0.66 L (P=0.19) and 1.82±0.92 L (p=0.003) after 2, 24hrs COT group, FEV1 increased from 1.43±0.65 L to 1.46±0.53 L and 1.64±0.6 L. PaO$_2$ and SPO$_2$ increased SS both in 1st 2 hours. 1 COT Escalated

Author & Year	Study Design & Aim	Population			Intervention		Comparator	Findings
		Description	N	Setting	Therapy & settings	Time	Therapy & settings	Details
Rittaya mai 2015	RCT Single centre Parallel	ARF	40	ED THAI	NHF *N*=20 Initial 35 L/min FiO_2: N/A Duration: 1 HR	1HR	COT *N*=20 NP or NRB Initial Settings: N/A	NHF, compared to COT, reduced the levels of dyspnoea in ED patients with ARF.
Ruangso mboon 2021	RCT Single centre	ASTHMA + HYPOX	37	ED THAI	NHF *N*=19 Initial 35 L/min adjusted from 30 to 60 L/min according to comfort level. FiO2 adjusted	2HR	COT *N*=18 NC or NRM Flow rate not stated	RR lower NHF (MD = 4.7 [95% CI = 1.5 to 7.8], p = 0.001). NS in ABG NHF reduced the severity of dyspnea and RR in asthma.
Ruangso mboon 2020	RCT Single centre Cross over	Palliative Care	48	ED THAIL	NHF *N*=24 initial 35 L/min then 30-60 L/min	1HR + 1HR	COT *N*=24 NC or NRM Adjusted to maintain SpO_2> 95%	At 60 minutes, mean Borg COT and NHF was 4.9 (SM 0.3) and 2.9 (SM 0.3), MD 2.0; 95% CI 1.4-2.6). BRs lower NHF (MD 5.9; 95% CI 3.5-8.3)

Table Notes

ACPO	Acute Pulmonary Oedema
AECOPD	Acute Exacerbation COPD
ARF	Acute Respiratory Failure
BR	Breath Rate
CI	Confidence Interval
CO	Carbon Monoxide
COPD	Chronic Obst. Pulmonary Disease
COT	Conventional Oxygen
CPE	Cardiogenic Pulmonary Edema
CRF	Chronic Respiratory Failure
CV	Cardiovascular
DC	Decompensated
Dz	Disease
fCOHb	Fraction Of Haemoglobin Present As Carboxyhaemoglobin
FiO_2	Fraction O_2 Delivered
FM	Face Mask
hCPAP	Helmet CPAP
HF	Heart Failure
HRS	Hours
HYPOX	Hypoxia
IBW	Ideal Body Weight
IMV	Invasive Mechanical Ventilation
MD	Mean Difference
NC	Nasal Cannula
NHF	Nasal High Flow
NIV	Non-Invasive Ventilation
NP	Nasal Prongs
NRM	Non-Rebreather Mask
NS	Not Significant
PF	Pao_2:Fio_2 Ratio
PR	Pulse Rate
R/A	Room Air
RCT	Randomised Controlled Trial
RR	Respiratory Rate
SM	Standardised Mean
SS	Statistically Significant
VM	Venturi Mask
WOB	Work Of Breathing