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**Non-invasive measurement of stress and pain in cattle using infrared
thermography**

A thesis submitted in partial fulfilment of the requirements for
the degree of

Doctor of Philosophy
in
Animal Science

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This thesis is dedicated to my late mother; my inspiration

Mrs Ann Stewart

who, alongside my father Don and brother Sean, provided the encouragement and
inspiration to succeed

Abstract

The aim of this thesis was to validate the use of infrared thermography (IRT) to non-invasively measure stress and/or pain in cattle. The main approach was to measure changes in heat emitted from superficial capillaries around the eye (referred to as eye temperature) in response to various aversive husbandry procedures used routinely on farms. In addition, various exogenous challenges were given to investigate the role of the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system (ANS) in regulating the eye temperature response. No evidence was found to support the hypothesis that an increase in eye temperature was due to HPA activity in cattle. A rapid drop in eye temperature occurred immediately after disbudding, an electric prod, startling and shouting. It is suggested that this was caused by the redirection of blood from the capillary beds via sympathetically-mediated vasoconstriction. Therefore, the role of the ANS was tested by measuring eye temperature, heart rate variability (HRV) and plasma catecholamine responses simultaneously. Somatic pain from disbudding and initial responses to surgical castration included a synchronised drop in eye temperature, increases in catecholamines and changes in HRV indicative of increased sympathetic activity. The role of the sympathetic nervous system was further confirmed by a drop in eye temperature that occurred following an epinephrine challenge. In contrast, deeper visceral pain from castration caused a more marked increase in eye temperature and changes in HRV indicative of increased parasympathetic tone. The underlying mechanism driving the increase in eye temperature is unknown; however, it is possible that it may be caused by vasodilation due to increased parasympathetic activity. These differences in ANS responses to different procedures, detected by IRT and HRV, may be due to the nature of the pain and the relative fear associated with the procedure. In summary, this research showed that during stress or pain, the heat emitted from superficial capillaries around the eye changes as blood flow is regulated under ANS control and these changes can be quantified using IRT. A combination of IRT and HRV is a non-invasive way to measure ANS activity and assess acute welfare impacts of husbandry practices in cattle. Further research using pharmacological inhibition and stimulation of the ANS activity would be beneficial to fully understand the underlying regulatory mechanisms of the eye temperature and HRV responses in cattle and other species during stress and/or pain. The full capability of IRT and HRV for detection of disease and emotional states and the effects of different intensities of pain, individual traits and previous experience also deserve attention.

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Declaration

Each chapter in this thesis is set out as a paper in the style and format required of the journal to which it has been published or is in the process of being submitted to at the date of submitting this thesis. Consequently, there is some repetition, particularly in the methods, and there are inconsistencies with the style and format between the chapters. Contributions to the research have been made by co-authors indicated in each chapter, however, my input was greatest, as I designed the research, undertook the fieldwork, analysed the data and wrote the manuscripts.