New Zealand Veterinary Journal

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/tnzv20

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To cite this article: AL Ridler, EL Gulliver & F Castillo-Alcala (2024) Deaths due to suspected hypothermia in sheep and alpacas on a Manawatū farm in New Zealand in mid-summer, New Zealand Veterinary Journal, 72:1, 39-44, DOI: 10.1080/00480169.2023.2251425

To link to this article: https://doi.org/10.1080/00480169.2023.2251425

Published online: 14 Sep 2023.

NEW ZEALAND VETERINARY JOURNAL
2024, VOL. 72, NO. 1, 39–44
https://doi.org/10.1080/00480169.2023.2251425

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Deaths due to suspected hypothermia in sheep and alpacas on a Manawatū farm in New Zealand in mid-summer

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ABSTRACT

Case history: In mid-summer (February), 42 of a flock of 68 ram hoggets (approximately 5 months of age) and two of a group of 14 alpacas on a farm in the Manawatū region of New Zealand were found recumbent or dead following a period of persistent rain, strong winds and relatively low temperatures. The hoggets and alpacas had been shorn 4 and 53 days previously, respectively, and were in adequate to good body condition with access to *ad libitum* pasture. Post-mortem and histological examinations were undertaken on four hoggets and two alpacas.

Clinical findings: Apart from hypothermic body temperatures from four recumbent hoggets, nothing of significance was identified on clinical or gross pathological examination. Histological changes of vacuolar hepatopathy, renal tubular degeneration and pulmonary congestion were present in all animals examined.

Diagnosis: Based on the history and clinical and pathological findings, hypothermia was highly probable to have been the cause of the deaths.

Clinical relevance: These cases emphasise the importance of shelter for recently shorn sheep and alpacas regardless of the season.

Abbreviations: BCS: Body condition score; C3: Third compartment of the camelid stomach; LCT: Lower critical temperature

ARTICLE HISTORY
Received 25 May 2023
Accepted 18 August 2023
Published online 14 September 2023

KEYWORDS
Sheep; alpaca; hypothermia; cold exposure; climate; mortality

Introduction

Acute, sudden death in non-pregnant young sheep can be due to a variety of reasons. Common causes include nitrate toxicity, ingestion of toxic plants (e.g. redroot (*Amaranthus* spp.), fathen (*Chenopodium* spp.; Ellison 1994), infectious diseases (e.g. clostridial diseases, acute fibrinous form of pneumonia), and gastrointestinal nematode parasites, particularly *Haemonchus contortus*. Misadventure or weather-related phenomena such as lightning strike or hypothermia are also possible.

Hypothermia in sheep has also been called exposure, cold stress, cold exposure, or post-shearing exposure syndrome. Deaths due to hypothermia in sheep are most usually associated with perinatal lambs, in which the starvation-exposure-mismothering complex is the most reported cause of perinatal lamb mortality in Australia and New Zealand (Jacobsen *et al*. 2020).

Losses due to hypothermia are less common in older sheep and typically occur in winter when shearing of pregnant ewes in mid or late pregnancy is followed by a period of inclement weather, in particular snow or a blizzard (Bailey 1993). During these extreme conditions very high losses have been reported (Bailey 1993). The amount of time spent off feed before and after shearing, nutritional levels after shearing, time interval between shearing and inclement weather, amount of shelter available and the body condition and liveweight of the sheep have all been identified as possible risk factors for mortality (Hutchinson 1968; Mavor 1975; Bailey 1993). Use of a shearing comb that leaves some fleece (a cover comb), has been shown to reduce post-shearing mortality (Dabiri *et al*. 1995) and is likely used frequently for mid-winter shearing in New Zealand, although data on shearing methods are not available. The risk of hypothermia in sheep following winter shearing is well known in New Zealand and it is probable that farmers routinely take steps to reduce this risk in the colder months of the year. Such steps include use of a cover comb, putting freshly shorn sheep into paddocks with a high level of shelter and nutrition, and potentially bringing them back into the woolshed if particularly inclement weather occurs (Cranston *et al*. 2023).

Mavor (1975) reported that in the Southland region, where mid-winter shearing of ewes was generally not

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done, most post-shearing exposure cases occurred in lambs shorn in late summer or autumn. However, hypothermia deaths in summer or autumn do not appear to have been reported in other parts of New Zealand and it is unknown how frequently these occur. Suspected deaths due to hypothermia during the summer months have been reported in parts of Australia following adverse weather conditions after shearing (Holm Glass and Jacob 1991).

Deaths of adult alpacas from hypothermia due to inclement weather following shearing have been reported anecdotally but there do not appear to be published reports of this occurring either in New Zealand or elsewhere.

This case study reports on acute deaths of hoggets and alpacas in summer in the Manawatū region of New Zealand due to suspected hypothermia.

Case history

On 7 February 2022, a veterinarian was called to a mixed-species farm in the Manawatū region of New Zealand to investigate sudden deaths in ram hoggets. The affected group of sheep comprised 68 ram hoggets (approximately 5 months of age) purchased 1 month earlier from a farm in the lower North Island. They were of unknown breed but were likely to have a predominantly Romney base. They had reportedly received an anthelmintic treatment by the vendor before sale (anthelmintic and administration date unknown). Nine faecal samples were collected 4 days prior to the veterinary visit for faecal egg counts. Six were found to contain no nematode eggs and the remaining three contained 100, 200 and 400 epg. Clostridial vaccination history was unknown. The hoggets had not received any supplements or animal health treatments after purchase.

The ram hoggets had been grazing permanent pasture in the same paddock for the previous 2.5 weeks. Pasture cover in the paddock was estimated as 2000 kg DM/ha and consisted primarily of older permanent ryegrass (*Lolium perenne*) along with some dead weed plants that resembled redroot (*Amaranthus powellii*). The paddock was flat, on top of a small hill at approximately 90 m above sea level and with limited shelter, primarily offering protection from the sun and the prevailing south-westerly wind. Water was from a reticulated water supply that also supplied the rest of the farm. There was one concrete trough in the paddock, which was in clean condition. The hoggets were shorn on 3 February 2022 and returned to same paddock. At that stage they were all reported to be in good health with no identified clinical problems.

The hoggets were checked each morning, and no problems were observed on 4 or 5 February 2022. Early February is mid-summer in New Zealand and the 30-year mean maximum and minimum temperatures for Manawatū in February were 23.3°C and 11.2°C, respectively, with a 30-year mean monthly rainfall of 100.4 mm (https://cliflo.niwa.co.nz/pls/niwp/wgenf.genform1). On the morning of 6 February it was noted that many hoggets were standing huddled together at the gate at the north-west edge of the paddock. At the time, the weather conditions were poor, with a reduction in temperature compared to previous weeks, persistent rain, and a strong south-easterly wind. The following day, a large number of hoggets were found dead or recumbent. Most were in the gateway at the north-west edge of the paddock and additional groups of two to six were found in other parts of the paddock. The remaining hoggets were immediately moved to a more sheltered paddock with good pasture cover.

The following day (8 February 2022) 2/14 adult alpacas on the same farm were found dead. They had been shorn 53 days previously, and since shearing had been kept in a steeply sloping paddock with numerous dips and hollows and with the hill facing north-west and thereby providing some shelter to the south-east. The paddock also had a scattering of semi-mature scrub and rushes throughout, as well as scattered mature trees and a long, solid farm building along the southern boundary. Apart from shearing, the alpacas had not recently received any animal health treatments or undergone any husbandry procedures. The first of the dead alpacas (alpaca 1) was an older male with worn incisor teeth and a history of chronic skin lesions and difficulty maintaining good body condition. Alpaca 2 was a younger male with no history of health issues. Both had been on the property for a few years, but their ages were unknown. They had last received an anthelmintic treatment approximately 5 months previously. Both carcasses were submitted to the Massey University Pathology Department (Palmerston North, NZ) for post-mortem and histological examination.

Anecdotally, there were other reports of deaths in recently shorn sheep in the Manawatū district during the period from 6–8 February 2022, suspected to be due to hypothermia (Bayler[1] pers. comm).

Clinical findings

Of the 68 hoggets in the mob, 38 were dead and four were recumbent. These 42 were found lying in lateral or sternal recumbency with no signs of struggle or discharges from the nose, mouth or rectum. The carcasses appeared fresh with no signs of autolysis or bloating.

[1]S Bayler, Massey University, Palmerston North, NZ

The hoggets had not been weighed or body condition scored previously but the four recumbent hoggets had a good body condition score (BCS) of 3/5–3.5/5 and were estimated to weigh 32–36 kg.

Of the four hoggets that were still alive, one (hogget 1) was in sternal recumbency and weakly responsive with a temperature of 35.2°C. The remaining three (hoggets 2–4) were in lateral recumbency and were non-responsive with temperatures of < 32°C. The mucus membranes of all four were pale pink and there were no other obvious clinical signs.

Hoggets 2–4 were euthanised with a captive-bolt gun followed by exsanguination. Field necropsies were done within 15 minutes of euthanasia. Post-mortem examinations were unremarkable apart from multifocal SC haemorrhages on the dependant side of two of the hoggets. Livers were slightly more pale than normal, there were scant abomasal and ruminal contents of variable consistency, and the urinary bladders of all three were full of urine which was normal in appearance. Pelleted faeces were present in the rectum of all three. There were no visible nematodes within the abomasum of any. Samples from all three hoggets of spleen, liver, kidney, heart, lung, abomasum, rumen, and small intestine were collected in 10% formalin solution and submitted to the Massey University Pathology Department (Palmerston North, NZ), for histological examination.

Nitrate toxicity from possible *Amaranthus* ingestion was considered a possible, although unlikely, differential diagnosis and the clinical presentation had similarities to hypocalcaemia, which has been reported following ingestion of oxalate-containing plants such as fathen (*Chenopodium* spp.; Ellison 1994). Hence, vitreous humour was collected from all three hoggets by aspirating material using a 10-mL syringe and a 16-gauge x 1-inch hypodermic needle, which were submitted to a commercial laboratory (IDEXX New Zealand Ltd., Palmerston North, NZ) the following day for assessment of nitrate and calcium concentrations.

Hogget 1 was in sternal recumbency and was marginally responsive to human presence so was transported to a barn, covered, and surrounded in a deep bed of hay. It survived the night and was more alert the following day but was still unable to stand and was considered unlikely to recover. It was euthanised by the farm manager and transported to Massey University for post-mortem examination.

From the original mob of 68 ram hoggets, the remaining 26 had been moved to a paddock with substantial shelter provided by a block of trees. The farm manager reported that one had appeared depressed and lethargic during the move; however, on inspection 1 hour later they were all bright, alert, and responsive and were grazing with normal behaviour. No further deaths occurred.

Based on the history, clinical findings and post-mortem examination findings, a provisional diagnosis of hypothermia was made. No deaths were reported in the other 240 sheep on the property, none of which had been recently shorn, or in the remaining 12 alpacas on the property.

Laboratory and pathological findings

The concentrations of nitrate in the vitreous humour of hoggets 2–4 were < 6 mg/L; nitrate toxicity is unlikely at these concentrations (Boermans 1990). The concentrations of calcium in the vitreous humour of hoggets 2–4 were 1.44, 1.61 and 1.44 mmol/L, respectively. Concentrations of < 1 mmol/L are indicative of hypocalcaemia in cattle and sheep (Edwards and Foster 2009), indicating that these hoggets did not have hypocalcaemia.

Gross pathology

The carcasses of one hogget and two alpacas were examined. Hogget 1 was in a good state of nutrition with adequate muscle mass and good fat stores (estimated BCS 3/5). The liver was more pale than usual. No other gross lesions were present.

Alpaca 1 was an adult male in a fair-to-poor state of nutrition with mildly reduced muscle mass and scant SC and visceral fat stores (estimated BCS 2/5, body weight 61 kg). There was marked dental attrition, with multiple missing or fractured lower incisors and worn molars. The skin overlying the entire ventrum and distal limbs was thickened, with patchy areas of alopecia and multifocal areas of epidermal crusting. The pericardial sac contained approximately 50 mL of thin, straw-coloured fluid. Approximately 200 mL of similar fluid was also present within the abdominal cavity. The lung parenchyma was mildly congested, and the liver had an enhanced hepatic lobular pattern. Multifocal petechial haemorrhages were present in the mucosa of the third compartment of the stomach (C3).

Alpaca 2 was an adult male in good body condition, with adequate muscle mass, fat reserves and hydration (BCS 3/5, total body weight 81 kg). The mucous membranes were slightly paler than usual. The lungs were diffusely congested. The liver was diffusely firm and had an enhanced hepatic lobular pattern. A focal, locally extensive area of consolidation was present in the right liver lobe with multifocal white caseous nodules (granulomatous inflammation). There were multifocal petechial haemorrhages of the gastric mucosa predominantly located between C3a and C3b.

Faeces were collected from the rectum of both alpacas and submitted to the Massey University Parasitology Laboratory for faecal egg counting. Alpaca 1 and 2 had 750 and 0 epg, respectively.

Histology

Tissues from four hoggets and two alpacas were examined histologically. The most common histological lesions present in the hoggets included generalised, mild-to-moderate congestion of the lung parenchyma (4/4); mild, generalised vacuolar hepatopathy (4/4); glomerular congestion (4/4); and rare, multifocal renal tubular degeneration (2/4). Similarly, the most common lesions present in the alpacas included mild-to-moderate congestion of the lung parenchyma (2/2); generalised, severe vacuolar hepatopathy (2/2); and renal tubular degeneration with intratubular haemorrhages (2/2). In addition to these findings, both alpacas had evidence of gastric haemorrhage in C3, and alpaca 2 had chronic hepatic granulomas likely associated with parasite migration.

No histological lesions were found in the brain, brainstem or cerebellum from hogget 1 or either of the alpacas.

Evaluation of climatic conditions

Weather data from 11 January to 11 February 2022 were downloaded from the National Institute of Weather and Atmospheric Research (NIWA) database (https://cliflo.niwa.co.nz/pls/niwp/wgenf.genform1) for the closest weather station to the property that recorded daily conditions (Palmerston North Airport). Daily rainfall (mm), maximum and minimum temperature (°C) and wind run (total km per day) were evaluated.

During this period the weather conditions were predominantly warm (mean maximum daily temperature of 25.2°C) and dry (total rainfall of 25 mm), but on 5 and 6 February 2023 the Manawatū district experienced 89 mm of rain, increased wind, and a reduction in maximum daily temperatures (17.6°C and 16.4°C, respectively) compared with the previous weeks. However, during these two days the minimum daily temperature did not drop below 14.9°C (Figure 1).

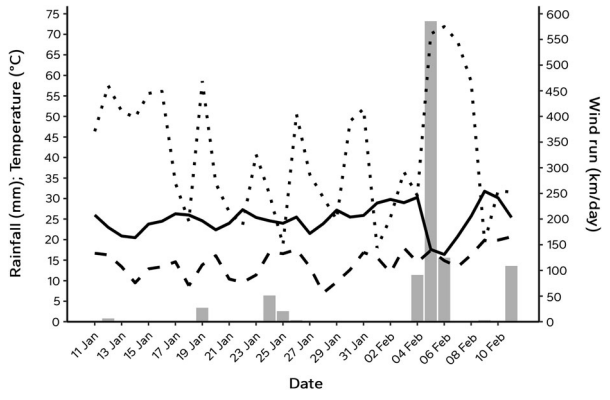

Figure 1. Daily rainfall (grey bars), maximum (solid line) and minimum (dashed line) temperature and wind run (dotted line) from 11 January to 11 February 2022, recorded at Palmerston North Airport in the Manawatū region (New Zealand), where deaths on a farm due to suspected hypothermia of 42/68 ram hoggets (shorn on 4 days previously) and 2/14 alpacas (shorn 53 days previously) were identified on 7 and 8 February, respectively.

Discussion

The clinical, post-mortem examination and histological features associated with hypothermia are non-pathognomonic, and diagnosis is primarily based on the history and clinical and diagnostic findings along with exclusion of other possible causes of death. On that basis, it was concluded that the deaths in this case were likely due to hypothermia.

Thermoregulation of sheep is complex and affected by environmental conditions, behavioural responses, and physiological factors (Joyce 1975). The lower critical temperature (LCT) is the temperature below which an animal must increase its heat production to maintain normothermia, and will vary depending on animal size, wind flow, whether it is wet or dry, and feeding levels (Gregory 1995). For a 40 kg sheep with a 1 cm fleece cover fed twice their maintenance requirement, in wet conditions at a low wind-speed (0.3 m/s) the LCT has been reported at 13°C, while at a high wind speed (1.1 m/s) it has been reported to be 21°C (Gregory 1995). Sykes and Slee (1969) demonstrated that sheep that were acclimatised to cold (8°C) showed higher resistance to body cooling during an acute cold exposure compared with sheep that had been kept at 30°C. Therefore, in this case, while the temperatures were not particularly cold (minimum 14.9°C) and the hoggets were in good body condition and were being well fed, the combination of a lack of acclimatisation to cold weather, recent shearing, persistent rain, high wind speed and lack of shelter will have meant they were well below their LCT. For those that died, their thermoregulatory mechanisms were presumably insufficient to maintain an adequate body temperature. A similar scenario has been documented previously in Australia, where Panaretto and Ferguson (1969) reported 14% losses from 25,000 sheep exposed to torrential rain 3–10 days after shearing despite temperatures being 15–21°C. This highlights that even in temperate weather, recently shorn sheep are at risk of hypothermia if a period of relatively cold, wet, windy weather occurs.

Other reported potential risk factors for hypothermia in sheep include time off feed pre- and post-shearing, nutritional levels, and body condition and liveweight of sheep (Hutchinson 1968; Mavor 1975; Bailey 1993). In this case the hoggets had been held off feed for approximately 12 hours prior to shearing but, due to the small size of the flock, shearing had been rapid, and they had immediately been returned to pasture and were offered access to ad-libitum

feed both before and after shearing. They were of reasonable body size and were in good body condition. Therefore, it appears that the deaths occurred primarily because of the combination of inclement weather and lack of adequate shelter.

In contrast, the alpacas were in a paddock that should have provided reasonable shelter from the wind and they had last been shorn almost 8 weeks previously. While one was only in a fair-to-poor body condition (estimated 2/5 BCS), the other was in good condition (estimated 3/5 BCS). These deaths suggest that, regardless of the time of year, in the face of inclement weather it may be advisable to house alpacas that have been shorn within the previous 2 months or so.

Establishing hypothermia as the primary cause of death via gross post-mortem and microscopic examination is challenging as there are no pathognomonic lesions. Turk (2010) reported that in humans the diagnosis generally relies on exclusion of other potential causes. In the cases presented here, both gross and histologic examination of the tissues revealed only subtle morphological changes with no evidence of significant injury to parenchymal organs.

In humans, the histological lesions associated with deaths caused by hypothermia include vacuolation and fatty change of hepatocytes, cardiomyocytes, adrenal cells, and renal tubular epithelial cells (Palmiere *et al*. 2013). Pulmonary oedema, areas of muscle haemorrhage and superficial erosions in the gastric mucosa associated with small dark blood flecks known as Wischnewsky spots are occasionally described (Turk 2010). Microinfarcts may be seen in any organ, along with "erythrocyte sludge" (Turk 2010). Physiologically, it has been suggested that altered cardiovascular perfusion, electrolyte abnormalities, and elevated circulating catecholamine concentrations ultimately result in cardiac failure and death in cases of severe hypothermia (Byard and Bright 2018).

Histological lesions similar to those mentioned above were present in the cases presented here, including mild hepatocellular vacuolation and renal tubular epithelial degeneration characterised by pyknotic renal tubular epithelial cells. Hepatocellular vacuolation was consistently present in all animals examined and could reflect reversible cell damage secondary to tissue hypoxia or, alternatively, reduced food intake over the 48-hour period of inclement weather.

Interestingly, both alpacas had small focal areas of mucosal haemorrhage in C3 that resembled the gastric lesions described in some human cases of death by hypothermia and classified as a periagonal, hypothermia-related, multifactorial phenomenon (Palmiere *et al*. 2013). Because camelids are prone to gastric ulceration and haemorrhage secondary to gastrointestinal parasitism and stress, these observations need to be interpreted with caution, as other comorbidities may have played a role in the development of these lesions in these alpacas. While one of the alpacas was in poor body condition and had evidence of internal parasitism potentially explaining the gastric ulceration, the second alpaca was in good body condition and had a negative faecal egg count. Whether these lesions are the result of hypothermia-related tissue damage in these cases remains speculative.

This case report highlights the potential risk of lethal hypothermia in recently shorn sheep and alpacas in the face of inclement weather, regardless of season. The importance of shelter for the welfare of farmed livestock has been emphasised throughout the years (Gregory 1995; Fisher 2007) and is reiterated by this case.

Acknowledgements

The authors would like to thank the farm staff involved.

Disclosure statement

No potential conflict of interest was reported by the authors.

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