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Infrared thermal imaging as a method to evaluate heat loss in newborn lambs

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ABSTRACT

Thermal imaging technology has been identified as a potential method for non-invasive study of thermogenesis in the neonatal lamb. In comparison to measurement of the core body temperature, infrared thermography may observe thermal loss and thermogenesis linked to subcutaneous brown fat depots. This study aimed to identify a suitable method to measure heat loss in the neonatal lamb under a cold challenge. During late pregnancy (day 125), ewes were subjected to either shearing (n = 15) or mock handling (sham-shorn for 2 min mimicking the shearing movements) (n = 15). Previous studies have shown an increase in brown adipose tissue deposition in lambs born to ewes shorn during pregnancy and we hypothesized that the shearing treatment would impact thermoregulatory capacities in newborn lambs. Lambs born to control ewes (n = 14; CONTROL) and shorn ewes (n = 13; SHORN) were subjected to a cold challenge of 1 h duration at 4 h after birth. During the cold challenge, thermography images were taken every 10 min, from above, at a fixed distance from the dorsal midline. On each image, four fixed-size areas were identified (shoulder, mid loin, hips and rump) and the average and maximum temperatures of each recorded. In all lambs, body surface temperature decreased over time. Overall the SHORN lambs appeared to maintain body surface temperature better than CONTROL lambs, while CONTROL lambs appeared to have higher core temperature. At 30 min post cold challenge SHORN lambs tended to have higher body surface temperatures than lambs ($P = 0.0474$). Both average and maximum temperatures were highest at the hips. Average temperature was lowest at the shoulder ($P < 0.05$), while maximum temperatures were lowest at both shoulder and rump ($P < 0.005$). These results indicate that lambs born to shorn ewes maintained their radiated body surface temperature better than CONTROL lambs. In conjunction with core temperature changes under cold challenge, this insight will allow us to understand whether increased body surface temperature contributes to increased overall heat loss or whether increased body surface temperature is indeed a mechanism contributing to maintenance of core body temperature under cold challenge conditions. This study has confirmed the utility of infrared thermography images to capture and identify different levels of thermoregulatory capacity in newborn lambs.

1. Introduction

Infrared thermography (IRT) has been shown to be a safe and non-invasive method for measuring and mapping the radiated heat loss at the body surface. In humans, Ng (2009) applied IRT to identify and visualize breast cancer, and Abbas and Leonhardt (2014) showed its use for neonatal monitoring. IRT also has a variety of practical applications in veterinary and animal science for detecting diseases (Poikalainen et al., 2012), lameness (Nikkhah et al., 2005), stress and more generally for assessing animal welfare (Schaefer et al., 1988; Stewart et al., 2005, 2009). In bats and voles, IRT has been used to study torpor and thermogenesis (Lancaster et al., 1997; Jackson et al., 2001). When compared to other methods such as calorimetry (Shuran and Nelson, 1991; Adams et al., 2000) or standard equations, IRT has proven to be a very useful method to quantify heat loss.

Heat loss radiating through the body surface is an important factor in the etiology of hypothermia due to cold exposure in neonates. Brown fat depots in neonatal lambs contribute through non-shivering thermogenesis to the maintenance of homeostasis but the mechanisms are difficult to study in vivo (Hergenhan, 2012). Indirect ways to assess non-shivering thermogenesis in lambs are the use of climate chambers to characterize lamb metabolic responses to the environment

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(Alexander and Peterson, 1961), and measurements of lamb oxygen consumption in response to noradrenaline injections (Alexander and Williams, 1968). Recently, McCoard et al. (2014) have described IRT continuous recording as a suitable and non-invasive method to study thermogenesis in the neonatal lamb. However, thermogenesis is traditionally assessed through core body temperature monitoring which does not specifically capture the infrared heat loss radiating from the skin of an animal, which can be measured as body surface temperature in the infrared frequency band of the light spectrum by IRT.

Late-pregnancy shearing (Symonds et al., 1992) and cold stress (Stott and Slee, 1985) have been shown to positively impact the deposition of brown adipose tissue (BAT) and thus the thermoregulatory capacity of the lambs. In the neonatal lamb, major BAT depots are located in the peri-renal abdominal and inguinal regions of lambs (Alexander and Bell, 1975; Everett-Hincks and Duncan, 2008). Subcutaneous fat in the pre-scapular and hind limb regions can also contain functional BAT, as shown for field voles by (Jackson et al., 2001), using IRT to identify regions of body with underlying BAT. Similarly, in lambs, infrared thermographs have been proposed as a method to identify the areas of heat production even though it might not provide measures of absolute temperature (Hergenhan, 2012) or be sensitive enough to quantify BAT quantity (Jackson et al., 2001). We hypothesized that infrared thermographs taken during a cold challenge could be used to discriminate different levels of thermogenesis in newborn lambs developed as a result of different levels of ewe prenatal stress.

2. Materials and methods

All experimental procedures were approved by the CSIRO FD McMaster Laboratory, Chiswick, Animal Ethics Committee, Armidale, Australia (AEC No.14/17). Weather observations were obtained from CustomWeather (Time and Date AS 1995–2017. All rights reserved.)

2.1. Animals and treatment

Pregnant Merino multiparous ewes were shorn at day 125 of pregnancy (n = 15; 13 single-bearing and 2 twin-bearing) while control ewes were sham-handled for 2 min alongside the shorn group (n = 15; 13 single-bearing and 2 twin-bearing). Temperature at shearing was 9 °C (5/15 °C daily min/max temp; 88% humidity). Following shearing (D0), shorn ewes, but not control ewes, were wetted (water temperature 8–10 °C) using ceiling sprinklers for 30 min, 3 occasions over 7 days (D0, D3 [11 °C; 9/14 °C daily min/max; 99% humidity] & D7 [12 °C; 8/21 °C daily min/max; 58% humidity]) as a controlled cold stress. Animals were grazed ad libitum on improved native pasture, except during the treatment period of 15 days, when animals were kept indoor in group pens (3 m^2/ewe) on slatted floor, separated according to treatment group. From 10 days before expected date of parturition the ewes were housed on straw bedding in indoor lambing pens at 3–4 ewes per pen (1.5 m^2 per ewe). During indoor periods animals were fed a 50:50 lucerne and oaten chaff mix supplemented with a 3:2 sheep pellets (based on wheat, millrun and lucerne; 17.5% protein, 2.5% fat, 17% crude fibre, 20% ADF, 34% NDF)/corn ration 200 g/day as required to maintain a body condition score of 3. Throughout the experiment all ewes maintained a BCS between 2.5 and 3.5 (scale 1–5). Ewes were visually checked at least every 30 min and video cameras were used to continuously monitor the lambing and early behaviours. Each camera provided a view of the entire lambing pens. The cameras were connected to digital video recorders and footage captured using IVMS4200 software (Hangzhou Hikvision Digital Technology Co., Ltd). Gestation lengths were 139–152 days, and lambing took place between 1st October and 17th October 2014 at the CSIRO property Chiswick, Armidale, New South Wales, Australia. Average temperature at lambing in the open-sided animal house was on average 13.5 °C (2C/24 °C min/max temperature; 59.5% humidity on average).

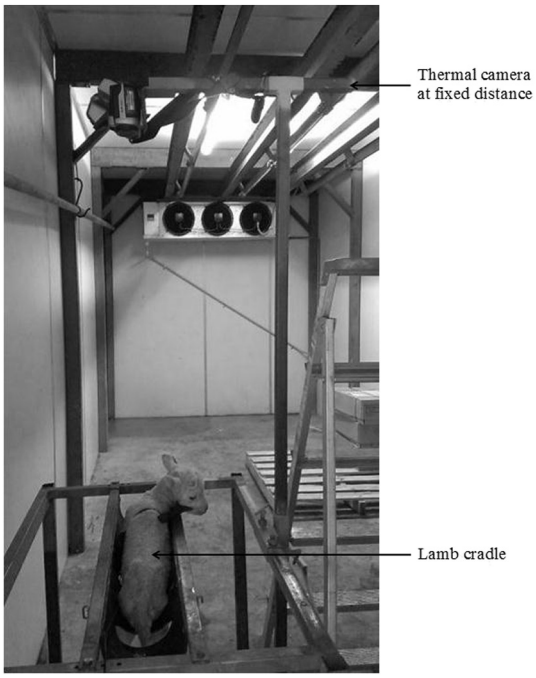

Fig. 1. Cradle used during the cold challenge to restrain the lamb. The IRT camera is mounted at 1 m above the back of the lamb.

2.2. Lambs measurements

From 30 ewes, 25 lambed during the experimental period, and a total of 29 lambs were born (21 single births and 4 twin births) and subsequently enrolled in the trial. Four cases of dystocia were observed in the cohort in which case lambing was assisted. Successful latching and suckling of colostrum was visually monitored for each lamb. Two lambs with insufficient suckling activity were withdrawn from the experiment, and both died within the following 24 h. At 4 h of age, lamb birthweight, sex and girth circumference (measured with a soft measuring tape behind the front legs). Immediately following these measurements, lambs (10 singles and 4 twins CONTROL lambs, born to control ewes; 9 singles and 4 twins SHORN lambs, born to shorn ewes) were wetted by brief immersion in cold water (8–10 °C) to ensure all lambs were equally wet as at this time after birth some lambs could be completely dry or still partially wet from amniotic fluid. Each lamb was then individually restrained in a lamb cradle (Fig. 1) in a cold room at 4 °C for 1 h (no use of fans for air movement). The cradle was designed to support the lamb ventrally to maintain in a stable upright position and consisted of a fabric mat suspended between two longitudinal metal bars, with four holes cut into the fabric to accommodate the legs. If required, the lamb was secured with a bandage around the shoulder girdle although we found that once placed into the cradle, lambs settled into the position and remained quiet.

Body surface heat map images of the back of the lambs were taken on entry into the cold room and at the following 10 min intervals (T0, T10, T20, T30, T40, T50 and T60) using an infrared thermography (IRT) camera (ThermaCam T640, FLIR Systems AB, Danderyd, Sweden). The IRT camera was mounted above the cradle at a fixed distance of 1 m from the dorsal surface of the lamb. Every 10 min when a thermal picture was taken, rectal temperature was measured using a digital rectal thermometer to monitor core body temperature. To prevent clinical hypothermia, lambs were removed from the cold room if their rectal temperature dropped below 36.5 °C, at which time they were placed in a warm environment and monitored until their body temperature had stabilized. Six lambs were removed prior to T60 under this protocol (4 SHORN and 2 CONTROL). Their data until the point of removal were included in the analysis. Wool length (< 3 mm 'short';