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THE STARVATION-EXPOSURE SYNDROME AND NEONATAL LAMB MORTALITY: A REVIEW

S. N. McCUTCHEON, C. W. HOLMES and M. F. McDONALD

Massey University, Palmerston North

SUMMARY

Approximately one-third of all pre-weaning lamb deaths are considered to be due to starvation and exposure. This paper reviews the physiological mechanisms involved in starvation and exposure and emphasises the importance of cold-exposure at birth as a factor in this type of mortality.

The possibility of reducing starvation and exposure mortalities by the use of shelter at lambing and by selection for a hardier type of lamb is discussed. Preliminary findings are presented from a study currently being undertaken to identify traits which confer improved resistance to cold-stress in the newborn lamb.

INTRODUCTION

Between 5% and 25% of all lambs born annually on farms in New Zealand die before weaning (McFarlane, 1955; Hight and Jury, 1970; Knight *et al.*, 1979). A commonly-accepted average of 15% pre-weaning mortality would account for at least six million lambs each year (Scott, 1962) and is therefore an important source of economic loss to the sheep industry in this country.

Upon post-mortem examination many lambs are seen to exhibit lesions of both starvation and exposure. Consequently these deaths are frequently combined into a single classification which may include mortalities considered to have been due to simple starvation (exhaustion of body reserves in the absence of hypothermia), simple exposure (lethal hypothermia with minimal depletion of body reserves) and to the combined effects of exposure and starvation. Recently there has been a trend towards the separation of 'simple exposure' deaths from the 'starvation-exposure' category despite the likelihood that they are linked through common physiological mechanisms.

Estimates derived from post-mortem studies suggest that the 'starvation-exposure syndrome' accounts for approximately 30% of all neonatal deaths, with the balance caused by dystocia (another 30%) and a variety of lesser causes including pre-natal death and post-natal infection (McFarlane, 1955; Hight and Jury, 1970; Knight *et al.*, 1979; Dalton *et al.*, 1980). Thus the 'starvation-exposure syndrome' may be responsible for the annual loss of at least two million lambs.

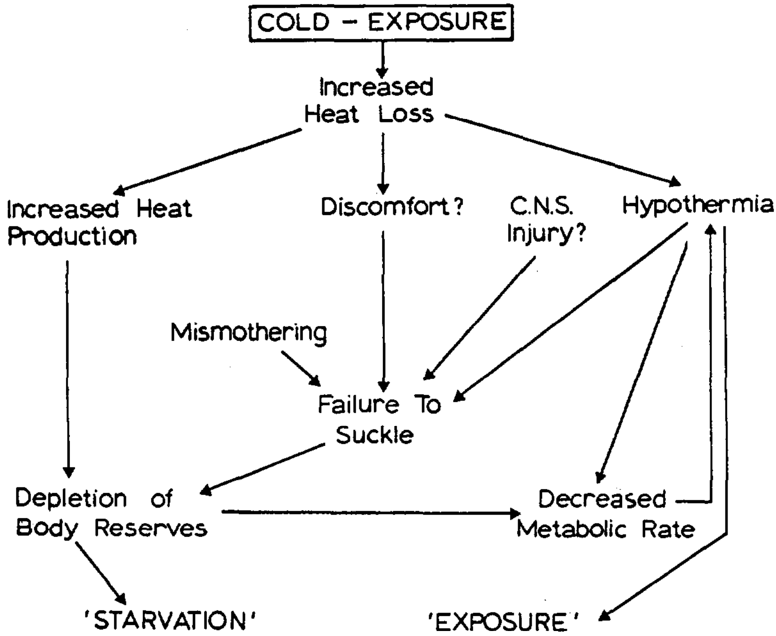

FIG 1: *Starvation-exposure interactions.*

STARVATION AND EXPOSURE MORTALITIES: THE INFLUENCE OF COLD-STRESS

At birth the lamb is delivered in a physiologically advanced state from the warm uterine environment to an external environment in which it must immediately increase its rate of body heat production by up to fifteen times the foetal level (Dawes and Mott, 1959; Alexander, 1962b) to compensate for body heat loss to the environment. When its maximum sustainable metabolic rate is exceeded by the rate at which heat is lost to the environment, deep body temperature falls (Fig. 1). Many lambs suffer a decline in deep body temperature immediately after birth (Alexander and McCance, 1958) although the decline is small if the lamb is delivered into a warm environment (Smith, 1961). The majority of these lambs subsequently regain normal deep body temperatures of 39 °-40 °C within a few hours of birth, but in some cases the decline continues until death occurs at deep body temperatures below 30 °C (Alexander and McCance, 1958). It is likely that these exposure deaths involve a 'vicious circle' of falling deep body temperature and falling heat production, since the lamb's 'summit metabolic rate' (the maximum sustainable rate of body heat production per unit bodyweight) declines proportionately with rectal temperature when the latter is less than 36 °C (Alexander, 1962b).

Cold-exposure may also predispose lambs to early mortality in the absence of severe body cooling. When the lamb experiences a high rate of body heat loss the associated requirement for a high metabolic rate results in a rapid utilisation and, unless the lamb suckles, eventual depletion of its limited body stores of energy-producing nutrients (Alexander, 1962c). Thus, while the energy derived from the breakdown of body reserves is sufficient to permit lamb survival for three to five days in a warm environment, survival time may be markedly reduced in severe cold. This may partly explain why most starvation-exposure deaths occur within three days of birth (McFarlane, 1961). A further consequence of starvation is that the lamb's ability to sustain a high metabolic rate declines as the utilisation of its body reserves proceeds (Alexander, 1962b). Hence starved lambs, and particularly those suffering a severe depletion of body reserves, are likely to be more susceptible to hypothermia than lambs which are well fed.

The physiological effects of cold-exposure on the lamb's drive to suckle provide another important link between starvation and exposure mortalities. Alexander and Williams (1966a) demonstrated that the lamb's suckling reflex is markedly depressed when deep body temperature falls below about 37 °C so that even mild hypothermia, while in itself non-lethal, may predispose to death by starvation. In addition Alexander and Williams (1966a) demonstrated a possible effect of 'discomfort' due to cold-exposure which, while apparently independent of the hypothermia effect, also decreases the vigour of the suckling drive. These effects are compatible with field observations that the time from birth to first suckling is prolonged in lambs born in cold, windy conditions compared with those born in less severe environments (McBride *et al.*, 1967). Conversely, the 'reward' of first obtaining milk encourages the lamb to continue suckling (Alexander and Williams, 1966b) which further enhances the importance of early suckling success.

The nature of these physiological interactions has led to a general acceptance of the view that the 'starvation-exposure syndrome' is a primary cause of about 30% of lamb mortalities and that the effects of cold-stress are implicated to some degree in the majority of these deaths (Alexander, 1962c; Sykes *et al.*, 1976). However, Haughey (1978) has suggested that the 'starvation-exposure syndrome' is merely a secondary cause of lamb mortality, the primary cause being damage to the lamb's central nervous system (CNS) sustained during the birth process. Haughey (1973b, 1978) reported that a high proportion of lambs assigned to the post-parturient mortality class (comprising mainly starvation-exposure deaths) exhibit lesions in or around the cranial and spinal meninges. These lesions occur during both assisted and unassisted births, probably as a result of anoxia or trauma (Haughey, 1973a, 1975).

In lambs which survive the birth process (i.e. do not die of dystocia) the primary effect of CNS damage is apparently a depression of the suckling drive, this effect interacting with the environmental conditions to which the lamb is exposed. Thus Haughey (1975) demonstrated that whereas 60% of CNS-injured lambs failed to suckle at an ambient temperature of 1 °C, the failure rate was only 5% at 28 °C which suggests that the effects of CNS injury may interact with the effects of hypothermia or 'discomfort' on the suckling drive. It also seems likely that the effects of CNS injury may be minimised by providing the lamb with a benign environment immediately after birth.

Two general approaches to reducing the incidence of starvation-exposure deaths may therefore be identified. Firstly, both the incidence of CNS injury in lambs on New Zealand farms and the relationship between severity of injury and severity of effect require further examination. For example, in a recent New Zealand study (X. J. Duff, unpublished), 34% of 103 lambs assigned to the 'starvation-exposure' classification were found to exhibit cranial and/or spinal lesions, but severe lesions were rarely seen. Furthermore, two Australian trials have demonstrated that 100% lamb survival can be achieved when lambs are given ideal conditions of food, warmth and assistance at birth (Alexander *et al.*, 1959; Alexander and Peterson, 1961). Again this supports the view that the effects of CNS injury can be minimised under certain conditions. In this connection further study of the mechanism by which CNS lesions and cold-exposure interact in their effects on the suckling drive would seem to be warranted. A second approach would be to select or manage lambs so that they are able to maintain deep body temperatures above 37-38 °C, thereby avoiding the depressions of summit metabolism and of the suckling drive which are associated with more severe hypothermia. Only the latter approach will be discussed further.

THE SELECTION AND MANAGEMENT OF LAMBS FOR RESISTANCE TO HYPOTHERMIA

The lamb experiences a decline in deep body temperature only when its rate of body heat production is exceeded by the rate at which heat is lost to the environment. Hence an improved resistance to hypothermia may be associated with; a rapid attainment of high summit metabolism; improved body insulation; and a reduction in the cooling power of the environment. Other factors such as bodyweight and blood type may also require consideration.

HEAT PRODUCTION

Considerable variation exists between lambs in the level of summit metabolism attained in the first days after birth (Alexander, 1962b) but little is known about the factors contributing to this variation. Alexander and Bell (1975a) measured the summit metabolism of lambs of five breeds and crosses (Merino, Border Leicester, B.L. x Merino, Corriedale, Dorset Horn) but were unable to detect significant breed differences. Recent studies with Romney lambs (S. N. McCutcheon, unpublished) have shown that they have a similar capacity for heat production to the other breeds. Attempts to relate summit metabolism to physiological characteristics such as the lamb's weight of heat-producing tissues, body energy stores or circulating levels of energy-producing nutrients have also been generally unsuccessful (Alexander and Bell, 1975a). Summit metabolism may, however, be limited by the supply of oxygen to the sites of body heat production (Alexander and Williams, 1970a, 1970b).

Lambs born in the field may suffer a considerable decline in rectal temperature during the first hours of life. In extreme cases this can exceed 10 °C in the first 30 minutes (Alexander and McCance, 1958; Sykes *et al.*, 1976). Hence a rapid attainment of summit metabolism is of considerable importance to survival. Little is known about factors affecting the rate at which summit metabolism is attained although Alexander (1962b) has commented that lambs which are poorly fed *in utero* tend to achieve high metabolic rates more slowly than those which receive a good nutrient supply. The final level of summit metabolism achieved is, however, independent of pre-natal nutrition.

Despite the considerable variation in summit metabolism observed between lambs and the obvious benefits of a high metabolic rate immediately after birth, the possibility of selecting for this trait is severely limited by the high costs and technical difficulties involved in its measurement. The relationship between pre-natal nutrition and the rate at which summit metabolism is attained may, however, warrant further study.

HEAT LOSS

Birthcoat characteristics

Field studies with both Australian Merino (Obst and Evans, 1970) and Welsh Mountain lambs (Purser, 1967; Purser and Karam, 1967) have demonstrated an effect of birthcoat type on survival. Fine-coated Merino lambs had lower survival rates than those with hairy coats when exposed to very cold weather, although these differences were minimised when the lambs were born in less severe environments. Among the Welsh Mountain lambs, those of the intermediate hairiness grade had higher survival rates than lambs at either extreme of the range.

The effect of birthcoat type on the ability of the newborn lamb to regulate body temperature has been studied in more detail by Alexander (1961, 1962a) and Slee (1978). Alexander estimated the external (coat plus air) insulation of fine-coated Merino lambs to be 60% that of hairy lambs when the lambs were dry and in still air. Exposure to high windspeeds halved the estimated external insulation of each coat type so that the superiority of the hairy coat was maintained. Slee (1978) similarly found that the resistance to body cooling of lambs of three breeds (Scottish Blackface, Tasmanian Merino, Welsh Mountain) was associated with breed differences in mean birthcoat depth. Studies with Romney and Drysdale x Romney lambs in New Zealand have confirmed the importance of birthcoat depth as a factor in coat insulation but also indicate that, as birthcoat depth increases, the gain in insulation achieved by each unit increase in depth declines (S. N. McCutcheon, unpublished). Thus there appars to be little point in selecting for coat depths greater than about 20 mm. These studies also suggest that although the insulative value of a unit depth of coat does not vary with the wetness of the coat, deep coats show a greater absolute reduction in depth upon wetting than do shallow coats. Hence wetting the coat may reduce its total insulative value, particularly in deep coats, in addition to increasing the rate of heat loss from the lamb's body by surface evaporation.

Selection for specific birthcoat types appears to offer one of the most simple methods of improving the newborn lamb's resistance to cold-stress. However, while the importance of birthcoat depth has been established, the role of other coat characteristics (such as fibre diameter and follicle density) as factors in coat insulation remains to be evaulated. The effects of selection for desirable birthcoat types on subsequent wool production in the ewe flock must also be assessed before recommendations for selection procedures can be made.

Control of surface blood flow

Since the body of the newborn lamb contains little subcutaneous fat (Alexander and Bell, 1975b), the resistance to heat flow provided by its body tissues will depend mainly on the rate of blood flow through those tissues. While there is some limited evidence of variation between lambs in the rate of blood flow through vasonconstricted tissues (Alexander *et al.*, 1973), the extent to which this may affect their ability to conserve body heat is not known.

The use of shelter at lambing

The provision of shelter for ewes at lambing may be a useful method of minimising lamb losses, at least in intensive farming systems. In cold environments lamb losses associated with hypothermia may be halved by the provision of 1 m-high shelter belts of phalaris or polythene mesh established at 10-20 m intervals (Lynch *et al.*, 1980). Unshorn ewes tend to make less use of shelter than do ewes which have recently been shorn, and as a consequence lambs born to shorn ewes tend to have lower mortaltiy rates (Alexander and Lynch, 1976; Lynch and Alexander, 1976). However the usefulness of shelter belts may be limited in more extensive farming systems because, as the distance between the belts increases, the proportion of time spent by ewes in the sheltered areas declines (Alexander *et al.*, 1979). In addition the tendency for ewes to seek isolation during parturition may lead them to lamb away from shelter if the main flock is concentrated near the shelter belts. Since lambing ewes cannot be forced into shelter under extensive systems, best use may perhaps be made of shelter by the placement of low shelter belts in areas where the ewes prefer to lamb (Alexander *et al.*, 1979). The development of a 'wind-chill index' combining the cooling effects of wind, rain and cold for newborn lambs would allow the overall 'coldness' of different environments to be evaluated and so would assist in the most effective placement of shelter belts.

Haemoglobin Type

An association between dam haemoglobin type and lamb survival has been demonstrated in both Australia (Obst and Evans, 1970) and the U.K. (Hall and Purser, 1979). The mechanism of this effect is unknown but it may be partially explained by the greater twinning rate of haemoglobin Type B ewes whose lambs also have the higher mortality rates. Any effect of haemoglobin type independent of the differential twinning rate appears to be associated with a poor resistance to cold-stress of fine-coated lambs born to Type B ewes (Obst and Evans, 1970).

Birth Weight

Considerable importance has been attached to the role of birth weight as a factor in lamb mortality because of the susceptibility of small lambs to starvation and exposure (Hight and Jury, 1970; Dalton *et al.,* 1980). This is considered to be primarily due to their higher ratio of surface area to volume (Alexander, 1974) as a consequence of which their rate of heat loss per unit bodyweight is higher than for larger lambs. Since the summit metabolism per unit bodyweight of newborn lambs is constant over a range of weights (Alexander, 1962b) small lambs cool more quickly, and in less severe environments, than do larger lambs (Alexander and McCance, 1958). They may also be disadvantaged by disproportionately low levels of body reserves and, in extreme cases, by abnormal development of the birthcoat and of body tissues and organs (Alexander, 1974).

CONCLUSIONS

In recent years much discussion has been devoted to the problem of how to reduce variation in birth weight and so improve lamb survival. It must be stressed, however, that while the mortality of very small lambs may be spectacularly high, their incidence in the flock and contribution to the overall mortality rate are less so. Even at optimum birth weights, mortality may still exceed 10% (Hight and Jury, 1970). Clearly techniques other than the control of birthweight are also required if the incidence of starvation and exposure mortalities is to be significantly reduced. In this respect the efficient use of shelter, and the selection for specific birthcoat types, may have an important role in the future.

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