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Article *in* The Indian journal of animal sciences · June 2019

4 authors:

Chander Prakash Swarnkar
Central Sheep and Wool Research Institute

Gopal R. Gowane
ICAR-Central Sheep and Wool Research Institute

Leslie Leo Prince
ICAR-Directorate of Poultry Research, Hyderabad

Ganesh Sonawane
Central Sheep and Wool Research Institute

Indian Journal of Animal Sciences **89**(6): 640–644, June 2019/Short communication

Risk factor analysis for neonatal lamb mortality in Malpura sheep

C P SWARNKAR[1], G R GOWANE[2], L L L PRINCE[3] and G G SONAWANE[4]

ICAR-Central Sheep and Wool Research Institute, Avikanagar, Rajasthan 304 501 India

Received: 12 June 2018; Accepted: 5 November 2018

Key words: Malpura sheep, Neonatal mortality, Rajasthan, Risk factors

High mortality rate in lambs (up to 40%) is a worldwide problem (Binns *et al.* 2002) and decisively reduce the profitability of sheep production (Osteras *et al.* 2007). In lambs, neonatal period (birth to first 28 days of life) is the most critical (Gokcea *et al.* 2014). Neonatal mortality (NM) includes death during the first week of life (hebdomadal) and death subsequently to the first week and until the 28th day of life (post-hebdomadal). Within first week of life, death of a lamb is defined as immediate (initial 24 h of life), delayed (24–72 h of life) or late (72 h to 7 days of life) (Sharif *et al.* 2005). Neonatal lamb mortality is a multi-factorial issue and associated with environment, ewe and lamb (Vatankhah and Talebi 2009). The timing of lamb loss is remarkably consistent throughout the world with the majority of loss occurring during during the first 24 h (Dwyer 2008) as a reflection of the transition from a dependent intrauterine life to an independent extra-uterine life (Radostits *et al.* 1994). In Rajasthan, sheep husbandry plays a key role for the sustainable livelihood of the rural poor and lambs are usually sold at the age of 3–4 months (Swarnkar and Singh 2010) thus, their survival is highly important for the shepherds to earn more returns. In this process, survival of young animals is imperative for livestock propagation; however, neonatal mortality is the cause of considerable economic loss. A study was undertaken to assess extent and factors affecting neonatal mortality in lambs in order to restructure the management strategies to keep neonatal lamb mortality as low as possible.

Data on 5,722 Malpura lambs born during 1991–2016 at the institute were used for present study. Malpura is a mutton type native breed of semi-arid Rajasthan, known for their adaptability to the harsh environment (Gowane *et al.* 2010). Flocks were managed semi-intensively and lambing restricted to the spring (January–February) and autumn (August–September). At lambing, both lambs and dams were weighed and the lambing date, sex and type of birth of each lamb were recorded. A concentrate mixture was offered *ad lib.* to suckling lambs from 15 days of age until weaning (90 days). Each died lamb was subjected to post mortem examination on a daily basis. The overall NM rate (%) was calculated using the formula: (Number of lambs died during the first 28 days of life/ Number of lambs born alive) × 100. Similarly, phase specific (as described above) mortality rates were also calculated. The factors considered in analysis were dam's age, parity, body weight at lambing, birth weight and sex of lamb, year and season of birth, and ratio of lamb weight to dam's weight at lambing. The data were analysed by cross-tabulation and tested for significance by chi-square test using SPSS 25.0. The phase specific causes of death were calculated as their % contribution during particular neonatal phase. Association of factors influencing lamb mortality were obtained by odds ratio (OR). The value of OR ≥ 1 was considered as presence of association between causal factor and neonatal mortality.

During the study period, out of 5,722 lambs born, 233 (4.07%) died during neonatal phase (Table 1). Around 3-times higher mortality rate was observed to occur in hebdomadal phase (3.15%) as compared to post-hebdomadal phase (0.93%). Among hebdomadal phase, higher mortality was in immediate and delayed phase compared to late phase. An inverse relation was observed between the overall neonatal mortality and birth weight of lamb (1.20% in lambs with >3.50 kg birth weight to 18.96% in lambs with <2.00 kg birth weight). Similar effect of birth weight on NM was observed for all the stages of neonatal phase, however it remained non-significant (P>0.05) during post-hebdomadal phase. The probability of risk for overall NM exhibited that in comparison to lambs with >3.50 kg birth weight, the odd ratio (OR) varied from 2.03 (birth weight 3.01–3.50 kg) to 19.29 (birth weight <2.00 kg). Similar trend with variable magnitudes was also observed for major causes of NM with maximum risk (10.85 times for enteritis, 16.43 times for pneumonia, 24.03 times for septicaemia/ toxaemia and 48.05 times for EIS) in lambs with birth weight <2.00 kg as compared to those with birth weight of >3.50 kg.

Sex of lamb had non-significant (P>0.05) influence on NM rate during all the phases of neonatal period. Age of dam at lambing had significant (P<0.001) effect on NM with maximum deaths (6.51%) in lambs born to younger

Present address: [1]Scientist (swarnkarcp@yahoo.com), [4]Principal Scientist (sganesh413@gmail.com), Division of Animal Health; [2]Senior Scientist (gopalgowane@gmail.com), Division of Animal Genetics and Breeding. [3]Senior Scientist (drlleslie @gmail.com), ICAR-Directorate on Poultry Research, Hyderabad, Telangana.

Table 1. Factor-wise neonatal lamb mortality rate in Malpura sheep at an organized farm in semi-arid Rajasthan

Factor	No. born	No. died (%)					
		Hebdomadal (0–7 day)				Post-hebdomadal	Grand Total
		Immediate (0–1 day)	Delayed (2–3 day)	Late (4–7 day)	Total	(8–28 day)	(0–28 day)
Overall	5722	71 (1.24)	72 (1.26)	37 (0.65)	180 (3.15)	53 (0.93)	233 (4.07)
Birth weight (kg)		**	**	**	**	NS	**
Up to 2.0	327	28 (8.56)	17 (5.20)	12 (3.67)	57 (17.43)	5 (1.53)	62 (18.96)
2.01–2.50	749	16 (2.14)	16 (2.14)	11 (1.47)	43 (5.73)	10 (1.34)	53 (7.08)
2.51–3.00	1775	19 (1.07)	19 (1.07)	9 (0.51)	47 (2.65)	16 (0.90)	63 (3.55)
3.01–3.50	1700	7 (0.41)	16 (0.94)	3 (0.18)	26 (1.53)	15 (0.88)	41 (2.41)
> 3.50	1163	1 (0.09)	4 (0.37)	2 (0.17)	7 (0.60)	7 (0.60)	14 (1.20)
Sex of lamb		NS	NS	NS	NS	NS	NS
Male	2885	41 (1.42)	39 (1.35)	20 (0.69)	100 (3.47)	25 (0.87)	125 (4.33)
Female	2837	30 (1.06)	33 (1.16)	17 (0.60)	80 (2.82)	28 (0.99)	108 (3.81)
Dam age (yr) at lambing		*	*	**	**	NS	**
Up to 2	906	19 (2.10)	20 (2.21)	11 (1.21)	50 (5.52)	9 (0.98)	59 (6.51)
2–4	2688	27 (1.00)	29 (1.08)	18 (0.67)	74 (2.75)	20 (0.74)	94 (3.50)
4–6	1483	13 (0.88)	16 (1.08)	1 (0.07)	30 (2.02)	18 (1.21)	48 (3.24)
> 6	645	12 (1.86)	7 (1.09)	7 (1.09)	26 (4.03)	6 (0.93)	32 (4.96)
Parity of dam		*	NS	**	**	**	**
1	1915	36 (1.88)	33 (1.72)	22 (1.15)	91 (4.75)	16 (0.84)	107 (5.59)
2	1385	11 (0.79)	18 (1.30)	6 (0.43)	35 (2.53)	9 (0.65)	44 (3.18)
3	1070	13 (1.21)	11 (1.03)	2 (0.19)	26 (2.43)	7 (0.65)	33 (3.08)
4	746	4 (0.54)	5 (0.67)	2 (0.27)	11 (1.47)	8 (1.07)	19 (2.55)
>4	602	7 (1.16)	5 (0.83)	5 (0.83)	17 (2.82)	13 (2.16)	30 (4.98)
Dam weight (kg) at lambing		**	**	**	**	NS	**
<20.0	34	5 (14.71)	5 (14.71)	1 (2.94)	11 (32.35)	0 (0.00)	11 (32.35)
20.1–25.0	471	17 (3.61)	10 (2.12)	9 (1.91)	36 (7.64)	6 (1.27)	42 (8.92)
25.1–30.0	2010	26 (1.29	24 (1.19)	17 (0.85)	67 (3.33)	20 (1.00)	87 (4.22)
30.1–35.0	2117	13 (0.61)	19 (0.90)	7 (0.33)	39 (1.84)	18 (0.85)	57 (2.69)
>35.1	1034	9 (0.87)	13 (1.26)	3 (0.29)	25 (2.42)	9 (0.87)	34 (3.29)
Lamb weight : Dam weight		**	**	**	**	*	**
<0.10	3115	57 (1.83)	52 (1.67)	30 (0.96)	139 (4.46)	37 (1.19)	176 (5.65)
>0.10	2540	13 (0.51)	19 (0.75)	7 (0.28)	39 (1.54)	16 (0.63)	55 (2.17)
Period		*	NS	*	*	NS	*
P1 (1991–96)	870	13 (1.49)	5 (0.57)	1 (0.11)	19 (2.18)	9 (1.03)	28 (3.22)
P2 (1996–01)	811	15 (1.85)	14 (1.73)	11 (1.36)	40 (4.93)	7 (0.86)	47 (5.80)
P3 (2001–06)	1055	8 (0.76)	19 (1.80)	4 (0.38)	31 (2.94)	6 (0.57)	37 (3.51)
P4 (2006–11)	1355	23 (1.70)	18 (1.33)	12 (0.89)	53 (3.91)	10 (0.74)	63 (4.65)
P5 (2011–16)	1631	12 (0.74)	16 (0.98)	9 (0.55)	37 (2.27)	21 (1.29)	58 (3.56)
Season		**	NS	NS	NS	*	*
Dec–Mar	4612	53 (1.15)	58 (1.26)	28 (0.61)	139 (3.01)	36 (0.78)	175 (3.79)
Apr–Jul	273	11 (4.03)	3 (1.10)	1 (0.37)	15 (5.49)	3 (1.10)	18 (6.59)
Aug–Nov	837	7 (0.84)	11 (1.31)	8 (0.96)	26 (3.11)	14 (1.67)	40 (4.78)

*Significant at P<0.05; **Significant at P<0.001; NS, nonsignificant at P>0.05. No. of missing observations: Birth weight (8); Parity (4); Dam weight at lambing (56), Lamb weight: Dam weight (67).

dams (up to 2 yr). The OR showed around two times higher risk for NM in lambs from younger ewes (up to 2 yr old) compared to those from ewes between 4–6 yr of age. Compared to lambs from 4 to 6 yr old ewes, lambs from ewes of up to 2 yr of age had higher risk for mortality due to EIS (OR=4.84) and pneumonia (OR=3.84). The risk of death due to enteritis was observed to be 3.47 times higher in lambs from old aged (>6 yr) ewes compared to those from 4 to 6 yr old ewes. Parity of dam had significant (P<0.001) effect on NM with minimum and maximum mortality in lambs born to ewes in 4^{th} (2.55%) and 1^{st} (5.59%) parity. Around 2-times higher risk for NM was observed for lambs born to ewes in their 1^{st} parity compared to those in 4^{th} parity.

Dam's weight at lambing revealed significantly (P<0.001) maximum (32.35%) mortality in lambs born to ewes with <20.0 kg body weight. In comparison to ewes with 30–35 kg body weight at lambing, the probability of risk for neonatal mortality was maximum (OR=17.28) in lambs born to ewes with <20.0 kg body weight at lambing. Like-wise the lambs born from ewes of 30.1–35.0 kg body weight at lambing, the lambs from weak ewes (<20.0 kg body weight) had 49.6, 26.40 and 3.74 times higher risk for neonatal mortality due to EIS, pneumonia and septicaemia/ toxaemia, respectively. The NM was significantly (P<0.001) higher (5.65%) in the lamb to dam weight ratio group of <0.100 compared to those with ratio of >0.100 (2.17%). The overall neonatal mortality was significantly (P<0.05) affected by period and season of birth. The OR for lamb weight: dam weight ratio suggested 1.22 (enteritis) to 3.56 (EIS) times more risk for NM in <0.100 group lambs compared to >0.100 group lambs. Compared to major lambing season (December-March), the OR for NM was 1.79 for lambs born during April-July.

The overall profile of causes of neonatal lamb mortality exhibited predominance of septicaemia/ toxaemia with 25.75% contribution in total deaths followed by neonatal inanition (21.89%), pneumonia (12.02) and enteritis (8.58%) (Table 2). Among different phases of neonatal period, septicaemia/ toxaemia, neonatal inanition, low birth weight/debility and enteritis were major affections responsible for mortality in 0–1 day old lambs. The predominant causes of mortality in decreasing orders were neonatal inanition, pneumonia, septicaemia/ toxaemia and enteritis in 2–3 days old lambs, neonatal inanition, septicaemia/ toxaemia and pneumonia in 4–7 days old lambs and septicaemia/ toxaemia, pneumonia and neonatal inanition in 8–28 days old lambs. The analysis for predominant causes of NM revealed significant (P<0.001) influence of birth weight on mortality rate due to pneumonia, septicaemia, enteritis and exposure-inanition syndrome (EIS-including low birth weight, exposure and inanition). An inverse relation was observed between cause specific mortality rate and birth weight for all the entities except enteritis. Compared to lambs with >3.5 kg birth weight, lambs with <2.0 kg birth weight had considerably higher mortality due to EIS (7.65% vs 0.26%), septicaemia (3.98% vs 0.17%), pneumonia (2.75% vs 0.17%) and enteritis (1.83% vs 0.17%). The sex of lambs had non-significant variation in all the cause specific mortality rates. The dam's age at lambing had significant effect only on EIS (P<0.001) and enteritis (P<0.05) related mortality. Parity of dam had significant (P<0.001) influence only on NM due to EIS with minimum of 0.67% in lambs from ewes in 4th parity to 2.09% in lambs from ewes in 1st parity. Dam's weight at lambing had significant influence on NM due to all the major causes except enteritis with higher mortality in lambs born from ewes with <25.0 kg body weight. The year of birth (periods) had significant (P<0.003) influence on EIS related mortality only while season of birth (P<0.017) had significant influence on pneumonia related deaths mostly in Dec-March born lambs.

Lamb mortality is a complex trait that is influenced by the ewe's maternal ability and the lamb's capability for survival, in addition to management practices and environmental variables at the time of birth and during the early phase of life. Present study reported standard incidence of NM in Malpura sheep flock (4.07%). Neonatal mortality rates ranging from 4 to 20% have been reported from different countries (Binns *et al.* 2002, Sawalha *et al.* 2007, Ahmed *et al.* 2010, Gowane *et al.* 2018), representing an important economic loss for farmers. A realistic target for NM rate in a well-managed flock should be 3%, the upper acceptable limit under any circumstances should be 5% (Haughey 1991, Bernal 2001). There was significant dispersion of NM in Malpura lambs in relation to several factors. Various studies have reported effect of age of dam, type of birth, sex of lamb, season and year of birth, birth

Table 2. Causes of overall neonatal mortality and their % contribution

Cause	No. died (%)					
	Hebdomadal (0–7 day)				Post-	Grand
	Immediate (0–1 day)	Delayed (2–3 day)	Late (4–7 day)	Total	hebdomadal (8–28 day)	total (0–28 day)
No. died	71	72	37	180	53	233
Debility/ low birth weight	5 (7.04)	3 (4.17)	0 (0.00)	8 (4.44)	2 (3.77)	10 (4.29)
Exposure	2 (2.82)	4 (5.56)	2 (5.41)	8 (4.44)	1 (1.89)	9 (3.86)
Septicaemia/ Toxaemia	24 (33.80)	13 (18.06)	8 (21.62)	45 (25.00)	15 (28.30)	60 (25.75)
Enteritis	5 (7.04)	7 (9.72)	2 (5.41)	14 (7.78)	6 (11.32)	20 (8.58)
Hepatitis	0 (0.00)	1 (1.39)	2 (5.41)	3 (1.67)	2 (3.77)	5 (2.15)
Liver rupture	1 (1.41)	0 (0.00)	0 (0.00)	1 (0.56)	1 (1.89)	2 (0.86)
Internal haemorrahage	2 (2.82)	1 (1.39)	0 (0.00)	3 (1.67)	1 (1.89)	4 (1.72)
Anaemia	0 (0.00)	1 (1.39)	0 (0.00)	1 (0.56)	0 (0.00)	1 (0.43)
Pneumonia	2 (2.82)	11 (18.92)	7 (18.92)	20 (11.11)	8 (15.09)	28 (12.02)
Fracture	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (1.89)	1 (0.43)
Otitis	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (1.89)	1 (0.43)
Pneumoenteritis	1 (1.41)	1 (1.39)	0 (0.00)	2 (1.11)	0 (0.00)	2 (0.86)
Navel ill	1 (1.41)	0 (0.00)	2 (5.41)	3 (1.67)	1 (1.89)	4 (1.72)
Tetanus	0 (0.00)	1 (1.39)	2 (5.41)	3 (1.67)	3 (5.66)	6 (2.58)
Neonatal inanition	16 (22.54)	19 (26.39)	10 (27.03)	45 (25.00)	6 (11.32)	51 (21.89)
Colibacillosis	1 (1.41)	3 (4.17)	1 (2.70)	5 (2.78)	1 (1.89)	6 (2.58)
Miscellaneous	11 (15.49)	7 (9.72)	1 (2.70)	19 (10.56)	4 (7.55)	23 (9.87)

weight, body weight of dam and rearing system on lamb mortality (Mandal *et al.* 2007, Sawalha *et al.* 2007). The high mortality rate during the first 7 days of life was in agreement with previous reports (Sharif *et al.* 2005, Ahmed *et al.* 2010, Barazandeh *et al.* 2012, Abdelqader *et al.* 2017).

Similar to present findings, the significant effect of birth weight of lamb on the mortality has also been reported earlier (Mukasa-Mugerwa *et al.* 2000, Mandal *et al.* 2007). Birth weight has been reported as the single greatest contributor to lamb mortality (Fogarty *et al.* 2000) with a curvilinear (U-shaped) relationship (Barazandeh *et al.* 2012, Refshauge *et al.* 2016, Abdelqader *et al.* 2017). Extreme-low birth weight lambs are less vigorous at birth, take longer time to stand and suck successfully, thereby increasing their risk of infection and have a reduced ability to maintain body temperature compared to heavier lambs (Dwyer 2008) and die due to exposure and starvation (Clarke *et al.* 1997), whereas extreme-high birth weight lambs are more likely to die due to dystocia, particularly single lambs (Dalton *et al.* 1980). Therefore, the optimal birth weight, rather than maximum birth weight, should be the target for survival rate improvement.

The higher mortality in male lambs compared to female lambs has been reported in majority of studies (Vatankhah and Talebi 2009, Ahmed *et al.* 2010, Abdelqader *et al.* 2017). However, Turkson and Sualisu (2005) in Ghana reported higher mortality for female lambs. This difference has been attributed to sex linked determinants which according to Mandal *et al.* (2007) are yet to be identified. Similar influence of age and parity of dam on NM as observed has also been reported earlier with higher lamb mortality in those born from younger ewes (Morris *et al.* 2000, Vatankhah and Talebi 2009, Ahmed *et al.* 2010). The preponderance of mortality among lambs from younger ewe lambs may be due to their poor maternal instincts (Dwyer *et al.* 2001), leading to hypothermia and starvation. The parity had an influence on lamb mortality due to birth of lighter lambs (Dalton *et al.* 1980), negative maternal behaviour, such as rejection and fear-like behaviour (Dwyer and Lawrence 2005). Increased body weight of the dam significantly decreased the lamb mortality in our study. Ewes with poor body weight usually deliver lighter lambs with impaired sucking ability, inadequate lactation or maternal interactions can prevent the lamb ingesting sufficient colostrum to meet its nutritional needs and higher lamb mortality due to inanition (Dwyer *et al.* 2005). The significant yearly variation in lamb losses may be attributed to variation in the environmental conditions, differences in feed/fodder availability and other managerial factors (Mandal *et al.* 2007, Vatankhah and Talebi 2009). Similar to present observation on seasonal neonatal mortality, Berhan and Van Arendonk (2006) reported higher mortality rate for lambs born in the dry season compared to those born during the wet seasons.

The prevalence of the different causes of mortality varies with different management systems with starvation or exposure as predominant cause in outdoor lambing systems compared to infectious diseases in indoor systems (Binns *et al.* 2002). Pneumonia and starvation were observed as main causes of early lamb mortality (within 15 days of birth) by Mandal *et al.* (2007). Lambs born with low birth weight were 5.5 times more likely to die from starvation and 3.6 times more likely to die from hypothermia when compared with lambs born with an intermediate birth weight (Abdelqader *et al.* 2017). Cold-stressed young lambs often become hypothermic because of excessive heat loss from exposure to inclement weather and because of depressed heat production due to severe hypoxia at birth or to starvation (Eales *et al.* 1982). A lamb poorly bonded to its mother or with low vigour is unable to suck sufficient milk and produce sufficient heat and hence died due to hypothermia and starvation (Dwyer and Morgan 2006). To reduce the risk of neonatal mortality due to hypothermia efforts should be on lambing at a time of year that reduces the likelihood of adverse weather keeping in mind other factors like pasture availability, timing of weaning, cropping activities etc. The other strategies are provision of shelter to overcome bad weather, use of curtain around lambing pen to prevent exposure of lambs to chill wind.

The study revealed that higher neonatal mortality during early phase of life was primarily influenced by birth weight of lamb and age, parity and body weight of ewe. Strategies should be adopted for proper nutritional care of primiparous and weak ewes during gestation, improving birth weights, intensive monitoring of lamb and ewes during the neonatal periods with ensured colostrum or milk replacer feeding and suitable housing facility to prevent losses due to exposure – inanition syndrome.

SUMMARY

The magnitude of risk for neonatal mortality (NM) due to non-genetic factors was assessed using data on 5,722 Malpura lambs born during 1991–2016 at ICAR-Central Sheep and Wool Research Institute, Avikanagar, Rajasthan. The association of non-genetic factors influencing lamb mortality was obtained by odds ratio (OR). The overall annual NM was 4.07% with around 3 times higher in hebdomadal (3.15%) than post-hebdomadal (0.93%) phase. In comparison to lambs with >3.50 kg birth weight, the OR varied from 2.03 (birth weight 3.01–3.50 kg) to 19.29 (birth weight <2.00 kg). Neonatal mortality was significantly higher (6.51%) in lambs born to younger ewes (up to 2 yr). The parity of dam had significant effect on NM with maximum mortality in lambs born to ewes in 1st (5.59%) parity. Dam's weight at lambing revealed significantly maximum (32.35%) mortality in lambs born to ewes with <20.0 kg body weight. In comparison to ewes with 30–35 kg body weight at lambing, the OR for NM was maximum (17.28) in lambs born to ewes with <20.0 kg body weight at lambing. The causes of neonatal lamb mortality exhibited predominance of septicaemia/ toxaemia with 25.75% contribution in total deaths followed by neonatal inanition (21.89%), pneumonia (12.02) and enteritis (8.58%). The study revealed that NM during early phase of life was

primarily influenced by both lamb and ewe factors. Strategies should be adopted for proper nutritional care of primiparous and weak ewes during gestation, intensive monitoring of lamb and ewes during the neonatal period with ensured colostrum or milk replacer feeding and suitable housing facility to minimize the neonatal losses.

ACKNOWLEDGEMENTS

Authors acknowledge the support and facility provided by the Director, ICAR-CSWRI, Avikanagar. All India Network Program on Neonatal Mortality in Farm Animals (ICAR) is duly acknowledged for funding support. Authors also acknowledge the efforts put forth by all the people involved in management of the sheep flocks since inception of the project.

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