Uterine Torsion as a cause of dystocia in sheep:

Occurrence, nature and predisposing factors

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“Sometimes things aren’t clear right away. That’s where you need to be patient and persevere and see where things lead”

-Mary Pierce-

CONTENTS

LIST OF ABBREVIATIONS

e.g.	for example
i.p.	intra partum
a.p.	ante partum

I. INTRODUCTION

Dystocia is a common challenge for farmers and veterinarians alike when working with the ovine species. It poses a threat to animal welfare and causes considerable financial losses (LANE et al., 2015). One cause of dystocia of maternal origin is torsion of the pregnant uterus. Although this condition is well studied in large ruminants, it still largely remains a terra incognita in sheep. Diagnosis of the condition in small ruminants is hampered by the small size of the patient, which does not allow rectal examination. This may lead to underdiagnosis of the disease. Taking into consideration that the duration and the severity of the condition strongly affects the prognosis for survival of both mother and offspring, an accurate and timely diagnosis and timely intervention can be life-saving. Additionally, predisposing factors for uterine torsion are largely unstudied in sheep. It is thus unclear which factors influence the occurrence of this condition in the ovine species, and if factors previously suggested as influential in cattle also apply to sheep. Taking the above into consideration combined with the striking lack of published information concerning uterine torsion in sheep, this study was conducted to collate existing knowledge, to generate new information regarding the frequency and nature of uterine torsion in sheep, and to identify potential risk factors for its occurrence.

II. LITERATURE REVIEW

1. Ovine Dystocia

1.1. Definition

The term “dystocia” derives from the Greek words “dys” (difficult) and “tokos” (parturition). In sheep, it is defined as “failure of transition from stage I to stage II labor or when little to no progress is made for 30 minutes or more after the start of stage II labor” (ANDERSON, 2014). It may be caused by problems originating from either the lamb(s) (foetal dystocia) or the ewe (maternal dystocia). In sheep, commonly reported foetal causes of dystocia are foetal maldisposition, foetal oversize, simultaneous presentation of more than one lamb, emphysematous foetus(es) and, less commonly, foetal monsters (NOAKES et al., 2018). Maternal causes of dystocia are insufficient cervical dilatation (ringwomb), foetomaternal disproportion (e.g. narrow pelvis of the dam), primary or secondary uterine inertia, vaginal prolapse and, less frequently, uterine torsion (PARKINSON et al., 2019c). Uncommon maternal causes of ovine dystocia are hydrallantois or hydramnion, and paralysis of the sciatic nerve (JACOBSON et al., 2020).

1.2. Frequency and importance

Dystocia is a frequent problem in sheep and varies according to the breed, parity of the dam and litter size (SPEIJERS et al., 2010; JACOBSON et al., 2020). Breed influences have been previously studied, with dystocia rates varying from 4.0% in Merino to 34.0% in Dorset ewes (GEORGE, 1975, 1976). Different authors showed that Texel lambs were three times more likely to require veterinary assistance at birth than other studied breeds (Scottish Blackface, Mule), with only 44.0% of Texel lambs born without assistance (DWYER and BÜNGER, 2012). In crossbreeding scenarios in a study conducted on six hill farms in Northern Ireland, the breed of the ram was also shown to have a significant effect on the incidence of dystocia (SPEIJERS et al., 2010). Ewes suffered from proportionally less dystocia events when they were mated with Blackface rams as compared to ewes served by larger breeds such as Lleyn or Texel (SPEIJERS et al., 2010).

The true incidence of dystocia in field settings is difficult to assess, as most studies on the subject are based on pre-selected cases presented for veterinary attention. Large-scale field studies are rare: Data from the "Sheep Ireland" database concerning the incidence of lambing difficulties recorded by the farmers (ranging from slight assistance to veterinary intervention) were evaluated from a total of 839 Irish sheep flocks between 2008 and 2014. Between years, recorded dystocia rates ranged between 1.5% to 1.8% of all parturitions (McHUGH et al., 2016). Mahmoud et al (2018) reported an incidence of dystocia of 3.9% (122 cases of dystocia in 3168 sheep) in a field study from 42 flocks in Algeria. Considerably higher results were obtained in a study conducted in an experimental sheep flock, where the incidence of dystocia (from the grade where assistance was needed) was 13.4% of all litters (LEEDS et al., 2012). In a report by SMITH (1977) the percentage of dystocia cases ranged between 12.0% for Coarse Wool sheep to 22.0% in Corriedale ewes in the several breeds studied. (McSPORRAN et al., 1977) studied the breeding and lambing records of a flock in New Zealand from 1964 to 1972. Annual dystocia rates varied between 20.0 and 31.0% in this flock.

Many other studies on ovine dystocia have been conducted in veterinary hospitals or are based on case cohorts presented to veterinary practices. They are thus based on a pre-selected case load and do not allow conclusions regarding the incidence of dystocia in the wider sheep population (DURRANI and KAMAL, 2009; BADAWI et al., 2016; YERIMA et al., 2021).

1.3. Foetal causes of dystocia

Foetal causes are the predominant causes of dystocia in field settings (SCOTT, 1989; DWYER and BÜNGER, 2012; PARKINSON et al., 2019d). CLOETE et al. (1998) studied birth difficulties in one South African mutton merino (n=335 ewes) and one Dormer flock (a cross breed between German merino and Dorset Horn, n=273 ewes) and reported a proportion of dystocia of foetal origin of 56.3% (36/64 assisted deliveries) in the Merino and 68.0% (17/25 assisted deliveries) in the Dormer flock. MAHMOUD et al. (2018), while evaluating 3,168 ewes from 42 farms in the lambing period in an entire region in Algeria, reported that 122 ewes suffered from dystocia, with 95 of these cases (77.9%) due to foetal causes.

Studies conducted on cases presented for veterinary attention frequently report lower percentages of foetal causes of dystocia than those reported in the field. While a study conducted in a veterinary teaching hospital in Iraq identified foetal causes in 178 (53.6%) of 332 dystocia cases (MAJEED and TAHA, 1995), a considerably lower proportion of foetal dystocia was reported by ENNEN et al. (2013), who analysed ovine dystocia cases presented to a teaching hospital in Germany. In this study, 35.9% (69/192) of ewes with dystocia presented for veterinary attention were diagnosed with foetal causes. Foetal causes of dystocia are mostly due to a faulty position of the extremities or head of the foetus (CLOETE et al., 1998; DWYER and BÜNGER, 2012), however, foetal oversize or simultaneous delivery of multiple litters (ALI, 2011; SHARMA et al., 2014b) are also relatively frequent. Amongst others, less frequent foetal causes include foetal emphysema (SOBIRAJ, 1994) or foetal monsters, which may develop due to teratogenic agents, viral diseases or individual developmental or genetic factors (HUNTER et al., 2002; PANDEY et al., 2017; STOKES et al., 2018; DINESH et al., 2020).

1.3.1. Foetal Maldisposition

Faulty disposition of the lambs is one of the major causes of dystocia in sheep (MAJEED and TAHA, 1995; PUROHIT et al., 2006; SHARMA et al., 2014b; PARKINSON et al., 2019d). In a study conducted in 98 ruminant holdings in two regions in Nigeria, where the farmers had to record all difficult parturitions, the most common cause of ovine dystocia was due to foetal maldisposition, accounting for 26.2% (11/42) of all recorded ovine dystocia cases (AKPA et al., 2002). A higher percentage of foetal maldisposition, accounting for 36.0% of the difficult parturitions, was reported in a study from New Zealand, which analysed lambing records from a flock over an eight-year period (McSPORRAN et al., 1977). In Algeria, MAHMOUD et al. (2018) reported that 70 of 122 field based dystocia cases (57.4%) were caused by this problem. Of the 3,252 lambs born in flocks during a study assessing lambing difficulties in four different breeds, 25.1% of all lambs were incorrectly presented at birth (DWYER and BÜNGER, 2012).

In studies covering animals presented for veterinary attention, the percentage of foetal maldisposition accounted for 54.3% (38/70 of presented dystocia cases) in India (BHATTACHARYYA et al., 2015) and 21.1% (38/180 of all presented cases) in Saudi Arabia (ALI, 2011). Numbers obtained in other studies conducted in veterinary clinics which evaluated both manual and surgical deliveries are variable, with numbers ranging from 16.7% (5/30 of all cases) in India (SHARMA et al., 2014b) to 57.5% (50/87 of all presented cases) in Algeria (MOSTEFAI et al., 2019). In Germany, previous hospital based studies covering both manually corrected and surgical cases presented for veterinary attention reported a percentage of foetal maldisposition of 25.2% (74/293 of all cases; (SOBIRAJ, 1994) and 30.2% (58/192 of all cases; (SCHOLZ, 2006) of the dystocia cases submitted, respectively.

The most commonly reported types of foetal maldisposition are deviation of the head, flexion of the forelimb/s, flexion of the hind limb/s and breech position (McSPORRAN et al., 1977; PUROHIT et al., 2006; SHARMA et al., 2014a; MOSTEFAI et al., 2019).

1.3.2. Foetal oversize

Background information concerning the breeding and nutritional management of a flock can give useful information about the potential incidence of dystocia due to foetal oversize (WINTER, 1999; SCOTT, 2005, 2017). Mating small breeds such as Blackface or Cheviot ewes with large males like Texel rams (CARSON et al., 2001), as well as the presence of large single lambs can result in dystocia due to foetal oversize (PARKINSON et al., 2019d) as a result of the high birth weight (SPEIJERS et al., 2010) or the conformation of the lambs (DWYER and BÜNGER, 2012). Particularly meat breeds are prone to dystocia due to foetal oversize, as shown by a study by DWYER and BÜNGER (2012), who reported that a high percentage of Suffolk and Texel lambs (28.0% and 34.0%, respectively) required major assistance at birth when compared to Scottish Blackface and crossbred ewes (Mule x Texel). The authors suggested that the size and body shape of lambs of these breeds played a role in the occurrence of dystocia. Two percent of all Texel lambs born during the study had to be delivered by caesarean section (DWYER and BÜNGER, 2012). Dystocia due to foetal oversize is an absolute indication for caesarean section (SCOTT, 1989).

In studies covering dystocia cases submitted for veterinary attention, the reported percentage of dystocia due to large lambs was highly variable. In a publication by ENNEN et al. (2013), this condition accounted for less than 10.0% of the dystocia cases, together with other less frequent causes presented to a veterinary hospital; The thesis by SCHOLZ (2006), which forms the basis of this publication, mentions the detailed percentage of this condition in the same study as 2.1% (4/192 presented dystocia cases). In other studies, evaluating dystocia cases submitted to veterinary care, the percentage of foetal oversize ranged from 4.8% (8/293 presented cases; (SOBIRAJ, 1994), 9.6%

(32/332 presented cases; (MAJEED and TAHA, 1995) to 12.7% (14/110 presented cases; (AHMED et al., 2017) and 15.0% (27/180 presented cases; (ALI, 2011) of cases presented to veterinary hospitals. However, when cases of caesarean sections were the focus of a study, higher percentages were partly observed: while VOIGT et al. (2021) reported a percentage of foetal oversize of 14.9% in a German study (31/212 caesarean sections), large lambs accounted for 28.5% (37/130 caesarean sections) in a study from Iraq (MAJEED et al., 1993) and even 40.1% (55/137 caesarean sections) in a Scottish study (SCOTT, 1989).

1.3.3. Other foetal causes

Other reported foetal causes of dystocia are foetal monstrosities or malformations, or foetal emphysema (VERMUNT et al., 2019). Foetal congenital defects were an important cause of dystocia in a study covering dystocia cases between 2002 and 2005 in Iraq. In this study, 13.9% (27/193) of the cases presented to a veterinary clinic were due to foetal malformations, most commonly arthrogryposis (7/27 congenital defects, 29.5%) (BASHER, 2006). Viral diseases such as, for instance, Schmallenberg Virus, Akabane and Aino Viruses, Bluetongue Virus, Rift Valley Fever Virus or Wesselsbron Virus (WINDSOR, 2019) and environmental temperatures (BASHER, 2006) are often associated with such outbreaks. Foetal malformations can be diverse in appearance and may also be caused by inherited mutations or metabolic errors (WINDSOR, 2019). Cases of foetal monsters such as schistosoma reflexum or hydrocephalus are however often limited to individual animals as demonstrated by individual case reports (WANI et al., 1994; KISANI and WACHIDA, 2012; BHATTACHARYYA et al., 2015; PERIYANNAN et al., 2021). In the majority of studies, foetal malformations accounted for only a small percentage of the dystocia cases presented for veterinary attention, with percentages ranging from 0.7% (2/293 of all dystocia cases; SOBIRAJ, 1994), 1.0% (2/192 of all ovine dystocias; SCHOLZ, 2006), 3.3% (7/212 of all caesarean sections;

VOIGT et al., 2021), 4.4% (8/180 of all dystocia cases; ALI, 2011) up to 7.7% (10/130 of caesarean sections; MAJEED et al., 1993).

1.4. Maternal causes of dystocia

Maternal dystocia is difficulty in parturition deriving from the dam due to either insufficient expulsive forces or inadequacy of the birth canal (PARKINSON et al., 2019a). A breed association has been suggested by CLOETE et al. (1998), who observed an increased frequency of foetopelvic disproportion in South African mutton merinos (16/28 maternal dystocias; 57.1%), while Dormer ewes (German merino x Dorset Horn) more frequently suffered from uterine inertia (7/8 maternal dystocias; 87.5%; CLOETE et al., 1998).

1.4.1. Ringwomb

Failure of the cervix to dilate sufficiently to allow the foetus to be successfully delivered is referred to as "ringwomb" and is considered one of the most common causes of maternal dystocia in sheep (PARKINSON et al., 2019c). Mineral or hormonal imbalances have been suggested as predisposing factors (PUROHIT et al., 2006). The aetiology of inadequate cervical dilatation is however unclear. It may be due to insufficient secretion of hormones that induce and control labour, or a failure of the cervical tissue to respond to hormonal signals (KERR, 1999). This condition has been reported in both primiparous and multiparous ewes (MAJEED et al., 1993; ALI, 2011; KUMARI and DUTT, 2020). In field settings, maternal causes of dystocia are less frequent than foetal causes. CLOETE et al. (1998) reported an incidence of ringwomb of 4.5% (4/89) of all difficult parturitions on a flock level. In case cohorts presented for veterinary attention or specifically for caesarean section, maternal causes are usually over-represented. Ringwomb was diagnosed in up to 57.6% (15/26; BHATTACHARYYA et al., 2015) or 64.0% (73/114; KLOSS et al., 2002) of the maternal cases of dystocia presented for veterinary attention, and in up to 50.0% (65/130) of all dystocia cases treated by caesarean section in a veterinary hospital (MAJEED et al., 1993). Similar results were obtained by VOIGT et al. (2021), who diagnosed ringwomb in 44.3% of all ovine caesarean sections (n=212).

1.4.2. Foetomaternal disproportion

Foetomaternal disproportion can either be due to a narrow ewe pelvis or due to an oversized foetus (see foetal oversize). A narrow pelvis appears to be an important factor increasing the incidence of dystocia (FOGARTY and THOMPSON, 1974). Pelvic measurements differ between breeds. A study by CARSON et al. (2001) reported that Blackface ewes bred by Blackface rams had less difficulties in parturition than Cheviot sheep bred by Cheviot rams. The mating of ewes by big rams can also increase the problem. The sire should therefore be chosen wisely, particularly in primiparous animals (McHUGH et al., 2016). Parity has been reported to influence the chance of suffering from foetomaternal disproportion: primiparous animals are more prone to suffering from this condition compared to multiparous ewes (PARKINSON et al., 2019b). McHUGH et al. (2016) reported that age at first lambing (8 - 18 months versus >18 and ≤ 28 months) played an important role in two aspects: incidence of dystocia and offspring survival.

1.4.3. Uterine inertia

This term describes the inability of the uterus to expel the foetus and uterine inertia can either be primary or secondary. The frequency of this condition varies according to the literature, with a reported percentage of 2.2% (5/229; KLOSS et al., 2002), 4.6% (4/87; MOSTEFAI et al., 2019) or 18.0% (16/89; (CLOETE et al., 1998) of the dystocia cases which required human intervention at veterinary clinics. Primary uterine inertia can be associated with reduced hormonal signals, pregnancy toxaemia, metabolic stress such as hypocalcaemia or stress during labour (BARBAGIANNI et al., 2015; SHARUN and ERDOĞAN, 2019; JACOBSON et al., 2020). Exhaustion of the uterine wall due to prolonged labour, abdominal hernia, foetal malpresentation or stress can lead to secondary uterine inertia (CLOETE et al., 1998; PUROHIT, 2006).

1.4.4. Other maternal causes

Other maternal causes of dystocia include vaginal prolapse intra partum with or without concurrent insufficient dilatation of the cervix, lesions due to vaginal prolapse ante partum or other injury, inadequacy of the cervix (duplication), vagina (stricture, cystocele, vestigial structures) or vulva (stricture, incomplete relaxation), displacement of the uterus, and uterine torsion (KLOSS et al., 2002; PUROHIT et al., 2006; PARKINSON et al., 2019a; SHARUN and ERDOĞAN, 2019). Less common maternal causes of dystocia reported in the literature are rupture of the prepubic tendon (ALI, 2011; DAHMANI et al., 2019) vaginal and cervical tumours or hydrallantois (PUROHIT et al., 2006) Uterine torsion is discussed in detail in Chapter 2.

2. Uterine torsion

2.1. Definition and frequency in domestic animals

Uterine torsion is defined as the rotation of the pregnant uterus around its long axis (PARKINSON et al., 2019c-). This condition is well studied in cattle and buffaloes, but less researched in small ruminants, and can endanger the life of mother and offspring. Uterine torsion is the most common cause of dystocia in buffaloes, accounting for up to 75.0% of all dystocias in this species (PUROHIT, 2011; PUROHIT and GAUR, 2014). It is also a relatively common maternal cause of dystocia in cattle with a reported incidence of 0.3% of all parturitions (PARKINSON et al., 2019c) and 3.9% of the caesarean sections performed in a cattle veterinary practice (LYONS et al., 2013). Uterine torsion is also a frequent problem in mares and has been observed with a frequency of between 5.0% and 10.0% of all equine obstetrical emergencies (MARTENS et al., 2008; YORKE et al., 2012; FOTARIYA et al., 2020). Other domestic animals that may suffer from this condition are rats (ERLWANGER et al., 2011) and goats (CHAHAR et al., 2018; JAYAGANTHAN et al., 2020). Uterine torsion has also been observed in bitches and cats (DARVELID and LINDE-FORSBERG, 1994; KURODA et al., 2017) but possibly due to the pluriparous nature of the canine or feline pregnancy, most case reports refer to a unilateral uterine horn torsion (THILAGAR et al., 2005; DOĞRUER et al., 2018). New world camelids can also suffer from this condition (CEBRA, 2007; PEARSON et al., 2012), however, detailed studies on the prevalence of this condition do not exist in these species (TIBARY et al., 2008).

In small ruminants, uterine torsion has been thought to be of less importance as a cause of dystocia, as its reported frequency is very low (PARKINSON et al., 2019c). Many available publications are based on individual case reports, thus highlighting the rare character of the condition (IJAZ and TALAFHA, 1999; WINZAP et al., 2000; PHOGAT et al., 2007; SCOTT, 2011; NAIDU, 2012; VELLADURAI et al., 2016; BALAMURUGAN et al., 2019; JONES et al., 2020; MAHAL et al., 2020). A rare case of unilateral uterine torsion has also been documented in sheep (CASTILLO et al., 2018).

2.1.1. Classification

Uterine torsion can be classified according to different aspects of the condition: the time of occurrence: during pregnancy, i.e. before the onset of parturition, (ante partum – a.p.,) or during parturition (intra partum – i.p.); the localization of the torsion in relation to the cervix (pre-cervical, intra-cervical, post-cervical); the degree of torsion, and its direction: to the right (ad dextram, clockwise) or to the left (ad sinistram, counterclockwise) (PARKINSON et al., 2019c).

2.1.2. Aetiology and occurrence in cattle

In cattle, uterine torsion is mostly observed during the late first stage or at the beginning of the second stage of labour (PARKINSON et al., 2019c) . However, antepartal cases can also occur (GHOSH et al., 2013), but are considered less frequent. In a study conducted by FRAZER et al. (1996), who analysed 164 cases of uterine torsion referred to a veterinary hospital, only 13 (8.0%) of the 160 cases for which the stage of gestation or parturition was documented were more than one week before term. Most authors agree that the majority of bovine uterine torsion cases are counterclockwise, with a reported percentage of 62.0 to 63.0% (FRAZER et al., 1996; AUBRY et al., 2008). In a study by TAMM (1997), who analysed clinical records of 655 cattle with uterine torsion presented to a veterinary hospital in Germany, 67.5% (364/539 of the cases where the direction of the torsion was documented) were diagnosed with a counterclockwise torsion.

The main reason why the pregnant uterus can rotate is instability of the organ due to the anatomy of the ruminant and especially bovine genital tract, and the subsequent development of the uterus during pregnancy. The uterine horns are supported by the broad ligaments, which are attached ventrally to the uterine surface. During late pregnancy, the gravid organ grows and is then located cranially to the broad ligament attachment. As the organ increases in size, the ligaments do not increase in length accordingly (TRIPATHI et al., 2019) resulting in the uterus resting on the bottom of the abdomen, and rendering it unstable (AUBRY et al., 2008; ERTELD et al., 2012).

Another predisposing factor that seems to allow the organ to rotate more easily is a single litter pregnancy (SCHÖNFELDER and SOBIRAJ, 2005; DE AMICIS et al., 2018). Twin pregnancies in cattle are almost always bicornual, a fact that seems to stabilize the uterus (PARKINSON et al., 2019c). However, a uterine torsion in this species is also possible when twins are carried (PUROHIT et al., 2019). In a study by AUBRY et al (2008), 4.0% (2/53) of the uterine torsion cases delivered two calves. Less twin pregnancies were reported in a study by FRAZER et al (1996): Of 164 patients with uterine torsion, only three (1.8%) were presented with twins. In the study by TAMM (1997), however, the percentage of cows carrying twins (1.3% of all parturitions) was very similar to the number of uterine torsions where twins were carried (1.1%).

Breed is another factor that has been shown to predispose to uterine torsion in cattle, with the Brown Swiss breed being more prone to suffering from this condition (FRAZER et al., 1996; SCHÖNFELDER and SOBIRAJ, 2005; ERTELD et al., 2012), possibly due to its large body frame with a capacious abdomen (TRIPATHI et al., 2019). In a study performed among veterinary offices in Switzerland, 573 bovine dystocia cases were analysed. Of the 218 Brown Swiss cases assigned to the study, uterine torsion was diagnosed in 45.0%, compared to a frequency of 38.5% in all breeds (BÜHLER et al., 2018). A review by ERTELD et al (2012) also highlights reports presenting Brown Swiss cattle as being one of the most well-known breeds for suffering from uterine torsion. According to FRAZER et al (1996), breeds such as Hereford, Jersey and Angus have significantly lower chances to be presented with uterine torsion than Holsteins and other studied cattle breeds (Charolais, Guernsey, Simmental and other breeds). These findings show a breed predisposition, but according to the same authors, a beef or dairy direction of the animals does not seem to be the deciding factor (FRAZER et al., 1996).

Age and parity are two controversial factors that appear to influence the occurrence of uterine torsion in cattle in some studies. AUBRY et al. (2008) found cows to have 5.2 greater odds than heifers of suffering from uterine torsion. Multiparous animals are supposed to have a higher predisposition for suffering from uterine torsion due to weaker musculature and a lack of tonicity in the broad ligaments (GHOSH et al., 2013). In a study by DORRESTEIJN (2018), who analysed 731 uterine torsions from five veterinary practices, age and parity did however not appear to significantly influence the incidence of this condition. The results by TRIPATHI and MEHTA (2015) even indicate a lower susceptibility for older animals: these authors showed that cows with an age >5 years appeared to be at less risk of suffering from uterine torsion, probably due a thickening of the uterine muscles as the animals get older, a fact that may help the pregnant organ to resist possible rotation.

Weakening of the abdominal muscles due to indoor housing and lack of exercise are also referred to as a predisposing factor for torsion of the pregnant uterus (ERTELD et al., 2012). However, controversial results were obtained by AUBRY et al 2008: in a study covering 55 bovine uterine torsion cases, heifers calving in tie stalls had increased chances of suffering from uterine torsion, while the opposite result was seen in cows: Cows calving in group stables had higher chances of suffering from torsion than cows kept in tie stalls. On the other hand, the aforementioned opinion concerning lack of exercise as a factor increasing the likelihood of suffering from torsion is also supported by (SINGH et al., 2020) in his study on buffaloes. In this survey of 507 farms, 37.5% of farms had torsion cases, and the authors reported that intensive farming with indoor housing and thus a lack of daily exercise raised the chances of the occurrence of the condition.

Nutrition and more specifically ruminal capacity can also affect the occurrence of uterine torsion, with an empty rumen allowing the pregnant uterus to rotate (DROST, 2007). High concentrate and low roughage rations thus presumably increase the risk of uterine torsion (PARKINSON et al., 2019c). SINGH et al (2020) reported that stall-fed buffaloes had higher odds to be presented with this type of dystocia. On the contrary, DESLIENS (1967) reported that the cases of uterine torsion assigned to this study during the pasture season (May to October) were twice as many as during the housing period. However, no statistical analysis was performed in this study. Interestingly, the same author notes that the volume and density of the rumen in grass fed cattle should also be taken into consideration when discussing factors predisposing to uterine torsion.

Other factors that have been discussed as potentially influential factors for the occurrence of uterine torsion in ruminants include behavioural aspects of the animals, especially the manner of rising and lying down, or downhill walking, as well as the weight and thus, indirectly, the sex of the foetus, since male foetuses tend to be heavier (SCHÖNFELDER and SOBIRAJ, 2005; ERTELD et al., 2012; KRUSE, 2014; PARKINSON et al., 2019c).

2.2. Ovine uterine torsion

Studies and reports on the detailed pathology of the condition, potential predisposing factors, therapeutic possibilities and its influence on survival rates of mother and offspring are sparse or lacking in sheep. Information and data about volvulus of the uterus are predominantly available from studies in dairy cattle. The condition is much more frequent and more easily diagnosed in bovines, as rectal palpation comes into assistance, a procedure that is not possible in small ruminants.

2.2.1. Prevalence

The prevalence of uterine torsion is generally considered low in sheep (PARKINSON et al., 2019c). In the published literature concerning ovine dystocia, the reported prevalence of this condition varies considerably, ranging from 0.0% (0/110) (AHMED et al., 2017) to 9.9% (28/284) (SKLADANY et al., 1988) of ovine dystocia cases presented for veterinary attention. In reports analysing caesarean sections only, the percentage of uterine torsion varied between 0.0% (0/134 SCOTT, 1989; 0/130 MAJEED et al., 1993) and 26.3% (15/57) (MOSDØL, 1986). A similarly high percentage to the latter study has also been reported by VOIGT et al. (2021), who diagnosed uterine torsion in 23.6% (50/212) of sheep treated by caesarean section. Table 1 summarises the available studies reporting the frequency of uterine torsion in case cohorts presented for veterinary attention. There are no available reports on the true incidence of this condition in field-based populations or deriving from whole flock studies.

Table 1: Literature review regarding the occurrence of uterine torsion in small ruminant dystocia patients presented for veterinary attention – individual case reports have been excluded

Author	Study population	Percentage of uterine torsion cases
AHMED et al. (2017)	110 ovine dystocia cases – clinic	0.0%
ALI (2011)	180 ovine dystocia cases – clinic	4.4%
ANUSHA et al. (2016)	64 small ruminant dystocia cases – clinic	21,6%
BHATTACHARYYA et al. (2015)	70 small ruminant dystocia cases – clinic	5.7%
BROUNTS et al. (2004)	110 small ruminant caesarean sections – clinic	2.6%
DAHMANI et al. (2019)	171 ovine dystocia cases – clinic	8.8%
HAWKINS et al. (2021) and ANGELL - coauthor (2022, personal communication)	429 ovine dystocia cases – veterinary practice	0.5%

KLOSS et al. (2002)	229 ovine dystocia cases – clinic	3.9%
MAJEED et al. (1993)	130 ovine caesarean sections – clinic	0.0%
MAJEED and TAHA (1995)	332 ovine dystocia cases – clinic	0.0%
MOSDØL (1986)	57 ovine caesarean sections - clinic	26.3%
MOSTEFAI et al. (2019)	87 ovine dystocia cases – clinic	2.3%
NAOMAN et al. (2013)	132 ovine dystocia cases – clinic	0.0%
SCHOLZ (2006)	192 ovine dystocia cases – clinic	3.1%
(SCOTT, 1989)	137 ovine caesarean sections – veterinary practice	0.0%
(SHARMA et al., 2014b)	30 small ruminant dystocia cases – clinic	6.7%
(SKLADANY et al., 1988)	284 ovine dystocia cases – clinic	9,9%
(SOBIRAJ, 1994)	293 ovine dystocia cases – clinic	1,4%
(VOIGT et al., 2021)	212 ovine caesarean sections – clinic	23.6%
(WEHREND et al., 2002)	305 ovine dystocia cases – clinic	8.0%

2.2.2. Aetiology and pathogenesis

Little is known about potentially predisposing factors for uterine torsion in sheep. The ovine genital tract and its anatomy present similarities to cattle making the gravid uterus extremely unstable (see chapter 2.3) (IJAZ and TALAFHA, 1999). This instability can aid rotation around its long axis (SCHÖNFELDER and SOBIRAJ, 2005; DE AMICIS et al., 2018). Many authors suggest that single pregnancies and, in general, an unequal number of foetuses in the uterus tend to increase this instability (BALAMURUGAN et al., 2019), while twin pregnancies seem to provide greater stability to the organ, as suggested for goats (JAYAGANTHAN et al., 2020). Although twins and multiples are common features of small ruminant pregnancy, SKLADANY J. et al. (1988) reported that all sheep evaluated with uterine torsion (n=24) carried only one lamb. On the other hand, in a study by MOSDØL (1986) more than one lamb was delivered in 7 out of 15 uterine torsion cases (46.7%).

2.2.3. Diagnosis

Diagnosis of uterine torsion in cattle is performed by rectal and vaginal examination, where tight broad ligaments and, in cases of an intra or post cervical torsion, vaginal folds are palpated and lead to confirmation of the diagnosis (TAMM, 1997; AUBRY et al., 2008; ERTELD et al., 2012). Rectal palpation is a particularly useful tool in the diagnosis of pre-cervical cases in cattle, but such a manipulation is impossible in sheep due to the small size of the species. This leads to difficulties in diagnosing these cases in sheep (SHARUN and ERDOĞAN, 2019). Pre-cervical torsions can thus easily be mistaken for insufficient cervical dilatation (SKLADANY et al., 1988; SCOTT, 2011). In these cases, a torsion of the pregnant uterus is frequently only diagnosed during caesarean section or at post mortem examination (WINZAP et al., 2000; PHOGAT et al., 2007; ALI, 2011; SCOTT, 2011; JONES et al., 2020). Transrectal doppler sonography is used in cattle to estimate and evaluate the blood supply to the uterus and its blood vessels (ABROL et al., 2020), however, as mentioned above, such a method is difficult to apply in sheep. In this species, and in cases where a diagnosis cannot be ascertained by vaginal examination, transabdominal ultrasonography can be of assistance (WEHREND et al., 2002; SCOTT, 2011). The main feature evaluated in these cases is the presence of oedema in the uterine wall, due to strangulation of the vessels, via measurement if its thickness. Other parameters that could be indicative of this condition are non-homogeneous foetal fluids or the presence of dead foetuses, and such findings should be co-evaluated (SCOTT, 2011; SCOTT, 2012). With the aid of this tool a single case of uterine torsion ante partum has been successfully diagnosed by WEHREND et al. (2002).

When taking into consideration the extensive or semi extensive character of small ruminant husbandry (JONES et al., 2020), in combination with the difficulty in diagnosis of uterine torsion in this species, under-reporting of the condition cannot be ruled out (SKLADANY et al., 1988). According to SCOTT (2011), little veterinary involvement in cases of ovine dystocia in general could also be a possible explanation for the fact that ovine uterine torsion has not frequently been reported.

2.2.4. Nature of uterine torsion in sheep

Ovine uterine torsion has most frequently been observed during parturition. Antepartal cases seem to be rare, but have also been reported. One case presented with clinical signs of poor general condition has been reported by WEHREND et al. (2002). A similar clinical presentation was documented by WINZAP et al. (2000), who initially suspected a diagnosis of pregnancy toxaemia. A delayed case of uterine torsion during pregnancy leading to foetal mummification and an incidental diagnosis at post mortem examination has also been reported in Australia (JONES et al., 2020)

Concerning the location of the torsion, most of the studies and case reports that reported these details in sheep mentioned predominantly post cervical torsions (SKLADANY et al., 1988; NAIDU, 2012; CHAUNAN et al., 2018; GUPTA et al., 2021, PERIYANNAN et al., 2021). However, SKLADANY et al. (1988) also reported some cases (4/28 torsion cases with available data) of uterine torsion located cranial to the cervix. Similar results are published by GUPTA et al. (2021), who studied 27 uterine torsions in small ruminant patients in a veterinary hospital (16 ewes and 11 does), and only five of these 27 torsions were pre-cervical.

Concerning the direction of the torsion, there is variation in the available reports. In a study from Norway, 11 of 15 ovine torsion cases were to the left (MOSDØL, 1986). However, all four additional uterine torsion cases covered in a later study by the same author were to the right (MOSDOL, 1999). Rotations to the right are also recorded in most of the individual case reports (NAIDU, 2012; CHAUHAN et al., 2018; PERIYANNAN et al., 2021). In a study by BHATTACHARYYA et al. (2015), two of the four uterine torsion cases seen by these authors were pre-cervical and counterclockwise (to the left), while the other two were clockwise (to the right) and post-cervical.

The degree of uterine torsion in sheep has mostly been reported in individual cases, ranging from 180° to 360° in case reports (NAIDU, 2012; CHAUHAN et al., 2018; MAHAL et al., 2020). More severe cases with higher degrees of torsion have been reported in Norway: (MOSDØL, 1986) diagnosed a severity of 720° in 4/15 (26.7%) in the ovine torsion cases studied. One similar case involving a 720° torsion has also been reported by SCOTT (2011).

2.2.5. Treatment

Treatment of the condition varies according to the nature and severity of the torsion and the condition of the animal at the time of presentation. Simple rolling (IJAZ and TALAFHA, 1999; GUPTA et al., 2021), modified Schäffer’s method (KUMAR et al., 2016; VELLADURAI et al., 2016; BALAMURUGAN et al., 2019) and caesarean section (SCOTT, 2011; ÖZDEMİR SALCI and SHAHZAD, 2021; SALCI, 2021) are the three methods used and are all applicable both in the field and in a veterinary hospital setting. The modified Schäffer’s method is performed with the assistance of a small wooden plank and slight pressure onto the abdomen with the hand (BALAMURUGAN et al., 2019). In cases where the first two approaches fail to correct the torsion, a surgical approach via caesarean section must be undertaken. Torsions that are left untreated beyond a reasonable period of time can pose a challenge to treatment, as adhesions may develop, which can then prevent the release of the rotated uterus. Rupture of the vagina with subsequent intestinal prolapse (MOSDOL, 1999) or damage to the supplying blood vessels leading to severe haemorrhage (BLANCHARD, 1981) have also been reported as a consequence of untreated uterine torsion. A rare case of hydroureteronephrosis secondary to uterine torsion has also been recently documented in Australia (JONES et al., 2020)

III. PUBLICATION

Retrospective analysis of 302 ovine dystocia cases presented to a veterinary hospital with particular attention to uterine torsion

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Retrospective analysis of 302 ovine dystocia cases presented to a veterinary hospital with particular attention to uterine torsion

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Abstract

Background: Dystocia is common in sheep, and foetal causes are predominant. Among maternal causes, insufficient cervical dilatation is the most frequent problem. Uterine torsion has been considered rare by many authors.

Objectives: This study was conducted to investigate causes of dystocia in sheep presented for veterinary attention, and particular focus was set on the description of uterine torsion and analysis of potentially predisposing factors for this condition.

Methods: Clinical records of 302 sheep treated for dystocia were evaluated retrospectively. Known and proposed risk factors for uterine torsion in cattle were analysed regarding their potential importance in sheep. These included lamb birth weights, ewe age, parity, season, nutrition, breed type, litter size and husbandry.

Results: Maternal causes of dystocia accounted for 67.2% (203/302) of the presented cases. Of these, insufficient cervical dilatation (121/203, 59.6%) was the most frequent diagnosis. Another substantial proportion of maternal causes (60/203, 29.6%) was identified as uterine torsion. Husbandry, breed type and litter size showed significance in univariate analyses, with lower odds for meat breeds (OR 0.22; $p < 0.001$), twin- (OR 0.49; $p = 0.020$) or multiple-bearing ewes (OR 0.19; $p = 0.013$) and higher odds for fully housed animals (OR 17.87; $p < 0.001$). Year-round housing was identified as the most influential factor in a subsequent multivariate analysis.

Conclusions: Uterine torsion was identified as a relevant cause of dystocia in our case load. The condition is likely to be underdiagnosed in sheep, and increased farmer and veterinary awareness is necessary to ensure adequate treatment of affected animals and to prevent unnecessary suffering.

KEYWORDS
dystocia, predisposing factors, sheep, uterine torsion

1 | INTRODUCTION

Dystocia is common in sheep (Jacobson et al., 2020; Phythian et al., 2019) and can lead to increased perinatal lamb (Dwyer & Bünger 2012; Holst et al., 1997; Mahmoud et al., 2018) and dam mortality (Scott, 2005), with a negative impact on farm income (Lane et al., 2015) and animal welfare (Scott, 2005). The reported incidence of ovine dystocia is variable and largely depending on breed. Foetal causes such as foetal maldisposition or foetomaternal disproportion are the most common problems (Parkinson et al., 2019a). The relative frequency of the various foetal causes and various types of malpresentation has also been shown to vary between breeds (Dwyer & Bünger, 2012). Faulty disposition of the foetus can often be resolved by farmer intervention (Scott, 1989), thus leading to an under-representation of these causes in studies involving animals presented for veterinary attention, particularly for caesarean section. Maternal causes of dystocia are therefore often the leading causes reported in these study types (Brounts et al., 2004; Ennen et al. 2013; Sobiraj, 1994; Voigt et al., 2021). Among maternal causes of ovine dystocia, incomplete cervical dilatation is the most frequently reported problem, while other causes such as uterine torsion are considered rare in sheep (Jacobson et al., 2020; Parkinson et al., 2019a, b; Winter, 1999) in contrast to other ruminants. In bovine dystocia cases presented for veterinary attention the reported percentage of uterine torsion varied between 2.7% and 65% (Erteld et al., 2012), while the condition is the most common cause of dystocia in water buffaloes altogether, accounting for up to 75% of all dystocia cases (Purohit, 2011; Purohit & Gaur, 2014). Publications on ovine uterine torsion often refer to individual cases, thus highlighting the rare character of the condition (Ijaz & Talafha, 1999; Jones et al., 2020; Scott, 2011; Winzap et al., 2000). Among previous wider studies reporting ovine dystocia cases presented for veterinary attention, or studies exclusively describing cases of ovine caesarean sections, the observed proportion of uterine torsion was variable and ranged from none to more than a quarter of the cases. No torsion cases (0%) were reported in a cohort of 137 ovine caesarean sections examined by Scott (1989) and likewise in 130 caesarean deliveries reported by Majeed et al. (1993). Mosdøl (1986) however identified uterine torsion in 15 of 57 (26.3%) surgical deliveries. More details of a literature review regarding the occurrence of uterine torsion in sheep are provided in Table 1.

While intra- and post-cervical torsions can be diagnosed by vaginal examination, pre-cervical torsions are more difficult to diagnose (Sharun & Erdoğan, 2019). These can thus easily be mistaken for insufficient cervical dilatation (Scott, 2011; Skladany et al., 1988) and the diagnosis is often incidental at caesarean section or post-mortem examination (Ali, 2011; Jones et al., 2020; Phogat et al., 2007; Scott, 2011; Winzap et al., 2000). Transabdominal ultrasonography can be a useful aid in diagnosis by detecting increased thickness (oedema) of the uterine wall, thickened foetal membranes, altered foetal fluids and, in protracted cases, the potential presence of a dead foetus (Scott, 2011; Scott, 2012; Wehrend et al., 2002).

In cattle, the anatomy of the genital tract (Aubry et al., 2008; Erteld et al., 2012), single pregnancies (De Amicis et al., 2018; Parkinson et al., 2019b; Schönfelder & Sobiraj, 2005), age, breed, parity, housing, abdominal capacity due to high concentrate rations, behaviour and foetal weight (Aubry et al., 2008; Erteld et al., 2012; Klaus-Halla et al., 2018; Kruse, 2004; Parkinson et al., 2019b; Schönfelder & Sobiraj, 2005) are all factors identified to influence the occurrence of uterine torsion. No attempts have so far been undertaken to study potentially predisposing factors in sheep, and detailed descriptions of larger case numbers are rare in this species. This retrospective analysis thus aims to create more detailed knowledge on this condition in sheep, and to help identify potentially influential factors on its occurrence by evaluating known and proposed risk factors in cattle in a cohort of sheep with dystocia presented for veterinary attention.

2 | MATERIALS AND METHODS

The clinical records of all sheep with dystocia admitted to a Southern German veterinary hospital between January 2008 and February 2021 were evaluated retrospectively. Ovine dystocia has been defined by Anderson (2014) as a failure of transition from stage I to stage II labour, or little to no progress being made for 30 min or more after the start of stage II labour. Problems may be related to a failure of either the expulsive forces or the adequacy of the birth canal, or the disposition of the foetus (Parkinson et al., 2019a). The studied cohort included all animals presented for veterinary attention which met this definition during the given time period, irrespective of diagnosis and treatment method. At the time of admission, a standardised history was taken and clinical findings and treatments were documented in detail by the veterinary surgeon on duty. The history included age, breed, parity, husbandry conditions, nutrition and owner-observed duration of labour, as well as any additionally reported clinical signs or treatments prior to admission. The clinical signs at presentation and during hospitalisation, clinical diagnoses, treatment methods, clinical outcome until hospital discharge, the duration of hospitalisation, litter size, birth weight and viability of the lambs were also recorded. Based on the clinical records, each dystocia case was assigned a single primary cause.

Uterine torsion is defined as a rotation of the uterus around its long axis (Liang et al., 2020). For cases fulfilling this criterion, and a rotation of $\geq 90°$, information on direction, degree and location of the torsion was also collected from the clinical records. Cases of uterine torsion were subsequently analysed and compared to other causes of dystocia.

To allow statistical evaluation, potential predictors for the occurrence of uterine torsion available from the history were categorised as follows: Husbandry systems were assigned to three categories: pasture with seasonal housing, fully housed all year and transhumance/shepherding systems. For parity records, two categories were used: primiparous (no previous lambing experience) or multiparous ($\geq$1 previous parturition). Similarly, nutrition during late pregnancy was assigned to two categories: additional concentrates during pregnancy or roughage-only diet, while the breeds were classified as meat breeds and more extensive (leaner) breeds. To account for potential seasonal differences, the cases were assigned to the pasture season (April to October) or housing season (November to March) based on their admission date. For statistical analyses involving the various

TABLE 1 Literature review regarding the reported proportion and percentage of uterine torsion in previous studies examining ovine dystocia cases presented for veterinary attention (Dystocia) or case cohorts limited to ovine caesarean sections (C-section), plus geographical origin of the presented data

Case pre-selection	Number of uterine torsion cases within studied cohort	Percentage of uterine torsion	Reference	Country
Dystocia	2/429[1]	0.5%[1]	Hawkins et al. (2021) and Angell (2021, personal communication)[1]	United Kingdom
Dystocia	3/122	2.5%	Mahmoud et al. (2018)	Algeria
Dystocia	6/192	3.1%	Scholz (2006)	Germany
Dystocia	8/180	4.4%	Ali (2011)	Saudi Arabia
Dystocia	15/171	8.0%	Dahmani et al. (2019)	Algeria
Dystocia	28/284	9.9%	Skladany et al. (1988)	Former Czechoslovakia
C-section	0/137	0%	Scott (1989)	United Kingdom
C-section	0/130	0%	Majeed et al. (1993)	Iraq
C-section	4/168	2.4%	Sobiraj (1994)	Germany
C-section	3/110[2]	2.7%[2]	Brounts et al. (2004)[2]	United States
C-section	50/212	23.6%	Voigt et al. (2021)	Germany
C-section	15/57	26.3%	Mosdøl (1986)	Norway

Note: Individual case reports are not included

[1]The exact number of uterine torsions in the reported case load is not stated in the publication, the proportion and percentage of torsion cases presented here are therefore based on a personal communication by one of the authors.

[2]The case load included 85 sheep and 25 goats. The authors did not differentiate between the two species when reporting the less frequent causes of dystocia such as uterine torsion. The exact proportion and percentage in ovine cases may thus be higher than the values given in the table, with a maximum of 3 out of the 85 ovine cases (3.5%) if all torsion cases were diagnosed in sheep.

individual breeds, the less frequent breeds (less than 10 animals per breed) were combined as 'other'.

The data were checked for normality by Shapiro–Wilk Test. Levene's test was used to assess the homogeneity of the variances. Simple logistic regressions were initially performed for the predictors age, parity (primiparous yes/no), the most frequent individual breeds (Merino, Texel, Suffolk, Alpine Sheep, crossbred, other), breed type (meat/extensive), husbandry (pasture, transhumance, fully housed all year), nutrition (concentrates yes/no), season (pasture season/housing season) and litter size (single, twin, multiples) to check for potential differences between uterine torsion and non-torsion dystocia cases. All predictors with $p < 0.2$ were included in the subsequent multiple logistic regression model (Dohoo et al., 1997).

A potential influence of lamb birth weight(s) was analysed with Welsh's *t* tests. The high number of missing values for birth weights did not allow integration of this parameter into the multiple logistic regression model.

Analyses involving the direction of torsion were performed using chi-square goodness-of-fit test. A potential influence of uterine torsion on the duration of hospitalisation or ewe mortality was tested using Mann–Whitney tests as the data were not normally distributed.

Factors potentially affecting foetal viability were tested by multiple mixed-effects logistic regressions with stepwise backwards selection with the individual ewe as random effect, and included the cause of dystocia, ewe age, parity, breed type, concurrent disorders of the dam (yes/no), owner-observed duration of labour prior to presentation (<6, 7–12, >12 h) and litter size.

Analyses were performed using R (version 3.6.3; R Core Team, 2020); $p < 0.05$ was considered significant, while $p \geq 0.05$ and < 0.1 was considered a tendency. Animals with missing values on the studied parameters were excluded from the relevant analyses.

3 | RESULTS

The inclusion criteria were met by 302 sheep. These originated from 58 different flocks. Husbandry information was unavailable for three animals. The majority of the remaining 299 cases was kept on pasture with seasonal housing (225/299, 75.3%), followed by fully housed animals (42/299, 14.0%) and transhumance flocks (32/299, 10.7%). Additional concentrates were fed to 185 of the 296 ewes with available information on nutrition (62.5%), while the remainder received a roughage-only diet (111/296, 37.5%). The majority of the cases were presented during the housing season between November and March (215/302, 71.2%), while 28.8% (87/302) were treated during the pasture season (April to October). Information on litter size was available for 301 ewes. Singletons were present in 45.5% of these cases (137/301), while twin pregnancies were seen in 129 of these 301 ewes (42.9%). Triplets were delivered from 33 sheep (33/301, 11.0%), while individual ewes had quadruplets or quintuplets (1/301, 0.3% each). The animals were between 10 months and 12 years old (median age: 4 years, based on 292 ewes with available information on age). Of 295 animals with parity records, 68 (23.1%) had no previous lambing experience, while 227 were multiparous (76.9%). Meat breeds accounted for 111 of the 302

TABLE 2 Descriptive statistics for ewes presented with dystocia to a veterinary hospital between January 2008 and February 2021

Cause of dystocia	Relative frequency of diagnosis		Treatment method		
Maternal causes	All dystocia cases ($n = 302$)	Maternal causes ($n = 203$)	Caesarean section	Manual correction	Partial foetotomy
Insufficient cervical dilatation ($n = 121$)	121/302 (40.0%)	121/203 (59.6 %)	100/121 (82.6%)	21/121 (17.4%)	0/121 (0%)
Uterine torsion ($n = 60$)	60/302 (19.9%)	60/203 (29.6%)	56/60 (93.3%)	4/60 (6.7%)	0/60 (0%)
Vaginal prolapse intrapartum ($n = 12$)	12/302 (4.0%)	12/203 (5.9%)	12/12 (100%)	0/12 (0%)	0/12 (0%)
Metabolic/compromised ($n = 6$)	6/302 (2.0%)	6/203 (3.0%)	3/6 (50.0%)	3/6 (50.0%)	0/6 (0%)
Lesions due to vaginal prolapse antepartum ($n = 4$)	4/302 (1.3%)	4/203 (2.0%)	4/4 (100%)	0/4 (0%)	0/4 (0%)
Foetal causes	**All dystocia cases ($n = 302$)**	**Foetal causes ($n = 95$)**	**Caesarean section**	**Manual correction**	**Partial foetotomy**
Foetal maldisposition ($n = 44$)	44/302 (14.6%)	44/95 (46.3%)	6/44 (13.6%)	34/44 (77.3%)	4/44 (9.1%)
Foetal oversize ($n = 42$)	42/302 (13.9%)	42/95 (44.2%)	33/42 (78.6%)	7/42 (16.7%)	2/42 (4.8%)
Foetal malformation ($n = 9$)	9/302 (3.0%)	9/95 (9.5%)	9/9 (100%)	0/9 (0%)	0/9 (0%)
No definite diagnosis ($n = 4$)	4/302 (1.3%)	n/a	2/4 (50.0%)	2/4 (50.0%)	0/4 (0%)

n/a, not applicable.

dystocia cases (36.8%), while 63.2% (191/302) were of leaner, more extensive breeds. Meat breeds included Texel (61/302, 20.2%), Suffolk (34/302, 11.3%), Shropshire (9/302, 3.0%) and Blackhead Mutton (7/302, 2.3%), while the following breeds were assigned to the extensive (leaner) category: Merino (133/302, 44.0%), Alpine sheep (15/302, 5.0%), crossbred ewes (15/302, 5.0%), Coburg Fox (8/302, 2.6%), Jura (7/302, 2.3%), Jezersko–Solčava (5/302, 1.7%), East Friesian (4/302, 1.3%), Cameroon (2/302, 0.7%), Alpine stone sheep (1/302, 0.3%) and Grey heath sheep (1/302, 0.3%).

Maternal causes of dystocia accounted for 203 of the 302 cases (67.2%), while foetal causes were diagnosed in 95 ewes (95/302, 31.5%). The clinical records did not allow a definitive diagnosis in the remaining four animals (4/302, 1.3%), mostly due to protracted dystocia with emphysematous foetuses, so the initial problem was no longer obvious at the time of presentation. The most common maternal cause of dystocia was insufficient cervical dilatation (121/203, 59.6%), followed by uterine torsion (60/203, 29.6%). Other less frequently observed maternal causes included vaginal prolapse intrapartum (12/203, 5.9%), lesions due to vaginal prolapse antepartum (4/203, 2.0%) and compromised animals due to metabolic or other disease (6/203, 3.0%). Among the foetal causes, foetal maldisposition (44/95, 46.3%) and foetal oversize (42/95, 44.2%) were the most commonly observed problems. Some cases of foetal malformation were also observed (9/95, 9.5%). Dystocia was resolved by manual correction in 71 of the 302 cases (23.5%), while 225 animals (74.5%) were treated by caesarean section as previously described (Voigt et al., 2021). A partial foetotomy (Winter, 1999) was performed in six ewes (2.0%). Table 2 summarises the various diagnoses and associated treatment methods of the 302 animals submitted, while Table 3 presents the diagnoses in relation to breed.

Overall ewe survival was 88.7% (268/302). The mean hospitalisation period of the studied 302 dystocia cases was 4.3 days (range: 0–22 days) and depended on the clinical condition of ewes and/or lambs and owner preference regarding collection and care. Birth weights were recorded for 289 of the 507 lambs delivered. Lamb viability records were available for 505 of the 507 lambs. Of these, 184 (36.4%, 184/505) were stillborn, and another 59 (11.7%, 59/505) were delivered alive but died until hospital discharge. Overall lamb survival was thus 51.9% (262/505).

A diagnosis of uterine torsion was either reached by palpation of spiral folds during vaginal examination, or during caesarean section. Uterine torsion was diagnosed in 19.9% (60/302) of all 302 dystocia cases presented for treatment, and the torsion cases derived from 19 different flocks. Eighty-four lambs were delivered from the 60 ewes suffering from uterine torsion. The median age of the affected ewes was 4.1 years (range: 1–10 years) and included 14 primiparous and 45 multiparous animals plus one animal of unrecorded age and parity. Extensive breeds accounted for the majority of torsion cases (52/60, 86.7%). Caesarean section was required in 93.3% (56/60) of the cases, while four torsions (4/60, 6.7%) were resolved manually. The direction of the torsion was recorded in 49 cases. Nearly two-thirds of these (30/49, 61.2%) were counterclockwise. This was however not

TABLE 3 Descriptive statistics for ewes presented with dystocia to a veterinary hospital between January 2008 and February 2021

Total number of studied cases ($n = 302$)	Merino 133/302 (44.9%)	Alpine sheep 15/302 (5.0%)	Crossbred 15/302 (5.0%)	Texe l61/302 (20.2%)	Suffolk 34/302 (11.3%)	Other 44/302 (14.6%)
Insufficient cervical dilatation ($n = 121$)	64/121 (52.9%)	7/121 (5.8%)	6/121 (5.0%)	14/121 (11.6%)	12/121 (9.9%)	18/121 (14.9%)
Uterine torsion ($n = 60$)	39/60 (65.0%)	5/60 (8.3%)	3/60 (5.0%)	2/60 (3.3%)	3/60 (5.0%)	8/60 (13.3%)
Vaginal prolapse intrapartum ($n = 12$)	7/12 (58.3%)	0/12 (0%)	1/12 (8.3%)	2/12 (16.7%)	0/12 (0%)	2/12 (16.7%)
Metabolic/compromised ($n = 6$)	2/6 (33.3%)	0/6 (0%)	0/6 (0%)	1/6 (16.7%)	0/6 (0%)	3/6 (50.0%)
Lesions due to vaginal prolapse antepartum ($n = 4$)	3/4 (75.0%)	0/4 (0%)	0/4 (0%)	0/4 (0%)	0/4 (0%)	1/4 (25.0%)
Foetal maldisposition ($n = 44$)	6/44 (13.6%)	2/44 (4.5%)	3/44 (6.8%)	18/44 (40.9%)	9/44 (20.5%)	6/44 (13.6%)
Foetal oversize ($n = 42$)	6/42 (14.3%)	1/42 (2.4%)	1/42 (2.4%)	22/42 (52.4%)	7/42 (16.7%)	5/42 (11.9%)
Foetal malformation ($n = 9$)	5/9 (55.6%)	0/9 (0%)	1/9 (11.1%)	1/9 (11.1%)	2/9 (22.2%)	0/9 (0%)
No definite diagnosis ($n = 4$)	1/4 (25.0%)	0/4 (0%)	0/4 (0%)	1/4 (25.0%)	1/4 (25.0%)	1/4 (25.0%)

Note: Proportions and percentages of the five most frequent breeds are given in relation to the number of animals with a given diagnosis (supplied in parenthesis). The category 'other' includes nine different, less frequent breeds with one to nine animals per breed.

TABLE 4 Degree of uterine torsion intrapartum in 60 ewes presented for veterinary attention at a veterinary hospital between January 2008 and February 2021

Degree of uterine torsion	Proportion of cases	Percentage
90°	1/60	1.7%
180°	18/60	30.0%
270°	4/60	6.7%
360°	18/60	30.0%
540°	6/60	10.0%
720°	4/60	6.7%
Undocumented	9/60	15.0%

significant ($p = 0.116$). Of the 28 animals with available information on the location of the torsion, a pre-cervical torsion was diagnosed in 14 (14/28, 50%), plus 4 intra- and 10 post-cervical cases. The degree of uterine torsion was measured by re-torsion efforts by counting the number of 180° rotations (or fractions thereof) necessary for the organ to resume its normal position, or by the number of rolling attempts necessary to resolve the torsion in non-surgical cases. This was documented in 51 animals and ranged from 90° to 720° (Table 4).

Animals suffering from uterine torsion carried a single foetus in 63.3% of the cases (38/60), while 20/60 ewes (33.3%) had twins and 2/60 (3.3%) carried triplets (statistical analyses see below). Lamb birth weights from ewes with uterine torsion did not differ significantly from those born to ewes with other causes of dystocia ($p = 0.267$, $n = 289$ lambs with available information on birth weights).

For cases of uterine torsion, the duration of hospitalisation ranged from 0 to 14 days (mean: 4.1 days). Three torsion cases had to be euthanised, leading to a survival rate of 95% (57/60) for this condition. Uterine torsion was thus not associated with any increased ewe mortality ($p = 0.254$) or prolonged hospitalisation ($p = 0.845$) when compared to other causes of dystocia in our study cohort.

Of the 84 lambs delivered from cases of uterine torsion, 44 (52.4%) were delivered alive, of which 7 subsequently died. Forty lambs were dead at the point of delivery (40/84, 47.6%). A diagnosis of uterine torsion was excluded as a potentially influential factor on foetal mortality (stillbirth) in the studied animals, as were age, parity and breed type of the dam ($n = 466$ lambs from 278 ewes with complete data sets). The presence of concurrent, underlying diseases in the dam showed a tendency for decreased lamb viability (OR 0.33, $p = 0.097$), while a tendency of increased survival was shown for twins (OR 3.00, $p = 0.075$). An observed duration of labour >12 h prior to seeking veterinary attention was the most important factor negatively affecting lamb viability (OR 0.01, $p = 0.021$) in the studied cases.

The number of torsion and non-torsion cases in the studied categories are summarised in Table 5. Age, parity, season and concentrate feeding were shown to be non-significant for the occurrence of uterine torsion in our case load by simple logistic regressions. The breed type was identified as significant, with lower odds of suffering from uterine torsion for meat breeds. Fully housed animals showed significantly higher odds of being diagnosed with uterine torsion. The litter size was also identified as significant, with ewes carrying more than one foetus having lower odds of suffering from torsion. Detailed results of these analyses are shown in Table 6.

TABLE 5 Descriptive statistics for ewes presented with dystocia to a veterinary hospital between January 2008 and February 2021 comparing uterine torsion to other dystocia causes

Total number of studied cases ($n = 302$)	Other causes 242/302 (80.1%)	Uterine torsion 60/302 (19.9%)
Husbandry		
Pasture ($n = 225$)	199/225 (88.4%)	26/225 (11.6%)
Transhumance ($n = 32$)	28/32 (87.5%)	4/32 (12.5%)
Fully housed ($n = 42$)	12/42 (28.6%)	30/42 (71.4%)
Information unavailable ($n = 3$)	3/3 (100%)	0/3 (0%)
Nutrition		
Additional concentrates ($n = 185$)	144/185 (77.8%)	41/185 (22.2%)
Roughage-only diet ($n = 111$)	93/111 (83.8%)	18/111 (16.2%)
Information unavailable ($n = 6$)	6/6 (100%)	0/6 (0%)
Season		
Housing season ($n = 215$)	175/215 (81.4%)	40/215 (18.6%)
Pasture season ($n = 87$)	67/87 (77.0%)	20/87 (23.0%)
Parity		
Primiparous ($n = 68$)	54/68 (79.4%)	14/68 (20.6%)
Multiparous ($n = 227$)	182/227 (80.2%)	45/227 (19.8%)
Information unavailable ($n = 7$)	6/7 (85.7)	1/7 (14.3%)
Breed type		
Meat breeds ($n = 111$)	103/111 (92.8%)	8/111 (7.2%)
Extensive breeds ($n = 191$)	139/191 (72.8%)	52/191 (27.2%)
Litter size		
Single ($n = 137$)	99/137 (72.3%)	38/137 (27.7%)
Twins ($n = 129$)	109/129 (84.5%)	20/129 (15.5%)
Multiples ($n = 35$)	33/35 (94.3%)	2/35 (5.7%)
Information unavailable ($n = 1$)	1/1 (100%)	0/1 (0%)

Note: Proportions and percentages are given in relation to the number of animals within the studied category (supplied in parenthesis)

Paired comparisons between the five most frequent breeds showed a significant difference between Merino and Texel (0 = 0.0081), and a tendency when Merinos were compared to Suffolks ($p = 0.096$), with a higher percentage of uterine torsion in Merinos in both cases. There was no significant difference between the three most frequent extensive breeds (Merino, Alpine sheep, crossbred ewes) or the two most frequent meat breeds (Texel, Suffolk).

Breed type, husbandry and litter size were used in the subsequent multiple logistic regression model, which included 298 animals with complete data sets. Year-round housing was identified as the most

TABLE 6 Results of simple logistic regressions of potentially influential factors on the occurrence of uterine torsion

Factors(observations)	Odds ratio	95% Confidence interval	*p* Value
Age (*n* = 292)	1.04	0.91–1.19	0.530
Parity (*n* = 295)			
Multiparous (*Reference*)			
Primiparous	1.05	0.52–2.01	0.892
Breed type (*n* = 302)			
Extensive (*Reference*)			
Meat	0.22	0.09–0.43	**<0.001**
Husbandry (*n* = 299)			
Pasture (*Reference*)			
Transhumance	1.03	0.29–2.95	0.957
Fully housed	17.87	8.89–43.26	**<0.001**
Concentrate feeding (*n* = 296)			
No (*Reference*)			
Yes	1.45	0.81–2.77	0.223
Season (*n* = 302)			
Housing season (*Reference*)			
Pasture season	1.44	0.79–2.62	0.226
Litter size (*n* = 301)			
Single (*Reference*)			
Twin	0.49	0.27–0.90	**0.020**
Multiple	0.19	0.05–0.71	**0.013**

Note: Animals with missing information on the studied parameter(s) were excluded from the relevant analyses. A *p* value < 0.05 was considered significant. Significant *p*-values are indicated in bold.

significant factor increasing the odds for uterine torsion in the studied animals, with decreased odds in meat breeds. The litter size was no longer significant in this mixed model. The detailed results are shown in Table 7.

4 | DISCUSSION

Similar to many previous studies on ovine dystocia (see Table 1), there was a strong and inevitable case pre-selection by only being able to include animals presented for veterinary attention. Although the study was carried out in a hospital setting, the vast majority of the animals were first opinion cases directly submitted by the farmer. Further bias by veterinary referral can therefore be ruled out. The causes of dystocia in the studied cohort are however not representative for a wider sheep population, where foetal maldisposition has been observed as the most frequent birth difficulty in whole flock studies (Dwyer & Bünger, 2012; Grommers et al., 1985). Despite these limitations, we were able to include a large dataset to study causes of moderate to severe (Dwyer & Bünger, 2012) ovine dystocia. Due to the case preselection, maternal causes were over-represented. The percentage of most causes of dystocia in our case load was similar to comparable previous studies (Ennen et al. 2013; Sobiraj, 1994), with the notable exception of uterine torsion. The observed frequency of this condition was

TABLE 7 Results of multiple logistic regressions to study the potential influence of breed type, husbandry and litter size on the occurrence of uterine torsion (*n* = 298 ewes with complete data sets)

Predictors	Odds ratio	95% Confidence Interval	*p* Value
(Intercept)	0.27	0.15–0.49	**<0.001**
Breed type			
Extensive	*Reference*		
Meat	0.38	0.16–0.89	**0.025**
Husbandry			
Pasture	*Reference*		
Transhumance	0.67	0.22–2.00	0.471
Fully housed	10.71	4.71–24.36	**<0.001**
Litter size			
Single	*Reference*		
Twin	0.63	0.32–1.26	0.191
Multiple	0.30	0.07–1.21	0.089
R^2 Tjur[1]	0.286		

Note: A *p* value < 0.05 was considered significant. Significant *p*-values are indicate in bold.

[1]The coefficient of determination R^2 Tjur (Tjur, 2009) indicates the explanatory power of the model. Interpretation of R^2: <0.02: very weak; 0.02 to <0.13: weak; 0.13 to <0.26: moderate; ≥0.26: substantial (Cohens, 1988).

considerably higher in our study cohort than in all previous publications comparable in case preselection (animals with dystocia presented for veterinary attention), with 9.9% being the highest reported percentage in a comparable case load (Skladany et al., 1988). It also exceeds the observed frequency in many studies on caesarean sections (Table 1). The reasons for these discrepancies are unclear and may be explained with regional differences in breed, husbandry or other factors. Potential underdiagnosis seems unlikely in these veterinary-led studies.

Uterine torsion between 180° and 360° accounted for the majority of the 51 cases with available information on the degree of torsion (40/51; 78.4%). This observation is in accordance with previous publications in cattle, with the majority of observed bovine torsions ranging from 180° to 360° (Frazer et al., 1996; Tamm, 1997). Individual case descriptions in sheep also reported a severity of up to 360° (Chauhan et al., 2018; Mahal et al., 2020; Naidu, 2012). However, 19.6% (10/51) of our torsion patients with available information on the degree of torsion suffered from a more severe rotation of up to 720°. Such severe torsions have also previously been reported by Mosdøl (1986), who diagnosed a 720° torsion in 4 out of 15 ovine torsion cases (26.7%), and in a case described by Scott (2011).

Sheep with uterine torsion showed an above average survival rate of 95%, and the diagnosis was not associated with prolonged hospitalisation. The condition thus seems to be better tolerated by sheep than by cattle, where 24.1% dam mortality was reported by Zerbe et al. (1998), who studied 518 bovine torsion cases. Compared to cattle and buffaloes (Erteld et al., 2012; Purohit, 2011), uterine torsion still seems to be less frequent in sheep. Some authors suggest that difficulties in diagnosis may lead to under-reporting of the condition (Skladany et al., 1988), particularly given extensive management conditions (Jones et al., 2020) or a lack of veterinary involvement (Scott, 2011). It is also possible that less severe cases of uterine torsion (in the absence of severe uterine damage or oedema) may be underdiagnosed even at caesarean section, if the attending veterinary surgeon does not actively check for the presence of rotation during surgery. Pre-cervical torsions in particular are not commonly associated with palpable vaginal spiral folds and are likely to be mistaken for insufficient cervical dilatation on vaginal examination (Scott, 2011; Skladany et al., 1988) as rectal palpation, which is used to aid diagnosis in cattle, cannot be performed in sheep due to the small size of the species (Sharun & Erdoğan, 2019). The location of uterine torsion was only documented in 28 of the 60 studied torsion cases, so conclusions on the frequency of a diagnostically challenging pre-cervical location can only be based on this relatively small dataset. The high percentage of pre-cervical torsions in these animals (14/28, 50%) however highlights the considerable risk of underdiagnosis in sheep. In ewes showing signs of obvious dystocia, this does not hinder the adequate treatment of the animal as timely caesarean section would be performed if the animal is presented for veterinary attention, even if the attending veterinarian misdiagnoses the condition for suspected cervical non-dilation. However, Scott (2003) raised concerns about a very low percentage of ovine dystocia cases receiving veterinary treatment. In cases solely attended by farmers, the risk of misdiagnosis is high if farmers are not aware of the condition, leading to delayed or inadequate treatments and subsequent foetal and/or maternal death. Even more severe diagnostic problems arise in antepartal cases or animals not exhibiting clear signs of dystocia, leading to a high risk of under- or misdiagnosis. Cases may present as recumbency in a late pregnant ewe and thus be mistaken for metabolic disease (Winzap et al., 2000) or may entirely be missed and go untreated for prolonged periods. Foetal death and mummification, uterine tissue necrosis, peritonitis and additional organ damage with prolonged suffering of the ewe have been reported (Jones et al., 2020; Scott, 2011). Other potential consequences of untreated uterine torsion include vaginal rupture and subsequent intestinal prolapse (Mosdøl, 1999), or severe haemorrhage due to rupture of large blood vessels (Blanchard, 1981), a condition that has also been seen by the authors in an antepartal case presented with recumbency (not included in this study). Accurate diagnosis and timely intervention are therefore paramount in terms of animal welfare and will also aid to raise lamb survival rates.

Predisposing factors for the occurrence of uterine torsion in cattle have been reviewed by Erteld et al. (2012). The anatomical properties of the bovine genital tract and uterine instability caused by the monocornual nature of mostly single bovine pregnancies are being discussed as causes for a relatively high incidence in cattle (De Amicis et al., 2018; Erteld et al., 2012; Schönfelder & Sobiraj, 2005). It is likely that the condition is truly less frequent in sheep despite the discussed potential of underdiagnosis. Slight differences in small ruminant anatomy with a sublumbar rather than subileal attachment of the broad ligaments may lead to improved uterine stability in sheep (Blanchard, 1981; Chahar et al., 2018; Parkinson et al., 2019b). The higher twinning rate in small ruminants, bicornual pregnancies and thus higher uterine stability may additionally contribute to a lower incidence of uterine torsion in sheep. The generally higher weight of bovine foetuses as opposed to relatively light-weight ovine foetuses may also play a role. Bicornual twin pregnancies have a stabilising effect. In addition, twins would have to synchronise their movements in order to cause the pregnant uterus to rotate. However, uterine torsion has also been observed in cattle carrying twins (Aubry et al., 2008; Erteld et al., 2012), and Tamm (1997) observed twin pregnancies in bovine torsion cases at a comparable rate to all studied parturitions (1.1% as opposed to 1.3%). Reports on the number of foetuses in ovine torsion cases are variable. Gupta et al. (2021) observed mostly single pregnancies in small ruminant cases (24/27, 88.9%), an observation supported by Dahmani et al. (2019), while Mosdøl (1986) reported that 7/15 cases (46.7%) carried more than one lamb. Based on our study cohort, simple logistic regressions suggested that ewes carrying singletons had higher odds of suffering from uterine torsion, a factor that was however outweighed by breed type and particularly husbandry in the multiple logistic regression model.

Age and parity have also been discussed as potentially predisposing factors in cattle. Aubry et al. (2008) found cows to have 5.2 times greater odds of suffering from torsion than heifers. According to Ghosh et al. (2013), this may be attributed to weaker abdominal muscles and a lack of tonicity of the broad ligament in multiparous animals. Higher susceptibility to subclinical hypocalcaemia in older cattle with subsequently reduced muscle tone has also been discussed as a potential explanation for this observation, but Aubry et al. (2008) did not find a conclusive association between hypocalcaemia and the occurrence of uterine torsion. Kruse (2004) could not show a correlation between uterine torsion and age in dairy cattle. Similarly, an age-related predisposition could not be shown for sheep in our study population.

Cattle fed high concentrate rations seem to be predisposed to uterine torsion, possibly due to a reduced rumen size in relation to abdominal capacity (Drost, 2007; Parkinson et al., 2019b). A nutritional effect could not be proven for the sheep in our study. However, nutrition was predominantly roughage-based in both nutritional categories, so the relatively small amounts of concentrates fed to the supplemented animals are unlikely to have significantly affected rumen capacity.

A breed predisposition has been reported for Brown Swiss cattle (Erteld et al., 2012; Frazer et al., 1996; Schönfelder & Sobiraj, 2005), and Frazer et al. (1996) showed lower odds for beef cattle. Similar results were obtained here, with ovine meat breeds showing lower odds of suffering from torsion, while extensive breeds were significantly more prone to the condition. Among the most frequent extensive breeds, a direct breed predisposition could however not be proven. Ovine meat breeds are more prone to dystocia associated with foetal oversize and foetal malpresentation than leaner breeds (Dwyer & Bünger, 2012). We also made a similar observation in our study cohort (Table 3). The relative over-representation of meat breeds within the group of foetal causes is a factor that will have led to a lower percentage of uterine torsion cases in the animals belonging to these breeds. The true incidence of uterine torsion in the various breeds remains unknown. Whether meat breeds are truly less likely to suffer from uterine torsion than more extensive breeds remains to be determined.

Cows confined to stables or kept in tie-stalls had a higher incidence of uterine torsion (Aubry et al., 2008), possibly due to a lack of exercise leading to weakening of the abdominal muscles (Erteld et al., 2012). Low exercise levels were also considered a predisposing factor for uterine torsion in goats (Jayaganthan et al., 2020). We made a similar observation in sheep, as year-round housing was identified as the most influential factor increasing the odds of suffering from uterine torsion in our study population. Stabling also increases the chances of animals being pushed, causing sudden movements that may accidentally lead to uterine torsion (Aubry et al., 2008; Ghosh et al., 2013; Parkinson et al., 2019b). It is interesting to note that short-term, seasonal housing did not seem to affect the odds of suffering from torsion. However, the classification of pasture and housing season by admission date may not reflect the true husbandry conditions at a given time, with shorter or longer housing periods applied in the various flocks. These categories may therefore be unreliable. The proportion of fully housed animals was relatively high in our study cohort, which may serve as an explanation for the higher number of torsion cases in comparison to the majority of previous studies. While the cases reported by Voigt et al. (2021) are also part of this analysis and thus do not form an independent population, the only other previous study reporting a very high proportion of uterine torsion cases originated from Norway (Mosdøl, 1986). Norwegian climatic conditions warrant an extended winter housing period, which supports the assumption that prolonged housing and possibly an associated lack of exercise may indeed be an important factor in the pathogenesis of ovine uterine torsion. It however remains to be determined whether additional factors such as stocking density or other elements of husbandry may also be important.

5 | CONCLUSION

Uterine torsion was a relevant maternal cause of ovine dystocia in our study cohort. Fully housed ewes and extensive breeds were particularly prone to the condition in our case load. Single pregnancies may also have some predisposing effect. There is a risk of underdiagnosis of uterine torsion in sheep, and it is important that veterinarians and farmers consider this condition in their treatment decisions as an important differential diagnosis to insufficient cervical dilatation, as well as in compromised, late pregnant ewes to ensure timely and adequate treatment, and to prevent unnecessary suffering of these animals.

AUTHOR CONTRIBUTIONS

Conceptualisation: KV. Data curation: VB. Formal analysis: VB and YZ. Investigation: VB and KV. Methodology: YZ and KV. Project administration: KV and HZ. Resources: HZ. Supervision: KV and HZ. Validation: KV. Visualisation: VB. Writing – original draft: VB and KV. Writing – review & editing: KV, VB, YZ and HZ. Final approval VB, YZ, HZ and KV.

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CONFLICT OF INTEREST

The authors confirm that there is no conflict of interest.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICAL STATEMENT

All animals were treated to best practice standards and according to German and EU animal welfare legislation and received appropriate veterinary treatment based on the nature of their clinical condition(s). All veterinarians were proficient in performing ovine obstetrical procedures. This clinical retrospective study did thus not involve any procedures requiring formal ethical approval. Informed client consent was obtained in writing upon submission of the animals for treatment.

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REFERENCES

Ali, A. M. H. (2011). Causes and management of dystocia in small ruminants in Saudi Arabia. *Journal of Agricultural and Veterinary Sciences*, *4*, 95–108.

Anderson, D. E. (2014). *C-section in small ruminants*. University of Tennessee, Knoxville. https://www.semanticscholar.org/paper/1-C-Section-in-Small-Ruminants-Anderson/bdb2ac89e36ad8e3e240c81b8368b1485a8c2cc0 (accessed 23.2.2022)

Aubry, P., Warnick, L. D., DesCôteaux, L., & Bouchard, E. (2008). A study of 55 field cases of uterine torsion in dairy cattle. *Canadian Veterinary Journal*, *49*, 366–372.

Blanchard, T. L. (1981). Uterine torsion with ovarian vein rupture in a ewe. *Journal of the American Veterinary Medical Association*, *179*, 1402–1403.

Brounts, S. H., Hawkins, J. F., Baird, A., & Glickman, L. T. (2004). Outcome and subsequent fertility of sheep and goats undergoing cesarean section because of dystocia: 110 cases (1981–2001). *Journal of the American Veterinary Medical Association*, *224*, 275–281. https://doi.org/10.2460/javma.2004.224.275

Chahar, S. K., Dholpuria, S., & Choudhary, A. K. (2018). Management of uterine torsion in goat: A case report. *International Journal of Applied Engineering Research*, *13*, 11034.

Chauhan, P., Patelia, H., Patel, D., Suthar, B., & Sharma, V. (2018). Clinico-obstetrical management of clockwise 180° post cervical uterine torsion in a ewe. *Journal of Pharmacognosy and Phytochemistry*, *SP1*, 3162–3164. https://www.phytojournal.com/archives/2018/vol7issue1S/PartAX/SP-7-1-880-270.pdf

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd Ed.). New York: Routledge.

Dahmani, A., Dahmani, H., Rahal, K., & Kaidi, R. (2019). Description of dystocia in ewes of the Ksar el Boukhari region (Algeria). *Agriculture*, *3–4*, 111–112.

De Amicis, I., Veronesi, M. C., Robbe, D., Gloria, A., & Carluccio, A. (2018). Prevalence, causes, resolution and consequences of bovine dystocia in Italy. *Theriogenology*, *107*, 104–108. https://doi.org/10.1016/j.theriogenology.2017.11.001

Dohoo, I. R., Ducrot, C., Fourichon, C., Donald, A., & Hurnik, D. (1997). An overview of techniques for dealing with large numbers of independent variables in epidemiologic studies. *Preventive Veterinary Medicine*, *29*, 221–239. https://doi.org/10.1016/s0167-5877(96)01074-4

Drost, M. (2007). Complications during gestation in the cow. *Theriogenology*, *68*, 487–491. https://doi.org/10.1016/j.theriogenology.2007.04.023

Dwyer, C. M., & Bünger, L. (2012). Factors affecting dystocia and offspring vigour in different sheep genotypes. *Preventive Veterinary Medicine*, *103*, 257–264. https://doi.org/10.1016/j.prevetmed.2011.09.002

Ennen, S., Scholz, M., Voigt, K., Failing, K., & Wehrend, A. (2013). Puerperal complications in ewes following dystocia: A retrospective analysis of two approaches to caesarean surgery. *Veterinary Record*, *172*, 554. https://doi.org/10.1136/vr.101370

Erteld, E., Wehrend, A., & Goericke-Pesch, S. (2012). Torsio uteri beim Rind – Häufigkeit, klinische Symptomatik und Theorien zur Pathogenese (Uterine torsion in cattle – Frequency, clinical symptoms and theories about the pathogenesis, in German). *Tierärztliche Praxis. Ausgabe G, Grosstiere/Nutztiere*, *40*, 167–175.

Frazer, G. S., Perkins, N. R., & Constable, P. D. (1996). Bovine uterine torsion: 164 hospital referral cases. *Theriogenology*, *46*, 739–758. https://doi.org/10.1016/s0093-691x(96)00233-6

Ghosh, S., Singh, M., Prasad, J., Kumar, A., & Rajoriya, J. (2013). Uterine torsion in bovines – A review. *Intas Polivet*, *14*, 16–20.

Grommers, F. J., Elving, L., & Van Eldik, P. (1985). Parturition difficulties in sheep. *Animal Reproduction Science*, *9*, 365–374.

Gupta, C., Murugan, M., Ramprabhu, R., & Kumar, S. S. (2021). Uterine torsion in small ruminants – Outcome and fertility following different management approaches. *Indian Journal of Small Ruminants*, *27*, 139–141. https://doi.org/10.5958/0973-9718.2021.00020.9

Hawkins, E. L., McDonnell, S., & Angell, J. W. (2021). Estimation of immediate and 7-day clinical prognostic indicators for ewe and lamb survival in the UK following vaginal delivery and caesarean section at a single veterinary practice. *Small Ruminant Research*, *204*, 106511. https://doi.org/10.1016/j.smallrumres.2021.106511

Holst, P., Fogarty, N., Hopkins, D., & Stanley, D. (1997). Lamb survival of Texel and Poll Dorset crossbred lambs. *Proceedings of the Association for the Advancement of Animal Breeding and Genetics*, *12*, 313–316.

Ijaz, A., & Talafha, A. Q. (1999). Torsion of the uterus in an Awassi ewe. *Australian Veterinary Journal*, *77*, 652–653. https://doi.org/10.1111/j.1751-0813.1999.tb13154.x

Jacobson, C., Bruce, M., Kenyon, P. R., Lockwood, A., Miller, D., Refshauge, G., & Masters, D. G. (2020). A review of dystocia in sheep. *Small Ruminant Research*, *192*, 106209. https://doi.org/10.1016/j.smallrumres.2020.106209

Jayaganthan, P., Palanisamy, M., Prabaharan, V., Rajkumar, R., & Raja, S. (2020). Successful management of uterine torsion in a Kodi Aadu goat by modified Schaffer's method. *International Journal of Science, Environment and Technology*, *9*, 486–488.

Jones, E. M., Neef, A., Shearer, P. L., & Gunn, A. J. (2020). Hydroureteronephrosis and fetal mummification secondary to uterine torsion in a Merino ewe. *Australian Veterinary Journal*, *98*, 529–532. https://doi.org/10.1111/avj.12999

Klaus-Halla, D., Mair, B., Sauter-Louis, C., & Zerbe, H. (2018). Torsio uteri beim Rind: Therapie sowie Verletzungsrisiko für die Kuh und Prognosestellung für das Kalb (Uterine torsion in cattle: Treatment, risk of injury for the cow and prognosis for the calf, in German). *Tierärztliche Praxis Ausgabe G Grosstiere Nutztiere*, *46*, 143–149.

Kruse, M. (2004). Genetische und umweltbedingte Einflüsse auf das Auftreten von Torsio uteri bei Milchkühen (Genetic parameters and environmental influences on the incidence of uterine torsion in dairy cattle, in German). *Dissertation, Tierärztliche Hochschule Hannover*, https://elib.tiho-hannover.de/receive/etd_mods_00002472

Lane, J., Jubb, T., Shephard, R., Webb-Ware, J., & Fordyce, G. (2015). Priority list of endemic diseases for the red meat industries. Final Report, Meat & Livestock Australia Limited. http://era.daf.qld.gov.au/id/eprint/5030/1/B.AHE.0010_Final_Report_Priority%20list%20of%20endemic%20diseases%20for%20the%20red%20meat%20industries.pdf

Liang, R., Gandhi, J., Rahmani, B., & Khan, S. A. (2020). Uterine torsion: A review with critical considerations for the obstetrician and gynecologist. *Translational Research in Anatomy*, *21*, 100084. https://doi.org/10.1016/j.tria.2020.100084

Mahal, J., Honparkhe, M., Ahuja, A., & Anand, I. (2020). Successful uterine detorsion with plank method and fetal delivery in a ewe. *Journal of Entomology and Zoology Studies*, *8*(2), 864–865. https://www.entomoljournal.com/archives/2020/vol8issue2/PartO/8-2-110-110.pdf

Mahmoud, D., Abdelhadi, F., Khiati, B., Smail, N., & Abdelhadi, S. (2018). Etude des dystocies ovines et de la pertinence de la césarienne dans des élevages de la wilaya de Tiaret (Algérie) (Study on sheep dystocia and caesarean section in farms of Tiaret wilaya (Algeria), in French). *Livestock Research for Rural Development*, *30*, Article #189. http://www.lrrd.org/lrrd30/11/si_am30189.html

Majeed, A. F., Taha, M. B., & Azawi, O. I. (1993). Cesarean section in Iraqi Awassi ewes: A case study. *Theriogenology*, *40*, 435–439. https://doi.org/10.1016/0093-691x(93)90280-i

Mosdøl, G. (1986). Keisersnitt på søye I alminnelig praksis. Indikasjoner og betydning for fertilitet (Indications for and fertility after cesarean section in the ewe in common practice, In Norwegian). *Norsk Veterinaertidsskrift*, *98*, 441–444.

Mosdøl, G. (1999). Spontaneous vaginal rupture in pregnant ewes. *Veterinary Record*, *144*, 38–41.

Naidu, G. V. (2012). A case of uterine torsion in sheep. *Indian Journal of Animal Reproduction*, *33*(2), 102–103.

Parkinson, T. J., Vermunt, J. J., & Noakes, D. E. (2019a). 12 – Prevalence, causes and consequences of dystocia. In: D. E. Noakes, T. J. Parkinson, & G. C. W. England (Eds.) *Veterinary reproduction and obstetrics* (10th edn., pp. 214–235). St. Louis: W.B. Saunders.

Parkinson, T. J., Vermunt, J. J., & Noakes, D. E. (2019b). 13 – Maternal dystocia: Causes and treatment. In: D. E. Noakes, T. J. Parkinson, & G. C. W. England (Eds.), *Veterinary reproduction and obstetrics* (10th edn., pp. 236–249). St. Louis: W.B. Saunders.

Phogat, J., Behl, S., Singh, U., & Singh, P. (2007). Uterine torsion in sheep: A case report. *The Haryana Veterinarian Journal*, *46*, 110–111.

Phythian, C. J., Angell, J. W., Crilly, J. P., & Martin, A. D. (2019). Ewe Caesarean section: reviewing the evidence base and sharing cross-country experiences part one. *Livestock*, *24*, 90–101. DOI: 10.12968/live.2019.24.2.90

Purohit, G. N. (2011). Maternal dystocia in cows and buffaloes: A review. *Open Journal of Animal Sciences*, *1*(2), 41–53. https://doi.org/10.4236/ojas.2011.12006

Purohit, G. N., & Gaur, M. (2014). Uterine torsion in buffaloes: A critical analysis. *Buffalo Bulletin*, *33*, 363–378.

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/

Scholz, M. (2006). Untersuchungen zur puerperalen Entwicklung von Schafen nach Schwergeburt unter besonderer Berücksichtigung zweier unterschiedlicher Operationsverfahren der Sectio caesarea (Studies on the puerperal development of sheep following dstocia with particular focus on two different approaches to caesarean section, in German). Dissertation, Justus-Liebig-Universität Gießen, VVB Laufersweiler, Gießen.

Schönfelder, A., & Sobiraj, A. (2005). Ätiologische Aspekte der Torsio uteri beim Rind: Eine Übersicht (Etiology of torsio uteri in cattle: A review; in German). *Schweizer Archiv für Tierheilkunde*, *147*, 397–402.

Scott, P. R. (1989). Ovine caesarean operations: A study of 137 field cases. *British Veterinary Journal*, *145*, 558–564. https://doi.org/10.1016/0007-1935(89)90118-8

Scott, P. R. (2003). A questionnaire survey of ovine dystocia management in the United Kingdom. *Animal Welfare*, *12*, 119–122.

Scott, P. R. (2005). The management and welfare of some common ovine obstetrical problems in the United Kingdom. *The Veterinary Journal*, *170*, 33–40. https://doi.org/10.1016/j.tvjl.2004.03.010

Scott, P. (2011). Uterine torsion in the ewe. *UK Vet Livestock*, *16*, 37–39.

Scott, P. (2012). Applications of diagnostic ultrasonography in small ruminant reproductive management. *Animal Reproduction Science*, *130*, 184–186. https://doi.org/10.1016/j.anireprosci.2012.01.013

Sharun, K., & Erdoğan, G. (2019). A review: Obstetrical emergencies in small ruminants. *Alexandria Journal of Veterinary Sciences*, *62*, 1–16. https://doi.org/10.5455/ajvs.40558

Skladany, J., Balascak, J., & Kiss, M. (1988). Die Torsio uteri als Ursache für Geburtsstockungen beim Schaf (Kurzmitteilung) (Uterus torsion – Cause of obstruction of labour in sheep (brief communication), in German). *Monatshefte für Veterinärmedizin*, *43*, 212–213.

Sobiraj, A. (1994). Geburtsschwierigkeiten bei Schaf und Ziege – Auswertung des Patientenaufkommens aus sieben Ablammperioden an einer geburtshilflichen Klinik (Dystocia in sheep and goats – A survey of seven lambing periods at a clinic for obstetrics, in German). *Deutsche Tieärztliche Wochenschrift*, *101*, 471–476.

Tamm, T. (1997). Untersuchungen zur Gebärmutterverdrehung des Rindes (Studies on uterine torsion in cattle, in German). Dissertation, Tierärztliche Hochschule Hannover.

Tjur, T. (2009). Coefficients of determination in logistic regression models – A new proposal: The coefficient of discrimination. *The American Statistician*, *63*(4), 366–372. https://doi.org/10.1198/tast.2009.08210

Voigt, K., Najm, N. - A., Zablotski, Y., Rieger, A., Vassiliadis, P., Steckeler, P., Schabmeyer, S., Balasopoulou, V., & Zerbe, H. (2021). Factors associated with ewe and lamb survival, and subsequent reproductive performance of sheep undergoing emergency caesarean section. *Reproduction in Domestic Animals*, *56*, 120–129. https://doi.org/10.1111/rda.13855

Wehrend, A., Bostedt, H., & Burkhardt, E. (2002). The use of trans-abdominal B mode ultrasonography to diagnose intra-partum uterine torsion in the ewe. *The Veterinary Journal*, *164*, 69–70. https://doi.org/10.1053/tvjl.2002.0736

Winter, A. (1999). Dealing with dystocia in the ewe. *In Practice*, *21*, 2–9. https://doi.org/10.1136/inpract.21.1.2

Winzap, B., Bächler, C., & Hässig, M. (2000). Torsio uteri als Differentialdiagnose der Trächtigkeitstoxikose beim Schaf (Torsio uteri as the differential diagnosis for gestational ketosis in sheep, in German). *Schweizer Archiv für Tierheilkunde*, *142*, 391–392.

Zerbe, H., Tamm, T., & Grunert, E. (1998). Zur Problematik der Behandlung der Torsio uteri sub partu beim Rind (Treatment of uterine torsion sub partu in the cow, in German). *Der Praktische Tierarzt, collegium veterinarium*, *28*, 50–53.

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IV. DISCUSSION

Dystocia in sheep is of great relevance to animal welfare. According to the review by JACOBSON and colleagues (2020), dystocia is one of the major causes of perinatal lamb mortality and can be responsible for up to 67% of deaths in this age group. In addition to its welfare implications, dystocia causes significant financial losses (LANE et al., 2015). One cause of dystocia of maternal origin is torsion of the pregnant uterus. Given that the duration and severity of the condition greatly affect the prognosis for maternal and offspring survival, accurate and timely diagnosis and timely intervention can be life-saving. Furthermore, predisposing factors for uterine torsion in sheep are largely unexplored.

Due to the striking lack of published information on uterine torsion in sheep, this study was undertaken to gather existing knowledge, generate new information on the frequency and type of uterine torsion in sheep, and identify potential risk factors for its occurrence. The dissemination of this information is intended to contribute to a more professional handling of birth difficulties in sheep and thus to a reduction in ewe and lamb mortality.

1. Maternal causes of dystocia as a primary reason for presentation in the studied case cohort

The case load of the present study cohort consisted of dystocia patients presented to a veterinary teaching hospital. A strong case pre-selection was therefore inevitable. However, most patients were directly presented to the clinic without any prior veterinary intervention, thus ruling out further bias by veterinary referral, and the case load varied from moderate to severe dystocia cases (DWYER and BÜNGER, 2012). It is therefore important to note that the causes of dystocia and their prevalence in this specific study are not representative for the whole sheep population of the study area. Due to this case pre-selection, most presented animals suffered from maternal causes of dystocia (203 of 302 dystocia cases). Comparable results concerning the frequency of maternal dystocia were also obtained in other similar settings (ENNEN et al., 2013; SOBIRAJ, 1994). This is not the case when dystocia is studied on a flock level, where the most common causes for difficult parturitions are of foetal origin, with foetal malpresentation observed as the most common problem (McSPORRAN et al., 1977).

2. Foetal dystocia is more common in meat breeds

In the present study, foetal causes accounted for 31.5% (95/302) of the presented dystocia cases, a percentage similar to other German hospital-based studies, which reported dystocia of foetal origin in 25.2% (74/293; SOBIRAJ, 1994) or 30.2% of the treated animals (58/192; SCHOLZ, 2006). In our studied case load, meat breeds (n=111) accounted for a much higher percentage of foetal causes (65/111, 58.6%) than extensive breeds (30/191, 15.7%).

Several authors have reported that different breeds seem to be prone to different causes of dystocia. For instance, DWYER and BÜNGER (2012) observed that a high number of Texel lambs needed assistance during delivery due to foetal oversize. This report is in accordance with the present study, which also identified foetal oversize as the most common cause for veterinary intervention in the Texel ewes presented to the hospital (22 of 61 Texel ewes suffering from dystocia; 36.1%). In Suffolks, seven of the 34 presented cases (20.6%) were admitted due to this problem. In total, 32 of the 111 ewes (28.8%) assigned to the meat breed category were diagnosed with foetal oversize as the cause of dystocia, while only 10 of 191 ewes of extensive breeds (5.2%) suffered from this condition. Similar to foetal oversize, foetal malpresentation was also most frequently observed in Texels. This breed accounted for 18 of the 44 cases of foetal malpresentations (40.9%), making this condition the second most common diagnosis in the Texel ewes presented for treatment (18/61; 31.1%). In Suffolk ewes, foetal maldisposition accounted for 26.5% (9/34) of the presented problems. This observation is most likely also related to the fact that these meat breeds tend to produce larger lambs, as malpresentations, particularly those affecting deviation of the head and forelimbs, are frequently associated with larger foetuses (DWYER and BÜNGER, 2012).

The observed percentages of foetal maldisposition (44/302 dystocia cases, 14.6%) and foetal oversize (42/302 dystocia cases, 13.9%) were considerably lower than in a comparable study performed by MAJEED and TAHA (1995) from a different region, where foetal causes accounted for 53.6% (178/332) of the dystocia cases presented to a veterinary teaching hospital. In this Iraqi study, foetal maldisposition was the most common foetal cause (126/178; 70.8%), followed by foetal oversize (32/178; 18.0%) and pathological foetuses (20/178; 11.2%). Similarly, high percentages of foetal malpresentations have also been observed in other comparable settings, where dystocia cases presented to veterinary hospitals were evaluated (SHARMA et al., 2014b; MOSTEFAI et al., 2019).

These differences in the frequency of foetal causes, particularly foetal malpresentation, between the mentioned hospital-based studies and our case load may be influenced by the experience levels of the farmers, breed differences, and the severity of the dystocia encountered. In many cases, dystocia due to foetal maldisposition can be easily corrected in the field, a reason why these cases reach high numbers in flock-based cohorts (McSPORRAN et al., 1977; DWYER and BÜNGER, 2012; MAHMOUD et al., 2018) and are generally under-represented in hospital-based studies.

3. Ringwomb: the most frequent maternal cause of dystocia

In the present study, extensive breeds were more frequently diagnosed with maternal causes of dystocia and these breeds accounted for 127 of the 203 maternal dystocia cases (62.6%). Insufficient cervical dilatation (ringwomb) was the overall most frequent cause of dystocia in the ewes presented for treatment (121/302 cases; 40.0%). Comparably high numbers of ringwomb have also been reported in other studies conducted in veterinary hospitals (KLOSS et al., 2002; BHATTACHARYYA et al., 2015). In case cohorts exclusively studying caesarean sections, the percentages of animals diagnosed with ringwomb were even higher, reaching 44.3% (VOIGT et al., 2021) and 50.0% (MAJEED et al., 1993) of the studied caesarean sections, respectively. These high percentages in studies covering surgical treatment can be explained by the fact that ringwomb is a condition that is frequently an absolute indication for caesarean section, unless the cervix responds to manual dilation efforts.

4. Uterine torsion: what could be the reason for the observed high proportion in the present case cohort?

Very notable differences between the present study and the vast majority of other reports are evident in the observed percentage of uterine torsion. In our case cohort, the overall incidence of this condition was much higher than in all other previous studies covering ovine dystocia presented for veterinary attention. The condition accounted for 19.9% (60/302) of all studied dystocia cases (equalling 29.6% (60/203) of the maternal causes). Of all previous studies covering dystocia cases presented for veterinary treatment, the highest percentage of uterine torsion has so far been reported by SKLADANY et al (1988), who reported a percentage of 9.9% of all dystocia cases presented. Even in studies covering surgical cases only, the reported numbers of uterine torsions are generally low in the vast majority of publications (see Table 1), with the notable exception of two studies reporting a percentage of 23.6% (VOIGT et al., 2021) or 26.3% (MOSDØL, 1986) of the studied ovine caesarean sections. The present study included the caesarean section cases studied by VOIGT et al. (2021), extending the analysis to all dystocias irrespective of threatment method, and covering a longer time period. However, due to an overlap in some studied cases, these two studies are closely related. The study by MOSDØL (1986) is therefore the only other report of an equally high percentage of uterine torsions in an independent case load. While different breeds to ours were included in this Norwegian study, a similarity between the two case cohorts may lie in a predominance of extensive breeds, and our results show significantly higher odds for extensive breeds to be diagnosed with uterine torsion. In addition, long-term housing was identified as the most influential factor in our case cohort. Long Norwegian winters require extended housing periods, and may have thus contributed to the high percentage of torsion cases seen in this country. In contrast, other studies covering ceasarean sections did not observe any uterine torsion cases at all even though they involved large proportions of extensive breeds (SCOTT, 1989; MAJEED et al., 1993). In these countries (Scotland, Iraq), long-term housing is however unlikely, which may serve as an explanation for the low percentage of torsion cases observed. However, the still existing knowledge gap concerning factors influencing the occurrence of this condition makes definite conclusions challenging in terms of identifying potential causes for the high variation of uterine torsion numbers between the various studies.

5. Nature and diagnosis of uterine torsion in sheep: a diagnostic challenge for farmers and veterinarians

Information concerning the severity of the torsion was availiable for 51 of the 60 uterine torsion cases assigned to the study. The majority of these ranged from 180° to 360° (40/51; 78.4%). In cattle, ZERBE et al. (1998) reported a severity of intrapartal uterine torsion of 90 – 270° in 86.0% of the animals presented to a bovine hospital. Similarly, most bovine cases studied by FRAZER et al. (1996) also sufferd from a 90° up to a complete (360°) torsion of the organ (90.8%; 138/152 cases with availiable information on severity). More severe ovine cases of up to 720° have also been reported (MOSDØL, 1986; SCOTT, 2011). In the first study, these severe torsions of 720° accounted for 26.7% (4/15) of the cases. Similarly, in our cases, almost 20% (10/51; 19.6%) of the animals with available information on the degree suffered from a torsion >360° up to 720°. It is possible that such severe cases can be generally under-represented or missed by the owners, who may attribute them to "sudden death" without considering the possibility of dystocia or, more specifically, uterine torsion.

In cattle, several authors agree that counterclockwise torsions are significantly more common (FRAZER et al., 1996; AUBRY et al., 2008). Similar results were seen in sheep by MOSDØL (1986), who observed a counterclockwise torsion in eleven of 15 cases. In the present study, counterclockwise torsions also accounted for 61.3% (30/49) of the cases with full records, but this result was not significant. In contrast, all four cases later described by MOSDØL (1999) showed a clockwise torsion. Rotations to the right were also recorded in most of the reports covering ovine individual cases (NAIDU, 2012; CHAUHAN et al., 2018; PERIYANNAN et al., 2021). Other authors found both directions equally represented in their case load (BHATTACHARYYA et al., 2015). In sheep, there is therefore no clear indication of either direction being more frequently encountered than the other, and our results did not achieve clarification of this matter.

Regarding the location of the torsion, GUPTA et al. (2021) reported that most of the cases (22/27) were presented with a post cervical uterine torsion, while only five animals were diagnosed intra operationem (pre-cervical torsion). In our own case load, the percentage of pre-cervical torsions was much higher, accounting for 50% (14/28) of the animals with full records. The absence of vaginal involvement in pre-cervical torsions makes clinical diagnosis more difficult, which is likely to result in underdiagnosis of the condition, thus increasing the risk for mother and offspring when left untreated. SCOTT (2003) raised concerns of a general lack of veterinary involvement in ovine obstetrics, thus highlighting the welfare aspect of this topic. Farmers are particularly likely to be unaware of less frequent conditions such as uterine torsion, thus leading to mis- or underdiagnosis of the condition in the field, particularly if no veterinary help is sought. This problem is highlighted in case reports of delayed presentation (SCOTT, 2011) or incidental findings at post mortem examination (JONES et al., 2020) or at a planned caesarean section following suspected metabolic disease (WINZAP et al., 2000). These findings support the large potential of underdiagnosis in sheep, as rectal examination, which would aid diagnosis at this point, is not possible due to the small size of the species (SHARUN and ERDOGAN, 2019). Despite the challenging diagnosis of this condition, ewes showing signs of dystocia should be adequately treated regardless of the suspected diagnosis, and veterinary attention should be sought, as timely intervention and caesarean section is lifesaving and prevents prolonged suffering.

6. Animal-related factors potentially contributing to the occurrence of uterine torsion

Many factors have been discussed to predispose to uterine torsion in cattle (ERTELD et al., 2012). This study could only examine some of these, many questions therefore remain unanswered. The anatomical characteristics of the bovine uterus have been suggested to play a role in the development of this condition in cattle. Despite the relatively high number of ovine torsion cases in the present study, the frequency of this condition still seems to be generally lower than in bovines. Differences in ovine and bovine anatomy have been suggested as a likely cause for this observation. The small ruminant genital tract and its slightly different anatomy, with a sublumbar rather than subileal attachment of the broad ligaments, could possibly provide greater stability to the pregnant uterus of this species (BLANCHARD, 1981; CHAHAR et al., 2018; PARKINSON et al., 2019c). More work however needs to be done to study potential anatomical differences between various ovine breeds, which might help to explain the observed differences in frequency of uterine torsion in meat or extensive sheep breeds.

The higher incidence of uterine torsion in cattle has also been explained by uterine instability caused by the monocornual nature of most bovine pregnancies (SCHÖNFELDER and SOBIRAJ, 2005; DE AMICIS et al., 2018), as twins tend to provide greater stability. A similar suggestion has been made regarding an observed low frequency of uterine torsion in goats – these authors assume that the frequently bicornual (twin or multiple) nature of caprine pregnancy reduces the risk of suffering from torsion (PUROHIT et al., 2006; JAYAGANTHAN et al., 2020).

The hypothesis that single litters predispose to uterine torsion in sheep was supported by the results of the simple logistic regression model in the present study, which indicated higher odds of uterine torsion for single pregnancies as opposed to twins or multiples, which were, however, also observed. One step further though, when a multiple logistic regression model was applied to simultaneously assess several potentially influential factors, the litter size was no longer significant, indicating that other factors, such as prolonged housing and breed type, play a more important role for the occurrence of ovine uterine torsion. The role of close confinement and lack of exercise, thus leading to reduced muscle tonicity or sudden movements, has previously been discussed for cattle and buffaloes (AUBRY et al., 2008; SINGH et al., 2020), and the same factors are likely to apply to sheep in continuously housed husbandry systems.

Breed type, body shape and potential differences in uterine anatomy between different sheep breeds are factors that require further detailed studies. Quite possibly, meat breeds have a slightly different anatomy when compared to leaner, extensive breeds due to their different body shape, and muscle and fat distribution. The exact causes for higher odds in extensive breeds therefore remain to be determined. In cattle, the body shape of the Brown Swiss breed has been suggested to predispose this breed to uterine torsion (TRIPATHI et al., 2019). It is however unclear whether the observed breed effect in sheep in our study is caused by a true predisposition of extensive breeds to uterine torsion, or whether it is caused by the fact that meat breeds more frequently suffered from foetal oversize and malpresentation due to their body type and shape, thus leading to a lower percentage of uterine torsion in the submitted cases assigned to this breed category. Whole flock studies would be necessary to assess the true incidence of uterine torsion in various breeds or breed types. A clear breed effect could not be proven in our study cohort. Although German merino ewes were more frequently affected by uterine torsion than other breeds, the difference between the three most frequent extensive breeds was not significant.

Age and parity have also been discussed as potentially predisposing factors in cattle. In a retrospective analysis of 550 uterine torsion cases from 218 farms, 74.2% of the animals had calved at least once (MOCK et al., 2016), however, a potential age predisposition was not statistically examined by these authors. Most of the affected ewes (45/60) in the present study were also multiparous and the median age of affected animals was 4.1 years (range: 1–10 years), but this median age of affected ewes did not differ from the median age of 4.0 years of all studied animals. No age or parity-related predisposition could therefore be proven in our study cohort. These results are in accordance with the situation in cattle, where a suggested age or parity predisposition remains controversial (AUBRY et al., 2008; GHUMAN, 2010; DORRESTEIJN, 2018).

Our results concerning the birth weight and gender of the offspring are not in accordance with findings reported in cattle. According to FRAZER et al. (1996), 89.0% of the cows with uterine torsion carried calves with an increased body weight. ERTELD et al. (2012) suggest that a high birth weight of the calves leads to a lower amount of allantoic fluids, which predisposes to torsion of the uterus. The birth weight and gender of the foetus is easy to assess in single pregnancies as commonly observed in cattle. In sheep, however, the high number of twin and multiple pregnancies confounds these measurements. Due to the pluriparous nature of this species, one single lamb can be lighter than the combined weight of two or three foetuses, and multiple foetuses can be of different sex. The variety of breeds and their associated breed-specific birth weights also confound this matter, as some breeds like, for instance, Suffolks or Texel crosses have heavier lambs than, for instance, Scottish Blackface (DWYER and BÜNGER, 2012). These facts can serve as an explanation why the birth weight did not prove significant in the presented case cohort. On the other hand, AUBRY et al. (2008) stated that although increased calf body weight increases the risk of uterine torsion, foetomaternal disproportion is not associated with the condition. Fourty percent of the heifers with dystocia assigned in their study had foetopelvic disproportion, and none of them suffered from uterine torsion. However, it has to be noted that birth weights were only available for 57.0% (289/507) of the lambs born to the study cohort. Higher case numbers may have led to different results.

7. Husbandry-related factors: year-round housing as the most important predisposing factor for uterine torsion in sheep

Farm management such as housing systems and nutrition are two factors that have been shown to influence the incidence of uterine torsion in cattle. Weakness of the abdominal muscles is a possible consequence of little or no exercise (ERTELD et al., 2012), which can then lead to an increased likelihood of developing uterine torsion. In the present study, animals housed year-round showed significantly higher odds of being presented with uterine torsion, and this was identified as the most influential factor in the multiple logistic regression model. Many authors agree that sudden movements can possibly lead to torsion of the pregnant uterus. Narrow stables can increase the chances that animals in the last stages of pregnancy are being pushed. These sudden movements can then accidentally lead to uterine torsion (AUBRY et al., 2008; GHOSH et al., 2013; PARKINSON et al., 2019c). This fact, in combination with overcrowded stables or high stocking densities can be the underlying reason for the high percentage of uterine torsion in fully housed animals in the present study. The influence of stocking density or other management factors however still need to be further determined. High numbers of torsion cases in a Norwegian study (MOSDØL, 1986), a country where extended winter housing periods are applied, also support the assumption that prolonged housing may indeed be an important factor in the development of uterine torsion. Short term, seasonal housing however did not seem to affect the occurrence of uterine torsion in our study, since there was no significant difference between the pasture and the winter housing seasons. However, the retrospective classification merely by time of year may not adequately reflect the true husbandry conditions of pasture-based flocks at any given time, since the timing and length of winter housing periods can vary greatly between flocks, and the clinical records were not detailed enough to retrospectively specify the given husbandry conditions at the time of presentation for pasture-based flocks with winter housing.

High amounts of concentrated feed in the ration seem to have an influence on the incidence of uterine torsion in cattle, with cattle receiving high concentrate rations thought to be more prone to uterine torsion, possibly due to the proportionally empty rumen leaving more space in the abdomen for the uterus to rotate (DROST, 2007). In our study, nutrition was not significantly associated with the occurrence of uterine torsion in sheep. However, even animals receiving supplemental concentrates usually received ad libitum roughage, so relevant differences between the nutritional categories regarding rumen fill are highly unlikely, which explains the absence of a nutritional effect. Also, the types of roughage and concentrates fed on the various farms were highly variable, so only very rough nutritional categories could be applied. This makes an evaluation more difficult and might additionally explain this outcome. Further studies with controlled groups and standardized rations would be necessary in order to finally answer the question of whether nutrition plays a role in the incidence of uterine torsion in sheep.

8. Prognosis in cases of ovine uterine torsion is not poorer than for other causes of dystocia

Uterine torsion was not associated with decreased ewe survival or prolonged hospitalization when compared to other causes of dystocia. BHATTACHARYYA et al. (2015) mentioned that the mortality of lamb(s) and ewe depended on the clinical status of the dam, and the type of obstetrical intervention did not play a significant role. These results are supported by VOIGT et al. (2021), who showed decreased survival of ewes following caesarean section in compromised patients suffering from debilitating, concurrent conditions, but the type of dystocia did not significantly affect ewe or lamb survival. These results differ from findings reported in cattle, where the severity of the torsion played an important role in the clinical condition of the animals and, consequently, in the survival of the dam (ZERBE et al., 1998). Uterine torsion thus seems to be better tolerated by sheep than by cattle. In addition, a diagnosis of uterine torsion was also not significant for lamb mortality. Delayed veterinary intervention (duration of labour >12 hours) was the most important factor negatively affecting lamb viability. This finding agrees with previous studies which evaluated the survival rates of ewes and lambs following dystocia, where lamb and dam mortality were significantly affected by the duration of labour (BHATTACHARYYA et al., 2015) or the time until veterinary intervention (ISMAIL, 2017).

9. Conclusion

Uterine torsion was an important cause of maternal dystocia in the present study, with animals being fully housed being more prone to the condition. Extensive breeds also appeared to be more susceptible, while the litter size was of less importance. The small size of the species, which prevents rectal examination, poses a diagnostic challenge to farmers and veterinarians alike, leading to a high risk of mis- or underdiagnosis and, in consequence, delayed intervention with prolonged suffering and potentially fatal outcomes for mother and offspring. Uterine torsion therefore needs to be considered as an important differential diagnosis in cases of dystocia where ringwomb is suspected, or in compromised, late pregnant ewes, and adequate and timely intervention should be undertaken.

V. SUMMARY

Uterine torsion as a cause of dystocia in sheep: occurrence, nature and predisposing factors.

Viktoria Balasopoulou

Uterine torsion has been considered a rare cause of dystocia in sheep by many authors. This study describes cases of ovine uterine torsion and analyzes potentially influential factors on its occurrence.

Clinical records of 302 sheep with dystocia admitted to a veterinary hospital were evaluated retrospectively. Sixty (19.9%) animals were diagnosed with uterine torsion. Other frequent causes were insufficient cervical dilatation (40%), foetal maldisposition (14.6%) and foetal oversize (13.9%). Statistical analyses were performed in R (version 3.6.3), using simple and multiple logistic regression models to identify potentially pre-disposing factors.

Lamb birth weights did not differ significantly between ewes with uterine torsion and other causes of dystocia ($p=0.267$). Univariate analyses excluded age, parity, season, and nutrition as non-significant, while breed type, litter size and husbandry showed significant results, with lower odds for meat breeds (OR 0.22; $p<0.001$), twin- (OR 0.49; $p=0.020$) or multiple-bearing ewes (OR 0.19; $p=0.013$) and higher odds for fully housed animals (OR 17.87; $p<0.001$). A subsequent multiple logistic regression model identified year-round housing as the most influential factor (OR 10.71; $p<0.001$). The breed type remained significant ($p=0.025$) while the litter size was no longer significant in this mixed model (twins $p=0.191$, multiples $p=0.089$).

In contrast to previous publications, uterine torsion was identified as a relevant cause of dystocia in our case load. Year-round housing was the most influential predisposing factor for the condition in the studied cohort.

Uterine torsion is most likely underdiagnosed in sheep, and it is important to raise awareness for the condition in farmers and veterinarians alike to ensure adequate and timely treatment, and to prevent unnecessary suffering.

VI. ZUSAMMENFASSUNG

Uterustorsion als Ursache von Dystokie beim Schaf: Vorkommen, Art und prädisponierende Faktoren

Viktoria Balasopoulou

Dystokie ist bei Schafen weit verbreitet, wobei die fötalen Ursachen überwiegen. Unter den maternalen Ursachen ist die ungenügende Öffnung der Zervix das häufigste Problem. Torsio uteri wird von vielen Autoren als selten angesehen.

In dieser Studie wurden die Dystokieursachen bei Schafen untersucht, die zur tierärztlichen Behandlung vorstellig wurden, wobei der Schwerpunkt auf der Beschreibung der Uterustorsion und der Analyse potenziell prädisponierender Faktoren für diesen Zustand lag. Die klinischen Daten von 302 Schafen, die wegen Dystokie behandelt wurden, wurden retrospektiv ausgewertet. Bekannte Risikofaktoren bei Rindern wurden bei Schafen untersucht. Dazu gehörten das Geburtsgewicht der Lämmer, das Alter der Mutterschafe, die Parität, die Jahreszeit, die Ernährung, der Rassetyp, die Wurfgröße und die Haltungsbedingungen.

Maternale Ursachen machten 67,2 % (203/302) der vorgestellten Fälle aus. Davon war die mangelhafte Öffnung der Zervix (Ringwomb) (121/203, 59,6 %) die häufigste der mütterlichen Ursachen. In 60 maternal bedingten Dystokiefällen (60/203, 29,6 %) wurde als Ursache des Problems eine Gebärmutterverdrehung identifiziert. Haltungsform, Rasse und Wurfgröße zeigten in univarianten Analysen eine signifikante Bedeutung, mit einer geringeren Wahrscheinlichkeit für Fleischrassen (OR 0,22; $p < 0,001$), Zwillings- (OR 0,49; $p = 0,020$) oder Mehrlingsträchtigkeiten (OR 0,19; $p = 0,013$) und einer höheren Wahrscheinlichkeit für ganzjährig im Stall gehaltene Tiere

(OR 17,87; $p < 0,001$). In einer anschließenden multivariaten Analyse wurde die ganzjährige Stallhaltung als der einflussreichste Faktor ermittelt.

Die Gebärmuttertorsion wurde in unserem Untersuchungsgut als relevante Ursache für Dystokie identifiziert. Diese Erkrankung ist bei Schafen wahrscheinlich unterdiagnostiziert. Eine stärkere Sensibilisierung der Landwirte und Tierärzte ist deshalb notwendig, um eine angemessene Behandlung der betroffenen Tiere zu gewährleisten und unnötiges Leiden zu vermeiden.

VII. REFERENCES

Abrol A, Singh M, Sharma A, Kumar P. A review on diagnostic and prognostic techniques employed during bovine uterine torsion. Research in Veterinary Science. 2020; 6: 7-13.

Ahmed A, Balarabe A, Jibril A, Sidi S, Jimoh A, Gobe R. Incidence and Causes of Dystocia in Small Ruminants in Sokoto Metropolis, Northwestern, Nigeria. Scholars Journal of Agriculture and Veterinary Sciences 2017; 4: 114-118.

Akpa G, Ifut O, Mohammed F. Indigenous management of Dystocia in ruminant livestock of northern guinea savanna of Nigeria. Nigerian Journal of Animal Production 2002; 29: 264-270.

Ali AMH. Causes and management of dystocia in small ruminants in Saudi Arabia. Journal of agricultural and Veterinary Sciences 2011; 4: 95-108.

Anderson, D. E. (2014). C-section in small ruminants. University of Tennessee, Knoxville. https://www.semanticscholar.org/paper/1-C-Section-in-Small-Ruminants-Anderson/bdb2ac89e36ad8e3e240c81b8368b1485a8c2cc0 (accessed 28.2.2023)

Anusha K, Praveenraj M, Naidu GV. Incidence of dystocia in small ruminants - a retrospective study. Indian Veterinary Journal 2016; 93: 40-42.

Aubry P, Warnick LD, DesCôteaux L, Bouchard E. A study of 55 field cases of uterine torsion in dairy cattle. The Canadian Veterinary Journal 2008; 49: 366-372.

Badawi M, Omar A, Satti A, Ahmed H, Mohammed N, Akasha O. Dystocia cases presented at veterinary teaching hospitals in Khartoum State, Sudan. Assiut Veterinary Medical Journal (special issue); 17 Scientific Congress 2016, Fac. Vet. Med., Assiut Univ., Egypt.; 1-5.

Balamurugan B, Reddy YP, Jyothi K. Dystocia due to pre-cervical uterine torsion in a Nellore brown ewe. Journal of Entomology and Zoology Studies 2019; 7: 412-413.

Barbagianni M, Spanos S, Ioannidi K, Vasileiou N, Katsafadou A, Valasi I, Gouletsou P, Fthenakis G. Increased incidence of peri-parturient problems in ewes with pregnancy toxaemia. Small Ruminant Research 2015; 132: 111-114.

Basher E. Clinical study on fetal congenital defects causing dystocia in Awassi ewes. Iraqi Journal of Veterinary Sciences 2006; 20: 181-189.

Bhattacharyya HK, Bhat FA, Buchoo BA. Prevalence of dystocia in sheep and goats: a study of 70 cases (2004-2011). Journal of Advanced Veterinary Research 2015; 5: 14-20.

Blanchard TL. Uterine torsion with ovarian vein rupture in a ewe. Journal of the American Veterinary Medical Association 1981; 179: 1402-1403.

Brounts SH, Hawkins JF, Baird A, Glickman LT. Outcome and subsequent fertility of sheep and goats undergoing cesarean section because of dystocia: 110 cases (1981–2001). Journal of the American Veterinary Medical Association 2004; 224: 275-281.

Bühler C, Hüsler J, Hirsbrunner G. Dystocia in Cattle: Prospective Analysis in Daily

Veterinary Practice (N= 573 Parturitions). Open Journal of Veterinary Medicine 2018; 8: 241-249.

Carson A, Irwin D, Kilpatrick D. A comparison of Scottish Blackface and Cheviot ewes and five sire breeds in terms of lamb output at weaning in hill sheep systems. The Journal of Agricultural Science 2001; 137: 221-233.

Castillo JM, Dockweiler JC, Cheong SH, Diel de Amorim M. Pyometra and unilateral uterine horn torsion in a sheep. Reproduction in Domestic Animals 2018; 53: 274-277.

Cebra C. Uterine Torsion in Llamas and Alpacas. American Association of Bovine Practitioners Proceedings of the Annual Conference. 2007; 174-175.

Chahar SK, Dholpuria S, Choudhary AK. Management of Uterine Torsion in Goat: A Case Report. International Journal of Applied Engineering Research 2018; 13: 11034.

Chauhan P, Patelia H, Patel D, Suthar B, Sharma V. Clinico-Obstetrical management of clockwise 180° post cervical uterine torsion in ewe. Journal of Pharmacognosy and Phytochemistry, SP1 2018: 3162-3164.

Cloete SWP, Scholtz AJ, Ten Hoope JM, Lombard PJA, Franken MC. Ease of birth relation to pelvic dimensions, litter weight and conformation of sheep. Small Ruminant Research 1998; 31: 51-60.

Dahmani A, Dahmani H, Rahal K, Kaidi R. Description of dystocia in ewes of the Ksar el Boukhari region (Algeria). Agriculture 2019; 3-4: 111-112.

Darvelid AW, Linde-Forsberg C. Dystocia in the bitch: A retrospective study of 182 cases. Journal of Small Animal Practice 1994; 35: 402-407.

De Amicis I, Veronesi MC, Robbe D, Gloria A, Carluccio A. Prevalence, causes, resolution and consequences of bovine dystocia in Italy. Theriogenology 2018; 107: 104-108.

Desliens L. Torsion of the uterus in the cow. Etiology and practical considerations. Bulletin de l'Académie Vétérinaire de France 1967; 40: 147-156.

Dinesh M, Kalaiselvan E, Manikandan R. A rare case of Holocardius acephalus monster with fetal anasarca in a non-descriptive goat kid. The Pharma Innovation Journal. 2020; 9: 01-04.

Doğruer G, Köse AM, Koldaş Ürer E, Doğruer A. Unilateral uterine torsion in a pregnant bitch. Eurasian Journal of Veterinary Sciences 2018; 34: 60-64.

Dorresteijn J. Incidence of uterine torsions in dairy cattle in five veterinary practices in the Netherlands. Dissertation; Veterinary Medicine University Utrecht; 2018. https://studenttheses.uu.nl/handle/20.500.12932/28658 (accessed 28.02.2023)

Drost M. Complications during gestation in the cow. Theriogenology 2007; 68: 487-491.

Durrani A, Kamal N. Prevalence of genital tract problems in clinical cases of various species of animals. Journal of Animal and Plant Sciences 2009; 19: 160-162.

Dwyer CM, Bünger L. Factors affecting dystocia and offspring vigour in different sheep genotypes. Preventive Veterinary Medicine 2012; 103: 257-264.

Ennen S, Scholz M, Voigt K, Failing K, Wehrend A. Puerperal development of ewes following dystocia: a retrospective analysis of two approaches to caesarean section. Veterinary Record 2013; 172: 554.

Erlwanger KH, Costello MA, Meyer LC. Uterine torsion in a Sprague Dawley rat (Rattus norvegicus). Journal of the South African Veterinary Association 2011; 82: 183-184.

Erteld E, Wehrend A, Goericke-Pesch S. Uterine torsion in cattle - Frequency, clinical symptoms and theories about the pathogenesis. Tierärztliche Praxis. Ausgabe G, Grosstiere/Nutztiere 2012; 40: 167-175.

Fogarty NM, Thompson JM. Relationship between pelvic dimensions, other body measurements and dystocia in Dorset Horn ewes. Australian Veterinary Journal 1974; 50: 502-506.

Fotariya A, Dalsaniya U, Chaudhary B, Gurjar K, Chaudhari R, Chaudhari C, Sutaria T. Dystocia due to post–cervical uterine torsion in a Sindhi mare. International Journal of Livestock Research 2020; 10: 173-177.

Frazer GS, Perkins NR, Constable PD. Bovine uterine torsion: 164 hospital referral cases. Theriogenology 1996; 46: 739-758.

George JM. The incidence of dystocia in fine-wool Merino ewes. Australian Veterinary

Journal 1975; 51: 262-265.

George JM. The incidence of dystocia in Dorset Horn ewes. Australian Veterinary Journal 1976; 52: 519-523.

Ghosh S, Singh M, Prasad J, Kumar A, Rajoriya J. Uterine torsion in bovines-A Review. Intas Polivet 2013; 14: 16-20.

Ghuman SPS. Uterine torsion in bovines: a review. Indian Journal of Animal Sciences 2010; 80: 289-305.

Gupta C, Murugan M, Ramprabhu R, Kumar SS. Uterine torsion in small ruminants–outcome and fertility following different management approaches. Indian Journal of Small Ruminants 2021; 27: 139-141.

Hawkins E, McDonnell S, Angell J. Estimation of immediate and 7-day clinical prognostic indicators for ewe and lamb survival in the UK following vaginal delivery and caesarean section at a single veterinary practice. Small Ruminant Research 2021; 204: 106511.

Hunter P, Erasmus BJ, Vorster JH. Teratogenicity of a mutagenised Rift Valley fever virus (MVP 12) in sheep. Onderstepoort Journal of Veterinary Research 2002; 69: 95-98.

Ijaz A, Talafha AQ. Torsion of the uterus in an Awassi ewe. Australian Veterinary Journal 1999; 77: 652-653.

Ismail ZB. Dystocia in Sheep and Goats: Outcome and Fertility Following Surgical and Non-Surgical Management. Macedonian Veterinary Review 2017; 40: 91-96.

Jacobson C, Bruce M, Kenyon PR, Lockwood A, Miller D, Refshauge G, Masters DG. A review of dystocia in sheep. Small Ruminant Research 2020; 106209.

Jayaganthan P, Palanisamy M, Prabaharan V, Rajkumar R, Raja S. Successful management of uterine torsion in a kodi aadu goat by modified schaffer's method. International Journal of Science, Environment and Technology, 2020; 9: 486-488.

Jones EM, Neef A, Shearer PL, Gunn AJ. Hydroureteronephrosis and fetal mummification secondary to uterine torsion in a Merino ewe. Australian Veterinary Journal 2020; 98: 529-532.

Kerr NJ. Occurrence, etiology and management of ringwomb in ewes. West Virginia University Graduate Theses, Dissertations, and Problem Reports 1999; 981. https://researchrepository.wvu.edu/etd/981

Kisani A, Wachida N. Dystocia due to mummified foetal monster in a Yankasa ewe: A case report. International Journal of Animal and Veterinary Advances 2012; 4: 167-169.

Kloss S, Wehrend A, Failing K, Bostedt H. Investigations about kind and frequency of mechanical dystocia in ewes with special regard to the vaginal prolapse ante partum. Berliner und Münchener Tierärztliche Wochenschrift 2002; 115: 247-251.

Kruse M. Genetische und umweltbedingte Einflüsse auf das Auftreten von Torsio uteri bei Milchkühen. Dissertation, Tierärztliche Hochschule Hannover 2014 https://elib.

tiho- hannover.de/receive/etd_mods_00002472.

Kumar KP, Naidu GV, Teja A. A Case of Uterine Torsion in Ewe and its Correction by Adopting Schafer’s Method. The Indian Veterinary Journal 2016; 93: 55-56.

Kumari S, Dutt R. Surgical management of dystocia due to ring womb in sheep: a case report. Veterinary Clinical Science 2020; 8: 50-52.

Kuroda K, Osaki T, Harada K, Yamashita M, Murahata Y, Azuma K, Tsuka T, Ito N, Imagawa T, Okamoto Y. Uterine torsion in a full-term pregnant cat. Journal of Feline Medicine and Surgery Open Reports 2017; 3: 2055116917726228.

Lane J, Jubb T, Shephard R, Webb-Ware J, Fordyce G. Priority list of endemic diseases for the red meat industries. Meat and Livestock Australia, North Sydney. Meat & Livestock Australia Limited 2015

Leeds TD, Notter DR, Leymaster KA, Mousel MR, Lewis GS. Evaluation of Columbia, USMARC-Composite, Suffolk, and Texel rams as terminal sires in an extensive rangeland production system: I. Ewe productivity and crossbred lamb survival and preweaning growth. Journal of Animal Science 2012; 90: 2931-2940.

Lyons N, Gordon P, Borsberry S, Macfarlane J, Lindsay C, Mouncey J. Clinical Forum: Bovine uterine torsion: a review. Livestock 2013; 18: 18-24.

Mahal JS, Honparkhe M, Ahuja AK, Anand I. Successful uterine detorsion with plank method and fetal delivery in an ewe. Journal of Entomology and Zoology Stidies 2020; 8: 864-865.

Mahmoud D, Abdelhadi F, Khiati B, Smail N, Abdelhadi S. Etude des dystocies ovines et de la pertinence de la césarienne dans des élevages de la wilaya de Tiaret (Algérie). (Study on sheep dystocia and caesarean section in farms of Tiaret wilaya (Algeria), in French). Livestock Research for Rural Development, 30, Article #189.

Majeed AF, Taha MB, Azawi OI. Cesarean section in Iraqi Awassi ewes: A case study. Theriogenology 1993; 40: 435-439.

Majeed AF, Taha MB. Obstetrical disorders and their treatment in Iraqi Awassi ewes. Small Ruminant Research 1995; 17: 65-69.

Martens K, Govaere J, Hoogewijs M, Lefevre L, Nollet H, Vlaminck L, Chiers K, de Kruif A. Uterine torsion in the mare: a review and three case reports. Vlaams Diergeneeskundig Tijdschrift 2008; 77: 397-405.

McHugh N, Berry DP, Pabiou T. Risk factors associated with lambing traits. Animal 2016; 10: 89-95.

McSporran KD, Buchanan R, Fleiden ED. Observations on dystocia in a Romney flock. New Zealand Veterinary Journal 1977; 25: 247-251.

Mosdøl G. Spontaneous vaginal rupture in pregnant ewes. Veterinary Record 1999; 144: 38-41.

Mosdøl G. Keisersnitt på søye I alminnelig praksis. Indikasjoner og betydning for fertilitet (Indications for and fertility after cesarean section in the ewe in common practice, In Norwegian). Norsk Veterinaertidsskrift 1986; 98: 441-444.

Mostefai E, Kouidri M, Selles SMA. Causes of sheep dystocia in Djelfa area (Algeria). Revue Marocaine des Sciences Agronomiques et Veterinaires 2019; 284-287.

Naidu GV. A case of uterine torsion in sheep. Indian Journal of Animal Reproduction 2012; 33: 102-103.

Naoman UD, Jabbo SS, Ahmed MA, Ahmed AE. Causes and treatment of dystocia in iraqi awassi ewes. Basrah Journal of Veterinary Research 2013; 12: 250-255.

Özdemir Salci ES, Shahzad AH. Fetal retention due to unilateral partial uterine horn torsion in an ewe. Large Animal Review 2021; 27: 237-239.

Pandey AK, Kumar S, Singh G, Kumari S, Phogat J, Sharma S, Kumar L, Mittal D. Delivery of monster fetus with catlin mark and agnathia in sheep-a rare case report. The Indian Veterinary Journal 2017; 94: 59-60.

Parkinson TJ, Vermunt JJ, Noakes DE. 11- Approach to an Obstetrical Case. In: Veterinary Reproduction and Obstetrics. Noakes DE, Parkinson TJ, England GCW, eds. St. Louis (MO): W.B. Saunders 2019a: 203-213.

Parkinson TJ, Vermunt JJ, Noakes DE. 12- Prevalence, Causes and Consequences of Dystocia. In: Veterinary Reproduction and Obstetrics. Noakes DE, Parkinson TJ, England GCW, eds. St. Louis (MO): W.B. Saunders 2019b: 214-235.

Parkinson TJ, Vermunt JJ, Noakes DE. 13- Maternal Dystocia. In: Veterinary Reproduction and Obstetrics. Noakes DE, Parkinson TJ, England GCW, eds. St. Louis (MO): W.B. Saunders 2019c: 236-249.

Parkinson TJ, Vermunt JJ, Noakes DE. 14- Fetal Dystocia in Livestock. In: Veterinary Reproduction and Obstetrics. Noakes DE, Parkinson TJ, England GCW, eds. St. Louis (MO): W.B. Saunders 2019d: 250-276.

Pearson L, Rodriguez J, Tibary A. Uterine torsion in late gestation alpacas and llamas: 60 cases (2000–2009). Small Ruminant Research 2012; 105: 268-272.

Periyannan M, Selvaraju M, Senthilkumar K, D Palanisamy M. Unusual incidence of uterine torsion in a mecheri ewe with bicornual twin pregnancy and its successful management. Pharma Innovation 2021; 10: 01-03.

Phogat J, Behl S, Singh U, Singh P. Uterine torsion in sheep: A case report. Haryana Veterinarian 2007; 4: 110-111.

Purohit G, Gupta A, Gaur M, Sharma A, Bihani D. Periparturient disorders in goats. A retrospective analysis of 324 cases. Dairy Goat Journal 2006; 84: 24-33.

Purohit G, Kumar A, Mehta MGJ. Uterine torsion in a non-descript cow with twins: The Pharma Innovation Journal 2019; 8: 707-708.

Purohit GN. Maternal dystocia in cows and buffaloes: a review. Open Journal of Animal Sciences 2011; 1: 41-53.

Purohit GN, Gaur M. Uterine torsion in buffaloes: A critical analysis. Buffalo Bulletin 2014; 33: 363-378.

Refshauge G, Brien FD, Hinch GN, Van De Ven R. Neonatal lamb mortality: factors associated with the death of Australian lambs. Animal Production Science. 2015; 56:726-735.

Salci ESO. Fetal retention due to unilateral partial uterine horn torsion in an ewe. Large Animal Review 2021; 27: 237-239.

Scholz M. Untersuchungen zur puerperalen Entwicklung von Schafen nach Schwergeburt unter besonderer Berücksichtigung zweier unterschiedlicher Operationsverfahren der Sectio caesarea. (Studies on the puerperal development of sheep following dstocia with particular focus on two different approaches to caesarean section, in German). Dissertation, Justus-Liebig-Universität Gießen, VVB Laufersweiler, Gießen. 2006.

Schönfelder A, Sobiraj A. Etiology of torsio uteri in cattle: a review. Schweizer Archiv für Tierheilkunde 2005; 147: 397-402.

Scott PR. Uterine torsion in the ewe. Livestock 2011; 16: 37-39.

Scott PR. Applications of diagnostic ultrasonography in small ruminant reproductive management. Animal Reproduction Science 2012; 130: 184-186.

Scott PR. Ovine caesarean operations: a study of 137 field cases. British Veterinary Journal 1989; 145: 558-564.

Scott PR. A questionnaire survey of ovine dystocia management in the United Kingdom. Animal Welfare 2003; 12: 119-122.

Scott PR. The management and welfare of some common ovine obstetrical problems in the United Kingdom. The Veterinary Journal 2005; 170: 33-40.

Scott PR. Use of ultrasonographic examination in sheep health management—A general appraisal. Small Ruminant Research 2017; 152: 2-9.

Sharma A, Kumar P, Singh M, Vasishta N. Retrospective analysis of dystocia in small ruminants. Intas Polivet 2014a; 15: 287-289.

Sharma A, Kumar P, Singh MM, Vasishta N. Retrospective Analysis of Dystocia in Small Ruminants of North Western Himalayas. Vet. Res. 2014b; 7: 9-12.

Sharun K, Erdoğan G. A Review: Obstetrical Emergencies in Small Ruminants. Alexandria Journal of Veterinary Sciences 2019; 62: 1-16.

Singh N, Gandotra VK, Ghuman SS, Singh R, Verma HK. Management factors associated with the occurrence of uterine torsion in buffaloes. International Journal of Current Microbiology and Applied Sciences 2020; 9: 2278-2282.

Skladany J, Balascak J, Kiss M. Die Torsio uteri als Ursache für Geburtsstockungen beim Schaf (Kurzmitteilung) (Uterus torsion –Cause of obstruction of labour in sheep (brief communication), in German). Monatshefte für Veterinärmedizin 1988; 43: 212–213.

Smith GM. Factors affecting birth weight, dystocia and preweaning survival in sheep. Journal of Animal Science 1977; 44: 745-753.

Sobiraj A. Geburtsschwierigkeiten bei Schaf und Ziege – Auswertung des Patientenaufkommens aus sieben Ablammperioden an einer geburtshilflichen Klinik (Birth difficulties in sheep and goats-evaluation of patient outcome from seven lambing periods in an obstetrical clinic, in German). Deutsche tierärztliche Wochenschrift 1994; 101: 471-476.

Speijers MH, Carson AF, Dawson LE, Irwin D, Gordon AW. Effects of sire breed on ewe dystocia, lamb survival and weaned lamb output in hill sheep systems. Animal 2010; 4: 486-496.

Stokes JE, Tarlinton RE, Lovatt F, Baylis M, Carson A, Duncan JS. Survey to determine the farm-level impact of Schmallenberg virus during the 2016-2017 United Kingdom lambing season. Veterinary Record 2018; 183: 690.

Tamm T. Untersuchungen zur Gebärmutterverdrehung des Rindes (Studies on uterine torsion in cattle, in German). Dissertation, Tierärztliche Hochschule Hannover. 1997.

Thilagar S, Yew YC, Dhaliwal GK, Toh I, Tong LL. Uterine horn torsion in a pregnant cat. Veterinary Record 2005; 157: 558-560.

Tibary A, Rodriguez J, Anouassi A, Walker P. Management of dystocia in camelids. American Association of Bovine Practitioners Proceedings of the Annual Conference. 2008; 41: 166-176.

Tripathi A, Mehta J. Factors associated with uterine torsion in cattle: a retrospective study. The Bioscan 2015; 10: 1135-1137.

Tripathi A, Shukla M, Singh A, Singh R, Dayal R. Maternal, foetal, managemental and seasonal factors predisposing to uterine torsion in bovines: a review. Veterinary Practitioner 2019; 20: 233-237.

Velladurai C, Selvaraju M, Napolean R. Schäffer's method for the treatment of an ewe with uterine torsion. The Indian Journal of Animal Reproduction 2016; 38: 64-65.

Vermunt JJ, Parkinson TJ, Noakes DE. 16- Defects of Presentation, Position and Posture in Livestock. In: Veterinary Reproduction and Obstetrics. Noakes DE, Parkinson TJ, England GCW, eds. St. Louis (MO): W.B. Saunders 2019: 291-314.

Voigt K, Najm NA, Zablotski Y, Rieger A, Vassiliadis P, Steckeler P, Schabmeyer ST, Balasopoulou V, Zerbe H. Factors associated with ewe and lamb survival, and subsequent reproductive performance of sheep undergoing emergency caesarean section. Reproduction in Domestic Animals 2021; 56: 120-129.

Wani N, Wani G, Bhat A. Schistosoma reflexus in a Corriedale ewe. Small Ruminant Research 1994; 14: 95-97.

Wehrend A, Bostedt H, Burkhardt E. The use of trans-abdominal B mode ultrasonography to diagnose intra-partum uterine torsion in the ewe. Veterinary Journal 2002; 164: 69-70.

Windsor P. 9- Abnormalities of Development and Pregnancy. In: Veterinary Reproduction and Obstetrics. Noakes DE, Parkinson TJ, England GCW, eds. St. Louis (MO): W.B. Saunders 2019: 168-194.

Winter A. Dealing with dystocia in the ewe. In Practice 1999; 21: 2-9.

Winzap B, Bachler C, Hassig M. Torsio uteri as the differential diagnosis for gestational ketosis in sheep. Schweizer Archiv für Tierheilkunde 2000; 142: 391-392.

Yerima J, Shitu H, Idi Y, Abdussamad A, Kalla D. Incidence of reproductive disorders and mastitis among small ruminants of Nigeria. Nigerian Journal of Animal Science 2021; 23: 93-99.

Yorke EH, Caldwell FJ, Johnson AK. Uterine torsion in mares. Compendium: Continuing Education for Veterinarians 2012; 34: E2.

Zerbe H, Tamm T, Grunert E. Zur Problematik der Behandlung der Torsio uteri sub partu beim Rind. (Treatment of uterine torsion sub partu in the cow, in German). Der Praktische Tierarzt, collegium veterinarium 1998; 27: 50-53.

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