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REVIEW



Rumenotomy in small ruminants – a review

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ABSTRACT

Rumenotomy is one of the most widely used surgical techniques for the diagnosis and treatment of different rumen conditions in ruminants. It is commonly used for large ruminants, such as cattle. Although this technique is also applied to small ruminants, there is a lack of standardization. To date, it has not been fully described in the available literature, which is mostly from developing countries with a small number of peer-reviewed publications. This review is thus intended to summarize the body of knowledge related to the technique that has been published so far and make it available for clinical practice. The indications for rumenotomy, preoperative management of patients, different surgical techniques and postoperative management, including complications from the procedure, are discussed.

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Rumenotomy; small ruminants; surgery; goat; sheep; rumen

Introduction

The digestive system of ruminants has the peculiarity of being made up of four different compartments: the rumen, reticle, omasum, and abomasum. The production of digestive enzymes is reserved for the abomasum, so this chamber is responsible for breaking down food (Phillipson 1999). Ruminants are able to consume fibrous plant material, because the fermentation processes carried out by the microorganisms found in the rumen (mainly ciliated protozoa and bacteria, but also yeasts) produce volatile fatty acids (VFAs). VFAs are obtained from complex carbohydrates and other products (such as proteins and B vitamins) (Ducharme 1990), and they are absorbed mainly through the ruminal wall, or later in the omasum and abomasum (Barcroft et al. 1944).

In small ruminants, the ruminal volume is estimated to be approximately 5.3 litres, accounting for approximately 13% of their body weight (Owens and Goetsch 1993). Other authors estimate that the ruminal content in sheep is approximately 4–6 kg (Phillipson 1999), but these data may vary according to the diet and transit through the digestive tract. In the case of adult cattle, the estimated rumen volume varies between 102 and 148 litres (Oehme 1982) and accounts for around 16% of their body weight (Ducharme 1990).

Although most of the diseases affecting the gastroenteric tract in ruminants are managed medically, some require surgical treatment (Radostits et al. 2007). Rumenotomy is one of the most widely used surgical techniques in ruminants, and in some regions it represents as much as 94% of all surgeries in goats (Hayder 2004). Although the surgical technique is very

similar for small and large ruminants, the technique has been widely described in cattle (Niehaus 2008; Callan and Applegate 2017; Martinez et al. 2019), but not so much in small ruminants. However, rumenotomies are a common practice for the removal of foreign bodies in goats (Hayder et al. 2006), and this technique is also used for zootechnical or research purposes (Martinez et al. 2019). Yet, it should be noted that several particularities must be considered when the technique is performed on small ruminants.

Indications

Several conditions have been reported that require the emptying of the rumen. They can either be a dysfunction caused primarily by failures in the transit or filling capacity of the rumen, reticulo-pericarditis or reticulo-peritonitis – which has rarely been reported in small ruminants (Radostits et al. 2007) – or processes that require greater urgency, such as cases of acute ruminal acidosis or acute bloat (Das and Behera 2011; Lozier and Niehaus 2016).

It is estimated that 50% of this type of surgery is performed to remove foreign bodies from the rumen or reticulum (Niehaus 2008). The accumulation of foreign bodies inside the rumen reduces the absorption of volatile fatty acids and, consequently, reduces the productivity of the animal. This therefore has a great economic impact (Igbokwe et al. 2003).

In the specific case of small ruminants, they show a great appetite for various materials difficult to digest, which can produce bezoars or on occasion, an obstruction in the

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reticulo-omasal transit, lesions in the mucosa of the reticulum and alterations in ruminal fermentation, absorption or mobility (Gutierrez et al. 1998), as well as ruminitis (Hailat et al. 1998). Although it seems that goats could manifest a greater appetite for indigestible materials (Gutierrez et al. 1998), some authors have reported a higher incidence in sheep, despite their more selective feeding behaviour (Baillie and Anzuino 2006; Mozaffari 2009; Semieka 2010; Fromsa and Mohammed 2011). Also, this feeding behaviour would explain why ropes, plastics and threads are more frequently observed in goats (Gutierrez et al. 1998; Kuotsu et al. 2019), while thick plant material that ends up forming phytobezoars is more frequently found in sheep (Misk et al. 1984).

These types of diseases are more frequent in developing countries, triggered by conditions related to feeding management and farm design. The ingestion of foreign bodies can be associated with a phenomenon known as pica (Pugh and Baird 2012), a disorder characterized by a craving and appetite for non-edible substances – particularly for elements and trace elements, such as salt, cobalt or phosphorus – which is sometimes observed in some states of nutritional deficiency (Fraser and Bergeron 1991; Radostits et al. 2007). It is also observed in diseases affecting the central nervous system (Gutierrez et al. 1998), and can also be behavioural in origin (Pugh and Baird 2012). The accumulation of indigestible material can lead to the generation of a hard mass in the rumen (Geehan et al. 2006), which could cause impaction (Kumar and Sangwan 2017; Singh et al. 2019), the accumulation of gas (Das and Behera 2011) and even death (Hailat et al. 1998). Under these circumstances, rumenotomy is indicated.

Perioperative management

Ideally, the animal should fast for several hours before the procedure, in order to facilitate the surgical technique. Furthermore, fasting has the same beneficial effects as sedation drugs. However, in an emergency, the fasting period should not be enforced (Greene 2002; Hendrickson and Baird 2013).

Recent studies suggest that the use of perioperative non-steroidal anti-inflammatory drugs, such as flunixin meglumine or meloxicam, should be considered (Callan and Applegate 2017) even up to 7 days after the intervention (Das and Behera 2011).

Because rumenotomy is a non-aseptic procedure, broad-spectrum antibiotics such as oxytetracycline (Saidu et al. 2020), penicillin (Haven et al. 1992; Hayder 2004; Geehan et al. 2006) ampicillin or ceftiofur (Callan and Applegate 2017) should be administered. Some authors have reported that the prophylactic use of penicillin significantly reduces the incidence of abscess formation after a rumenotomy. They also demonstrated that an initial dose of antibiotic at the time of surgery was all that was needed, as continuing the therapy for several days after the surgery did not significantly decrease the incidence of abscesses or the rate of infection (Haven et al. 1992). Other concurrent diseases such as peritonitis, pericarditis and ruminal acidosis, among others, should also be treated (Niehaus 2008; Callan and Applegate 2017). In certain cases, some authors recommend fluid therapy prior to the surgical procedure (Saidu et al. 2016; Dharmaceelan et al.

2017) and/or during surgery (Das and Behera 2011; Saidu et al. 2016).

In clinical practice, general anesthesia in small ruminants is challenging (Ghurashi et al. 2009). A combination of drugs for the induction of anesthesia is usually the best option (Udegbumam and Adetunji 2007). Side effects such as arousal during induction or recovery, or increased muscle tone and salivation, are generally counteracted with the use of sedatives such as xylazine, acepromazine and diazepam (Udegbumam and Adetunji 2007; Saidu et al. 2016). Some protocols recommend prior sedation of the animals. For this effect, a dose of 0.15 mL of 2% xylazine per 15 kg – the equivalent of 0.2 mg xylazine per kg – is recommended, administered either intramuscularly (Gutierrez et al. 1998) or subcutaneously (Saidu et al. 2020). Other authors have recommended the intravenous administration of pre-anesthetics drugs such as acepromazine (0.1 mg/kg) or ketamine (22 mg/kg) (Chávez García et al. 2018).

Another successful protocol is the combination of diazepam and ketamine (Udegbumam et al. 2019). Diazepam is a potent long-acting sedative that produces muscle relaxation with low cardiovascular effects (Koshy et al. 2003), which in combination with ketamine, alleviates the cardiovascular effects of the latter. However, this combination has been shown to produce short-term anesthesia and inadequate analgesia in goats (Ghurashi et al. 2009).

Callan and Applegate (2017) even reported that the procedure should rarely be performed with sedation, opting instead to simply immobilize the standing animal with a restraint halter. It is important to prevent any gas distension of the rumen before surgery, using either a gastric tube or by decompressing the rumen with a needle before making the incision through the abdominal wall. Anesthesia and sedation should only be avoided in those cases in which the anesthetic and/or sedative drugs are contraindicated due to the metabolic or medical condition of the patient (Das and Behera 2011).

Once the animal is sedated, a large surgical field is prepared in the left paralumbar fossa, shaving the area to avoid contamination with hair, especially in the case of woolly sheep or long-haired goats. The animal is placed in right lateral decubitus position and kept tied up on the operating table. Some authors have performed this surgical technique with the animal standing up (Saidu et al. 2020). The use of a hinged table has also been reported (Geehan et al. 2006). After placing the animal in lateral decubitus position, the table is turned so that the animal remains standing because it is tied to the table. This technique seems not only more comfortable for the surgeon, but also for the animal, and it is recommended to avoid post-operative complications (adhesions, infections, etc.). Once the entire surgical field is free of hair, it is washed with alcohol and povidone-iodine (Chávez García et al. 2018) or chlorhexidine (Saidu et al. 2016; Udegbumam et al. 2019) and povidone-iodine (Saidu et al. 2020).

Six different techniques have been described for performing paralumbar fossa and abdominal wall anesthesia: infiltration anesthesia, proximal paravertebral thoracolumbar anesthesia, lumbar distal thoracolumbar anesthesia, segmental dorsolumbar epidural anesthesia, lumbar segmental epidural anesthesia and subcutaneous thoracolumbar anesthesia (Tranquilli et al. 2007). The use of various analgesics has been reported, such

as 2% mepivacaine (Gutierrez et al. 1998), bupivacaine (Saidu et al. 2016) or 2% lidocaine (Abdel-hady et al. 2015; Dharmaceelan et al. 2017; Mousam et al. 2018; Saidu et al. 2020), for both paravertebral nerve block (proximal or distal) or for inverted L block (Das and Behera 2011; Edmondson 2016; Dharmaceelan et al. 2017). However, it should be noted that even at 1%, lidocaine can induce toxic effects in both goats and sheep (Das and Behera 2011; Fubini and Ducharme 2016).

Vaccination of the animal using tetanus toxoid before surgery (Dharmaceelan et al. 2017) or afterwards (Hayder 2004) has been reported to successfully prevent disease related to the procedure. Surgical drapes are also used to prevent contamination.

Surgical techniques*

Rumenotomy is considered a clean-contaminated surgical technique. The rumen should be accessed by approaching the left paralumbar fossa. A vertical incision is performed just behind the last rib, and about three centimeters from the transverse lumbar process (Dharmaceelan et al. 2017), just above the dorsal sac of the rumen (Lozier and Niehaus 2016). The main objective is to externalize the dorsal sac and secure the rumen wall to the skin, in order to prevent contamination of the abdominal cavity and muscle layers. A rumenotomy is performed immediately after an exploratory laparotomy (Niehaus 2008; Ordoñez Medina 2014; Abdel-hady et al. 2015).

The different surgical techniques differ from each other according to the method used to fasten the rumen, either to the body wall or to the skin (Niehaus 2008). Surgery begins with the incision of the skin. The subcutaneous layer – which may vary in thickness depending on the age and amount of adipose tissue – is then cut. Next, the oblique abdominal muscles (external, internal and transverse) are approached and then the peritoneum is located (Jennings 1989; Niehaus 2008). Once the peritoneum is opened, the rumen is exteriorized, trying to choose the less vascularized area (Gutierrez et al. 1998). The rumen must be fastened prior to making the incision.

Fixation using four holding sutures: In this technique, four sutures are used to anchor the rumen to the skin at the dorsal, ventral, cranial and caudal parts of the incision. The main disadvantage is that there are many areas where the ruminal content can leak into the abdominal cavity (Geehan et al. 2006; Niehaus 2008).

Skin clamp technique: The rumen is clamped to the skin with towel clamps at various locations around the incision (Niehaus 2008; Udegbumam et al. 2019).

Anchoring devices after exteriorization of the rumen: Different elements have been used to anchor the rumen. Michael and McKinley (1954) designed a rumenotomy ring formed by an aluminium ring with a rubber ring adhered to its internal circumference. The idea is that the rumen could be trapped in this rubber ring, shortening the surgery time by eliminating the need to suture the rumen to the skin. A modification of this ring was the Weingarh ring, designed to secure the hooks without an interior rubber ring. In this technique, the dorsal sac of the rumen is grasped dorsally and ventrally with large non-squash forceps. An incision is then made in the rumen ventrally, hooks are placed on the cut edge and

attached to the device. As the incision continues dorsally, more hooks are applied to the ventral forceps (Lozier and Niehaus 2016). Another similar device is the Gabel rumen retractor, which has screws to attach the rumen to the device, thus providing better contamination results and a shorter surgery time (Dehghani and Ghadrdani 1995).

Fixation with cutaneous suture: This is the most commonly used technique. The rumen is sutured to the skin in a continuous inverted pattern known as a Connell or Cushing pattern, which allows the rumen to be inverted. The edge of the skin is inverted to form a continuous seal, preventing the passage of ruminal content into the abdominal cavity (Dehghani and Ghadrdani 1995). The recommended suture thread is size #1 USP silk (Dharmaceelan et al. 2017). This suture must be performed in short runs with this Cushing pattern to create a seal between the serosa of the rumen (without entering the lumen of the organ) and the skin, but without the distance between the stitches being too short. This can be avoided by creating a bag effect. Some authors recommend attaching the rumen to the muscle wall for safety reasons before attaching it to the skin. However, post-operative problems have been reported using this method (Lozier and Niehaus 2016).

Dehghani and Ghadrdani (1995) compared these four techniques with regard to procedure time, postoperative body temperature and white blood cell count. The conclusions were that a rumenotomy with cutaneous sutures required significantly more time than the other 3 methods. On the other hand, the four-suture fixation method produced a significantly higher body temperature during the first four days after the intervention and a significantly higher white blood cell count and neutrophil-lymphocyte ratio during this time, as compared to animals on which any of the other three techniques was performed.

Ruminal mortise or shroud: This is a rubber device that has a similar large flat surface on one side and an internal edge that fixes it to the interior of the temporary ruminal fistula (Hendrickson and Baird 2013). It can also consist of plastic drapes with an adhesive surface to adhere to the outside of the patient or the patient's drape. It has an internal hole attached to a rubber ring that collapses, allowing it to be inserted through the rumenotomy. Once inside the rumen, it will expand and hold the cloth in place. This will prevent the rumen contents from coming into contact with the surgical site (Lozier and Niehaus 2016). This cover is sometimes made of polyethylene (Adamu et al. 1993).

Fixation to the peritoneum: In this case, the main disadvantage is that the union could be very weak, which would allow the rumen to retract into the abdominal cavity. In addition, it is easier for contamination of the musculature to occur (Niehaus 2008).

Once the rumen is fixed, a vertical incision (approximately 15 cm) is made in the rumen wall, while attempting to avoid vascularized areas (Gutierrez et al. 1998; Niehaus 2008; Udegbumam et al. 2019). In order not to interfere with the sutures in place, a 3 cm margin is left on the dorsal and ventral aspect (Lozier and Niehaus 2016). The incision must be large enough not only to allow entry of the surgeon's hand and forearm, but also to be able to remove material from within the rumen. Occasionally, due to its size, the content must be broken up manually before removal from the rumen (Gutierrez

et al. 1998). The reticulum, omasum and abomasum can be palpated transruminally. The ruminoreticular fold, esophageal orifice and omasal orifice should be palpated to detect any injury. The ventral sac of the rumen should also be thoroughly explored for foreign bodies. Although uncommon in small ruminants, the reticulum should be explored for foreign bodies, adhesions or abscesses (Lozier and Niehaus 2016).

It is recommended that, after removing the cause of the problem, a certain amount (around 1 kg) of concentrate or fibrous elements be left inside the rumen (Das and Behera 2011).

After removing the foreign bodies and completing the ruminal examination, the organ should be closed with 2 layers of sutures. The first layer is sutured while the rumen is still attached to the skin. Size #1 USP absorbable suture material has been used for this purpose, although some authors have used USP #2/0. The inverted Cushing suture pattern (Niehaus 2008; Das and Behera 2011) or the inverted Lembert suture pattern (O'Connor 2005; Dharmaceelan et al. 2017; Udegbumam et al. 2019) are recommended because they provide a sealed closure that prevents leakage of the rumen content into the peritoneal cavity. After being thoroughly washed out, the rumen is released from the skin and sewn back in an inverted pattern, using absorbable suture #2 USP. Some authors state that the second layer should be wide enough to sew the suture holes that were created when the rumen was sutured to the skin (Lozier and Niehaus 2016). Once the rumen is closed, it is thoroughly washed again and cleaned of any debris before it is released and allowed to return to the abdomen.

After this procedure, it is recommended to replace the material, as it will become a clean surgery (Niehaus 2008). The flank incision is closed in 3 layers with #2 or #3 USP absorbable suture material that closes the peritoneum and transverse abdominal muscle together and the external and internal abdominal oblique muscles together, using a simple continuous suture pattern (Udegbumam et al. 2019). Some studies have reported the use of a mattress suture pattern to close the oblique muscles (Dharmaceelan et al. 2017). The skin is closed with a non-absorbable #3 USP suture in a Ford interlocking suture pattern with 2–3 interrupted sutures at the bottom of the incision, which can be opened in the case of a seroma or incisional abscess (Lozier and Niehaus 2016). This last suture can also be performed with sterile cotton sutures (Dharmaceelan et al. 2017) or non-absorbable #2/0 USP sutures, using a simple discontinuous pattern (Udegbumam et al. 2019).

Postoperative management. Complications

Some authors recommend a single dose of penicillin at the time of surgery (Haven et al. 1992), while others have used broad spectrum cephalosporins (10 mg/IV) accompanied by 200 ml of physiological saline with dextrose (Das and Behera 2011), and more recently, 20 mg/kg oxytetracycline (Udegbumam et al. 2019). Still other authors add 200 ml of intravenous lactated ringer, in addition to 1 ml of intravenous tramadol for 5 days (Dharmaceelan et al. 2017). A number of studies using different antibiotic treatments, however, have found that antibiotic administration in the days after surgery does not decrease the likelihood of abscesses (Lozier and Niehaus

2016). The surgical wound must be cleaned daily with povidone-iodine and the sutures are removed on the 10th day (Dharmaceelan et al. 2017).

The most common complications of rumen surgery include abscesses at the incision site and peritonitis. Another potential complication is the formation of abscesses between the muscle and the skin, which is attributed to dehiscence of the sutures placed between the muscle and the rumen to provide additional anchoring after suturing the rumen to the skin. If these sutures are placed between the body wall and the rumen, they should ideally be removed once the rumen is attached to the skin (Lozier and Niehaus 2016). Serum levels of amyloid A could be used in advance as a biomarker for potential complications that may arise after this surgery in goats (Saidu et al. 2016). In cattle, the probability of post-operative complications from rumenotomies has been estimated as between 5–15%, depending on the general condition of the animal prior to surgery and concurrent diseases. Incisional infections, peritonitis, seromas and regurgitations are the most common complications (Niehaus 2008; Hartnack et al. 2015).

A very important point when evaluating post-operative pain and optimal pathophysiological responses is the type of suture used (Desborough 2000; Oguntayo and Adetunji 2009; Olaifa et al. 2009), since it will directly influence post-operative tissue reactions and related inflammatory processes (Saidu et al. 2016). It seems that the use of PGA-type (polyglycolic acid) sutures produces a lesser inflammatory reaction as compared to the use of catgut (Saidu et al. 2016).

To reduce pain during rumenotomy, both intraoperative and post-operative (Udegbumam et al. 2019) observations found that goats anesthetized with diazepam-ketamine, to which a subanesthetic dose of ketamine was applied during and before surgery, suffered less postoperative pain. However, they continued to manifest intraoperative pain (Udegbumam et al. 2019). Other authors defend that the diazepam-bupivacaine combination is ideal to reduce the stress caused by this technique in goats (Saidu et al. 2016).

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