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Rumenotomy

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The rumen in the adult cow comprises approximately 80% of the abdominal cavity [1] with a capacity around 80 L (roughly 16% of body weight) [2]. Some sources report capacities varying from 102 to 148 L for mature cattle [3]. The rumen lies primarily on the left side of the abdomen and its length extends from the seventh or eighth rib to the pelvis [1]. The ventral sac of the rumen extends to the right side of the abdomen. The rumen is typically described as a ''fermentation vat.'' Through the process of fermentation, microbes within the rumen convert complex carbohydrates that are useless to the host animal into volatile fatty acids, microbial protein, and B vitamins, which are useful products. By-products of fermentation include methane, carbon dioxide, ammonia, and nitrate, which need to be cleared [2]. The neonate has a very small rumen and relatively large abomasum. The relative size of the rumen increases with the age of the animal. Ingestion of forage and fermentation products is stimulus for rumen enlargement. The ratio of rumen volume to abomasal volume is 0.5:1 at 4 weeks of age and eventually reaches 10:1 in adult cattle [1].

Indications for rumenotomy

The apposition of the rumen against the left body wall makes it an easy portal though which to access other proximal gastrointestinal (GI) structures including the reticulum, the reticulo-omasal orifice, and the rumen itself. Indications for rumenotomy include traumatic reticulitis, reticuloperitonitis, or reticulopericarditis (hardware disease). It can also be used to remove rumenal or reticular foreign bodies not associated with inflammatory conditions (most commonly for removal of instruments that have been inadvertently swallowed during administration of enteral medications such as balling guns, Frick speculums, or broken or chewed off esophageal tubes).

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Using the rumen as access, the reticulum can be explored and foreign bodies penetrating the wall of the reticulum or causing reticular irritation can be removed. Perireticular abscesses that develop secondary to penetrating reticular foreign bodies can be surgically drained into the reticulum via a rumenotomy. In the author's practice, the indication for performing approximately half of the rumenotomy surgeries is for retrieval of a foreign body in cases of hardware disease. Other indications for performing a rumenotomy include removal of rumen contents in cases of acute toxin ingestion, grain overload, or frothy bloat.

Rumenotomy has also been used to decrease rumen fill to aid in other abdominal surgeries such as cesarean section. Rumen impaction leading to decreased rumen outflow can also be relieved by decreasing rumen fill and rumen lavage through rumenotomy. Impaction caused by ingestion of hair can be seen in calves and camelids (Fig. 1).

Surgical techniques

Multiple techniques have been described for performing laprorumenotomy in cattle. All techniques involve making an approach in the left paralumbar fossa to gain access to the rumen, exteriorization of the rumen, securing the rumen to the body wall or skin, and limiting contamination is a picture of a completed rumenotomy incision [4–6]. The techniques differ by the method in which the rumen is secured to the body wall or skin. A standard laparotomy incision is made in the left paralumbar fossa through the skin and external, internal, and transverse abdominal muscles followed by the peritoneum. It has been suggested to always perform an

Fig. 1. Trichobezoar removed from the first stomach compartment (C1) of an alpaca cria.

abdominal exploratory before performing the rumenotomy [4,7]. Although a thorough abdominal exploratory is limited from the left flank because of the overwhelming size of the rumen, the cranioventral abdomen can be palpated for the presence of reticular adhesions, a common sequela to reticuloperitonitis. Peritonitis can also be diagnosed from the left paralumbar fossa approach. Both of these findings are indications for continuing with the rumenotomy to search for penetrating foreign bodies [7]. It is recommended to palpate the area of suspected peritonitis last to avoid spreading contamination throughout the abdomen. The dorsal sac of the rumen is then exteriorized and secured before creation of the rumenotomy incision.

One technique described securing the rumen to the peritoneum [5]. The disadvantage with this technique is that the peritoneum can be weak and allow for retraction of the rumen into the abdomen. Contamination of the muscle layers will also result since the body wall muscle layers are exposed.

The stay suture technique uses four stay sutures to anchor the rumen to the skin at the dorsal, ventral, cranial, and caudal parts of the incision [6]. The stay suture technique has areas where rumen contents can pass between the rumen and the body wall and allow contamination of the peritoneal cavity. Similarly, the skin clamp technique uses towel clamps to secure the rumen to the skin in an overlapping fashion in several discrete locations around the incision.

Several devices have been developed to anchor the rumen following exteriorization and expedite the rumenotomy procedure. In 1954, a report on a rumenotomy ring was published. This consisted of an aluminum ring with a rubber ring attached to its inner circumference [8]. It was designed so that the rumen could be hooked to this rubber ring. The idea was that it would keep the rumen exteriorized and prevent abdominal contamination. The hook placement is faster than suturing the rumen to the skin and thus decreases time of the rumenotomy. Weingarth's ring was based on this previous ring with some modifications for securing the hooks and lacked the inner rubber ring. The Gabel rumen retractor (rumen board) is another similar instrument used to keep the rumen exteriorized (Fig. 2). This device has a hole in the center that the rumen is pulled through. A series of bolts around the circumference of the hole allows hooks to attach the rumen to the board. The board helps to decrease abdominal contamination and expedites the procedure but limits the accessibility of the rumen.

The technique used most commonly in the author's practice is skin suture fixation. With this technique, the rumen is sutured to the skin using a continuous inverting suture pattern such as a Connell or a Cushing [6]. If done properly, this suture everts the rumen and inverts the skin edge to form a continuous seal (Fig. 3).

Dehghani and Ghadrdani [6] compared skin suture fixation, stay suture fixation, Weingarth's ring, and the skin clamp technique in 20 cattle. They found that stay suture fixation was inferior to the other techniques with

Fig. 2. Gabel rumen retractor with hooks for securing the rumen to the board.

increased incidence of infection. The rumen shroud is a device that has been developed to help limit abdominal contamination with rumen contents. It is a rubber device that has a large flat surface similar to a rumen board on one side and an inner flange that secures it to the inside of the temporary rumen fistula [9].

An underlying principle with all of these techniques is to achieve a good seal between the rumen and the skin so that abdominal contamination is minimized. Blood and fibrin accumulation around the incision can be advantageous, as it can help to seal the incision and limit leakage of liquid contents from the rumen into the abdomen. It, however, can also trap debris and contamination from the rumen. Before release of the rumen back into

Fig. 3. Rumenotomy procedure. The rumen has been sutured to the skin in an inverting pattern achieving a seal. (*Courtesy of* Bruce L. Hull, DVM, MS, Columbus, OH.)

the abdomen, an effort should be made to remove excess blood and fibrin that has clotted around the incision.

Before opening the rumen, some surgical instruments should be set aside and kept sterile while the rumen is opened. These instruments will be used to close the body wall and skin following lavage and rumen closure. The minimum set of instruments to be set aside includes new drapes, surgery gowns, gloves, needle holders, suture, needles (if not using suture with swedged on needles), scissors, and towel clamps.

After completion of the rumen exploratory, the rumen is closed. A double-layer inverting pattern is typically recommended to achieve a good seal on the rumenotomy incision. The author typically uses a double-layer Cushing pattern. After the first layer of rumen closure (while the rumen is still attached to the skin), the rumen surface is lavaged multiple times to remove any rumen contents that may be adhered. Usually serosal irritation to the surface of the rumen will cause roughening and fibrin exudation, which will allow debris to stick. Any blood and fibrin clots should be removed. Following a good cleaning of the rumen surface, the stay sutures that are attaching the rumen to the skin are removed and the second layer of closure is performed before allowing the rumen to retract into the abdomen. The second layer of rumen closure should incorporate the suture holes made by the prior stay sutures. The animals should then be redraped, the surgeon regowned, and the instruments should be changed to a sterile set. From this point forward, the procedure should be considered a clean surgery.

Perioperative management

At best, rumen surgery is considered a clean-contaminated surgery, since a hollow, contaminated viscus is penetrated. Antibiotics are recommended in any surgery that is considered less than clean [10]. Haven and colleagues [10] showed that prophylactic use of penicillin significantly decreased the incidence of abscess formation following rumenotomy. They also demonstrated that an initial antibiotic dose at the time of surgery was all that was necessary and continuing the therapy for several postoperative days had no significant decrease on the incidence of abscess and infection rate.

Medical management should include treatment of concurrent diseases. Animals should be treated for peritonitis or pericarditis in severe cases of hardware disease. Animals diagnosed with grain overload should be treated medically for the severe rumenitis that results from acute rumen acidosis. Mycotic rumenitis and liver abscesses are possible sequela to grain overload and should be prophylactically treated if grain overload is diagnosed.

Complications

Overall in the authors practice, the apparent complication rate associated with rumen surgery is low ($<5\%$). The prognosis and outcome largely

depends on the presenting complaint and preoperative condition of the animal and not operative factors.

Peritonitis is a major complication associated with rumen surgery. Any spillage of rumen contents in the abdomen will result in some degree of peritonitis. The degree of peritonitis is dependent on the amount of contamination, blood and tissue levels of antibiotics, and the health status of the animal. Frequently in cases of hardware disease, peritonitis is already present before the surgical procedure so determination of whether peritonitis is a result of the surgery or the primary problem can be difficult to assess. Animals with peritonitis will show signs of a painful abdomen, and a mild fever may be observed. In lactating dairy cattle, affected animals will show an immediate and drastic drop in milk production.

In addition to contamination and infection of the abdomen, the body wall tissues may also be contaminated. Animals undergoing rumen surgeries will frequently develop incisional infections, seromas, and abscesses. These incisions are prone to dehiscence. If an incisional seroma or abscess develops, we recommend partly opening the incision at the ventral-most aspect to facilitate drainage. Warm water hydrotherapy can also be a useful adjunct to facilitate drainage and resolution of an infected incision.

First stomach compartment surgery in camelids

Camelids (llamas and alpacas) are pseudoruminants. They have two forestomach compartments that precede the true stomach, as opposed to three forestomach compartments in true ruminants. Their compartments are labeled C1, C2, and C3, which stand for the first, second, and third compartments. The third stomach compartment (C3) is the ''true stomach'' of the camelid, while the C1 compartment is analogous to the rumen in these species.

The same principles can be applied to ''rumen'' surgery in camelid species as in true ruminants. An anatomic difference between the rumen and the C1 compartment is the C1 compartment has sacculations. This can make creation of a seal between the stomach and the skin more challenging; however, the thinner nature of the wall usually allows a seal to be created. The thinner walled C1 is also more prone to tear from the skin so care must be taken to not place too much force on C1 after it has been sutured to the skin. Another difference that could pose complications for the novice surgeon is the lack of stratification of rumen contents in camelids. Where ruminants have a rumen mat and gas dorsal to the rumen mat, camelids have a more homogeneous makeup to their C1 compartment. In a ruminant, if the rumen is approached from the dorsal third, only gas will be encountered, decreasing the risk of spilling rumen contents. However, in camelids, C1 contents are more ''frothy'' in consistency even in the dorsal parts of the C1 compartment, and spillage of contaminated C1 contents is more likely.

It is the author's impression that camelids are more sensitive to abdominal contamination and subsequent peritonitis than are true ruminants. In

cattle, the hallmark clinical signs of peritonitis are a mild fever and a sharp drop in milk production; a clinical sign of peritonitis in camelids is frequently acute death.

Summary

If performed correctly, the rumenotomy procedure can be a safe and effective way to retrieve ingested foreign bodies and address other problems of the ruminant forestomachs. In the author's practice, rumen surgery has been associated with few postoperative complications. Morbidity and mortality in cases that have had a previous rumenotomy have mostly been associated with complications related to the original presurgical condition or from causes unrelated to the rumen surgery.

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