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Chapter 10

10.1 Diagnostic procedures

10.1.1 Paracentesis

paracentesis

Paracentesis is the puncturing of the abdominal cavity. A paracentesis is usually conducted for diagnostic purposes. The puncture is mainly made in order to determine the nature, and to a lesser degree also, the amount of fluid that is free in the abdominal cavity. Normal abdominal fluid is clear and light yellow in colour; erythrocytes are not present; the total amount of leucocytes is approximately comparable to that in the blood; and the total protein content is lower than 3 g/l. In a normal abdominal cavity, there is little abdominal fluid; in other words, when aspirating, only a few drops will be obtained.

Many types of disorders of the abdomen can lead to an increase in the amount of abdominal fluid and to the changing of its nature and contents. Fluid obtained can be cytologically, biochemically and bacteriologically examined. The results are then compared with results of blood work. In the cytological examination, it is important to determine the number and nature of the cells. Additionally, free or phagocytosed bacteria can indicate the presence of septic peritonitis. If the haematocrit of the abdominal fluid is the same as that of the blood, this is an indication of intra-abdominal bleeding. In biochemical research, the measure of the total protein content procures information of the nature of the fluid: transudate (< 3 g/l), exudate (> 3 g/l). Furthermore, the determination of urea, creatinine and potassium in the abdominal fluid is important to the diagnosis of uroabdomen (urine in the abdominal cavity). If a chyloabdomen (chyle in the abdominal cavity) is suspected, the measurement of trigylcerides and cholesterol will confirm the diagnosis. Bacteriological research and establishing antibiotic sensitivity are necessary in the suspicion of a septic peritonitis and for the choice of antibiotic therapy. In horses with colic, an abdominal puncture is often performed for both diagnostics and for determining a prognosis. The various types of fluid that can be observed are explained in Table 1.

transudate, exudate

uroabdomen, chyloabdomen

Sometimes, a paracentesis is conducted in the course of the treatment, for example, in uraemic patients with uroabdomen, in order to remove the urine from the abdomen and to correct the elevated concentrations of urea, creatinine and potassium in the blood by infusion. In severely dehydrated animals (calves, for example) the paracentesis can be done for intra-abdominal fluid administration (fluid infusion).

Figure 1. A paracentesis (in this case cystocentesis) is performed in a dog collecting the urine in a sterile fashion.

10.1.1.1 Paracentesis technique

It is preferable to perform the puncture on a standing animal in large animals. In small animals, this is usually done, however, with the animal lying on its side. Sedation is not usually necessary. Punctures based on diagnostic considerations are done at the lowest point of the abdominal cavity, thus, in the median line or directly next to it (paramedian) (Figure 1). In order to prevent pricking of the internal organs, the puncture is not performed with a sharp needle, but rather with a metal teat cannula in large animals. The cannula has a rounded-off end with two openings on the side.

Table1: Types of abdominal fluid

Fluid type	Findings	Cause
haemorrhagic	ht comparable to blood	intra-abdominal bleeding or haemorrhagic infarct, for instance in a strangulation of a bowel
transudate	total protein < 2.5 g/l < 1500 cells/ml	right-sided heart failure hypoalbuminaenia liver problems causing high pressure in the portal vein
exsudate	total protein > 3 g/l 5000 cells/ml normal leucocytes degenerative leucocytes and bacteria	normal after surgery sterile foreign body septic inflammation (bowel rupture, pancreatitis, penetrating wound)
urine	creatinin, urea, potassium level higher than in serum	ureter, bladder or urethra rupture (depending on species)
chylus	cholesterol and triglycerids levels higher than in serum	neoplasia, lymphangiectasia, trauma

The cannula is inserted into the abdominal cavity, after having sharply perforated the skin and the linea alba (median) or outer layer of the rectus sheath (paramedian) with a number 11 scalpel blade. In companion animals, the puncture is usually performed with an sharp injection needle. Working aseptically is important to prevent contamination to the abdomen. The location of the puncture must first be shaved, aseptically prepared, and then anaesthetised with local infiltration anaesthesia, if necessary. In the bovine, usually the right paramedian is punctured in order to avoid puncturing the rumen.

In the dog, a paramedian puncture on the right side is also indicated in order to prevent damage to the spleen. If only a small amount of fluid is found to be present in the abdomen, the puncture can be determined as being negative. In this case, the abdominal cavity can be irrigated with a physiological saline solution. After injection of approximately 20 ml/kg into the abdomen, the patient is carefully turned in order to disperse the fluid. After this, removal of fluid from the abdomen is again attempted. This is referred to as peritoneal lavage.

peritoneal lavage

10.1.2 Enterocentesis

enterocentesis

Enterocentesis is the puncturing of organs associated with the digestive tract. The puncture is usually performed for therapeutic reasons, usually to remove gas out of an overfilled abdominal organ. A provision to performing an enterocentesis is that the intestinal portion concerned must lie directly against the abdominal wall. The procedure is performed (among other methods) in bovine ruminal bloating (tympany; ruminocentesis), in cecal meteorismus in the horse, and in canine gastric dilatation volvulus in the dog. In serious situations, enterocentesis can be life-saving.

tympany, ruminocentesis

10.1.2.1 Technique of enterocentesis

ruminocentesis

The puncture is performed with a sharp metal needle or with a trocar. The puncture location must first be shaved, disinfected, and if necessary, anaesthetised. In the bovine or equine, the enterocentesis is often performed on a standing animal. The ruminocentesis is done in the upper left flank.

The needle or trocar is brought through the abdominal wall until it reaches the rumen, piercing in the direction of the contralateral elbow. The caecum of the horse is punctured via the upper right flank; in this case, also pierced in the direction of the contralateral elbow. Relief therapy could be administered by performing an enterocentesis of a hydroalantois or a hydramnion (amniocentesis), although this is uncommon practice. In this method, approximately 25 litres of amniotic fluid is allowed to drain out of the uterus through a trocar inserted into the right flank, through which heavy pressure in the abdominal cavity is relieved, while waiting for the result of a birth induction. In the dog, a puncture of the stomach is done with the animal lying down. A location to either the left or right behind the ribcage is prepared aseptically. The spleen is palpated or located by percussion and avoided. One or more injection needles are inserted through the abdominal wall into the stomach.

amniocentesis

10.2 Opening of the abdomen cavity

10.2.1 Introduction

coeliotomy
laparotomy

The terms 'coeliotomy' and 'laparotomy' are both used to refer to the surgical opening of the abdominal cavity. Coeliotomy means in general, the opening of the abdominal cavity. Laparotomy is actually the opening of the abdomen by means of a flank incision. The term laparotomy is, nevertheless, often used to indicate all methods of opening the abdomen. Most laparotomies are considered as therapeutic procedures, i.e. operative treatment of disorders of abdominal organs. Sometimes, however, a laparotomy is done for diagnostical purposes, i.e. an exploratory laparotomy. Before performing a laparotomy, a number of factors must be considered. These include:

- **the position of the animal: standing or lying;**
- **location of incision;**
- **the nature of the incision.**

The three above-mentioned considerations are not completely independent of one another. As an example, the position of the animal often determines the anatomical location where the laparotomy will take place.

10.2.2 Position of the animal

The determination of whether to operate a standing or lying animal comes into play only in the case of adult horses and cows. Smaller animals (dog, cat, foals) are almost always operated while in dorsal recumbency, and under general anaesthesia. Small ruminants (calf, sheep and goat) are often operated in a lying position under local anaesthesia. The laparotomy on a standing animal has advantages, but also disadvantages, just like the laparotomy on a recumbent animal. The consequence of the above-mentioned advantages and disadvantages is that usually is performed on a recumbent animal, and in adult cows mostly on the standing animal.

Position	Advantages	Disadvantages
standing, awake	physiologic; normal placement of organs; no general anaesthesia necessary; normal respiration	limited approach and visibility of the abdomen; analgesia sometimes insufficient, safety aspects for animal and surgeon
laying down under anaesthesia	excellent analgesia (most of the times) and anaesthesia, safer, better aseptic techniques possible, good visibility	more costly, logistics are necessary, non-physiologic position patient; respiratory depression (esp. in herbivores)

10.2.3 Location of incision

In determining the location where the abdominal cavity should be opened, the position of the animal certainly plays a role, as well as the indication for performing a laparotomy. In other words, the location of the abnormality in the abdomen and the expected procedure to be performed will influence the choice of abdominal approach. The abdomen can be opened in various locations depending on the animal. The possibilities are outlined as follows:

Cattle	left or right flank incision (standing) paracostal (lying down) (para)median (laying down)
Horse	flank (standing & laying down) paramedian, parapreputial (laying down) paracostal (laying down) median (laying down) via inguinal canal in cryptorchids (laying down) via vagina during sterilisation (standing & laying down)
Small ruminants	flank paramedian
Pig	flank (para)median
Dog	median flank combination median and paracostal
Cat	median flank

10.2.4 Type of incision

The type of incision pertains to the manner in which the abdominal cavity is opened; in other words, the manner in which an incision is made at a particular location of the abdominal wall in relationship to the anatomical structures at the location. The following further clarifies the nature of incisions.

10.2.4.1 Through-and-through incision

through-and-through incision

All layers of the abdominal wall (skin, abdominal muscles and peritoneum) are cut in the same direction when using a through-and-through incision. Because this usually occurs in a dorsoventral direction, the internal and external abdominal oblique muscles are cut at an angle to the direction of their fibres and the transverse muscle in the direction of its fibres:

- advantage: a large laparotomy wound comes about, through which the abdominal cavity and exposure of the digestive tract parts can be easily manipulated;
- disadvantages: more tissue damage, mainly due to the cut at an angle to the muscle fibres (greater chance of haemorrhage and complications during the wound healing); chance of undesired prolapse of intestines during the operation, for instance in a severely-overfilled abdominal cavity or with resistance and abdominal contracture of the animal.

10.2.4.2 Complete grid incision

complete grid incision

All abdominal muscles are bluntly dissected in the direction of the muscle fibres in the complete grid incision:

- advantages: minimal tissue damage; the wound can be sutured quickly and easily and minimal suture material is necessary; no undesired prolapse of the intestines (the wound closes around the arm of the surgeon and also when the arm is pulled out);
- disadvantages: decreased ease of manipulation and especially exposure of the organs.

10.2.4.3 Partial grid incision

partial grid incision

In the partial grid incision, the advantages remain of both of the above-mentioned methods, while the disadvantages for the most part are cancelled out. The external oblique muscle is incised at an angle to the muscle fibres while the internal oblique and transverse abdominal muscles are cut bluntly in the direction of the muscle fibres. The complete and partial grid incisions are mainly used in large animals in a standing position.

10.2.5 Laparotomy in the bovine

10.2.5.1 Indications

The most important indications for a laparotomy in the cow are:

- the surgical treatment of abnormalities of the digestive tract, for example abomasal displacements;
- surgical procedures to the urogenital system, such as a Caesarean section.

Laparotomies in adult cows are mostly conducted on the standing animal, where the affected organ is opened at one of the flanks. Depending on the indication for the operation, this will either be the left or the right flank. The Caesarean section, the operative treatment of the abomasum dislocated to the left (Utrecht method) and the rumenotomy are the most important indications

Caesarean section
Utrecht method

for a laparotomy of the left flank. The most important indications to a laparotomy in the right flank are the surgical treatment of an abomasal displacement to the right and of intestinal diseases (jejunum-intussusception, torsion of the caecum or the proximal loop of the colon). The through-and-through incision is actually used in the Caesarean section and in rumenotomy, because in these cases, a large laparotomy wound is necessary. In other therapeutic laparotomies, a partial grid incision is used, and especially during right flank laparotomies. A complete grid incision is seldom employed, only in exploratory (or diagnostic) laparotomies, where the expectation is that it will not be necessary to exteriorize abdominal organs.

The laparotomy in the standing animal is performed under local anaesthesia. This anaesthesia can be administered by means of local infiltration anaesthesia or by a paravertebral infiltration anaesthesia of the T13, L1, L2 and sometimes also L3 paracostal nerves. A paravertebral infiltration anaesthesia is preferred above a infiltration anaesthesia, but both techniques may be combined.

paravertebral infiltration anaesthesia

10.2.5.2 Through-and-through incision

through-and through

Ventral to the transverse processes of the lumbar vertebrae, a vertical (dorsoventral) through-and through incision is made through the skin and subcutis. Hereafter, the external abdominal oblique muscle and the internal abdominal oblique muscle are cut in the same direction, thus almost perpendicular and crosswise to the direction of the fibres. Bleeding vessels are clamped with vessel clamps and ligated. After this, a small incision is made in the transverse abdominal muscle. Depending on the location of the laparotomy wound (high or low in the flank), this involves either the muscled or tendinous portion. The tendinous portion is called the transverse fascia.

transverse fascia

Next, through this opening using forceps, the transverse fascia with the peritoneum attached is held somewhat raised and carefully incised into, whereby the abdominal organs lying directly underneath are not damaged. Using two fingers for protection and guidance, the incision is extended in both directions. Each incision in the separate layers of the abdominal cavity is shorter than those in the previous layer; the incision in the skin is therefore the longest; the incision in the transverse abdominal muscle, in this case, the transverse fascia and the peritoneum the shortest.

The laparotomy wound is closed in multiple layers. The peritoneum, the transverse fascia or the transverse abdominal muscle are sutured together with one single continuous suture. The internal oblique abdominal muscle and the external oblique abdominal muscle can either be sutured together or separately. This can be done with interrupted sutures, but is usually done in one (both muscles together) or two (each muscle apart) continuous suture pattern(s). For laparotomies high up in the flank, a separate subcutaneous suture is not necessary, because in that location there is very little subcutis. Lower in the flank, there is more subcutis present, and this is sutured as a separate layer using a continuous suture pattern. The skin muscle that is present here is not included in the subcutis suture. Finally, the skin is closed with an interrupted or continuous Feston (interlocking) suture pattern.

interlocking

10.2.5.3 Partial grid incision

partial grid incision

In a partial grid incision, the skin, the subcutis and the external oblique abdominal muscle are cut in a vertical direction. The internal oblique abdominal muscle is cut in the direction of its fibres. Following that, a small incision is made in either the transverse abdominal muscle or the transverse fascia (or both) and these are further opened together with the peritoneum in the same manner as in the through-and-through incision method. The peritoneum, the transverse fascia or the transverse abdominal muscle are sutured together in one continuous suture pattern. The internal oblique abdominal muscle is closed with a few (two or three) interrupted sutures, after which the external oblique muscle is sutured with a continuous suture pattern. The subcutis (if necessary) and the skin are closed as in the through-and-through incision technique.

10.2.5.4 The complete grid incision

complete grid incision

The complete grid incision, the skin and the subcutis are incised into vertically. Both oblique abdominal muscles are bluntly dissected in the direction of the muscle fibres. The transverse fascia or abdominal muscle and the peritoneum are opened as in both of the previous methods.
The peritoneum, the transverse fascia or abdominal muscle are sutured together in one continuous suture pattern. The internal oblique and the external oblique abdominal muscles are sutured separately with a few interrupted sutures, after which the subcutis (if necessary) and the skin are closed as described above.

10.2.6 Laparotomy in small ruminants

Small ruminants (sheep, goats and calves) are operated in the recumbant position. This applies for small ruminants as well as for the large ones pertaining to indications, location, and the manner in which the abdominal cavity is opened and will be ultimately closed. This means that laparotomies that are conducted as the result of disorders to the digestive tract are often performed through a flank incision. Another often-performed laparotomy technique (especially in bucks and rams) is one performed with the indication urolithiasis, in order to remove stones and/or gravel from the urinary bladder. In such an operation, the abdominal cavity is opened in it's caudal portion either paramedian directly next to the preputium and the penis, or in the median line under the preputium and the penis. In both instances, a through-and-through incision is made. For detailed explanation of the procedures, refer to the comparable laparotomy method for horses.

10.2.7 Laparotomy in the horse

10.2.7.1 Indications

The most important indications for a laparotomy in the horse are:
- surgical treatment of abnormalities of the digestive tract, for example displacements, strangulations, obstructions, and so forth;
- surgical procedures to the urogenital apparatus, such as:
  - in the mare: Caesarean section, ovariectomy, repositioning of a uterine torsion;
  - stallion or gelding: removal of abdominal testicles, removal of bladder stones, closing of a rupture to the bladder ent is placed in.

10.2.7.2 The median coeliotomy

The median laparotomy is almost always chosen as the surgical treatment for disorders to the digestive tract. In this procedure, with the animal lying on its back, the abdominal cavity is opened in the ventral median line, beginning directly forward of the umbilicus and from there further forward over the desired distance. A through-and-through incision is made. One-by-one in the same direction (caudocranial), the skin, the subcutis, the linea alba and the peritoneum are incised. The linea alba is a very sturdy band of connective tissue that lies in the ventral midline of the abdominal wall. The linea is formed by the aponeuroses of the flank muscles, and therefore of the so-called outside and inside layers of the rectus sheath. The dissection of the linea alba must occur carefully in order not to open the rectus sheath. The preferred manner of opening the peritoneum is by dissection of the remainder of the hepatic teres ligament which manifests itself as a connective tissue (of a few millimetres wide) in the peritoneum in the median line.
The closing of the wound occurs in four layers. The peritoneum is closed with a continuous suture pattern in the hepatic teres ligament. The linea alba can be closed with interrupted sutures, but is usually closed with a continuous suture, as is the subcutis. The skin is closed with interrupted sutures or with a continuous subdermal or intracutaneous suture. The median coeliotomy results in

a wound that is large enough to be able to manipulate and expose the intestinal organs and to carry out the necessary procedures (enterotomy, bowel resection and anastomosis). The wound is clearly arranged, there is little bleeding and the linea alba is easily closed. The latter is important, because the linea alba is the strongest layer of the ventral abdominal wall. A good closing of the linea alba is essential in order to obtain a proper healing of the abdominal cavity. A poor closing technique can result in postoperative ventral hernia.

10.2.7.3 The paramedian laparotomy

paramedian laparotomy

In the paramedian laparotomy, the abdominal cavity is not opened via the linea alba but instead via the left or right rectus sheath, located directly next to the linea alba. The sheath of the rectus abdominis muscle consists of an external and internal leaf. The external sheath lies on the outside and is formed by the aponeuroses of the external and internal abdominal oblique muscles, while the internal sheath is formed by the aponeurosis of the transverse abdominal muscle. The fibres of the rectus muscle run longitudinally. The paramedian laparotomy can be performed as a through-and-through incision or as a grid incision.
In cases where much room is needed in order to manoeuvre, a through-and-through incision is applied. This could be in the case of a re-laparotomy in the horse (which was recently operated via the linea alba) and where, in order not to disturb wound healing, a second opening of the abdomen is not recommended. In such a case, the abdomen is opened in the paramedian area next to the first laparotomy wound. In a craniocaudal or caudocranial direction, one-by-one the layers are cut: skin, the subcutis, the outside layer of the rectus sheath, the abdominal rectus muscle (bluntly in the direction of the muscle fibres), the inside layer of the muscle sheath and the peritoneum. The laparotomy wound is closed as follows: The peritoneum is sutured together with the inside layer of the rectus sheath with a continuous suture pattern. The abdominal rectus muscle is closed with a number of interrupted sutures. The outside layer of the rectus sheath can be closed with an interrupted suture pattern, but is usually closed with a continuous suture pattern. The subcutis and the skin are sutured as in the median laparotomy. Whenever less working space is necessary to manoeuvre inside the cavity, a grid incision is used, which is usually shorter than the above-described through-and-through suture. An example of this is the parapreputial laparotomy, which is performed next to and parallel to the preputium in the removal of a testicle in the abdominal cavity.

parapreputial laparotomy

In a craniocaudal or a caudocranial direction, an incision is made into the skin, the subcutis and the outer layer of the rectus sheath. The abdominal rectus muscle is bluntly dissected in the same direction. Following this, the inner layer of the rectus sheath is bluntly dissected in the direction of the muscle fibres, in other words, perpendicular to the median line; the peritoneum is opened in this direction as well. In closing the wound, the peritoneum and the inside layer of the rectus sheath are sutured together with a few interrupted sutures. The abdominal rectus muscle, the outside layer of the muscle sheath, the subcutis and the skin are closed as described in the above paramedian through-and-through incision.
It is more difficult to get a good visual overview of the paramedian laparotomy wound because there are more layers in the abdominal wall, and more bleedings occur in this type of laparotomy, especially in the abdominal rectus muscle. The closing of the peritoneum and the inside layer of the rectus sheath is often complicated. The most care must be given to the closing of the exterior layer of the rectus sheath, because this is the strongest layer of the abdominal wall. A proper closing of this type of laparotomy is essential for the proper healing of the laparotomy wound.

10.2.8 Coeliotomy in the dog and the cat

10.2.8.1 Indications

Indications for a laparotomy in the dog and the cat are numerous. The most common indication in the companion animal practice is the ovariectomy or the ovariohysterectomy. The median coeliotomy is the most used method of access to the abdominal cavity and is used for almost all indications. For special anatomic locations (such as access to the adrenal) a paracostal or flank laparotomy is also possible.

10.2.8.2 The median celiotomy

median coeliotomy
parapreputial incision

The patient is placed in dorsal recumbency. To start the median coeliotomy, the skin is incised in the mid line. In male dogs, the incision is branched off laterally along the penis (parapreputial incision). The subcutaneous fat is dissected from the median attachment to the rectus sheath until the linea alba is freely exposed. In male dogs, the branches of the superficial caudal epigastric artery which lead to the preputium are ligated and transected. Additionally, the preputial muscle is transected. The penis is pulled to the side and the linea alba is further exposed. The abdominal cavity is opened on the linea alba. In opening, the anatomical difference between the cranial and the caudal portions must be kept in mind. In the cranial portion of the linea alba, the abdominal rectus muscle is surrounded by the rectus sheath. This consists of sturdy connective tissue and is formed through the aponeurosis of the abdominal rectus muscle (outside) and the transverse fascia (inside). In the caudal portion of the linea alba, the abdominal rectus muscle is only covered on the outside by connective tissue fascia. If the abdominal cavity is opened precisely on the linea alba, the difference is clearly visible. Caudally, the abdominal rectus muscle is seen as a dark-coloured muscle; cranially, it is surrounded by white, non-translucent connective tissue. The point of transition lies a few centimetres caudal to the navel.

The linea alba is opened with a short scalpel incision. From this incision, the linea alba is further cut open using scissors. In the cranial portion of the incision, access to the abdominal cavity is now

falciform ligament

obstructed by the falciform ligament. This is a fat-filled pleat of the peritoneum, which extends from one side of the incision to the other and appears to hang like a curtain in the abdomen. The ligament is removed by cutting it loose from the rectus sheath at the location of the attachment. It contains a few larger blood vessels, which must be ligated or cauterised before the ligament can be removed. In this, attention must be paid to the cranial stump, which can pull back under the rib cage.

The abdominal wall is closed in layers. The incision in the linea alba is closed with a simple continuous suture of monofilament absorbable material. The suture is always begun caudally, because the last stitch must be done blindly, and the chance of damaging abdominal organs is smaller cranially than in the caudal portion of the abdomen. The thickness of the suture material depends on the weight of the patient and varies from 3-0 (cat, small dog) to 0 (large dog).

The sturdiness of the suture pattern depends especially on the distance between the edge of the wound and the location where the needle punctures the tissue. Through examination of (human) cadavers, it was determined that median incisions, where the sutures were placed laterally from the transition of the rectus sheath to the linea alba were twice as strong as incisions where the sutures in the linea alba were made, and three times as strong as paramedian incisions. This indicates that it is of great importance that the needle be inserted at sufficient distance (2 to 3 mm) from the edge of the wound. The abdominal rectus muscle is spared as much as possible through the placement of the sutures. The peritoneum is not closed separately in companion animals. In the cranial portion of the wound, this is not necessary, because the peritoneum here forms an integral component of the rectus sheath. In the caudal portion, the peritoneum pulls back after the opening of the abdominal cavity. It is not necessary, however, (and furthermore, not desired) to close the peritoneum and the rectus sheath apart. This practice was common before, because it was feared that a coarse peritoneal wound surface would lead to adhesions. Research shows, however, that defects in the peritoneum heal within one week, because the mesothelial cells in the peritoneal fluid

transform themselves into a new layer of mesothelium. The subcutaneous fat is closed with one or (in rare occasions) two simple continuous suture patterns (absorbable synthetic material, thickness 2-0 or 3-0). In male dogs, the preputial muscle must be sutured separately in order to prevent the penis from deviating to one side. With the first suture pattern, the fatty tissue is attached to the rectus sheath, in order to prevent formation of a cavity. If, after placing this suture, the wound edges still deviate far from each other, these edges can be brought closer together with a second, more superficially placed subcutaneous suture pattern. The skin can be closed with a continuous subdermal suture (absorbable, synthetic material, thickness 3-0 or 4-0), interrupted sutures (nonabsorbable monofilament synthetic material, thickness 3-0 or 4-0), or by using skin staples. The first method produces a more cosmetically attractive result; whereas, the latter is the fastest.

abdominal exploratory

During an abdominal exploratory it is of great importance to examine all the internal organs. To do so, the following steps (in order) are usually followed:

1. examination of the cranial portion of the abdomen:
    a. diaphragm (with oesophageal hiatus) and complete liver (palpate all lobes);
    b. gall bladder and bile ducts (the gall bladder can be compressed together to determine whether the bile duct is open);
    c. stomach, pylorus, proximal duodenum and spleen;
    d. pancreas (palapate carefully!), the right lobe of the pancreas is ventral to the duodenum, the left lobe in the Bursa omentalis, caudal to the stomach;
    e. portal and caval vein;
2. examination of the caudal portion of the abdomen:
    a. descending colon, bladder, urethra, prostate or uterus;
    b. inguinal canal;
3. exploration of the intestine:
    a. the entire intestine is palpated;
    b. check blood supply and lymph nodes;
4. exploration of the dorsal, partial retroperitoneal area:
    a. the mesoduodenum is used to retract all abdominal organs to the left: inspection of the right kidney, adrenal gland, ureter and ovary;
    b. the mesocolon is used to retract all abdominal organs to the right: inspection of the left kidney, adrenal gland, ureter and ovary.

10.2.8.3 The flank or paracostal incision

The flank incision is indicated in operations where the retroperitoneal area must be reached (for example, during adrenal gland surgery). During the incision, three layers are incised: the external abdominal oblique muscle, the internal abdominal oblique muscle and the transverse abdominal muscle. The muscles can be cut in the extension of the direction of the muscle fibre (grid incision) or from dorsal to ventral (through-and-through incision). The superficial and deep circumflex artery and vein should be tied off, if necessary. After the operation, all muscle layers are closed separately. In smaller dogs and cats, the individual layers of the muscle wall can also be closed at the same time. A continuous or interrupted suture pattern with a monofilament absorbable suture material can be used for this purpose.

grid incision
through-and-through incision

10.3 Minimally invasive techniques

gastroscopy
coloscopy, cystoscopy

Minimally invasive techniques are those that make possible the examination of and operation to abdominal organs without opening the cavity. By means of endoscopy, certain organs are examined, and if necessary, can be biopsied: these are, for example, the stomach (gastroscopy), the colon (coloscopy) and the bladder (cystoscopy). The endoscope, containing the optics and the canal for the instruments, is inserted via a natural opening (mouth, nose, anus). With a laparoscope, the scope and the work instruments are not brought internally via a natural body opening, but rather via one or more puncture incisions in the abdominal wall. In this manner, all abdominal organs can be examined, just as with the exploratory celiotomy.

laparoscopy

Additionally, certain operations can also be conducted using laparoscopy. The advantage of minimally invasive techniques is, of course, decreased pain for the patient, faster wound healing and, therefore, also a shorter stay at the clinic. These techniques are usually used on the horse and the dog. In the dog, the ovariectomy is the most frequent indication. In the horse, the most important indications for laparoscopy are removal of testicles in the abdomen or tumourous ovaries, and inspection of the intestines in chronic forms of colic.

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10.4 Abdominal procedures

In the framework of this book, only the opening and closing of the "hollow" organs in the abdomen will be discussed.

10.4.1 The rumen (bovine, small ruminants)

10.4.1.1 Introduction

rumenotomy
reticuloperitonitis

In the past, the rumenotomy (opening of the rumen) was frequently performed, especially in cows suffering from traumatic reticuloperitonitis (a perforating foreign body by a nail, metal wire, etc.) of the reticulum. The foreign body was removed by rumenotomy in order to prevent further increase of peritonitis. Because of modern industrial management and housing of animals, nowadays this disorder is uncommon. Whenever raumatic reticuloperitonitis is, however, diagnosed, the following non-operative procedure is presently employed: in addition to diet, the insertion of a magnet and a systemic administration of antibiotics. The desired result here is that the foreign body is "captured" in the cage magnet, so that it cannot cause any further damage. Afterwards, by administering antibiotics, the reticuloperitonitis cannot worsen, and is quelled. On the basis of the above passage, rumenotomy with the indication of traumatic reticuloperitonitis is, at most, seldom done.

Further rare indications include:
- **the removal of abnormal rumen content, as the result of fermentation disorders of the rumen;**
- **the removal of tumours (fibropapillomas) in the cardia, which lead to recurring tympanism;**
- **the removal of foreign objects, such as plastic;**
- **the removal of poisonous plants, such as rhododendron and yew.**

The latter two indications are seen especially in small ruminants, such as in goats that are kept as pets or are held in petting zoos.

10.4.1.2 Rumenotomy

laparorumenotomy

The following is a description of the laparorumenotomy. The operation is performed on a standing cow or lying small ruminant. The abdominal cavity is opened on the left upper flank, half way between the last rib and the tuber coxae, using a through-and-through incision. In order not to contaminate the cavity and the laparotomy wound with the contents of the rumen, various methods can be employed to open the rumen. The most common method for a rumenotomy of the standing cow is the method attributed to Weingard, where the Weingard instruments are used, which consist of a metal frame, two fixation tongs and six sharp rumen hooks. The metal frame is fixated in the dorsal wound corner of the skin wound using an inserted screw. After which, a vertical fold of the dorsal rumen is pulled through the laparotomy wound and the metal frame. This fold is attached to the frame using two fixation forceps, one ventral and one dorsal. After the pleat of the rumen wall is fixated outside the abdominal cavity and laparotomy wound, they are incised from ventral to dorsal in order to open the rumen.
The edges of the wound of the rumen are folded over the disinfected skin using the six rumen hooks, which are fixed onto the frame. In this manner, an opening of the dorsal rumen is obtained that is large enough to access with the hand and forearm, all the while during these manoeuvres contamination of the cavity and laparotomy wound with rumen contents is prevented. After the removal of the foreign body or the abnormal contents of the rumen, the rumen is again closed. This occurs in two layers: usually the first used is a continuous suture (Schmieden). The second suture above this is a continuous inverting suture: a Lembert suture or a Cushing suture. The laparotomy wound is closed in the usual manner.

10.4.2 The abomasum (bovine)

After the Caesarean section, displacement of the abomasum forms the most important indication for a laparotomy in the cow. A displacement of the abomasum can appear as a dislocation to the left or right.

10.4.3 The stomach (horse, dog and cat)

10.4.3.1 Introduction

gastrotomy
gastrectomy

Gastrotomy is the term for the opening of the stomach, while the removal of a portion of the wall of the stomach is referred to gastrectomy. In the horse, surgical procedures on the stomach are rarely conducted. Because on the one hand, there is very little indication for it; while on the other hand, the stomach, because of anatomical position of the stomach makes it almost unreachable to the surgeon. The most important indication for a gastrotomy in the dog and cat is the removal of a foreign object.
Foreign objects in the stomach can cause vomiting. The vomit consists of mucous

and contains no food. If the pylorus is closed off due to a foreign object, the vomiting can be quite expulsive, but this is the exception to the rule. Usually the symptoms are mild and appear intermittently. The history and the general examination usually produce no specific information. Foreign objects in the stomach can be visible by radiological examination (possibly after administering contrast liquid) or by using ultrasound. Foreign objects in the stomach can, besides using coeliotomy and gastrotomy, also be removed through gastroscopy.

10.4.3.2 Gastrotomy in the dog and the cat

Access to the abdominal cavity is obtained via a cranial medial coeliotomy. The stomach is palpated and pulled in a caudal direction. By using two stay sutures, the stomach is moved out of the abdomen as far as possible and held in place. An alternative is to use two Babcock forceps in order to hold the stomach in place. Around the stomach, damp towels are placed in order to prevent contamination with stomach contents.
The stomach is opened with a curved incision, parallel to and at the same distance from the lesser curvature and the greater curvature. The length of the incision depends on the size of the foreign body- it should be able to pass through easily. The incision is made in 2 steps. First, the serosa and the musculature are cut to the submucosa. In this location of the incision, the largest blood vessels are at the level of the submucosa. The mucosa is opened by making a puncture incision in one of the ends of the wound. From this puncture incision, the mucosa is cut open using straight scissors. The stomach is closed in two layers, using monofilament absorbable suture material (Figure 2). The first suture line is a simple continuous suture pattern through all layers of the stomach wall. The second suture line is an inverting suture pattern where only the serosa and the musculature are incorporated, which lessens the risk of stomach content leakage (Figure 2).

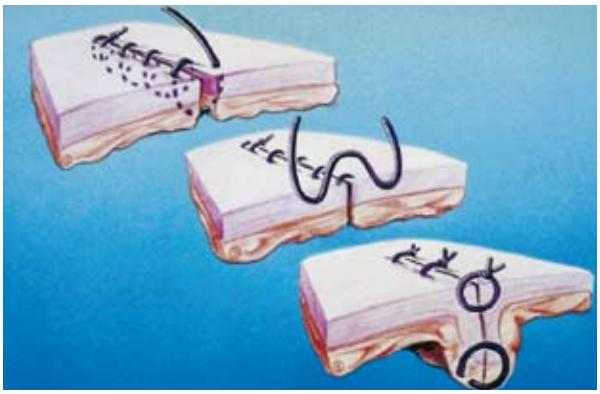

Figure 2. The proper way to suture a stomach

10.4.4 The small and large intestines

10.4.4.1 Introduction

ileus

The most common indication for surgery of the intestines is an obstruction or ileus. The term "ileus" means literally "intestinal coil," but in practice, the meaning of this is blockage of the transport of the intestinal contents in an aboral direction. The morbidity and mortality of the ileus varies with the nature of the obstruction, the localisation and the length of time it has been blocked. Blockages can occur for many reasons, but two of the main reasons are: mechanical ileus and paralytic or

mechanical ileus

functional ileus. The most common form is the mechanical ileus, the two main forms being simple mechanical ileus and strangulated ileus. In a simple mechanical ileus, only the intestinal lumen is closed. The blood supply of the intestinal wall remains

strangulated ileus

paralytic ileus

dynamic
adynamic

postoperative ileus

intact. In the case of a strangulated ileus inflicted by pressure on the intestinal wall, the blood supply is interrupted and can cause degeneration of the intestinal wall. The simple mechanical ileus is further subdivided into three forms: intraluminal, intramural and extramural blockage. In a paralytic ileus, the passage of the intestinal content is impeded by a functional motility disorder, that is, paralysis of the intestinal tract. Of this, two forms are distinguished: dynamic ileus and adynamic ileus. In dynamic ileus, there is a spastic contraction (cramping) of the intestinal wall. The adynamic ileus is characterised by a flaccid paralysis with atonia of the intestinal wall. This form can occur as a complication of abdominal surgery; in this case, it is also referred to as postoperative ileus.
In general, strangulating obstructions have much more severe consequences for the animal than the non-strangulating obstructions. The consequences are serious, not only for the digestive tract, but also for other organ systems, such as the respiratory and circulatory systems. Strangulating obstructions often lead to excessive fluid loss, causing hypovolaemia, or even, hypovolaemic shock, endotoxaemia and endotoxic shock. The symptoms of these would be fast deterioration of the patient, weak pulse, low blood pressure, poor peripheral circulation, haemoconcentration and acidosis.

10.4.4.1.1 Simple mechanical ileus

Intraluminal obstruction is the common form of ileus in the dog and cat. Because the oropharynx in these animals is wider than any other opening of the gastrointestinal tract, foreign objects can be swallowed that become lodged in the relatively narrow intestinal lumen. Large, round objects can close off the intestinal lumen completely. Polyps and linear foreign bodies usually cause only a partial obstruction, but in the case of threadlike objects, other effects can come about. The end of

linear foreign body

the linear foreign body can often become anchored under the tongue. Peristalsis impels the thread in the aboral direction, but because it is cranially anchored, this results in the rolling-up of the intestine around the thread. With this, the tension can increase to the point that the thread cuts through the intestinal wall, resulting in peritonitis.
Intraluminal obstructions can also be caused by obstipation. These are blockages with a too solid/dried intestinal content. Obstipation occurs regularly in the horse, and especially in the ascending colon (left ventral colon and right dorsal colon). Sometimes, an obstipation can occur in the ileum. Real obstructions in the horse, for example intestinal stones, occur randomly in the ascending colon. Intramural obstruction in the dog and cat is usually caused by tumours of the intestinal wall. Most intestinal tumours (malignant lymphoma, adenocarcinoma, leiomyosarcoma and leiomyoma) infiltrate the muscle layer of the intestinal wall. They not only narrow the lumen, but also decrease the elasticity and with that the extensibility of the intestinal wall. Intramural obstruction is almost always partial and develops over time. In horses, intestinal tumours rarely occur. Sometimes an intramural obstruction is seen as the result of an intramural haematoma.
Extramural obstruction is caused by a adhesion of the intestinal wall with surrounding structures. A known example of this in the dog and cat is adhesion of the intestine to a suture granuloma in one or both ovarian stump after an ovariectomy or ovariohysterectomy. In horses, growths in the abdomen are usually the result of an earlier surgical procedure to the intestinal canal. Extramural obstruction can vary in seriousness and develops gradually. Furthermore, in the horse, obstructions can occur through non-strangulating positional changes, especially of the ascending colon.

10.4.4.1.2 Strangulating ileus

This is the most common form of ileus in both the cow and the horse. In this form of ileus, circulation of the closed-off intestinal segment is severely hindered. First the veins are restricted, through which blood circulation ceases. Arterial flow continues temporarily, but eventually also

completely stops. A haemorrhagic infarction occurs, which leads to degeneration and ultimately to necrosis of the intestinal wall. This can either influence only a small portion of the intestine, or it can be more extensive. In the cow, examples of a strangulating ileus of the intestine include caecal torsion and the intussusception of the jejunum. In the horse, strangulations can occur in the small and large intestines. Common strangulations of the small intestine are: wedged hernias, such as mesenteric hernia, hernia through the epiploic foramen (Winslow's foramen) and the inguinal hernia (only in the stallion), the strangulation caused by a pedunculated lipoma and the invagination of the ileum and the caecum. The caecum can also invaginate the colon (intussusception). The most common strangulating obstruction of the large intestine is the colon torsion.

intussusception

Winslow's foramen

10.4.4.1.3 Paralytic ileus

dynamic ileus

cramp colic

adynamic ileus

postoperative ileus

worm aneurysm

In the dynamic ileus, there is no occlusion in the literal meaning of the word, but rather an obstruction of the passage of the intestinal contents through a spastic contraction of the muscle layer of the intestine. This form can be caused by medication (such as morphine). In the horse, intestinal cramps occur regularly and form the most common cause of colic: cramp colic.
In general terms, what applies to the adynamic ileus applies also to the dynamic ileus, but in the former the passage is obstructed by a flaccid paralysis, that is, atonia of the intestinal wall. This form of ileus can occur in peritonitis and after extensive abdominal surgery and is often referred to as postoperative ileus. An example of an adynamic ileus in the horse is the meteorismus of the caecum. Here, the whole caecum is either hypo- or atonic and heavily overfilled with gas. In the horse, a portion of the intestine can become atonic as the result of anaemic infarcts. These can occur in the small or large intestine, and are the result of thrombosis of one or more of intestinal arteries. In the past, this was regularly seen in conjunction with a worm aneurysm (an inflammation process in the wall of the mesenteric cranial artery caused by larvae of the Strongylus vulgaris). In current times, this occurs much less frequently; probably because horses are now regularly treated for intestinal parasites.

10.4.4.2 Diagnostics

The symptoms of ileus are not specific. In large animals, the most important symptom is colic. In companion animals, vomiting, lethargy, anorexia and weight loss can be seen, but these symptoms occur with many disorders and do not automatically indicate an ileus. In serious situations, especially strangulating ileus, the animals can also experience hypovolaemia and/or endotoxic shock (weak, increased pulse, pale mucous membranes, and delayed capillary refill). In companion animals, in addition to abdominal palpation, radiological examination or ultrasound of the abdomen can confirm the diagnosis.
As horses cannot vomit, this symptom will not occur in this species and because of this, the stomach can become severely overfilled, which can be diagnosed by inserting a stomach tube. If the stomach is not emptied quickly using such a tube, a fatal rupture of the stomach can occur.
The diagnosis, in other words, the cause of the ileus, is usually confirmed by means of physical examination and rectal exploration. In a number of situations, the diagnosis is clear. In others, it can only be determined that a strangulating closure of the small or large intestine exists, on which grounds a laparotomy is performed. After opening of the abdominal cavity, an exact diagnosis, that is, the actual cause of the strangulation, can be confirmed.

10.4.4.3 Therapy

Paralytic ileus is treated conservatively. In an adynamic ileus, peristalsis stimulation can be attempted using prokinetics (such as metoclopramide in dogs and cats, cisapride in horses).

In experimental paralytic ileus, the use of metoclopramide (especially in the cranial portion of the GI tract) brought about a recovery of the myoelectric activity, but it is not clear if in actual use in patients that the same results can be achieved. The same is known of use of cisapride in the horse. Cramp colic in the horse is treated with spasmolytics, sometimes combined with analgesics.

meteorismus

A severe caecal distension with gas (meteorismus) is treated by enterocentesis, that is, puncture of the caecum via the right flank. In companion animals, all forms of mechanical ileus can be treated surgically. In the horse, however, non-strangulating obstructions need not always be treated surgically. Colon obstipations are always first treated conservatively using laxatives.
When this does not lead to recovery, surgical treatment is indicated; this occurs more often when sand is present in the colon. Because in horses, most cases of ileus are caused by intestinal cramping, gas pockets or obstipation, only approximately 5% of all colics presented to the general practitioner should be treated surgically. In surgical treatment of ileus, two procedures are distinguished. In the case of a non-strangulating obstruction or a serious obstipation, if the intestinal wall is still vital (usually the case), it may be sufficient to only open the intestine in order to remove the abnormal contents (enterotomy). If a strangulating obstruction results in a segment of intestine that is no longer viable, then it must be removed. This procedure is termed enterectomy or intestinal resection and anastomosis.

enterotomy
enterectomy

10.4.4.3.1 Enterotomy

In dogs and cats, enterotomy is indicated in all cases of intestinal closure due to a foreign object, as long as the intestinal wall is still vital. In the cow, the most common indication is the emptying of the caecum in the case of a caecal torsion or proximal colon loop torsion. In the horse, an enterotomy is performed in those cases of obstipation, where conservative treatment is not successful. An intestinal stone that becomes lodged can only be removed by enterotomy (colotomy). In order to reposition a torsed colon (or colon torsion), its size often must be decreased. This occurs also by colotomy.

colotomy
colon torsion

Enterotomy in the dog and the cat

The antimesenteric side of the intestine is incised over the foreign body. The incision must be long enough in order to remove the object without further tearing the wall of the intestine. The incision must preferentially be made in healthy intestinal tissue. This can imply that the incision be made somewhat aboral to the foreign object. The intestine is occluded cranially and caudally to the incision, using atraumatic intestinal clamps (Doyen's clamps). In placing the clamps, care must be taken not to cut off the blood supply to the segment to be cut. After the object is removed, the incision is closed with a simple interrupted or continuous suture pattern of monofilament synthetic absorbable suture material (preferred thickness 4-0). The sutures are made through all layers of the intestinal wall, with the wound edges simply apposed. If necessary, the extruding mucosa can be removed carefully using small scissors.

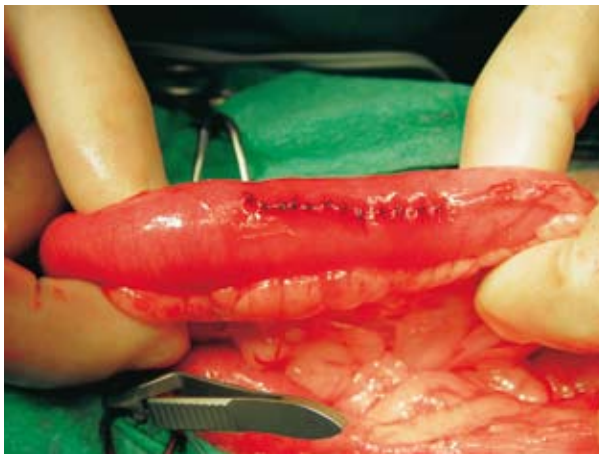

Figure 3. Interrupted, simple-appositional closure of the intestine of a dog

Enterotomy in the bovine

In order to reposition a caecum due to torsion, the caecum must first be emptied. This occurs via a relatively small (approximately 5 cm long) enterotomy in the point of the caecum (the apex caeci). The incision is sutured in two layers: two inverting seromuscular sutures over each other. Either synthetic absorbable monofilament or braided suture material of thickness 2-0 may be used.

Enterotomy in the horse

The small intestine is opened on the antimesenteric side. After removal of the abnormal intestinal contents is complete, intestinal clamps are placed on both sides of the incision. The intestine is closed in two layers. The first suture line is a simple continuous suture pattern of only the mucosa and submucosa. Over this, an inverting seromuscular suture pattern is applied (such as a Cushing's suture). The ascending colon is usually opened on the antimesenteric side, at the level of the pelvic flexure. After placement of intestinal clamps, the incision is closed in two or three layers. First, the mucosa and submucosa are sutured together with a simple continuous suture. On top of this, one or two inverting seromuscular sutures (Lembert or Cushing) are performed. The descending colon is also opened on the antimesenteric side, precisely in the middle of the taenia. The incision is closed in the same manner as in the small intestine, where the seromuscular suture penetrates completely the taenia. In all cases, synthetic monofilament, absorbable suture material, thickness 2-0 or 3-0 is used.

10.4.4.3.2 Enterectomy

intussusception

intussusceptum
intussuscipiens

In the dog and cat, intestinal resection is indicated in tumours and in all situations where the intestinal wall is no longer viable. these include the majority of intussusceptions, because these can only seldom be completely repositioned. It is, however, worthwhile to attempt a repositioning. With slight pressure, the invaginated portion (intussusceptum) is slowly pulled back out of the bowel (intussuscipiens). If the repositioning is not completely successful, the remaining segment is removed. With this, one must realise that the removed portion may three times as long as it appears from the outside. The invaginated segment is folded over and therefore two times as long as the segment of bowel where it is invaginated. The most common indication for an intestinal resection in the cow is the intussusception of the jejunum. Repositioning of the invaginated intestinal segment is rarely successful. In horses, an intestinal resection is necessary in all cases where non-viable intestinal segments in the abdomen are found. These can be segments of the small intestine affected by a strangulating obstruction or large intestinal segments caused by strangulating displacements. If only a portion of the jejunum is removed in a resection of the small intestine, the passage is corrected by creating an end-on-end or side-to-side jejuno-jejunostomy. Often, however, a portion of the ileum must also be resected. In this case, a side-by-side jejuno-caecostomy is performed. Resection of a portion of the colon is sometimes indicated in the case of colonic torsion. The torsion must be in a limited portion of the colon (only the left ventral and left dorsal colon). In many cases, however, the entire colon is involved in the torsion. In such an instance, resection of the non-viable portion of the colon is not possible, or speculative at best, and the animal must be euthanised. Resection of a portion of the colon can also be indicated on the basis of presence of anaemic infarctions.

Intestinal resection in dog and cat

Atraumatic intestinal clamps are placed on both sides of the segment that is to be removed. In placing the clamps, caution must be taken to avoid the occlusion of the blood supply to the

anastomosis. The arteries and veins of the segment to be removed are ligated and transected. This pertains also to the attachment of the mesentery to the marginal veins of the intestine.
The intestine is incised between the clamps. The incisions are continued in the mesentery in a V-shaped form, with the point at the hilus. The continuity is repaired preferably with an end-to-end anastomosis. Lateral side-to-side anastomoses are more complicated and therefore take more time and do not give a correct anatomic reconstruction of the intestine. These are only indicated if the ends to be joined differ greatly in thickness. This situation can better be avoided; small differences in diameter can be compensated for by taking advantage of the elasticity of the intestinal wall (the narrow portion easily allows some stretching) or by incising the narrow portion not perpendicular to the intestine but at an angle (with a maximum of 60 degrees). In the dog and cat, there is a definite preference for the use of appositional techniques. Inverting methods narrow the lumen and heal more slowly than appositional methods; everting techniques heal slowly as well, and cause more adhesions than the other techniques. In the dog, two sorts of end-to-end appositional anastomoses are described: the 'crushing' technique and the 'simple interrupted approximating' (SIA) method. In both methods, the sutures are brought through all the layers of the intestinal wall, but the tension with which they are tied differs. In the 'crushing' technique, the sutures are pulled so tightly that they cut through the seromuscular layer and the mucosa. The knot is buried to the level of the submucosa. In the SIA method, the sutures are knotted using normal tension. Experimental research in dogs has shown no significant difference in healing between these two techniques. Both methods are equally safe and effective, provided that they are carefully carried out. This implies that the submucosa must be incorporated in each suture, and that all layers are brought in alignment.
The first two sutures are placed on the mesenteric and the antimesenteric side of the anastomosis. It is recommended that the ends of these sutures be left long, so that they can be used as "stay sutures." The space between these stay sutures is proportionally filled in with simple interrupted sutures. The sutures perforate all layers of the intestinal wall and are made at a distance of 3-4 mm from one another (Figure 4). If the diameter of both ends differs, the sutures are placed further apart on the wider side than on the narrow side. Various types of suture material can be used, but the preference is to use 3-0 or 4-0 atraumatic monofilament, synthetic, absorbable suture material. The anastomsis is completed by closing the mesenterial defect. Normal intestinal function must be restored as quickly as possible. Drinking water is offered as soon as the patient has regained consciousness from anaesthesia, and feeding is resumed within 8-12 hours following the operation. The prognosis of ileus in the dog and cat depends on the cause. Intestinal torsion (volvulus) is a dramatic disorder with a high mortality rate. Intestinal tumours are usually malignant and but have a relatively good prognosis, with an average survival time of a year. Invaginations can recur, but most patients (70%) recover without complications. Foreign objects in the intestines have a good prognosis if trauma to the bowel was limited.

stay suture

volvulus

Figure 4. An end-to-end resection and anastomosis was performed

Intestinal resection in the bovine

The abdominal cavity of the standing animal is opened in the right flank, using a partial grid incision. Because the entire jejunum lies in the mesenterico-enteric recess (bursa supraomentalis), the invagination must be brought along the free back edge of the greater omentum (transition point from outside- to inside layer) to the laparotomy wound, and thereafter brought outside.
The intestinal resection follows. Before the attached mesentery can be detached, it must first be anaesthetised. This can be done by using a local infiltration anaesthesia in the mesentery or by

applying a local anaesthesia to both sides (lateral and medial sides) of the mesentery, where a superficial anaesthesia on both serosal layers of the mesentery is achieved. The mesentery of the cow contains much fatty tissue, through which the separate blood vessels are barely or not visible. For this reason, the mesentery must be carefully detached step-by-step in the usual V-formation. After placing the necessary intestinal clamps, the resection begins, followed by the creation of an end-on-end jejuno-jejunostomy. This can be done using various methods. A frequently used technique is closure in two layers. First, the edges of the far side of both intestinal ends are sutured together using a typical continuous suture pattern that perforates all layers of the intestinal wall, and begins at the attachment of the mesentery. When the antimesenteric wound edges are reached, the suture continues as a Schmieden suture pattern (Chapter 5.2.6.3), where the wound edges on the near side of both intestinal ends are sutured together. At the mesenteric attachment, the suture is finally tied off. Next, the first seam is over-sutured with a continuous seromuscular suture (a Lembert or Cushing suture): first, beginning on the near side at the connection of the mesentery, and after folding in the intestine, the far side, where the suture thread ultimately is tied off at the attachment of the mesentery. Finally, both wound edges of the mesentery are sutured on one another, after which the intestine is returned to the mesenterico-enteric recess. The laparotomy wound is closed in the usual manner. The prognosis of the resection of the small intestine in the cow, followed by an end-on-end jejuno-jejunostomy is relatively favourable. Depending on the general condition of the animal (the degree of haemoconcentration and disruption of the pH balance), there is medical treatment may be indicated, consisting of the infusion of fluids and electrolytes.

Resection of the small intestine in the horse

After it is determined which portion of the intestine must be resected, the mesentery and the mesenteric blood vessels are first ligated. These include the jejunal, terminal arcade and vasa recta vessels. Intestinal clamps are then placed: two over the aboral portion and two over the distal portion of the intestine. The intestinal clamps are not placed perpendicular to, but obliquely over the intestine, and at less than an angle of 60° to the longitudinal axis of the intestine. The intestine is incised between the intestinal clamps, likewise at less than an angle of 60° to the longitudinal axis of the intestine. Thereafter, the mesentery is amputated distal to the ligatures. Next follows the creation of the anastomosis: an end-to-end jejuno-jejunostomy. This anatomosis is performed in two layers.

end-to-end

In order to position the wound edges that are to be sutured together, two stay sutures are placed, one on the mesenteric side and the other on the antimesenteric side. The mucosa and submucosa are incorporated into these stay sutures. Next, the first suture is made: a simple continuous suture pattern through only mucosa and submucosa.
The suture begins at the attachment of the mesentery on the intestinal wall, and is also concluded in the same location. When the first suture is complete, both stay sutures are removed. Following this, two new stay sutures are placed, both of which are now seromuscular. Next, the second suture is made: this is a continuous, seromuscular suture pattern (usually a Cushing's suture). This second suture also begins and ends at the attachment of the mesentery. The intestinal clamps are removed and the anastomosis and surrounding area carefully irrigated and cleaned. The intestine is sutured with synthetic monofilament absorbable suture material, thickness 2-0 or 3-0. The defect in the mesentery is closed with a simple continuous or simple interrupted suture pattern. Next, the anastomosis is returned to the abdominal cavity. If not only a portion of the distal jejunum is removed, but also a portion of the ileum, an anastomosis is made between the jejunum and the caecum: a side-to-side jejunocaecostomy. The resection of the affected intestinal portion, in general,

side-to-side

follows the same procedure as that of the jejunum resection.
However, in this procedure, the distal marginal vessel, the ileal branch of the ileocaecocolic artery is tied off. This vessel runs in the mesentery next to the ileum in a proximal direction and anastomoses with the last jejunal artery. After this, the ileum can be incised and the intestinal resection can be further continued. Not only the jejunum but also the ileum is now incised perpendicular to the longitudinal axis of the intestine. The jejuno-caecostomy is done as a side-by-side anatomosis. This implies that after the removal of the intestine, the open end of the jejunum

must be closed, followed by the open end of the ileum. Both openings are closed in two layers. For the first layer, the preference is to use a Parker-Kerr suture pattern, but a Schmieden suture pattern is also possible. Over this, a second continuous seromuscular suture (Cushing or Lembert) is placed. The end of the ileum that has been closed is placed back in the abdomen.The jejunum stub is retained outside the cavity. The caecum is placed as far extra-abdominal as possible. The anastomosis is made in the body of the caecum, on the medial side of the dorsal taenia. The distal end of the jejunum is placed here along the caecum. The wall of the jejunum is sutured with a continuous inverting suture pattern (Lembert or Cushing) on the wall of the caecum. Next, the intestinal clamps are placed: a straight or curved clamp over the jejunum proximally to the location of the anastomosis and two curved clamps over that portion of the caecum where the anastomosis is to be made. The jejunum and caecum are both opened with two equal parallel incisions, but definitely shorter than the already-placed seromuscular suture. Both of the created openings are sutured together: first the ventral incision with a simple continuous, perforating suture pattern and then the dorsal incision with a Schmieden suture pattern. Severely bleeding vessels in the intestinal wall are first ligated, if necessary. The Schmieden suture is ultimately covered with the continuation of the already-present seromuscular suture. With this, the anastomosis is complete. For all sutures of the intestinal wall, synthetic monofilament, absorbable suture material, thickness 2-0 or 3-0 is used. The defect in the mesentery is closed with a continuous or interrupted suture pattern. After a final check and cleaning, the caecum is brought back to its normal position in the abdominal cavity.

Resection of the large intestine in the horse

If a portion of the ascending colon is amputated, the patent lumen is restored by making a side-to-side colo-colostomy. After resection of a portion of the descending colon, a end-to-end colo-colostomy is performed. The techniques of intestinal resection of portions of the colon and making of an anastomosis are highly specialised and are beyond the scope of this textbook.

Follow-up care

Many horses present before the operation with a poor general condition. Through the strangulation of intestinal segments, problems develop with respiratory and circulatory systems in addition to the closure of the intestinal lumen and the degeneration of the intestinal wall. Hypovolaemia and often also endotoxaemia can occur, causing the horses to go into various degrees of shock. Many horses develop acidosis and a disturbance of their electrolyte balance. The implications of this are that there are high demands to be placed on anaesthaesia in such horses, and on the administration of medications and infusion before and during the operation.
Also after the operation, an intensive recovery period and medical support is necessary for the horse to recover. The mortality after colic surgery is very high in horses in comparison to other animals. Of the total number of colic horses operated, 10% do not survive the surgery. Some die spontaneously and others are euthanised because of a bad prognosis or an inoperable situation Approximately 20 to 25% die or are euthanised during the postoperative period in the clinic. The most important reasons for this are postoperative paralytic ileus and peritonitis. Other complications, as well, such as laminitis can lead to death. The above passage implies that approximately 65 to 70% of horses are able to return home after an colic surgery. During the first year after an operation, 10% are either slaughtered or euthanised. The most important cause of this is recurrent colic as the result of adhesions in the abdominal cavity. All in all, approximately half of the colic surgeries are successful. The above-mentioned percentages are averages of all operated horses with colic, the reason of the colic not withstanding. It is clear that an intestinal resection in the horse in shock has a worse prognosis than the repositioning alone of a strangulating intestinal displacement in a horse with a relatively good general condition.

10.4.5 The bladder

10.4.5.1 Introduction

cystotomy
urolithiasis

Opening of the bladder is termed cystotomy. The most common indication for a cystotomy is the removal of bladder stones (urolithiasis).

10.4.5.2 Urolithiasis in bovine and equine

In ruminants, the cause of urolithiasis is often gravel or small stones in (mostly castrated) male animals. It is mostly seen in castrated (pygmy) male goats. The stones consist in most cases of radio-dense magnesium-ammonium-phosphate crystals. Oxalates also can be present and are radiolucent. Therefore it is desirable to catheterise and insert contrast dye in the bladder of ruminants when performing radiological examination. The stones often give problems once they begin to leave the bladder and become lodged in the urethra: obstructive urolithiasis. In order to remove this obstruction, a urethrostomy must be performed. If after this procedure, stones are still present in the bladder, it is desirable to remove these as well, in order to prevent an obstruction from recurring. Sometimes this can be done successfully by irrigating the bladder via a catheter, but usually a laparocystotomy is necessary. The prognosis is guarded, because urolithiasis in ruminants often recur.

obstructive urolithiasis

laparocystotomy

In horses, usually one or a few larger stones are present in the bladder. These stones occur more often in geldings and stallions, because in mares the stones often are expelled via the wider urethra. The bladder stones of the horse are divided into type I and type II stones. The type I stone consists of calcium carbonate and the type II stone of calcium carbonate with phosphate and magnesium. The type I stone has a very rough surface and because of this, sometimes attaches onto the mucosa of the bladder. This can explain why in the mare bladder stones are not always passed during urination. The attachment of the stone to the mucosa can complicate the surgical procedure. The type II stone has a smooth surface. As long as the stone remains in the bladder, few problems will occur. As the result of irritation and damage to the wall of the bladder, stranguria (difficulty urinating) and haematuria (blood in the urine) are sometimes observed. Depending on the type and the size of the stone, sometimes urination can be hindered. In such a situation, the horse will express pain during urination and small amounts of urine mixed with blood will be voided. Usually, this is the reason that an owner consults the veterinarian. A stone in the bladder can almost always be felt by performing a rectal examination.

stranguria
haematuria

With the present long, thin and flexible endoscopes, it is possible to see the entire urethra and bladder in stallions. It is also possible, however, fot the stone to make its way to the urethra and become lodged there. In this case, a full obstruction may occur, resulting in colic, straining (dysuria), etc. The stone is usually felt by carefully handling the penis; alternatively, the stone can be located by catheterisation. In order to remove the stone, an urethrotomy is performed, where the urethra is opened at the location of the stone. There are diverse surgical options to remove the stones from the bladder. One or more of the smaller stones can be removed via the urethra. In the mare, this can be done by slightly stretching the urethra. In male animals, this is accomplished using a proximal urethrotomy where the urethra is opened directly under the anus. Using long forceps, the stone can be removed from the bladder. When the stone is so large that removal via the urethra is not possible, it must be removed by cystotomy, more specifically a laparocystotomy or a pararectal cystotomy. The prognosis for surgical treatment of bladder stones in the horse is relatively favourable.

dysuria

10.4.5.3 Cystotomy in the horse

10.4.5.3.1 Laparocystotomy

In the laparocystotomy, the abdomen is opened in the midline behind the umbilicus. In stallions, this means that the preputium is dissected free and moved to the side. In some cases, the bladder is so small that it is difficult to locate it. The bladder is fixated by attaching two stay sutures in the ventral bladder wall. Between these stay sutures, the bladder is opened and the stone is removed. The bladder is closed in two layers: a simple continuous suture through the mucosa and submucosa, followed by a continuous seromuscular suture pattern. A disadvantage of this method is that the laparotomy, and the necessary general anaesthesia, present risks. The advantage is that the inside of the bladder can be thoroughly examined, ensuring that no stones remain.

10.4.5.3.2 Pararectal cystotomy

The pararectal cystotomy can be performed in the standing animal under a low epidural anaesthesia, if necessary, filled with local infiltration anaesthesia. It can also be done on a lying animal under general anaesthesia. A vertical skin incision is made between the anus and the semimembranosus muscle. After this, a blunt instrument is advanced along the rectal wall, until the neck of the bladder is reached. In the horse, this is located completely retroperitoneally. With a hand in the rectum, the stone in the neck of the bladder is manipulated and fixated. With the other hand, the wall of the bladder neck is cut over the stone using long scissors. The opening is enlarged, if necessary, in order to remove the stone. The bladder is irrigated to remove other possible stones. The wound is the bladder neck is not sutured. Perirectally, a hydrophilic gauze pad (saturated with a disinfecting fluid such as diluted povidone iodine solution) is placed as a drain. The skin wound is made smaller, but not completely closed. After one to two days, the gauze drain is removed. Initially during the elimination of urine, a great deal of urine will come out of the wound.
Over time as the wound heals, this will occur progressively less. Normally, the wound will close on its own after one to two weeks, and the animal will be able to urinate normally. Because of the danger of cystitis, antibiotics are administered peri-operatively.

10.4.5.4 Urolithiasis in the dog and the cat

In the dog, 95% of stones associated with urolithiasis are localised in the bladder or in the urethra. Of the 30,000 uroliths of dogs researched at The Minnesota Urolith Centre in the United States, the stones consisted of the following: 54% of magnesium ammonium phosphate, 25% of calcium oxalate, and the remaining 21% of urate crystals, cystine, calcium phosphate and mixed stones (Osborn and Finco). Using anamnesis and physical examination of the urinary tract, suspicion of and even presence of urolithiasis can be confirmed. The symptoms depend on the number, type and especially the localisation of the stones. Stones in the bladder, may cause dysuria, pollakiuria and recurring haematuria. Especially in the male dog, smaller stones can become lodged in the urethra (usually just caudal of the os penis). This can cause a partial or complete urethral obstruction, resulting in the bladder overfilling and postrenal uraemia. Unilateral kidney or ureter stones can be present without clinical signs, or can appear with other vague symptoms (pain in the abdomen, lethargy, fever) and sometimes recurring haematuria. When a ureter stone causes a complete obstruction, a dilatation occurs of the proximal portion of the ureter and of the kidney pelvis (hydronephrosis). Bilateral kidney and ureter stones often lead to chronic renal failure. By using abdominal palpation and rectal exploration, stones can sometimes be palpated in the bladder or urethra. Another method is using catheterisation to localise stones in the urethra. Ultrasound and radiological examination is, however, often necessary in order to confirm or rule out the diagnosis of urolithiasis. Calcium oxalate and struvite stones are radiodense. Cystine stones are relatively

urethral obstruction

hydronephrosis

radiodense, while urate stones are relatively radiolucent, and therefore require double contrast examination or ultrasound in order to bee seen. Once stones have been diagnosed, treatment should be chosen depending on the symptoms, the size, the number and the localisation of the stones. Small bladder stones, that appear to be able to pass in the urethra, can be removed by means of urohydropropulsion (bladder irrigation). A cystotomy is indicated in animals where bladder stones cannot be dissolved by diet or by using urohydropropulsion or diet. It is further indicated in animals where (for example) the results of radiological examination, ultrasound or cystoscopy show abnormalities in the wall of the bladder confirming that a surgical procedure is necessary (tumours, polyps, persistant urachus or ectopic ureter).

urohydropropulsion

10.4.5.5 Cystotomy in the dog and the cat

Before the operation, antimicrobial prophylaxis is initiated. The patient is positioned in dorsal recumbency. A sterile urinary catheter is inserted into the urethra until the end of the catheter is in the bladder. The abdomen is opened via a caudal midline incision. The ventral bladder ligament is cut, after which the bladder can be brought outside the abdomen. It is then stabilised using four stay sutures. The bladder is opened on the ventral side using a puncture incision, which is lengthened using scissors. A suction tube is used to prevent leakage of urine into the abdomen.
The incision is made on the ventral midline and close to the fundus of the bladder, where the chance of bleeding is relatively small. The incision can also be made in the dorsal part of the bladder. The most important step is to remain out of the vicinity of the ureter, the urethra and the large blood vessels. In the case of urolithiasis, the length of the incision must be large enough, in order to remove the largest stone. The larger stones can be removed using a teaspoon. The smaller stones and gravel are often in the neck of the bladder and are more difficult to reach. Using a catheter the urethra must be irrigated in order to be certain that all the stones have been removed from the urethra bladder and neck. In this manner, the smallest stones are also rinsed out of the bladder, where they can be intercepted with a suction tube or teaspoon. If in doubt, the irrigation should be repeated. The entire wall of the bladder is inspected including for the presence of a urachal diverticle. The bladder is closed in two layers. The first suture line is a simple continuous suture pattern of only the mucosa. Thin synthetic, absorbable, monofilament suture material (thickness 4-0) is advisable for this to prevent stone formation through contact of suture material with urine. The second layer is an inverting seromuscular suture pattern (Lembert or Cushing, continuous or interrupted). In this suture, use is made of 3-0 or 4-0 synthetic resorbable suture material. This second suture causes an inversion of the first suture though which ultimately a safe closure of the bladder is obtained. The bladder is returned to the abdomen and covered with omentum to prevent adhesions between the bladder and the abdominal wall. The abdomen is closed in a routine fashion. Directly after the surgery, the urine catheter is removed. Depending on the circumstances, antibiotic administration is continued for a minimum of 10 days. The removal of the stones is only a part of the treatment for urolithiasis. Just as important are the measures that must be taken in order to prevent recurrence. The type of stone plays an important role in this. Analysis of the stone is therefore necessary.

urachal diverticle

10.4.6 The uterus

ovariohysterectomy
Caesarean section

Procedures to the reproductive organs are common indications for abdominal surgery in ruminants and companion animals. In addition to the removal of the ovaries and uterus (see below: ovariohysterectomy), the Caesarean section is the most common operation of the uterus. There are various causes of complications in birthing (dystocia) that can lead to a Caesarean.

10.4.6.1 Opening and closing of the uterus

In ruminants, the uterus is approached by means of an incision left flank. In companion animals, the uterus is approached using a caudal, midline coeliotomy, from a few centimetres forward of the navel to the edge of the pelvis. In ruminants, the incision in the uterine wall continues from directly under the position of the foot to the heel in a lengthwise direction of the horn as close as possible to the major curvature, thus avoiding cutting the placenta. It is better to begin the incision under the claws so that after the incision is made, the legs cannot be stretched. In companion animals, the incision is made in the uterine horn, where most of the puppies will be found, in the major curvature, between the locations of the placenta, where no large blood vessels are located, close to the bifurcation. With this, care must be taken to avoid injuring the puppies. The incision must be long enough in order to remove the puppies without tearing the wall of the uterus. The incision is sutured in ruminants and companion animals with a modified Cushing suture (following the Utrecht method) with a continuous pattern using monofilament absorbable suture material.

10.4.6.2 Ovariectomy, ovariohysterectomy in the dog and the cat

ovariohysterectomy

An ovariohysterectomy can be performed for therapeutic or non-therapeutic reasons. Medical indications for an ovariohysterectomy include: disorders of the uterus and/or ovaria, pseudopregnancy, recurring vaginitis, diabetes mellitus or acromegaly. Even though a bitch is healthy, an owner can request an ovariohysterectomy for the termination of pregnancy or because of undesired attention of the bitch from male dogs when the bitch is in heat. When this is done at a young age, the chance of mammary tumours in the dog is significantly decreased. Neutering has been associated with urine incontinence, however, in both the male dog and the bitch.

Ovariectomy versus ovariohysterectomy

ovariectomy

In general, it is necessary to perform an ovariohysterectomy if the uterus is abnormal. If the uterus appears to be macroscopically normal and the bitch has no gynaecological problems, an ovariectomy is all that is necessary. Because the incision for an ovariectomy is shorter than in for an ovariohysterectomy, the trauma caused is suspected to be less, the surgery time shorter, and additionally, the endometrium remains closed.

Anatomy

bursa ovarica
foramen ovarica

The uterus of the dog is bicornuate. The cervix is short; the ostium externum and internum are almost the same. The endometrium can extend to the area of the ostium externum. The ovary is covered by a peritoneal pleat, the bursa ovarica. In this bursa, a split-like opening can be found on the medial side (foramen ovarica), where a portion of the fimbriae protrude through. Usually, these fimbriae are light pink, however during the heat they become bright red and increase in size. The almost 8 cm-long curled uterine horn lies mostly in the wall of the fatty bursa. Through this, it is often difficult to differentiate from its environs; the fallopian tube is easier to observe during the heat. The support bands of the genital system consist of the mesovarium, in which a sturdy band

runs cranially and is named the suspensory ligament and the broad ligament that often contains much fat in the dog but not in the cat. At the level of the tip of the uterine horn is the sturdy round uterine ligament attached to the broad ligament. The proper ligament is found between the tip of the uterine horn and the bursa. The uterus and the ovaries are supplied with blood from two important arteries, the ovarian and uterine arteries. The ovarian pedicle runs directly from the aorta. This artery is very irregular, both before entering the ovaries as well as inside. The artery supplies the cranial portion of the uterine horn with blood, after having branched off to the ovaries and the uterine horn. The uterine artery (which runs off the internal iliac artery via the vaginal artery and the internal pudendal artery) runs cranially through the broad ligament and ends at an important branch to the horn. Both arteries do not form an important anastomosis in the dog, but do so in many other types of animals. In the broad ligament, small anastomoses are present. At the level of the cranial portion of the uterine horn and caudally the arteries lie close to the body of the uterus. In contrast, at the level of the middle portion of the uterine horn, they are a few centimetres removed from the uterus. They both divide into a number of smaller arteries before they reach the uterus and split. These branches are connected together via anastomoses.

Technique of ovariectomy and ovariohysterectomy in the dog

The patient is positioned in dorsal recumbency. The operation area is cleaned and prepared aseptically. The approach via the midline is preferred (over the approach via the flank) for both an ovariectomy and ovariohysterectomy. This is because it is much easier to reach the uterus and both ovaries through this method. In the description of the ovariohysterectomy, only the approach via the linea alba will be discussed. The incision is made caudally to the umbilicus, a few centimetres forward of the edge of the pelvis. It is sometimes necessary to extend the incision cranially if the mesovarium appears to be very short or if the uterus is severely distended and under pressure. In order to gain perspective, a abdominal wound retractor can be useful. In order to bring the left uterine horn and the ovary in view, the colon is grasped and moved medially. In case of a smaller (key hole) incision, the ovary can be localised caudal to the kidney without lifting the colon.

key hole

The ovaries are connected via the suspensory ligament with the last two ribs.
This ligament is transected either with scissors, using electrocoagulation or torn in order to better mobilise the ovaries. The broad ligament is bluntly perforated at the level of the ovary. The opening must be large enough in order to place a ligature above (on the proper ligament and one or two sutures below the ovary (on the broad ligament). A large curvedt vessel clamp is placed on the proper ligament. An assistant can present the ovary to the surgeon using this clamp. The surgeon can place a synthetic absorbable suture through the opening and under the ovary on the ovarian pedicle. This suture must be long enough, must hold its strength for a sufficient period, and must be strong enough that it can be sturdily tied off. The first layer is pulled under constant tension as tightly as possible. Along with this, it must be carefully checked that there is no omentum, mesentery etc. caught in the ligature. After this, the knot is tied off with two throws. In order to be certain that there is sufficient room present between the ligature and the ovary, the bursa can be cut open via the ovarian foramen. After this, the ovary can be brought completely into view. In this manner, the ovary and the ligature can be excised under direct supervision. When only the ovaries are to be removed, a ligature is placed at the level of the proper ligament. This is accomplished in the same manner as above. The ovary can now be removed by cutting the tissue between the the ligature on the proper ligament and the ovary. The right ovary can be ligated and removed in the same manner. On this side the duodenum may be grasped and pulled medially in order to see the uterine horn. If it is decided that the uterus is to be removed, the broad ligament and the round ligament on both sides are transected up to a few centimetres from the uterus. Care must be taken here that the uterine artery and vein are removed after those of the uterus. The round uterine ligament is found by the transection of the broad ligament relatively far cranially. This ligament is often very sturdy and must sometimes be cut through. The uterus is ligated on the cervix. Before the uterus is cut cranially to the ligature, a clamp or ligature is placed on the body so that the contents of the uterus do not leak into the abdomen. In large or fat dogs or in dogs where the uterus is very

distended, it can be necessary to ligate the blood vessels separately. Before the abdomen is closed, the ovarian pedicles and the cervix are thoroughly checked for bleeding.

Ovariectomy and ovariohysterectomy in the cat

The principles of this surgery are the same as those in the dog. The only difference is that the suspensory ligament is clearly longer in the cat than in the dog and does not have to be cut through in order to be able to remove the ovaries from the abdomen. Also the suspensory ligaments contain less fat. For both the cat and the dog ovariectomy by flank incision have been described.

References: *van Goethem B, Schaefers-Okkens A, Kirpensteijn J. Making a rational choice between ovariectomy and ovariohysterectomy in the dog: a discussion of the benefits of either technique.Vet Surg. 2006;35:136-43.*