EVALUATION OF THE EFFECTS OF RECUMBENCY ON LAPAROSCOPIC-ASSISTED CYSTOSTOMY AND TUBE CYSTOTOMY IN MALE SHEEP

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Obstructive urolithiasis is a common disease of male, particularly castrated small ruminants, which often indicates the need for a surgical procedure on the urinary system (VAN METRE et al., 1996). Various surgical techniques have been described, namely the urethral process amputation, penis amputation, perineal urethrostomy, tube cystotomy and urinary bladder marsupialisation (VAN METRE, 2004). However, urolithiasis continues to challenge practitioners (FORTIER et al., 2004; GILL and SOD, 2004). Surgical tube cystotomy has shown good success rates for the resolution of this disease by creating a diversion of urine from the urethra, in turn allowing time for the urethritis to subside and the calculi to pass (RAKESTRAW et al., 1995; EWOLDT et al., 2006; VAN METRE et al., 2006). The opening of the bladder may be necessary in order to remove the calculi (PEARCE et al., 2003). Laparoscopy is a minimal invasive procedure that has been increasingly studied, in which laparoscopic-assisted cystostomy has good indications for dogs and horses (RAWLINGS et al., 2003; RÖCKEN et al., 2006) concerning this disease, as well as laparoscopic-assisted tube cystotomy (FRANZ et al., 2008), and a combination of the 2 techniques showed good results in sheep (FRANZ et al., 2009). Laparoscopic procedures in the pelvic region require the Trendelenburg position, in which the patient is positioned head down (RAGLE et al., 2000; WILSON, 2000). In addition, laparoscopy also requires the creation of space in the abdominal cavity in order to expose the viscera and to enable laparoscopic procedures, which can be achieved by insufflating gas in the peritoneal cavity (pneumoperitoneum). Most often, the insufflation is carried out with carbon dioxide (CUSCHIERI, 1999). However, positioning a small ruminant head down and pressurising the peritoneum with a gas soluble in the blood, may cause some adverse effects in the cardiovascular system, blood gas and acid-base status. The effects of the Trendelenburg position in small ruminants have not yet been reported in the literature. The effects of capnoperitoneum are reported in dogs, horses and llamas with or without a combination with a change in the position (IVANKOVICH et al., 1975; GALUPPO et al., 1996; LIN et al., 1997; DONALDSON et al., 1998; DUKE et al., 2002; LATIMER et al., 2003). In small ruminants, there have been experimental studies in pregnant ewes, which were horizontally positioned in dorsal recumbency, for human surgical purposes (CRUZ et al., 1996; CURET et al., 1996). These possible effects may be attenuated by positioning the animal in left lateral recumbency, due to some anatomical characteristics of small ruminants (MAY, 1970).
Therefore, the aims of the present study are the following:

1. Access the feasibility of a laparoscopic-assisted cystostomy with laparoscopic-guided
   implantation of a urinary catheter in left lateral recumbent sheep;

2. Investigate and compare the effects in blood gas, acid-base status and haemodynamic
   parameters of the Trendelenburg position and CO₂ pneumoperitoneum between the
   dorsal and left lateral recumbencies in sheep.
2. REVIEW OF THE LITERATURE

2.1. Urolithiasis in Small Ruminants

Urolithiasis is a disease that is caused by alterations in the solubility of the salts in urine, in turn forming uroliths, which are also called urinary stones or calculi (GRÜNDER, 2005). It is the most common urinary tract disease in rams and goats (pets and breeding animals), in turn affecting nearly exclusively males, particularly those that are castrated and more often those animals between the ages of 5 and 18 months (OEHME and TILLMANN, 1965). Urolithiasis is as common in females as in males, but females are less affected due to the wide urethra and rapid flow of urine at micturition, which allow for the easy passage of most concretions (MONOGHAN and BOY, 1990; RADOSTITS et al., 2000; GEORGE et al., 2007). In some management systems, where the ration is based on grain or where animals graze on certain types of pastures, for example alfalfa, 40 to 60% of the animals may form multiple calculi in their urinary tract (RADOSTITS et al., 2000), and obstructive urolithiasis is responsible for 4% of all deaths in feeder lambs (KIMBERLING and ARNOLD, 1983).

Uroliths are composed mainly of salts and minerals in a crystal lattice that surrounds an organic matrix of proteinaceous material (STRATTON-PHELPS and HOUSE, 2004). The composition of the stones is variable, but commonly based in calcium compounds - phosphate (apatite), oxalate and carbonate -, magnesium ammonium phosphate or struvite, and silica (STACY, 1969; STEWART et al., 1991; HAVEN et al., 1993; HALLAND et al., 2002).

The aetiology of urinary calculi formation in ruminants is recognized to be multifactorial (KIMBERLING and ARNOLD, 1983). The first step in the development of a calculus is the formation of a crystal nidus and its further growth depends on the ability to remain on the urinary tract and the continuous supersaturation of the urine with crystalloids. The degree of this supersaturation depends on diet, urine pH, water intake, and the presence of crystallization inhibitors in the urine (MONOGHAN and BOY, 1990).

Obstructive urolithiasis occurs more frequently in winter, and reduced water intake in this time of the year is thought to result in increase concentration of crystalloids in urine (MONOGHAN and BOY, 1990; SARGISON and ANGUS, 2007). Diet plays an important role in the beginning of the disease, since food rich in proteins, with high levels of phosphorus, like concentrates, disturb the balance of the Calcium-Phosphorus
ratio, which should be lower than 2:1, in turn leading to an increase of the concentration of phosphorus in urine (HOAR et al., 1969; MICHELL, 1989; STEWART et al., 1991; VAN METRE and FULEINI, 1996; STRATTON-PHELPS and HOUSE, 2004; DÜHLMIEIER et al., 2007).

After castration (often 8 months later), the testosterone levels decrease and, consequently, the diameter of the urethra also decreases, which also contributes to the obstruction (BEHRENS et al., 2001).

It is not recognized any breed predisposition to the disease (OEHME and TILLMANN, 1965; DÜHLMIEIER et al., 2007; GEORGE et al., 2007), but a genetic predisposition to calculus formation has been suggested, related to the individual animal's capacity for urinary excretion of phosphate (in cases of struvite calculi) (SARGISON and ANGUS, 2007).

The most common sites of obstruction in small ruminants include the urethral process, distal portion of the sigmoid flexure of the urethra, and isquiatic arch (OEHME and TILLMANN, 1965; MONOGHAN and BOY, 1990; VAN METRE and FULEINI, 1996; BEHRENS et al., 2001), but calculi may be found in the bladder or kidney without any signs of disease (STACY, 1969). VAN METRE and SMITH (1991) wrote that the urethral process was the site of an obstruction in 17 of 43 sheep and 22 of 51 goats (40% and 43%, respectively). KÜMPER (1994) reported in a retrospective study that 86% of the cases had the uroliths located in the urethral process.

The calculi become clinically important when they obstruct the urinary system, leading to the disease to be called obstructive urolithiasis. Obstruction can be total or partial, and if not corrected it leads to the perforation of the urethra (in most cases due to the necrosis of the urethral mucosa) or rupture of the bladder in approximately 48 hours. In case of the rupture of the urethra, urine leakage occurs into the connective tissue of the ventral abdominal wall and prepuce thereby causing an obvious fluid swelling that can spread as far as the thorax. This results in severe cellulitis and toxæmia. In case of the rupture of the bladder, immediate relief from the present discomfort occurs but anorexia and depression develop as uraemia settles in thereafter (RADOSTITS et al., 2000).

When animals are neglected and uraemia continues to increase, the prognosis is poor, in turn resulting in death due to metabolic derangements, such as hyponatraemia and hypochloraemia, and occasionally hyperkalaemia (VAN METRE and FUBINI, 2006).

Experimental urinary retention in 7 goats (TSUCHIYA and SATO, 1990) revealed that the first clinical signs of an obstruction were anxiety, anorexia and a decrease in water consumption. Tachycardia persisted from the initial stage of the obstruction, but abnormal body temperature and respiratory rate were not found until the animals became moribund.
Ammonia odour of the breath was never noted throughout the experience. In moribund animals, after 8 to 9 days of obstruction, agony, lethargy, drop in temperature, Cheyne-Strokes respiration, and neurological symptoms, such as nystagmus, trismus and opisthotonus were observed. Blood urea nitrogen and serum creatinine values increased at constant rates when an obstruction was present, and according to the authors they are the most useful indicator for the diagnosis of the uremic stage. The serum sodium and chloride decreased gradually after an artificial urethral obstruction. The potassium value increased just before moribundity. The inorganic phosphorus and calcium changed, but without a common pattern. In fatal obstruction cases (4 animals), there were significant changes in the leukocytes, erythrocytes and haematocrit values, especially after the rupture of the bladder. The elevation of the glucose values started immediately after the rupture of the bladder. All of the goats, in which the obstruction was not corrected, died or were euthanised. High serum potassium levels predispose the animals to cardiac abnormalities, in turn increasing the anaesthetic risk during surgery (MONOGHAN and BOY, 1990).

RADOSTITS et al. (2000) reported a high mortality in case of urethral obstruction, referring to field clinical cases.

The clinical signs described in literature (MONOGHAN and BOY, 1990; RADOSTITS et al., 2000; BEHRENS et al., 2001) as the first to appear in small ruminants' obstructive urolithiasis are dysuria (abdominal pain and painful urination) and stranguria (difficult and slow urination). Abdominal pain from urethral obstruction or distension of the bladder is then manifested by tail-switching, kicking at the belly, stamping of the feet, and repeated straining efforts to urinate accompanied by vocalization. Sudden depression, inappetence, decrease of the rumen movements, increase of the respiratory and pulse rate, muscular weakness and tremor follow the uremic state that settles due to the urinary stasis. Blood or crystals may be observed on preputial hair (VAN METRE et al., 1996).

OEHME and TILLMANN wrote in 1965 that ascending urinary tract infection was the most common sequela to urolithiasis, but recent papers show it is not a common concurrent finding in ruminants, although prolonged partial urethral obstruction may increase the risk of concurrent infection (VAN METRE, 2004).
2.2. Diagnosis of Urolithiasis

The diagnosis of urolithiasis is based on a complete anamnesis and physical examination, and may be complemented by laboratory tests (of blood and urine), ultrasonography and radiography of the urinary tract (MONOGHAN and BOY, 1990; RADOSTITS et al., 2000).

Physical Examination
After observation, a thorough physical examination of the urinary tract, including palpation of the urethral process and perineum — in the area of the sigmoid flexure —, has major importance in order to detect the presence of stones. Palpation of the abdomen is also primordial to examine the status of the bladder (KASARI, 2000; BAUMGARTNER, 2005). A differential diagnosis must be done between digestive causes of anorexia, and abdominal pain. Bowel obstruction and acute indigestion must be considered, due to the decreased or absent faeces. Subcutaneous abscesses, umbilical abscesses, umbilical or ventral hernias, hematoma of the penis, and injury or infection of the prepuce may assemble to the urine leakage and accumulation in the subcutaneous tissue. Dysuria and stranguria also occur in cases of cystitis and urethritis (MONOGHAN and BOY, 1990). Uremic ulcers can be found in the oral mucosa (DÜHLMIEIER et al., 2007).

Laboratory tests
Blood analyses may show possible metabolic disturbances during obstructive urolithiasis. BICKHARDT et al. (1995) studied the pathological alterations in cases of nephropathy, as well as urolithiasis in small ruminants. Proteinuria, glycosuria, excessive potassium excretion and often hypokalaemia, and hyperkalaemia in the final state of urolithiasis were findings encountered in 16 rams and 11 billy goats. Ruminants with acute urethral obstruction (< 24 hours) typically show haemoconcentration secondary to dehydration and mild-to-moderate prerenal and postrenal azotaemia. If present, disturbances in the acid-base balance and serum electrolytes are usually mild in these animals. After rupture of urinary bladder or urethra, haemoconcentration and azotaemia are more severe (VAN METRE, 2004). Hyponatraemia and hypochloraemia are consistent derangements, but hypocalcaemia and hyperkalaemia are inconstant findings and less easily predicted in ruminants (TSUCHIYA and SATO, 1990; VAN METRE and FUBINI, 2006). In 2007 GEORGE et al. reported a retrospective study of 107 goats with uroliths that showed high prevalences of uraemia (70% of the animals), hypercreatininaemia (80%), hyperglycaemia (90%), hyperkalaemia (17%), hypochloridaemia (44%), hypocalcaemia,
(51%) hypophosphataemia (67%), and hyponatraemia (12%) in animals with ruptured bladder.

Ultrasonography
In sheep and goats, determining the presence of free fluid within the abdomen, as well as visualising the bladder by abdominal ultrasound, may be useful for the diagnosis and prognosis of this disease (MONOGHAN and BOY, 1990).

SCHEFER (1991) reported the ultrasonographic examination of the urinary tract in ewes. BRAUN et al. (1992) studied by use of ultrasonography, the position, dimensions, and structure of the kidneys, ureters, bladder, and urethra in 20 healthy, adult male White Alpine sheep, in order to determine the normal sonographic appearance of the urinary tract. All kidneys could be visualised, but the course of the ureters not. The bladders had hypoechogenic content, the wall was uniform in thickness and smoothly demarcated inside and out, and its mean diameter bladder was 7.5 cm. The internal urethral region of the urethra could be visualised in 90% of the animals and presented mean diameter of 0.2 cm. The authors also examined 7 rams with obstructive urolithiasis to compare the findings with those in the healthy animals. The ultrasonographic examination in sick patients revealed a markedly dilated urethra, in its proximal part. The urinary bladder was also dilated and showed multiple, tiny, uniformly distributed echoes observed mainly in the ventral part of the lumen. In four patients, the renal pelves and medullary pyramids were dilated due to urinary stasis. In one ram, the right kidney was markedly enlarged and the ureter was ruptured in the region of the left renal hilus, resulting in fluid accumulation in the retroperitoneal space and in the abdominal cavity (sonographically visible). Only one urolith was visualized by ultrasonography, appearing hyperechoic with an acoustic shadow.

HALLAND et al. (2002) also examined the caudal abdomen of 16 goats with dysuria by ultrasonography. Diagnostic images showed distended bladders with diameters ranging between 4 and 15 cm (mean, 7 cm) in small breed animals and 8 to 12 cm (mean, 9.5 cm) in large breed animals.

Radiography
The radiographic image of the small ruminants' abdomen is not described in literature. Examination by use of X-Rays allows the visualization of uroliths composed by calcium carbonate and struvite, but not of calcium phosphate and silicate stones (HALLAND et al., 2002).
Survey radiographs are not a good method to diagnose urethral calculi in small ruminants, according to PALMER et al. (1998). The authors could only make the diagnosis in one of 35 patients. In addition, PECHMANN (1995) reported that this procedure may also yield falsely negative results for urethral disease.

A complementary method for the diagnosis and also management of urolithiasis is the contrast retrograde urethrography, reported for the first time in small ruminants by VAN WEEREN et al. (1987). The authors described a technique for catheterisation of the bladder in these species, with a pre-curved catheter (after the amputation of the urethral process), which made the examination by contrast retrograde cysto-urethrography of the low urinary tract of sheep and goats possible. When a calculus was present in the urethra, the catheterisation of the bladder was performed following urethrostomy. In their study, one normal goat and three goats with dysuria were used. In the normal animal, the retrograde cystogram demonstrated the usual position of the bladder and the smooth contours of the bladder wall. One of the three patients showed a round filling defect in the contrast medium, suggesting a large calculus. In the other two animals, granular filling defects indicated the presence of small uroliths and/or blood clots. Two of the three patients showed wall irregularities, in the urethrogram, suggesting disruption of the urethral mucosa. The results satisfied the authors and predicted a new help in the choice of therapy.

TODHUNTER et al. (1996) used contrast radiography to help in the diagnosis of obstruction of the blood flow through the corpus cavernosum penis caused by fibrosis, as a sequela to obstructive urolithiasis, leading to erection failure in a male goat. The images showed normal filling of the cavernous spaces of the corpus cavernosum penis distal to the bend of the sigmoid flexure, but not proximal to it. Additionally, leakage of contrast media at the injection site was evident outside the tunica albuginea.

PALMER et al. (1998) reported that cystourethrocgraphy is not a routine technique, nowadays, due to the cost of the procedure(s), the demand of good radiologic facilities and also due to difficulties in catheterisation by retrograde way (HINKLE et al., 1978). Therefore, the authors performed this technique via tube cystotomy (by normograde way), concluding that it was the most valuable method to monitor the urethral patency, evaluate the location and extent of urethral obstruction, or in the diagnosis of urethral laceration, against the inability to adequately visualise the low urinary tract by excretory urography (CEGARRA and LEWIS, 1977; SINGH et al., 1983).
Urethroscopy

Urethroscopy with a flexible endoscope was described in 16 goats by HALLAND et al. (2002) for the diagnosis of obstructive urolithiasis after other imaging diagnostic methods. It was performed under general anaesthesia, after urethral process amputation. There were found problems during the procedure due to friction of the fibroscope in the urethra (damaging some optical fibers) and the limited capacity of the light, not allowing the visualisation of the pelvic urethra in most patients. When circumferential necrosis of urethral mucosa was observed, a poor prognosis was established because of subsequent postoperative urethral stricture.
2.3. Treatments

2.3.1. Conservative

Conservative medical treatments of urolithiasis in small ruminants may be attempted in early stages of the disease; they are administration of antispasmodic agents, medical dissolution, fluid therapy, cystocentesis, and retrograde catheterization with flushing (MONOGHAN and BOY, 1990; VAN METRE et al., 1994; RAKESTRAW et al., 1995; RADOSTITS et al., 2000).

Administration of Antispasmodic Agents

Administration of antispasmodic agents, such as promazine or acepromazine (derivatives from phenothiazine) or butylscopolamine, aims to promote calculus passage reducing the urethral smooth muscle spasm and relaxing the retractor penis muscle (MURRAY, 1985; KÜMPER, 1994; VAN METRE et al., 1996). OHEME and TILLMANN (1965) reported in steers a 73% recovery rate in selected cases, but some authors only recommended it as an association with surgical treatments and anti-inflammatory drugs to reduce urethral swelling (VAN METRE et al., 1991; RAKESTRAW et al., 1995).

Medical Dissolution

Medical dissolution is based in the acidification of the urine, through feeding diet. Acidification of the urine (pH < 7.0) increases the solubility of the salts of calcium phosphate and carbonate and ammonium magnesium phosphate (VAN METRE and DIVERS, 2002), and may result in dissolution of the uroliths. Noncalculogenic diets - containing low quantities of magnesium and high quantities of sodium (formulated to promote formation of acid urine) are very common in dogs and cats to dissolve struvite calculi, whereas stones composed mainly by calcium salts (phosphate or oxalate) are resistant to dissolution (OSBORNE et al., 1990; RINKARDT and HOUSTON, 2004).

In small ruminants alkaline urine is a normal finding, reason why addition of ammonium chloride to the diet acidifies the urine and helps to prevent the precipitation of struvite, and can be used as a preventive measure. CROOKSHANK (1970) reported that ammonium salts, such as ammonium chloride and ammonium sulphate reduce the total number of cases of urolithiasis (not mentioning the composition of the stones), but only ammonium chloride showed no clinical cases, when added in a level of 0.5% of the mixed diet.
STEWART et al. studied the effects of dietary ammonium chloride on silica urolithiasis. In 1990 the authors concluded supplemental ammonium chloride was ineffective in reducing the incidence of stones, if sheep were being fed a diet containing high level on calcium, but supplemental phosphorus reduced the incidence of silica uroliths. In 1991 the same authors continued the study and investigated the variations of the calcium to phosphorus ratio in silica urolithiasis, concluding that ammonium chloride had reduced significantly the incidence of stones, in a diet that seemed to affect less severely in the formation of calculi than in the previous study, and also that the addition of limestone to the diet - to increase the calcium in diet to 0.6% - had no influence in the formation of stones comparing to the control group.

This choice of treatment, although together with a surgical procedure, had good results in a case of a four-year-old ram suffering of obstructive urolithiasis reported by COCKCROFT (1993). The ram was given 10 g of ammonium chloride dissolved in 40 ml of water by mouth daily, and the bladder was infused, through a Foley catheter placed surgically, with 200 ml of a mixture of one part sodium acetate and acetic acid buffer adjust to pH 4.5 and 10 parts normal sterile saline, daily. The ram urinated 14 days after laparotomy and was doing well one month later.

STATTON-PHELPS and HOUSE (2004) studied the effect of a commercial anion dietary supplement on acid-base balance, urine volume, and urinary excretion in male goats fed oat or grass hay diets. The results showed that the anionic supplement used increases urine volume, alters urine ion concentrations, and is an efficacious urinary acidifier in goats.

Fluid Therapy
It is requested in some cases, to correct the electrolytes imbalance and normalize the metabolic status, and also to increase diuresis and dilution of urine, mainly before surgery (MONOGHAN and BOY, 1990; RADOSTITS et al., 2000).

Intravenous fluids consisting in half-strength normal saline with 5% dextrose are effective in reducing the serum potassium concentration and help somewhat in restoring sodium and chloride concentrations (MONOGHAN and BOY, 1990).

VAN METRE et al. (1996) prefer physiologic (0.9%) saline solution in animals with ruptured bladder, for correction of typical hyponatraemia and hypochloraemia.

Cystocentesis
Cystocentesis consists in the transabdominal collection of urine from the urinary bladder, under ultrasonographic control, usually with the animal in the lateral position. It may increase the patient's comfort and temporarily alleviate bladder distension in turn reducing the risk of
necrosis and rupture, but bladder leakage and subsequent uroperitoneum must be anticipated and managed. It may also be indicated while postponing surgery (VAN METRE, 2004).

Repetitive cystocentesis has been associated with peritonitis and vesicul-intestinal adhesions and is not recommended. RAKESTRAW et al. (1995) reported a foul-smelling abdominal fluid and multiple adhesions between the loops of the small intestine and between the small intestine and bladder in a goat suffering from obstructive urolithiasis that had a history of repeated cystocentesis.

**Retrograde Catheterization with Flushing**

Catheterisation of small ruminants is known to be a difficult technique due to the entrance of the catheter in the urethral recess (HINKLE et al., 1978).

The potential complications of the catheter passage and urohydropulsion include traumatic urethritis and urethral rupture (VAN METRE, 2004). Attempts at retrograde catheterisation with flushing (attempted prior to surgery for tube cystotomy) have highly unsuccessful rates to either partially or completely relieve the obstruction (RAKESTRAW et al., 1995).
2.3.2. Minimal Invasive

The minimal invasive techniques that are described to treat urolithiasis are urethroscopy and laser disruption, as well as percutaneous tube cystotomy.

**Urethroscopy and Laser Disruption**

HALLAND et al. (2002) attempted laser lithotripsy in 3 goats, with a holmium:yttrium-aluminum-garnet laser (Ho:YAG), after attempting urethroscopy in 16 animals, which turned out to be impossible in some patients and damaged the equipment. The calculi were disrupted in the 3 goats, with some difficulties, namely the firm lodgement of the calculi in the distal urethra, or the movement of the non-fixed calculi.

**Percutaneous Tube Cystotomy**

Tube cystotomy performed percutaneously consists in the implantation of a suprapubic urinary catheter, as a way for the diversion of urine from the urethra, by allowing time for the urethritis to subside, and the urinary calculi to dissolve (in response to medical management) and pass. It is performed in the sedated animal, in lateral recumbency, advisably under ultrasonographic guidance (HALLAND et al., 2002; STREETER et al., 2002). Even when assisted by ultrasonographic guidance, it has high risks of visceral perforation and catheter dislodgment (STREETER et al., 2002).

This technique has been associated with a significantly increased requirement and decreased time to a second intervention, in a retrospective study of 45 male goats with obstructive urolithiasis, from FORTIER et al. (2004). The authors found the occurrence of tube displacement in 5 patients, persistent obstructive urolithiasis in 2, recurrence of obstructive urolithiasis in 1, and urethral rupture in 2 animals.
2.3.3. Surgical

Surgical treatments are often the only solution to save the patient's life, especially when a urethral obstruction is complete. The choice of the appropriate surgical technique depends on the value and future use of the animal, location of the obstruction, and the respective integrity of the urethra and bladder (RAKESTRAW et al., 1995).

The surgical techniques used are the amputation of the urethral process (VAN METRE, 2004), penile amputation, perineal urethrostomy (VAN WEEREN et al., 1987), urinary bladder marsupialisation (MAY et al., 1998) and surgical tube cystotomy (RAKESTRAW et al., 1995).

Amputation of the Urethral Process
It is a simple, inexpensive and quick technique. After exteriorisation of the glans penis the urethral process is removed with scissors or scalpel blade at its base (VAN METRE, 2004). It has good short-term results, although a low rate of long-term success due to the high probability of reobstruction, reason why is indicated only for animals intended for slaughter (HAVEN et al., 1993).

In VAN METRE and SMITH (1991) this procedure resolved obstruction in two-thirds of the treated animals, but recurrence was not uncommon. It has no adverse effect on breeding ability or fertility (VAN METRE et al., 1996).

OEHME and TILLMANN (1965) classified this method as a conservative treatment of urolithiasis due to the large numbers of calculi lodging in this part of the urethra and the simplicity of the process.

Penile Amputation
Penile amputation is a simply, inexpensive, salvage procedure used in animals intended for slaughter, performed under lumbosacral epidural anaesthesia. When it is the chosen method of treatment, it should be carried out as soon as possible, and the animal slaughtered in the following 4 weeks (OEHME and TILLMANN, 1965; VAN METRE et al., 1996). Urethral fistulisation and removal of the distal part of the penis are optional measures. It is not a common choice of treatment in small ruminants mostly to the complications associated, namely, trauma to the penile stump with the tail, urine scald of the perineum, and occlusion of the urethral opening by blood clots (VAN METRE et al., 1996).
OHEME and TILLMANN (1965) had success in 93% and 95% of the steers treated, with and without urethral rupture, respectively. GASTHUYS et al. (1993) reviewed 52 cases of bull calves with urethral rupture and reported a success rate of 38.5% treated by this technique.

**Urethrostomy**

It consists in the incision of the urethra at any site along the perineum, but wherein some authors prefer to place it low in the perineum (perineal urethrostomy) to minimise the urine scalding of the skin and to allow for upper incisions if an obstruction of the fistula occurs (VAN METRE et al., 1996).

The interruption of passage of sperm confirms a null prognosis for breeding, since it does not reach the penis. A reobstruction rate of 45% within 8 months of surgery and a 1-year survival rate of 17% have been reported in small ruminants, after the performance of this technique, due to additional calculi or stricture of the urethrostomy site (VAN WEEREN et al., 1987; VAN METRE et al., 1996). Some authors agree that ruminants should not be kept more than 3 to 4 months after urethrostomy, reasoning that the long-term prognosis is poor due to reobstruction, qualifying this technique as non-indicated for animals that are kept as pets (OEHME and TILLMANN, 1965; VAN WEEREN et al., 1996).

According to VAN WEEREN et al. (1987) and VAN METRE and SMITH (1991), urethral obstruction recurs in 58 to 78% of sheep and goats following perineal urethrostomy, often within several months after surgery.

For HAVEN et al. (1993) it became apparent that most of the postoperative complications that were encountered were associated with perineal urethrostomy, once it was that ten in 13 animals (77%) in their study matched this association. Therefore, the authors replaced this technique with another in their surgical protocol.

Once stricture has developed in those animals that have undergone this procedure, the subsequent surgical options are limited (RAKESTRAW et al., 1995).

STONE et al. (1997) reported a prepubic urethrostomy for the relief of a urethral obstruction in a sheep and goat, secondary to perineal urethrostomy, with no satisfactory results; the sheep developed renal failure presumably from pyelonephritis and the goat had a recurrence of the obstruction and was, therefore, euthanised.

GILL et al. (2004) described a buccal mucosal graft urethroplasty for the resolution of a urethral stricture secondary to perineal urethrostomy in a goat wether, with the successful result of normal urination for at least 24 months after the surgery.

Perineal urethrostomy can be associated with laser lithotripsy and normograde flushing, such as in the case reported by STREEFTER et al. (2001), in which a steer suffering from urethral obstruction was treated and showed a good long-term outcome.
尿道膀胱会阴移植

这是一种简单的技术，需要很少的外科器械，住院时间较短，治疗时间较短，术后护理需求减少，并发症较少，与造口术和管状造口术（MAY等，1998）相比。

这与膀胱脱垂在造口部位（在19只动物中），尿液在皮肤附近引起的轻微损伤和尿液气味（在所有动物中），造口部位狭窄（在19只动物中，由MAY等（1998）报告），以及在6只动物中由MAY等（2002）报告的膀胱炎的同样发生率有关。

它也可能提供最好的临床结果在尿道破裂或已进行多次手术的动物，但应谨慎推荐作为主要的外科干预措施在第一次尿道流出梗阻（FORTIER等，2004）。

外科管状造口术

管状造口术可经腹腔造口管流出尿液，作为尿道炎症的缓解，尿路结石在某些情况下（响应于医学管理）消失，并通过（RAKESTRAW等，1995）。RAKESTRAW等（1995）使用了Foley导管或蘑菇导管，成功地解决了15只治疗动物中的12只（80%）和60%的长期成功率（动物存活且没有复发）由随访信息证明。

HAVEN等（1993）表明，8只动物在造口术后的随访（几个月后），表明造口术加上适当的饮食管理是一个更有效的长期解决方案。

ISELIN等（2001）回顾了17只小反刍动物的病历，结论是，外科管状造口术相比造口术无管通入增加了短期生存率，并有有利于长期的结局在那些患有尿路结石的患者。

PEARCE等（2003）描述了一只山羊的病例，尿道梗阻和尿路结石在管状造口术，使用Foley导管。5天后动物出院，在6周后尿道通畅，7周后手术后，导管被移除。10个月后，患者尿道正常，每天补充氯化铵。

这被一些作者作为尿道梗阻的初始治疗（PALMER等，1998）。
Complications of tube cystotomy include the failure to resolve urethral obstruction, peritonitis, adhesions, urethral rupture, catheter dislodgment, and occlusion of the catheter with blood or calculi, including sand-like deposits or sludge (RAKESTRAW et al., 1995; FORTIER et al., 2004; VAN METRE et al., 2006).

Potential disadvantages of the tube cystotomy technique include lengthy and costly hospitalisation from the time of the catheter placement to discharge, and/or potential urethral or bladder rupture if the catheter is occluded too soon following surgery or for excessively prolonged periods of time (PALMER et al., 1998).

In a retrospective study in order to evaluate the outcome of surgical tube cystotomy in small ruminants, EWOLDT et al. (2006) revealed that the success rate of tube cystotomy is 76%, although 90% of the patients were discharged from the hospital. Less than 20% had a recurrence after 6 to 12 months. The prognosis and long-term survival after cystotomy without urethral flushing was, in this study, good (up to seven years); better for goats than for sheep.

Additional combination of retrograde with normograde flushing had successful results in surgery, followed by the placement of a temporary indwelling urethral catheter (VAN METRE and SMITH, 1991).

Normograde flushing alone, through the cystotomy site in order to relieve the obstruction obtained unsuccessful results and may predispose the animals to the rupture of the urethra (RAKESTRAW et al., 1995).
Laparoscopic-Assisted Tube Cystotomy

FRANZ et al. (2008) performed an experimental study by using laparoscopy to combine the advantages of both percutaneous and surgical tube cystotomy. The authors placed a urinary catheter with minimal invasiveness under direct visualisation. The six animals were placed in dorsal recumbency, in the Trendelenburg position, at an angle of 20° (head down). The laparoscope portal was located in the right paramedian area at a point midway between the umbilicus and the preputial orifice. After the creation of the CO₂ pneumoperitoneum, until a constant intraabdominal pressure of 13 mmHg was reached, an instrumental portal was created in the left paramedian area in the region of the teats. The bladder was grasped by the forceps, while a pigtail catheter was introduced percutaneously in the ventral region of the urinary bladder, under laparoscopic control. The catheter was fixed in the bladder by filling the balloon, and in the abdominal external wall by means of a Chinese fingertrap suture. A daily control of the physical parameters and urine was carried out for two weeks, and on the fourteenth day after surgery (4 days after the removal of the urinary catheter), a second laparoscopy was performed in each animal for the inspection of the abdominal cavity. The results showed no complications related to the implantation of the catheter during surgery; no major alterations in the animals' health status besides for a significant increase in the polymorphonuclear neutrophils and a significant decrease in the lymphocytes values, after surgery; and no signs of inflammation or adhesions among the organs, in the second laparoscopy.

Afterwards, FRANZ et al. (2009) attempted to perform, in dorsally positioned healthy male sheep, a laparoscopic-assisted cystostomy (opening of the bladder) followed by the implantation of a urinary catheter (tube cystotomy) under laparoscopic visualisation, in which the combination of the two techniques led to good results.
2.4. Laparoscopy

2.4.1. History of Laparoscopy

The History of laparoscopy is well documented by NAKAJIMA et al. (2006). It was a response to the curiosity to observe directly the interior of the living bodies. Light instruments were invented to fulfil illumination problems in the body cavities, like the 'Lichtleiter' by BOZZINI (1806) which had a system of tubes and mirrors reflecting a candle light, and seven decades after the cystoscope by NITZE, using electricity and a continuous stream of water as cooling system.

Laparoscopy was first attempted with oxygen filtered through sterile cotton and a cystoscope in the peritoneal cavity of live dogs (KELLING, 1901). JACOBEUS (1911) examined the abdomen and the thorax of humans, describing hepatic diseases (cirrhosis, tuberculosis, metastatic tumors, and syphilis), gastric cancer, and 'chronic peritonitis'. From here on several reports started to appear. BERNHEIM (1911) reported an 'Organoscopy' using an ordinary proctoscope or cystoscope, with illumination from an electric headlight. The instruments were improved by GOETZE (1918) who developed the first automatic spring-loaded needle to insufflate oxygen in the abdomen and declared artificial pneumoperitoneum was not harmful or dangerous, and by ORNDOFF (1920) who created the sharp pyramidal trocar to facilitate trocar insertion into the abdomen, currently still in use. After oxygen, air usage was described by STONE (1924) in two reports about 'peritoneoscopy' in dogs, using a nasopharyngoscope, claiming that 'the procedure could provide the way to an exact diagnosis without doing laparotomy'. STEINER in the same year described Abdominoscopy, 'a new method of examining the organs of the abdominal cavity'. Ignoring or unaware of the previous publications, this author performed an 'innovator' technique using a cystoscope, trocar, and oxygen to insufflate the abdomen.

Carbon dioxide insufflation was for the first time described by ZOLLIKOFER (1924) laparoscopy with, and many others followed. SHORT (1925) reported his experience with 'coelioscopy', as an advantage over exploratory laparotomy, because 'it can be done at the patient's own house' and it is 'principally valuable for what is definitely seen and not for what is apparently absent'. In 1925 the first review of the 'endoscopy of the abdomen' technique and instruments was published by NADEAU and KAMPMEIER, with 42 references and experimental study in only three patients. The authors claimed the procedure as a simple and relatively less demanding technique relating to instrumentation. Improvement of the instruments continued with innovations such as an oblique scope (45°) and dual puncture technique (KALK, 1929) which open the way to operative laparoscopic procedures; a modified spring-loaded needle that increased safety in the creation of pneumoperitoneum (VERESS, 1938); a rod-shaped lens to improve the resolution and
contrast of the telescopes and increase the illumination (HOPKINS, 1953), a principle still used in our days; and a controlled, automatic CO₂ insufflator (SEMM, 1967).

In 1933, FEVERS performed the first therapeutic laparoscopic procedure - lysis of adhesions. The first incidental laparoscopic appendectomy is credited to SEMM in 1981, and the first laparoscopic cholecystectomy in humans to MÜHE (1985).

BERCI (1987) introduced the computer chip TV camera to the world and, one year later, MOURET performed the first videolaparoscopic cholecystectomy. In 1991, JACOBS followed with the first colectomy.

In 1987, laparoscopy was described in 52 human patients by RAATZ, using artificial ascites, meaning 2 to 3 l of physiologic saline. No complications were reported and, according to the author, laparoscopy with artificial ascites provided a higher diagnostic yield than with a pneumoperitoneum, since water has a greater specific gravity than gases and allows the separation of the air-containing loops of bowel or the stomach from neighbouring organs. But the technique never gained many followers, and pneumoperitoneum continued to be the favourite way to perform laparoscopy.
2.4.2. Advantages of Laparoscopy

Nowadays, thousands of laparoscopies are performed every year around the world, since laparoscopy has had a great expansion in human medicine in the last century and more recently in veterinary medicine. The main advantage is reduced tissue trauma (minimal invasive), which allows for faster recovery (Cuschieri, 1999). Several studies show more advantages from the laparoscopic technique versus laparotomy, namely less formation of adhesions between the intestinal loops after the exploration of the intestine (Tittel et al., 1994), stimulation of the immune system instead of immunosuppression (Vittimberga et al., 1996; Szabó et al. (2007), low incidence of infectious complications (Lacy et al., 1997), better cardiovascular situation (Hahn et al., 1997), and lower pain scores (Davidson et al., 2004).

2.4.3. Laparoscopy in Veterinary Medicine

2.4.3.1. Horses

The first published reports of 'peritoneoscopy' in animals came from Witherspoon and Talbot (1970), related to an exploratory laparoscopy as a gynaecologist tool to observe the ovaries in the mare.

Some years later, the laparoscopic anatomy of the abdomen was described in standing horses by Fisher et al. (1986), in the dorsally recumbent animal by Galuppo et al. (1996), and in foals positioned in dorsal recumbency by Bouré et al. (1997).

Nowadays, the endoscopic surgery of the abdomen is a common procedure in horses. Laparoscopic colopexy can be successfully performed with minimal abdominal invasion (Trostle et al., 1998), as well as mesenteric rent repair (Sutter and Hardy, 2004), nephroshpentic space closure in standing horses (Marién et al., 2001; Rocken et al., 2005), adhesiolysis (Boure et al., 2002; Lansdowne et al., 2004), and inguinal hernia repair (Fisher et al., 1995; Rossignol et al., 2007).

An experimental study performed by Fisher (1999) described a technique for laparoscopic-assisted resection of the umbilical structures in foals in the dorsal position.

Laparoscopic surgery has become commonplace in the field of equine urogenital surgery (Hendrickson, 2006). Nephrectomy (Keoughan et al., 2003; Rocken et al., 2007), ovariecotomy (Hanson and Galuppo, 1999), ovariohysterectomy (Delling et al., 2004), removal of ovarian tumours (Rodgerson et al., 2002), cryptorchidectomy (Davis, 1997;
HENDRICKON and WILSON, 1997; RAGLE et al., 1998) are all procedures that can be performed with minimal invasive surgery.

Related specifically to the urinary system, EDWARDS et al. (1995) reported a case of the diagnosis of a bladder rupture and surgical treatment by using laparoscopy with good results, WALESBY et al. (2002) repaired laparoscopically a ruptured urinary bladder in a stallion that was discharged from the hospital 5 days after surgery and showed no signs of urological disease in the subsequent 2 years; and laparoscopic-assisted cystostomy and urolith removal in geldings with cystic calculi were described by RAGLE (2002) and reported by RÖCKEN et al. (2006) along with no complications and a good long-term outcome in all the animals.

2.4.3.2. Small Animals
Laparoscopic techniques in canine and feline patients have been performed for minimal invasive evaluation, with or without biopsy, of several organs, including the kidneys (GRAUER et al., 1983), liver (JONES et al., 1985), bowel (PHILLIPS et al., 1994), genitourinary tract (RICHTER, 2001), and pancreas (WEBB and TROTT, 2008). Furthermore, hernia repair is possible with minimal invasive surgery (THOMPSON and HENDRICKSON, 1999), as well as several procedures in the gastrointestinal system (FREEMAN et al., 1999), thorax (POTTER and HENDRICSON, 1999), haemolymphatic system (FREEMAN and POTTER, 1999), reproductive system (FREEMAN and HENDRICKSON, 1999), joints (MCCARTHY, 1999), and urinary system (RUDD and HENDRICKSON, 1999).

Minimal invasive surgery of the bladder in dogs is described for the resection of inflammatory polyps in two case-reports (RAWLINGS, 2007), for laparoscopic-assisted cystopexy in eighteen animals (RAWLINGS et al., 2002), and for laparoscopic-assisted cystoscopy for the removal of calculi in three animals (RAWLINGS et al., 2003), which were all performed with good results.
2.4.3.3. Birds and Reptiles

BUSH et al. (1978) adapted the technique of laparoscopy and utilized it in zoological medicine for various mammals, birds, and reptiles for reproductive and diagnostic studies as well as clinically related research. The authors concluded that since anaesthesia was routinely required for most manipulative procedures in zoo animals, and since laparoscopy adds little additional risk, the use of this technique provides an additional diagnostic aid when indicated. Laparoscopy was found to be effective for evaluating reproductive status, particularly ovarian anatomy and function, direct visual biopsy of internal organs, sex determination in selected birds, and as a surgical means of fertility control.

In birds, laparoscopy (celoscopy) is performed with the animals positioned in right lateral recumbency, without the creation of pneumoperitoneum. Therefore, the risks are minimized and laparoscopic examination may be a routine procedure used in exotic patients, in many clinics and hospitals (SAMOUR, 2000).

In reptiles, laparoscopy is described to be a valid, minimally invasive, diagnostic tool when abdominal disease is suspected, proved to be beneficial to perform secure biopsies of altered organs, and permit the determination of the sex of monomorphic species independent from species, size and reproductive stage (SCHILDMER et al., 1991; SCHILDMER, 1999).

2.4.3.4. Pigs

Many laparoscopic procedures have been performed in swine for human medicine, considered as an excellent model for surgery practice (SRINIVASAN et al., 1999), but few studies are reported for veterinary medicine. Most of all are related to reproduction sciences. The technique for routine observation of the reproductive tract of gilts was described in the 70's (DUKELow and ARIGA, 1976; PATERSON and OLDHAM, 1978). WILDT et al. (1973) observed directly the ovaries in the pig by mean of laparoscopy and two years later described the performance of laparoscopic pregnancy diagnosis and uterine fluid recovery in swine (WILDT et al., 1975). In the last two decades, laparoscopy has been used in swine to improve artificial insemination techniques (MORCOM and DUKELOW, 1980; FANTINATI et al., 2005) and to perform embryo transfer (HAZELEGGER and KEMP, 2001; HUANG et al., 2002) and recovery (RÄTKY and BRÜSSOW, 1995). Recently, TANTASUPARUK et al. (2005) studied the relationships between the ovulation rate and the number of total piglets born in purebred gilts under tropical climatic conditions. Laparoscopy continues to be a very costly procedure for the swine industry and, therefore, not used in large scale.
2.4.3.5. Llamas

In llamas, laparoscopy was applied in order to study the anatomy of the abdomen in sternal recumbency (YARBROUGH, 1995) and in three different laparoscopic surgical approaches - left paralumbar, ventral midline and right paralumbar (ANDERSON et al., 1996).

Unilateral cryptorchidectomy in this species is reported in a case by ZULAUF et al. (2002).

2.4.3.6. Ruminants

Laparoscopy in ruminants started to be a complementary diagnostic tool, when WISHART and SNOWBALL (1973) observed the ovary of the cow in situ, and NAOI et al. (1985) described the method to biopsy the kidney in bovine species; however it is steadily increasing as a therapeutic resource.

Diagnostic laparoscopy can be performed in the standing cow and sheep, where the normal laparoscopic abdominal anatomy is already described from the right and left paralumbar fossa (ANDERSON et al., 1993; LEBER, 2001), as well as in dorsal recumbent calves, from a cranioventral midline approach, as described by FUHRMANN (1991). It has also good indications for patients with the suspicion of an abdominal disease (FRANZ, 1998) or to exclude such diagnoses and biopsy internal organs such as the spleen (FRANZ et al., 2002).

In 2002, KLEIN et al. described a method to biopsy the small intestine of calves and sheep, under laparoscopic control. In 8 of the 9 cadavers, it was possible to perform the biopsy. In 4 (all sheep) of the 14 animals, it was impossible to carry out the sampling.

FRANZ et al. (2006) studied two different techniques for ruminoscopy in nine calves, concluding that the ruminoscopy via a ruminal fistula was well tolerated by all the animals, enabling direct visualisation and the evaluation of the mucosa and contractions of the rumen and reticulum. The ruminoscopy via the oral approach could not be performed in three non-cooperative calves, but guaranteed the good visualisation of the caudal rumen, none from the reticular groove and inconstant visualisation of the reticulum, with the advantage of being less invasive than the previous technique.

Laparoscopy is also used for therapeutic reasons in ruminants. Laparoscopic-guided abomasopexy was used as a method for the reposition and fixation of the abomasum after displacement (JANOWITZ, 1998) and then was studied in comparison to omentopexy via the right flank laparotomy in dairy cows (SEEGER et al., 2006; ROY et al., 2008).

Ovariectomies can be performed by laparoscopy with the cow in the standing position, via the left flank approach with minimal invasion and optimal visualisation (BLEUL et al., 2005). Experimental laparoscopic intervention in umbilical structures, in calves dorsally positioned, was attempted by BOURÉ et al. (2001), where the apex of the bladder and umbilical
structures were resected by the use of an endoscopic suturing device. BOURÉ et al. (2005) then compared two laparoscopic suture patterns for the repair of experimentally ruptured urinary bladders in normal neonatal calves.

In ovine species, rather few works are described regarding to laparoscopy, in which some are experimental studies for human surgery. The diagnosis of ovulation, pregnancy and estimation of the foetal numbers in sheep is possible by laparoscopy (PHILLIPPO et al., 1971; SNYDER and DUKelow, 1974), as well as follicle aspiration and the assistance of artificial insemination (DUKelow and ARIGA, 1976), and also successful recovery and transference of embryos (MCKELVEY et al., 1985). Liver biopsies can be performed under laparoscopic visualisation with the advantage of enabling the direct visualisation of the liver and the removal of much larger samples from specific areas, and the disadvantage of being more expensive, along with limited repetitions (HUMANN et al., 1999).

In 1996, DREyFUS et al. studied the pregnant ewe as an animal model for foetoscopic surgery by using CO₂-insufflation at a pressure not mentioned. Afterwards, CRUZ et al. (1996), CURET et al. (1996) and CURET et al. (2001) used this type of model to describe the effects of CO₂- and He-insufflation in the mother and foetus.

EWOLDT et al. (2004) laparoscopically evaluated uterine trauma in sheep and the preventive effect of sodium carboxymethylcellulose in adhesion formation. The authors created, with success, laparoscopically uterine trauma by the laparoscopic method, in which laparoscopy was an excellent method for the serial evaluation of adhesion formation.

STAFFORD et al. (2006) studied the stress caused by laparoscopy in sheep and its respective alleviation, concluding that laparoscopy, even after sedation with acepromazine, caused some distress in ewes, as evidenced by increased plasma cortisol levels.

Recently, a surgical technique for laparoscopic-assisted implantation of a prepubic-urinary catheter (FRANZ et al., 2008), as well as a laparoscopic performed cystostomy followed by catheter implantation (FRANZ et al., 2009) were developed with successful results, as well as no pathological findings in the abdominal cavity in a laparoscopic control, 14 days after surgery.
2.5. Laparoscopic Technique

Pneumoperitoneum
Pneumoperitoneum is a requirement in most laparoscopic procedures in mammals. It consists in the insufflation of the peritoneal cavity with gas, so that the abdominal wall separates from the viscera, allowing for the visualisation of the abdominal cavity and the insertion of laparoscopic instruments for organ manipulation.

The gases that are used for insufflation include carbon dioxide (CO₂), air, oxygen, nitrous oxide (N₂O), argon, helium and mixtures of these gases. Nowadays, CO₂ is the safest gas for insufflation, which is preferred over the others, with a few exceptional cases. It does not support combustion, which permits electrosurgery, and it is highly blood-soluble, is expired in the lungs, which gives a wider margin of safety regarding gas emboli when gas passes through the peritoneum to the blood and, furthermore, it is inexpensive and easy to acquire (CUSCHIERI, 1999).

The creation of the pneumoperitoneum can be performed through a Veress needle before trocarisation (BRIDGEWATER and MOUTON, 1999), directly through the trocar, or by an "open" laparoscopy, which was introduced by HASSON (1971) that consists in making a small incision in the skin, abdominal muscles and peritoneum before inserting the trocar in order to avoid trocar injury to the underlying viscera and larger vascular structures.

RUMSTADT et al. (1996) compared the open laparoscopy and Veress needle techniques in 1,000 procedures, concluding that the mini-laparotomy is a safer and quicker way of obtaining pneumoperitoneum. More recently, ALTUN et al. (2007) made a comparison between direct trocar and Veress needle insertion in laparoscopic cholecystectomy. The authors concluded that the direct trocar insertion is going to be more popular, due to the less frequent complication observed.

Moreover, in veterinary medicine some complications with the use of the Veress needle have been reported by KLEIN et al. (2002), namely the perforation of the rumen resulting in the insufflation of this organ in a standing sheep and the perforation of the recessus supraomialis in a dorsally recumbent sheep.

A pressure of 8-12 mmHg was recommended in dogs (IVANKOVICH et al., 1975), and 10-12 mmHg recommended in llamas (LIN et al., 1997) in order to decrease the harmful effects described in the literature, when laparoscopy is performed with higher intra-abdominal pressures, and in patients with some cardiopulmonary compromise (WITTGEN et al., 1991). Concerning humans, SAFRAN and ORLANDO (1994) wrote that a constant intraabdominal pressure of 15 mmHg decreases the undesirable side effects.
2.5.1. Effects of CO₂ pneumoperitoneum

The effects of CO₂ pneumoperitoneum have been studied in human medicine in some detail. The cardiovascular effects of CO₂-insufflation started to be described by SMITH et al. (1970) in a study of 13 human patients, in which the authors found an increase of the heart rate and blood pressure on the order of 10% with insufflation, in addition to an increase of the central nervous and intrathoracic pressures, as well as some other alterations. Two years later, KELMAN et al. (1972) went further and reported, in horizontal patients (21 women), a slight increase of PaO₂, and progressive increases of PaCO₂, even after disufflation, as well as an increase of the heart rate and arterial blood pressures.

Soon studies started to appear comparing the influences of insufflation within CO₂ and N₂O. The cardiovascular effects of intraperitoneal insufflation with these two gases were studied by IVANKOVICH et al. (1975) in dogs ventilated with 100% oxygen. Increased arterial blood pressures, heart rate, PaCO₂, and decreased pH and PaO₂ were found in CO₂-insufflation at high pressures (> 20 mmHg). In N₂O-insufflation, the same haemodynamic changes occur, but PaO₂, PaCO₂ and pH suffered no significant variations.

In the study by EL-MINAWI et al. (1981), the authors used 50 human patients during diagnostic laparoscopy and compared the physiologic changes during CO₂ and N₂O pneumoperitoneum. The results showed a significant increase in PaCO₂ and a significant decrease in PaO₂, a significant decrease in pH, and no significant changes in the values of HCO₃ and base excess, in the CO₂-group. In the N₂O-group, changes in PaCO₂, PaO₂, pH, HCO₃ and the base excess were statistically insignificant. In both groups - CO₂ and N₂O - pneumoperitoneum led to a significant increase of the heart rate. In addition, CO₂-pneumoperitoneum induced a significant decrease in the serum chlorides but an insignificant increase in Na, as well as an insignificant decrease in potassium, while the N₂O-group did not show any significant change in serum electrolytes.

In the 1990s, carbon dioxide insufflation was recognised as a cause of adverse local and systemic effects, such as gas embolism, hypercapnia, acidosis, and arrhythmia (FELBER et al., 1992).

LUIZ et al. (1992) utilised 11 human patients undergoing laparoscopic cholecystectomy, with controlled ventilation, to study ventilatory alterations. The results showed a significant increase in mean arterial pressure from the beginning of insufflation, which lasted until the end of the procedure and an increase up to 38% of the respiratory, carbon dioxide output, 60 minutes after the onset of the pneumoperitoneum; therefore, the minute volume had to be increased by approximately 30-40% to maintain normocapnia.
Specific cardiovascular and neuroendocrine and metabolic effects were described by CUSCHIERI (1999), which consisted of a reduction in the cardiac output, increase in the systemic and pulmonary vascular resistance, preload, and diminished hepatic, splanchnic and renal flow, release of renin and aldosterone, sympathicomimetic response, and renal vasoconstriction.

The animals were by this time used as models in order to investigate the deleterious effects of laparoscopic insufflation.

In 1992, HO et al. performed a trial in eight adult pigs with a constant pressure of 15 mmHg of CO₂ pneumoperitoneum during laparoscopic cholecystectomy. The results revealed an increase of the PaCO₂ and a concomitant decrease of the arterial pH, as well as an increase of the heart rate and systemic and pulmonary pressures. The authors concluded that CO₂ insufflation resulted in significant transperitoneal CO₂ absorption, with secondary hypercapnia and acidaemia. The accumulation of CO₂ was also associated with an increase in systemic and pulmonary arterial pressure, and a compensatory tachycardia.

WILLIAMS and MURR (1993) used a dog model, in which the authors found a decrease of the mean cardiac output to less than 80% of the baseline, and a significant increase in the mean arterial PaCO₂ and mean peak airway pressure. Hyperkalaemia was associated with the prolonged insufflation of carbon dioxide into the peritoneal cavity in an experimental study with pigs (PEARSON and SANDER, 1994).

Furthermore, in the area of veterinary medicine, several experimental and clinical studies were conducted.

HAHN et al. (1997) utilised 32 pigs for experimental partial colon resections, 27 by laparoscopy and 6 by laparotomy, and studied the problems during laparoscopy by using CO₂ pneumoperitoneum or capnoperitoneum (CP). The results showed an increase of PaCO₂ and decrease of the pH in the first phases of CP. There were no significant changes in HCO₃⁻. The heart rate was elevated from the IV phase until the end of the trial.

In horses, some effects were also studied in standing (LATIMER et al., 2003) and recumbent animals (GALUPPO et al., 1996; DONALDSON et al., 1998; DUKE et al., 2002). DONALDSON et al. (1998) utilised six horses in order to measure the blood gas values, heart rate and mean arterial blood pressure, among other parameters, in which the authors observed significant increases of the PaCO₂ and mean arterial pressure, as well as significant decreases of PaO₂ and pH.
In small ruminants, the effects of pneumoperitoneum have not been clarified. There are some studies in pregnant ewes as experimental models in order to study the influences of abdominal insufflation in the pregnant patient and foetus.

CRUZ et al. (1996) utilised nine pregnant ewes in order to investigate the maternal heart rate, mean arterial pressure and blood gases, and foetus vital parameters. No significant differences were found between the insufflation and control groups regarding to the haemodynamic parameters. Maternal PaO₂ decreased significantly and PaCO₂ increased in the initial 60 minutes of the study, but not significantly. No changes were appreciable in either group with respect to the acid-base status.

CURET et al. (1996) also utilised these models and recorded the parameters from the mother/ewe (heart rate, blood pressure, blood gases, and others) and from the foetus. The authors found an increase of the maternal heart rate in the beginning of insufflation at 10 mmHg, and continuing on throughout the study. There was no significant difference in the maternal blood pressure between the groups, even after insufflation at 15 mmHg. PaCO₂ increased and pH decreased in those animals undergoing pneumoperitoneum after 30 minutes of insufflation at 10 mmHg.

CURET et al. (2001) studied the effects of helium pneumoperitoneum in pregnant ewes, compared to CO₂ pneumoperitoneum, since the second gas showed a risk of acidosis for the mother and foetus in the authors' previous study. The results showed that helium insufflation led to an increase of the maternal heart rate, but no significant changes in PaCO₂ and pH.

In conclusion, there is unanimity in the following effects being caused by capnoperitoneum in the horizontal position: increase of the arterial blood pressures, decrease of the cardiac output and increase of the heart rate, decrease of PaO₂, decrease of PaCO₂ and pH, in turn leading to an acidotic status.

2.5.2. Effects of Trendelenburg position

A surgical procedure in the caudal abdomen requires the placing of the animal in the Trendelenburg position, elevating the hindquarters to facilitate visualisation (RAGLE et al., 2000; WILSON, 2000).

KELMAN et al. (1972) studied the effects of the Trendelenburg position in 18 human patients that were positioned 25° head-down, in turn comparing them with 21 patients in the
The results showed an increase of the heart rate when the IAP was between 10 to 20 cmH₂O (=7-14 mmHg), in both groups, but then it decreased in the tilted group when the IAP was between 20 and 30 cmH₂O (=14-22 mmHg). The mean arterial blood pressure increased by some 10 mmHg at IAP up to 20-30 cmH₂O; it then declined as IAP was increased further. In a few patients, an increase of IAP above 40 cmH₂O was accompanied by some degree of arterial hypotension. There were slight increases of PaO₂ and PaCO₂ with higher IAPs in both groups. There was no change in the patients' non-respiratory acid-base state.

TAN et al. (1992) studied the carbon dioxide absorption and gas exchange in twelve young women positioned head-down. In three study periods, the heart rate, systolic and diastolic blood pressures, PaCO₂, PaO₂, pH and base excess, among other cardiovascular parameters, were measured. All these parameters remained stable, with no significant alterations, but with an increase of 30% in the CO₂ load due to CO₂ absorption from the peritoneal cavity, which was well tolerated by these patients in the Trendelenburg position.

In 1995, HIRVONEN et al. wanted to elucidate the separate effects of anaesthesia, head-down tilt and pneumoperitoneum. Twenty women undergoing laparoscopic hysterectomy were used for the measurement of cardiovascular parameters, in the horizontal and Trendelenburg positions. Among other changes, the Trendelenburg position in awake and anaesthetised patients increased the mean arterial pressure (MAP) at the beginning of the laparoscopy and decreased the cardiac output towards the end of the laparoscopy. The heart rate was quite stable throughout the laparoscopy. The risk of systemic CO₂-embolus was increased during the laparoscopy.

Concerning veterinary medicine, the author is aware of only two studies in horses and ponies, in which the cardiopulmonary, acid-base and blood gases variations were compared during the head-down position, with or without CO₂ pneumoperitoneum (GALUPPO et al., 1996; DUKE et al., 2002). GALUPPO et al. (1996), while reporting the laparoscopic anatomy of the horse, studied the effects of the capnoperitoneum and positional changes on the arterial blood pressure and blood gas values in six horses. The blood pressures tended to be high during the Trendelenburg position and low during the reverse Trendelenburg position. The position, but not the intraperitoneal CO₂ administration or abdominal pressure, significantly affected the values of the blood pressure variables. PaCO₂ increased and pH decreased significantly after the Trendelenburg positioning and CO₂ insufflation, when compared with horizontal.
PaO₂ decreased significantly with the Trendelenburg position but not with CO₂ insufflation. HCO₃⁻ and the base excess never altered.

In the study by DUKE et al. (2002), five halothane-anaesthetised ponies were placed in the horizontal position for 30 minutes, and then repositioned head-down at an angle of 30° for 60 minutes. There were found increases in the mean and systolic arterial pressure values after the Trendelenburg position during insufflation. The heart rate remained steady without significant alterations. A significant increase of the PaCO₂, as well as a decrease in the pH and PaO₂ after insufflation was noted. PaO₂ also decreased after the head-down position, without insufflation.

In summary, the effects of Trendelenburg in humans and horses have many times described in combination with CO₂ insufflation, in which these include the increase of the arterial blood pressures and the aggravation of the capnoperitoneum effects – increase of the PaCO₂ and decrease of the PaO₂. The effects of the Trendelenburg position are not described in ruminants.

2.3.3. Effects of Position of the Patient during Laparoscopic Surgery

The lateral position in the laparoscopic procedures was reported in human medicine by KUMIKO et al. (1998) for surgery related to nephrectomies and adrenalectomies. This study shows the cardiovascular and oxigenative effects of CO₂-insufflation intra and retroperitoneally, and also compares these effects between the right and left lateral positions, in a 70-80° semilateral position. The authors found different haemodynamic effects between the right and left lateral positions in patients undergoing laparoscopic urological surgery. Baseline mean arterial pressure and indices of preload were higher in the right compared with the left lateral position. In conclusion, the insufflation of CO₂ in the right lateral position increased both the cardiac output and venous return, and decreased the systemic vascular resistance. The extent of these changes was less in the left lateral position. Intraperitoneal insufflation of CO₂ with retroperitoneal exposure in the lateral position did not affect the pulmonary oxygenation in healthy patients.

LIN et al. (1997) worked in anaesthetised llamas to study the combined effects of CO₂-insufflation, with an intraabdominal pressure of 10-12 mmHg, on the gas exchange and acid-base status, combined with changes in the body position, during laparoscopy. Three animals (preliminary study group) underwent the protocol without insufflation, and six animals (experimental study group) with insufflation. The recumbencies changed from the right
lateral, dorsal to left lateral. In the preliminary study group, significant decreases in the systolic and mean arterial pressures and $\text{PaCO}_2$ and increases in $\text{PaO}_2$ and $\text{pH}$ were all observed when the llamas were turned from the right lateral to dorsal recumbency. The values for $\text{HCO}_3^-$ were lower than the postinduction values, but they remained unaffected by the changes in position. In the experimental study group, the values for mean arterial pressure were significantly lower when the llamas were placed in the dorsal and left lateral recumbency than those observed during right lateral recumbency. $\text{PaO}_2$ during right lateral recumbency decreased significantly, but returned to preinsufflation values when the llamas were placed in the dorsal recumbency, and even increased significantly after left lateral recumbency. The authors concluded that the insufflation of $\text{CO}_2$ and changing body position in turn induce minor and transient changes in cardiovascular and respiratory function in llamas.

There are no reports of laparoscopy in the left lateral position, regarding to ruminants, in the literature. Some characteristics of the anatomy of small ruminants make them different from other species, namely the great volume of the digestive compartments and the location of the rumen on the left side (MAY, 1970), hypothesizing that positioning the animal in left lateral recumbency may reduce the supposed negative consequences of laparoscopy, mainly in patients with systemic signs of urolithiasis.

Knowing that surgical tube cystotomy is a good choice for treatment of urolithiasis in small ruminants, with a possible combination with cystotomy for the removal of stones in the bladder, and that laparoscopy has advantages and disadvantages compared to laparotomy, the aims of this study are to access the feasibility of a laparoscopic-assisted cystotomy and laparoscopic-guided implantation of a urinary catheter in left lateral recumbent sheep, and to investigate and compare the effects in blood gas, acid-base status, and haemodynamic parameters, of the Trendelenburg position and $\text{CO}_2$ pneumoperitoneum between the dorsal and left lateral recumbencies in sheep.
3. MATERIALS AND METHODS

The conducting of this study was approved by the University of Veterinary Medicine of Vienna, with the license number 68.205/0052-11/10b/2008.

3.1. Materials

3.1.1. Animals

The pre-trial utilised 2 male sheep, one Tyrolean mountain sheep-cross and one Blackhead sheep-cross, 10 months old, 38.0 and 46.5 kg, respectively.

The trial was performed in 8 male sheep. The animals were unpremedicated, with no history of abdominal disease, and healthy according to the physical and haematological examinations. Seven were Tyrolean mountain sheep, and one was a Black mountain sheep-cross. The animals were approximately 10 months old, and weighed between 35.0 and 42.0 kg. After being divided into two groups, the mean body weight of one group (dorsal) was 37 ± 3.4 kg and from the other group (lateral) was 38.0 ± 2.4 kg (mean ± SD).

During the study, the sheep were kept indoors and fed hay with free access to water.

3.1.2. Surgeon

The surgeon was the author herself, with no previous experience in endoscopic surgery, in which she was assisted by an equally inexperienced colleague.
3.1.3. Laparoscopic equipment

To perform the laparoscopies, there were used:

- Laparoscopic trocars (JOHNSON & JOHNSON, Vienna, Austria):
  1. 12 mm diameter and 10 cm length (for the laparoscope);
  2. 5 mm diameter and 10 cm length (for the forceps);
- Atraumatic forceps to grasp the urinary bladder, 37 cm long, with a tip 3.5 cm long (KARL STORZ, Vienna, Austria);
- A straight laparoscope, 0°, with a length of 33 cm and diameter of 10 mm (KARL STORZ, Vienna, Austria);
- A xenon light source (KARL STORZ, Vienna, Austria);
- An automatic insufflator (KARL STORZ, Vienna, Austria).

3.1.4. Additional equipment

Documentation and monitoring were achieved with an anaesthesia monitor (DATEX-OHMEDA, Finland), which measured and recorded continuously, heart rate and arterial pressures, and intra-operative body temperature; and a computer (KARL STORZ, Vienna, Austria) for storage of pictures and information from the laparoscopies, using software AIDA-System (Advanced Image and Data Archiving System) (KARL STORZ, Vienna, Austria).

A colour video monitor (SONY, Vienna, Austria) and a Telecam (KARL STORZ, Vienna, Austria) were connected to the computer for visualization of the abdominal cavity.

Blood collection was made in arterial line draw samplers (BAYER, Fernwald, Germany). Blood examination was performed with a blood gas analyzer (RADIOMETER, Copenhagen, Denmark).

The tube cystotomies were carried out with suprapubic catheters (RÜSCH, Duluth, USA).
3.2 Methods

3.2.1. Pre-trial

The feasibility of the technique in left lateral recumbency and the best sites for trocarisation were tested in two animals, under general anaesthesia, before the trial started. Moreover, the manipulation of the equipment and the timings of the protocol were practiced, as a preparation for the trial.

3.2.2. Trial

3.2.2.1. SURGERY

The eight animals were inserted randomly into two groups, in which the first group underwent a laparoscopic-assisted cystotomy and the implantation of a urinary catheter in dorsal recumbency, and the second group in left lateral recumbency.

The surgery consisted of two phases: first, the collection of the data in order to study the blood gas, acid-base status and haemodynamic parameters during the Trendelenburg position and CO₂ pneumoperitoneum; and second, laparoscopic-assisted cystotomy and the implantation of a urinary catheter.

Preparation of the animal

Food was withheld for 24 hours before surgery. Water was available ad libitum. Before surgery animals were clipped in the area of the ventral abdomen and weighed. Auricular arterial and venous catheters 22 G/1" (BRAUN, Melsungen, Germany) were inserted. Anaesthesia was induced with Sodium thiopental intravenously (SANDOZ, Kundl, Austria) in a dosage of 7-10 mg per kg, and the trachea was intubated. The maintenance of anaesthesia was achieved with Isoflurane (ESSEX PHARMA, Munich, Germany) in a mixture of oxygen and air (fraction of inspired oxygen [FiO₂] = 0.4). Adjuvant analgesia was obtained with a bolus of butorphanol of 0.2 mg/kg IV and a constant-rate infusion of this drug intra-operatively (0.05 mg/kg/h IV). A normal saline solution (MAYRHOFER PHARMAZEIUKA, Leonding, Austria) was administered intra-operatively, in a dosage of 10 ml/kg/h (IV). The animals were fixed to the surgical table in dorsal recumbency. An orogastric tube was introduced to prevent bloating. The ventral abdomen was prepared for aseptic surgery.
Collection of data

Five arterial blood samples were drawn and kept on ice and the analysis of blood gases [arterial partial pressure of carbon dioxide (PaCO₂), arterial partial pressure of oxygen (PaO₂)] and acid-base status [pH, concentration of hydrogen carbonate ([HCO₃⁻]) standard bicarbonate (SBC) and standard base excess (SBE)] was performed within the subsequent 20 minutes.

The exact time of the sampling was registered and corresponded to the 5 time points, according to the time from the anaesthesia monitor. At these exact time points, the data concerning to haemodynamics [heart rate (HR), mean arterial pressure (MAP), diastolic arterial pressure (DAP) and systolic arterial pressures (SAP)] was compiled and underwent posterior statistical analysis.

The design of the protocol during surgery (Figure 1) was intended for the time points to be preceded by a stabilization period, when the animals were not to be manipulated or touched: All of the animals in both groups were initially positioned in dorsal recumbency. After an incision in the right paramedian area of the abdomen – approx. 1 cm long, between the xiphoid and prepucial orifice - a laparoscopic trocar cannula was placed, by the open access technique. To confirm placement into the abdominal cavity, the telescope was briefly introduced and when confirmed, it was removed. Five minutes after trocarisation - a short period of time just enough to stabilise the animals - was the baseline or time point 1. After time point 1, the animals from the dorsal group were left in the dorsal position, and those from the lateral group were changed to left lateral recumbency and fixed to the table, with the right leg caudally distended. Ten minutes after - time enough to stabilise the animals from the lateral group in the new condition - was time point 2. After time point 2, the animals in both groups were positioned in the Trendelenburg position (head-down), at an angle of 20° to the horizontal position (Figure 2A). Fifteen minutes after - a longer period of time to allow the animals to adapt to the new condition - was time point 3. After time point 3, the abdomen was insufflated with CO₂, via the laparoscopic cannula, until a pressure of 13 mmHg, automatically established by the insufflator (Figure 2B). Fifteen minutes after - period of time for the stabilisation in the new condition - was time point 4. After time point 4, the abdomen was disufflated, the animals were returned to the horizontal position and ten minutes after - period of time to allow for any short-term effects to show regarding to the recovery from the previous conditions - was time point 5.

The first phase of the surgery was finished.
Figure 1: Schematic representation of the surgical protocol with the time points for data collection of blood gas, acid-base status and haemodynamic parameters (squares 1 - 5). Dorsal and lateral recumbencies, Trendelenburg position, and capnoperitoneum are illustrated.
Figure 2: A) Animal from the dorsal group, in Trendelenburg position, before time point 3. B) Animal from the lateral group, in Trendelenburg position and insufflated, before time point 4. Note the inclination at an angle of 20°.
**Laparoscopic-assisted cystostomy with the implantation of a urinary catheter**

The abdomen was insufflated with CO₂ until a pressure of 13 mmHg, in both groups – dorsal and lateral. The optic was introduced and a systematic laparoscopic observation of the abdominal cavity was performed. An instrumental portal for the forceps was performed under laparoscopic control, after a small incision of the skin with a scalpel. The best point was determined by pressing the abdomen from the outside with a finger. In the dorsal group, the second trocar was placed on the left paramedian area of the abdomen, at half length of the prepuce (Figure 3A); and in the lateral group, it was placed on the right paramedian area of the abdomen, approx. 4 cm lateral from the optic trocar and at half length of the prepuce (Figure 3B).

![Figure 3: Schematic representation of the sheep on the surgical table and the localisation of the portals used. A) Dorsal group, dorsal view; B) Lateral group, left lateral view; c = urinary catheter; f = grasping forceps; o = optic.](image)

The animals were positioned in the Trendelenburg position, in a 20° angle, for better visualisation and the manipulation of the bladder. The forceps (f) was introduced and the cranial aspect of the bladder (apex) grasped and elevated to the ventral abdominal wall, in an attempt to find the best place for its exteriorisation. In both groups, it was on the right parainguinal area, caudally, near the rudimentary teats. At this phase, the protocol differed between the groups.
DORSAL GROUP
On the right parainguinal area, a mini-laparotomy of 2 to 3 cm was performed. The bladder was exteriorised with the help of the grasping forceps, while the deflation of the abdominal cavity ran through the open trocar's automatic valves. When exteriorised, the bladder was held with two haemostatic clamps. The atraumatic forceps were removed. A 1 cm-cystostomy was performed near the apex. The bladder's mucosa was rinsed with a saline solution and then closed with a non-perforate discontinuous suture pattern. The haemostatic clamps were removed and the bladder returned to its physiological position, inside the abdominal cavity. The abdominal wall was closed in two layers, in a simple continuous pattern, with suture material (TYCO HEALTHCARE, Gosport, United Kingdom). For the implantation of the urinary catheter, the abdomen was again insufflated. The best place for implantation was determined by pressing the skin with a finger. The bladder was then grasped with the forceps, and the urinary catheter was inserted percutaneously next to the rudimentary teats, near the previous incision, and implanted in the dorsal part of the urinary bladder (according to the manufacturer) under laparoscopic control (Figure 4).

Figure 4: Laparoscopic view of the caudal abdomen in an animal from the dorsal group. The urinary bladder (b) is grasped by haemostatic forceps (f) and the percutaneous urinary catheter (c) is implanted inside the bladder. i = intestine; aL = left abdominal wall. The catheter was implanted near the mini-laparotomy site (arrow).
LATERAL GROUP

The catheter was implanted on the dorsal wall of the urinary bladder, at the chosen site for its exteriorisation (according to the manufacturer). After implantation, the punctual laparotomy that was caused by the catheter's cannula was extended cranially with an incision of the abdominal wall of approx. 2 to 3 cm with the scalpel. The exteriorisation of the urinary bladder was performed through this incision, with the help of the forceps, while the abdomen disufflated, after the opening of the trocar’s automatic valves. The bladder was then held with two haemostatic clamps. A 1 cm-cystostomy was performed near the apex, carefully ensuring not to damage the full balloon from the catheter, inside the bladder (Figure 5). The bladder's mucosa was rinsed with a physiologic saline solution and then closed with a non-perforate discontinuous suture pattern (TYCO HEALTHCARE, Gosport, United Kingdom). The haemostatic clamps were removed and the bladder replaced inside the abdominal cavity. The abdominal incision was closed in two layers with suture material.

Figure 5: Cystostomy in one animal from the lateral group, after implantation of the urinary catheter (arrow).
The end of the surgery had the same protocol for both groups. The abdomen was again insufflated, just enough for a visual control of the abdominal cavity, the bladder's wound and position of the catheter, as well as for documentation. After complete deflation, with supplementary manual compression of the abdomen, the optic and grasping forceps were removed, as well as the two laparoscopic cannulae, and the respective wounds were closed in two layers, in a simple continuous pattern. The catheter was fixed to the ventral abdominal wall in two or more sites so that it would lie close to the abdomen when the animal stands up (VAN METRE, 2004), by using a Chinese fingertrap ligature (Figure 6).

Figure 6: Fixation of the catheter to the abdominal wall with Chinese fingertrap ligature, in one animal from the lateral group.
Post-surgery
The distal tip of the urinary catheter was protected with a Heimlich valve (Figure 7) that was fashioned from a finger cut of a plastic glove and fastened to the catheter with adhesive tape to limit the risk of ascendant infections (VAN METRE, 2004; FRANZ et al., 2008). The animal was placed with the others when standing and eating.

Figure 7: Distal tip of the urinary catheter with protection.
3.2.2.2. DAILY CONTROL

Physical examination and Urinalysis
A physical examination (BAUMGARTNER, 2006) and urinalysis, with refractometer and chemical reagent strips (BOEHRINGER MANNHEIM, Vienna, Austria), were performed just before surgery and daily after surgery, for two weeks. Rectal temperature, pulse, respiratory frequency, appetite, abdominal tension, faeces, auscultation of lungs, heart and rumen were given special attention.

From day 1 to day 10, after surgery, urine was collected from the catheter. A clean protection of the catheter's tip was placed every day. On day 10, the urinary catheter was removed, after deflating the balloon with a 5 ml syringe. From day 10 till day 14, spontaneous urine was collected through the prepuce. Urine specific gravity (USG) was measured with a refractometer and visual observation of urine was reported for colour and transparency; chemical reagents strips were used for measurement of the urine pH and detection of proteinuria and haematuria.

3.2.2.3. LAPAROSCOPIC CONTROL

On day 14 after surgery, the animals underwent a second laparoscopic procedure for the inspection of the abdominal cavity. The preparation and laparoscopic control had the same protocol as for the surgery, except what concerned the collection of data. The trocarisation for the optic was made approx. 2 cm lateral or cranial to the previous one, ensuring to avoid large vessels. An instrumental portal was performed if the complete visualisation of the bladder was impossible. The abdominal cavity was inspected for ascites and signs of inflammation (peritonitis) and fibrinous adhesions between the urinary bladder and neighbouring organs.
3.2.2.4. OTHER PROTOCOLS

Blood cell count
A complete blood cell count, with special focus on total leukocytes, polymorphonuclear neutrophils and lymphocytes, was performed to check signs of inflammation and/or infection, and also compare the values between dorsal and lateral groups. The venous blood samples were obtained before surgery (day 0), one day after surgery (day 1), and before laparoscopic control (day 14).

Therapy
Antibiotherapy started 24 hours before surgery with Marbofloxacin (VÉTOQUINOL, Vienna, Austria), in a dosage of 2 mg per kg (SC), and Amoxicilin + Clavulanic Acid (PFIZER, Vienna, Austria), in a dosage of 3 ml per 60 kg (IM). It was continued immediately after surgery and daily till three days after laparoscopic control. Anti-inflammatory drugs, namely Carprofen (PFIZER, Vienna, Austria) were given in a dosage of 1.4 mg per kg after surgery (IV) and daily (SC) till day 4, if temperature was within normal range; and after laparoscopic control (IV) and in the following 4 days (SC). Tetanus anti-toxin (WDT, Garbsen, Germany) was administered once after surgery and laparoscopic control – 3000 IU per animal (SC). The wounds were daily disinfected with lode.

Statistic analysis
In this experimental, prospective study, a parallel group design was used. The data collected during surgery along with some parameters from the daily control (temperature, pulse and urine pH) underwent descriptive statistics with the parameters of location and dispersion, respectively, mean and range (difference between the lowest and highest values, in a certain time point).
4. RESULTS

4.1. PRE-TRIAL

The two surgeries from the pre-trial were both performed in left lateral recumbency. The protocol for the collection of data was adjusted to the one written hereinabove in 'Materials and Methods'. In the first surgery, trocarisation for the grasping forceps was attempted in the left paramedian abdomen, but it did not allow for the good manoeuvring of the forceps for grasping the bladder. It was then performed on the right side, with good results. The two animals had no postoperative complications.

4.2. TRIAL

4.2.1. SURGERY

4.2.1.1. Dorsal Group

The trocarisation sites for the optic were well located, since they allowed for a good visualisation for assisting the trocarisation of the instrumental portal, the grasping and manoeuvring of the bladder, as well as the implantation of the urinary catheter in all animals.

Concerning to the trocarisation site for the grasping forceps, there was a situation, in one animal, where a second trocarisation was necessary. The first instrumental portal was placed too caudal and medial, approx. 2 cm from the linea alba. This situation happened due to the high resistance from the abdominal wall felt during trocarisation. The pressure made against the abdominal wall displaced the trocar from the aimed site. This portal allowed no space to manoeuvre the organ and elevated it to the abdominal wall (on the contralateral side). After realising this limitation, the grasping forceps were removed and the portal was closed in two layers. A second trocarisation was performed approx. 3 cm laterally and 2 cm cranially to the previous one.

There were found no problems on grasping the urinary bladder before cystostomy, but after it, for the implantation of the urinary catheter, special care had to be taken to not open the suture near the apex. The exteriorisation of the bladder was performed with no complications, as well as the cystostomy and its suture.
The implantation of the urinary catheter was successful in all the animals, although in two just in the second attempt. After the cystostomy with a scalpel, the bladders in these two animals were empty along with a small lumen, which is fact that made it difficult to implant the catheter due to the risk of perforating the bladder twice. Following the puncture of the bladder with the catheter's cannula, the catheter was pushed inside the bladder, but the lumen of the organ did not facilitate the complete entrance of the pig tail tip of the catheter. An attempt to fill the balloon was made, but the balloon was still outside the bladder. In one of these two animals, the balloon was destroyed by the sharp cannula, and could not be filled. The catheter had to be disposed of and another one was implanted, in turn using the previous puncture site. A waiting period of approx. 5 minutes had to take place to permit the production of some urine and the implantation of the catheter in these animals. Two times the leakage of gas (CO₂) from the abdominal cavity was observed, more precisely, once from the optic portal site, and once from the instrumental portal site, provoking subcutaneous emphysema intraoperatively. It was never impeditive, however, to continue with the surgery.

All the animals recovered well from the anaesthesia and returned to the stable within 30 minutes after the termination of Isoflurane.

4.2.1.2. Lateral Group

The trocarisation sites for the optic were well located for the same reasons as described for the dorsal group. In one animal, the optic trocar had to be replaced by another, after placed, due to the incompetence of the automatic valve and impossibility of maintaining constant pressure. After the replacement, the surgery continued and the time points were respected. In one animal, problems during the disufflation phase were observed, before time point 5. When the valve of the optic trocar was open, the gas did not flow from the inside out. The optic was inserted for inspection. The reason for this occurrence was the placement of the trocar inside the bursa omentalis (Figure 8), and while the gas was flowing out the abdominal cavity, the serosa was sucked and in turn blocked the cannula. To solve this problem, the grasping forceps were introduced (after trocarisation) in order to grasp the bursa omentalis, under laparoscopic visualisation, and to create an entrance in order to remove the optic and trocar from the bursa.
Figure 8: Laparoscopic view of the caudal abdomen after trocarization and insufflation of the bursa omentalis. The vasculated serosa covers the organs - urinary bladder (b) and colon (c) - and the left (aL) and right (aR) ventral abdominal wall.

The instrumental portals had a good localisation. They allowed the manoeuvre of the bladder, although the grasping forceps stood in front of the image that was captured by the optic, blocking a part of the visibility of the bladder. It was never, however, impeditive to continue with the implantation of the catheter and the exteriorisation of the bladder (Figure 9).

Figure 9: Laparoscopic image after implantation of the urinary catheter (c) in one animal from the lateral group with its urinary bladder (b) grasped by the forceps (f).
The implantation of the urinary catheters was successful in all the animals, although in one, only in the second attempt. This situation was due to the rupture of the catheter's balloon while it was being filled, by the sharp cannula, because the pigtail tip was not completely inserted in the bladder. The catheter was disposed of, and a second attempt with a new catheter utilised the previous puncture site in the bladder.

There were no complications concerning the mini-laparotomies extended from the catheter's incision. There were never problems with the balloon inside the bladder, before, during or after the incision with a scalpel. All the animals recovered well from the anaesthesia and returned to the stable within 30 minutes after the termination of Isoflurane.
4.2.2. **BLOOD GAS AND ACID-BASE STATUS**

Table 1 shows the mean and range from blood gas and acid-base status' values, along the surgery, in both groups.

**Table 1:** Mean and range from values of blood gas and acid-base status, in dorsal and lateral groups, along surgery.

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<td>0.08</td>
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</tr>
<tr>
<td>[HCO₃⁻] (mmol/l)</td>
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<td></td>
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<td></td>
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<td>7.20</td>
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<tr>
<td>SBC (mmol/l)</td>
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</tr>
<tr>
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<tr>
<td>SBE (mmol/l)</td>
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<td></td>
</tr>
<tr>
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<td>2.73</td>
<td>5.90</td>
<td>3.98</td>
</tr>
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</table>

D = Dorsal, L = Lateral, PaCO₂ / PaO₂ = arterial partial pressure of CO₂ / O₂, [HCO₃⁻] = Concentration of hydrogen carbonate, SBC = standard bicarbonate, SBE = standard base excess
4.2.2.1. \( \text{PaCO}_2 \)
\( \text{PaCO}_2 \) increased in both groups tenuously after Trendelenburg positioning, and accentually after the insufflation. After disufflation, \( \text{PaCO}_2 \) maintained increased in both groups (Figure 10).

![Variation of PaCO2](image)

**Figure 10:** Variation of \( \text{PaCO}_2 \) along the surgery.

4.2.2.2. \( \text{PaO}_2 \)
\( \text{PaO}_2 \) maintained stable in the dorsal and decreased in the lateral group after Trendelenburg positioning; and decreased in both groups after insufflation. After disufflation, \( \text{PaO}_2 \) increased until values close to the baseline (Figure 11).

![Variation of PaO2](image)

**Figure 11:** Variation of \( \text{PaO}_2 \) along the surgery.
4.2.2.3. pH
Values of the pH decreased in the dorsal and maintained stable in the lateral group after Trendelenburg positioning; decreased with the accentuation after insufflation; and maintained low values after disufflation (Figure 12).

![Variation of pH](image)

**Figure 12:** Variation of pH along the surgery.

4.2.2.4. Concentration of Hydrogen Carbonate
\([\text{HCO}_3^-]\) increased after Trendelenburg positioning, in both groups; and continued to increase after insufflation only in the lateral group. After disufflation, tenuous alterations were observed, namely, a mild increase in the dorsal group, and a mild decrease in the lateral group (Figure 13).

![Variation of HCO3-](image)

**Figure 13:** Variation of \([\text{HCO}_3^-]\) along the surgery.
4.2.2.5. Standard Bicarbonate
The values of SBC showed a small range of variation; they increased after Trendelenburg positioning, and after insufflation continued high in the lateral group, decreasing in the dorsal group (Figure 14).

![Variation of SBC](Figure 14: Variation of SBC along the surgery.)

4.2.2.6. Standard Base Excess
Values of SBE were always positive and with a small range of variation. They increased after Trendelenburg positioning in both groups; decreased in the dorsal group and increased in the lateral group after insufflation; and increased again in both groups, after disufflation (Figure 15).

![Variation of SBE](Figure 15: Variation of SBE along the surgery.)
In summary, after Trendelenburg positioning, there was a slight increase of PaCO₂, [HCO₃⁻], SBC and SBE in both groups; a slight decrease of PaO₂ in both groups; and a decrease of the pH in the dorsal group. After CO₂ insufflation, there was a prominent increase of PaCO₂ in both groups; an increase of [HCO₃⁻], SBC and SBE in the lateral group, while these parameters showed a slight decrease in the dorsal group; and a distinctive drop in PaO₂ and pH in both groups.

4.2.3. HAEMODYNAMICS

Table 2 shows the mean and range of the values for haemodynamic parameters – heart rate, systolic, diastolic and mean arterial pressures.

Table 2: Mean and range from values of haemodynamic parameters, in dorsal and lateral groups, along surgery.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>range</td>
<td>mean</td>
<td>range</td>
<td>mean</td>
</tr>
<tr>
<td>HR</td>
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<td>94.50</td>
<td>44.00</td>
<td>91.75</td>
<td>49.00</td>
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<td>SAP</td>
<td>D</td>
<td>4.04</td>
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<td>4.37</td>
<td>4.84</td>
</tr>
<tr>
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<td>D</td>
<td>1.62</td>
<td>5.72</td>
<td>0.48</td>
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</tr>
<tr>
<td></td>
<td>L</td>
<td>-1.62</td>
<td>3.06</td>
<td>-3.40</td>
<td>2.53</td>
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<tr>
<td>MAP</td>
<td>D</td>
<td>2.84</td>
<td>4.97</td>
<td>2.32</td>
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<tr>
<td></td>
<td>L</td>
<td>1.60</td>
<td>2.26</td>
<td>0.42</td>
<td>2.34</td>
</tr>
</tbody>
</table>

D = Dorsal, L = Lateral, HR = heart rate, SAP / DAP / MAP = systolic / diastolic / mean arterial pressures.
4.2.3.1. Heart Rate
The findings show, in both groups, a stable heart rate after Trendelenburg positioning, and an increase after insufflation, which were more accentuated in the lateral group. The return of the heart rate to pre-insufflation values was observed after disufflation (Figure 16).

![Variation of heart rate](image)

**Figure 16:** Variation of heart rate during surgery.

4.2.3.2. Systolic Arterial Pressure
SAP increased after Trendelenburg positioning and insufflation, in the two groups, with more accentuation in the lateral group (Figure 17).

![Variation of SAP](image)

**Figure 17:** Variation of systolic arterial pressure during surgery.
4.2.3.3. Diastolic Arterial Pressure
DAP showed in both groups an increase after Trendelenburg positioning, more accentuated in the lateral group, continuing to increase after insufflation, and decreasing to values near the baseline after disufflation (Figure 18).

Figure 18: Variation of diastolic arterial pressure during surgery.

4.2.3.4. Mean Arterial Pressure
The MAP values describe a similar curve as for the DAP, showing in both groups an increase after Trendelenburg positioning, more accentuated in the lateral group, continuing to increase after insufflation, and decreasing until the baseline values after disufflation (Figure 19).

Figure 19: Variation of mean arterial pressure during surgery.
In summary there were increases of the SAP, DAP and MAP after Trendelenburg positioning, and again after CO₂ insufflation together with an increase of the heart rate, which was more accentuated in the lateral group.

4.2.4. PHYSICAL EXAMINATION

Before surgery, the physical examination showed no pathological findings. After surgery, appetite, rumen motility, respiratory rate, auscultation of the lungs and heart, colouration of the conjunctival mucosa, and faeces were always physiologic. The prepuce was always wet, although the flow of urine was not visible. Table 3 shows the mean and range of the values from body temperature and pulse rate, before (day 0) and after surgery (day 1 - 14), in both groups.

Table 3: Mean and range of the values from body temperature and pulse rate, along the 14 days after surgery, in dorsal and lateral groups.

<table>
<thead>
<tr>
<th>days</th>
<th>body temperature</th>
<th></th>
<th>pulse rate</th>
<th></th>
</tr>
</thead>
<tbody>
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<td>range</td>
<td>Dorsal mean</td>
<td>range</td>
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<td>39.5</td>
<td>1.0</td>
</tr>
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<td>0.2</td>
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<td>39.2</td>
<td>0.6</td>
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</table>
4.2.4.1. Body Temperature
The mean rectal temperature on the day of surgery was for the dorsal group 38.6°C and for the lateral group 38.9°C. Figure 20 shows an increase of the body temperature in both groups one day after surgery, with the stabilisation of the values in the following two weeks, within the physiological interval. The range of temperature was low in both groups, along the trial, from 0.1°C to 1.1°C (Table 3).

![Variation of body temperature](image)

**Figure 20:** Variation of body temperature along the daily control.

4.2.4.2. Pulse Rate
Figure 21 shows an increase of the pulse rate on the day after surgery, in both groups. The pulse rate remained stable throughout the two weeks after intervention, although the animals from the dorsal group presented each day mean values above the physiological range, from 81 to 87 beats/minute (Table 3).
4.2.4.3. Abdominal Tension

After surgery, the animal from the dorsal group, which developed a small herniation in the optic trocar site, showed a mild increase of the abdominal tension for 8 days. One animal from the lateral group showed a mild increase of this clinical sign for 5 days, and another showed a moderate increase for 2 days.

In summary, the physical examination revealed a slight increase of the mean body temperature and pulse on the day after surgery in both groups, and a mild increase of the abdominal tension in a few animals after surgery.
4.2.5. **URINARY CATHETER**

In some animals, the fixations with the Chinese fingertrap suture were found to be removed, or strangulating the catheter, and had to be replaced. Urine dribbling through the urinary catheter was observed after surgery and daily in all sheep, being permanent obstructions of the urinary catheter not observed during the 10 days of its permanence. The 8 catheters were removed on day 10 with no complications. In two animals, some clots - 5 mm diameter, with a fibrinous appearance (Figure 22A) - were found inside the pigtail tip of the catheter. Spontaneous micturition though the penis occurred in all the animals less than 15 minutes after the removal of the catheter.

![Figure 22: Urinary catheters after removal, on day 10 after surgery. A) Clots with fibrinous appearance in the pigtail tip of the catheter. B) Catheters with no clots found.](image)
4.2.6. WOUND-HEALING

In two animals, one from each group, mild oedema was observed after the surgery, near the site of the laparoscope's trocarization. However, it spontaneously resolved itself in the following three hours (Figure 23).

In one animal from the dorsal group, a hernia approx. 1 cm of diameter was observed in the wound of the optic portal, mildly painful at palpation, with no visceral incarceration. All the wounds showed good signs of healing in the following days of surgery.

After the removal of the catheters, the cystotomy sites did not dribble urine, were disinfected with iodine, and healed uneventfully by secondary intention.

Figure 23: Mild post-surgical oedema (white arrow) near the optic portal site (○).
4.2.7. **URINALYSIS**

Before surgery, it was impossible to collect urine from 1 animal due to a lack of cooperation from it and time constraints. All the urine collections showed normal colour and transparency, in which 3 animals presented urine specific gravity (USG) under the physiologic range, and 3 animals presented with mild microscopic haematuria (2 from the dorsal group and 1 from the lateral group). The values of the urine pH were normal in the dorsal group, but 2 animals from the lateral group showed decreased values (pH = 5 and pH = 7) with no other signs of disease.

After surgery, urine turbidity was present after the surgery throughout the whole period of implantation of the catheter, in one or more animals of both groups. After removal, urine became clear again. The urine colour was always physiologic.

All the animals from both groups showed moderate to severe microscopic haematuria till day 10. After the removal of the catheter, only one animal continued to present moderate microscopic haematuria, once.

Between days 1 to 8, USG was found increased in three animals from the dorsal group showed once; in two animals from the lateral group once; and in one animal three times, on days 2, 3 and 8.

On day 1, a trend to decreasing urine pH was observed in both groups. After 3 days, the values from the dorsal group returned to normal ranges, which only occurred after approx. one week, in the lateral group (Figure 24). The range of pH was punctually high, with the variations of pH ranging between 5 and 9 (Table 4).

**Table 4: Mean and range of the values of urine pH, along the 14 days of daily control, in dorsal and lateral groups.**

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<th>8</th>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
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<td>1</td>
<td>1</td>
<td>0</td>
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<td>4</td>
<td>4</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>
4.2.8. LAPAROSCOPIC CONTROL

In all the animals, trocarisations for laparoscopic control were performed with no complications; except in one animal, in which subcutaneous emphysema developed through the optic portal.

There were no signs of peritonitis, 14 days after the surgery. In all the animals, the abdominal serosa was pink coloured. There were no adhesions between the bladder and the neighbouring organs. From the dorsal group, one animal presented mild ascites, and another had two small blood clots (approx. 0.5 cm) - one in the cystostomy site, and one in the tube cystotomy site.

All the bladders showed a normal appearance. The cystostomy site was a reddish area, with signs of the absorption of the suture material. The tube cystotomy site was a small round red-yellow region, in some cases it was nearly undetectable (Figure 25).
Figure 25: Laparoscopic control in the lateral group. Physiologic appearance of the abdominal cavity. The suture (discontinuous arrows) shows good signs of healing and the tube cystotomy site (full arrow) appears as a yellowish area, during healing process. \( a_R \) = right abdominal wall; \( a_L \) = left abdominal wall; \( f \) = grasping forceps; \( b \) = urinary bladder; \( r \) = rectum.

The trocar sites had signs of advanced peritoneal healing, appearing as white or reddish, oval and raised structures (Figure 26).

Figure 26: Laparoscopic visualization of the trocarisation sites for the instrumental portal (arrows), 14 days after surgery, in advanced phase of healing. The picture relates to the animal with two attempts for trocarisation. \( a_L \) = left abdominal wall; \( b \) = urinary bladder; \( c \) = colon; \( i \) = intestine.
All the animals recovered from anaesthesia without complications, and were taken to the stables, wherein they demonstrated having appetite in the subsequent hour.

4.2.9. **BLOOD CELL COUNT**

Before surgery, blood cell count was within the physiological interval (Table 5). The total leukocytes increased one day after surgery, and decreased after 2 weeks, in both groups. This result was basically due to the polymorphonuclear neutrophils, which count followed the same trend. Regarding to the lymphocytes' count, the findings differed between groups - the values rose on the dorsal group and mildly decreased in the lateral group, after surgery.

**Table 5:** Blood cell count for the total leukocytes, neutrophils and lymphocytes, in dorsal and lateral groups, on the three blood samples collected.

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<th>DAY 14</th>
</tr>
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<tbody>
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<td></td>
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<td>range</td>
<td>mean</td>
</tr>
<tr>
<td>leukocytes / µl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>1590</td>
<td>10533</td>
</tr>
<tr>
<td>L</td>
<td>9005</td>
<td>2090</td>
<td>12765</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>1057</td>
<td>4899</td>
</tr>
<tr>
<td>L</td>
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<td>622</td>
<td>7006</td>
</tr>
<tr>
<td>lymphocytes / µl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
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</tr>
<tr>
<td>L</td>
<td>5631</td>
<td>2050</td>
<td>4897</td>
</tr>
</tbody>
</table>

D = Dorsal, L = Lateral, * Value over the physiological range.

Figure 27 (A, B, C) shows the variation of the mean of total leukocytes, neutrophils and lymphocytes.
Figure 27: Variation of Blood cell count of total leukocytes (A), neutrophils (B), and lymphocytes (C), from before surgery till two weeks after.
5. DISCUSSION

The main conclusions of the present study are that the surgical technique of a laparoscopic-assisted cystostomy and tube cystotomy is feasible in dorsal and left lateral recumbent rams with no major postsurgical complications; and during laparoscopy there is a trend for an increase of the arterial blood pressures after Trendelenburg positioning; a trend for an aggravation of these haemodynamic changes after CO₂ pneumoperitoneum plus an increase of the heart rate; a trend for the blood-gas and acid-base status to change to acidotic ranges after CO₂ pneumoperitoneum; and no distinctive differences in these trends between dorsal and in left lateral recumbency.

5.1. Surgical Technique

The left lateral positioning of the patient calls for a very good constraining of the right leg, which has to be distended caudally. Otherwise, its flexion and consequent abduction in turn limits the surgical field, and reduces the vision field and space allotted for manoeuvring for the surgeon-assistant. To ameliorate this disadvantage, the table may be set in a lower position, as was carried out in the present study.

Trocarisation carried out by an open laparoscopy technique showed to be a safe and quick method to insert the trocar and create pneumoperitoneum, as reported by RUMSTADT et al. (1996). The present study had good results with this technique since no large vessels or organs were damaged, although it led just once to the occurrence of the trocarisation of the bursa omentalis (recessus supraomentalis), like described by KLEIN et al. (2002), with the use of the Veress needle. The trocars that were used were certainly a good choice for the intended surgery, with the disadvantage being their costliness. Due to financial limitations, some trocars were reutilised and in some cases, during surgery, they had to be disposed of and replaced by news ones due to incompetence of the automatic valve.

Some authors, such as GALUPPO et al. (1996), RAGLE et al. (1996), DUKE et al. (2002) and RÖCKEN et al. (2006) used the Trendelenburg position in horses with an inclination of 30° or higher. In the present study, an inclination of 20° followed the method of FRANZ et al. (2008) and was accepted as adequate to perform the
cystostomy with the implantation of the urinary catheter in sheep, both in the dorsal and left lateral recumbencies. The abdominal organs were deviated cranially and allowed for the manipulation of the urinary bladder. Angles exceeding 20° might not bring an advantage in sheep and in turn add more risks in the case of respiratory distress.

It would be advisable to study the possibility to return animals to the horizontal position after the exteriorisation of the bladder, and before cystostomy, to minimise the period of time positioned with the head down, as described by RÖCKEN et al. (2006).

The surgical protocol was different in both groups, concerning to the order of the performance of the cystostomy and the implantation of the urinary catheter.

A new technique was attempted in the lateral group - the catheter was implanted beforehand – in order to try to ameliorate two possible disadvantages, which could occur when the cystostomy precedes the implantation of the catheter; this technique was first described in sheep by FRANZ et al. (2009). First is the fact that in patients suffering from obstructive urolithiasis it is common to find a very full bladder (if the rupture of the bladder is not present) and, therefore, in order to grasp it is necessary to empty it beforehand. Second, after cystostomy, the lumen of the bladder is very small and requires its filling.

The new technique had good results in the present study: the puncture of the bladder was easily performed (although the bladders had to be grasped because they presented their normal size); subsequent grasping and mobilisation of the bladder was facilitated by its emptiness and also by the absence of suture; and it might have reduced the time needed for surgery. The only disadvantage found is the fact that the operator has to be very careful with the balloon inside the bladder during its opening. In the present study, the puncture of the balloon never happened. This new technique could also be performed in dorsal recumbency, in which further studies should be carried out in this sense.

In the dorsal group, the grasping and mobilisation of the bladder were not difficult in the present study, but the animals were not patients. However, the emptiness of the bladder after cystostomy brought some complications in some animals during implantation of the catheter, since the small lumen of the bladder increased the risk of perforate it twice, and made difficult the insertion of the pigtail tip of the catheter inside the bladder. In these situations, a waiting period had to take place, so that the bladder again became filled with urine. These complications might have been avoided by filling the bladder again, but inexperience "blinded" the surgeon.
The difficulties and complications observed during the laparoscopies, such as those stated above, as well as the leakage of gas to the subcutaneous tissue and second trocarisation for the grasping forceps, happened mostly due to the inexperience of the surgeon as an endoscopist. SHETTKO (2000) stated that the probability of complications in surgeons with less than 100 laparoscopies is fourfold higher than for extensively experienced surgeons. HAHN et al. (1997) declared a long incision for the trocar was a possible cause for the subcutaneous emphysemas, as in the present study.

Thorough lavage of the bladder at surgery was possible and successfully performed. It may reduce the chance of future urethral obstruction after the catheter removal, in turn washing out any calculi that might travel through the urethra (RAKESTRAW et al., 1995).

The pigtail catheter was used in the present study because it has shown to be successful in urine drainage in sheep, throughout the experimental study by FRANZ et al. (2008), as well as in pleural drainage, treatment of ascites, drainage of pancreatic pseudocysts and percutaneous fluid (MATHUR et al., 1998; ABUZEID et al., 2003; SACHIN et al., 2006; MACHA et al., 2006). There are descriptions of complications after use of Foley catheters by RAKESTRAW et al. (1995), due to a lack of patency and the dislodgement of the catheter, although the authors reutilised many catheters, and some were supposedly obstructed along with a defected balloon. The size and shape of the catheter is of great importance, since there are complications that may advent from this factor, namely, the obstruction and dislodgement (FORTIER et al., 2004). The size should be as large as possible (VAN METRE, 2004) and, in the present study, as well in the study from FRANZ et al. (2008), the usage of pigtail catheters, size 12 F (4.0 mm), did not bring the complications noted above.

To finish, it must be stated that the use of an orogastric tube throughout laparoscopy in these animals was important in order to prevent bloating and to evacuate some ingesta, in agreement with SHETTKO (2000). In all the surgeries of the present study, at least two litres of ruminal fluid where expelled from it.
5.2. Effects of Laparoscopic Surgery on Blood-Gas, Acid-Base Status and Haemodynamic Parameters

The utilisation of the blood gas machine for the measurement of the blood gas was considered as a precise method to analyse the gradient of O_2 and CO_2. According to CURET et al. (1996), the O_2 saturation as measured by pulse oximetry was identical to that measured by arterial blood gases; but for the CO_2, CRUZ et al. (1996) observed in their study that the ETCO_2 did not accurately estimate this gradient, also preferring the measurement of the blood gas.

After placing the animals in the Trendelenburg position, there was a trend of a mild increase of the PaCO_2 and, correspondently, to a mild decrease of the pH and increase of the concentration of HCO_3^-

A trend of the increase of the arterial blood pressures - SAP, DAP and MAP - was also observed, showing some evidence that the Trendelenburg position was responsible for the trends of haemodynamic variations, which is in good agreement with the findings from CURET et al. (1996) and CRUZ et al. (1996) in pregnant ewes, where no alterations in blood pressure (and in heart rate, in the second mentioned study) occurred with the animals in the horizontal position. In the study of halothane-anaesthetised ponies (DUKE et al., 2002), the Trendelenburg position alone did not have any effects in these parameters.

After insufflation, there was a trend to an accentuated increase of PaCO_2, and decrease of the pH and increase of the concentration of HCO_3^-, according to the chemical reaction: CO_2 + H_2O ↔ H_2CO_3 ↔ H^+ + HCO_3^- (SPÖRRI and WITTKE, 1987), due to the absorption of CO_2 by the peritoneal surface. In pregnant sheep (CURET et al., 2001) there was also an increase of the PaCO_2 after 30 minutes of CO_2-insufflation.

The fact that CURET et al. (2001) did not find the He-insufflation as a potential risk to cause maternal or foetal acidosis indicates that the metabolic effects seen with CO_2, in their study and in the present one, are the result of the specific gas used.

IVANKOVICH (1975) also reported, in horizontally positioned dogs, an increase of PaCO_2 when the capnoperitoneum was set at 20 mmHg, and continued with increasing intraabdominal pressure, which was not observed by this author with N_2O insufflation. In horizontally recumbent llamas (LIN et al., 1997), changes in position between the right, dorsal and lateral, and CO_2-insufflation had no effect on PaCO_2, pH and [HCO_3^-]. PaO_2 showed a decreasing trend after insufflation, which is also in good agreement with the results from CRUZ et al. (1996), who report a significant decrease of the PaO_2.
during CO₂-insufflation at a intraabdominal pressure of 15 mmHg, in late pregnant ewes; and with IVANKOVICH (1975) who observed in mechanically ventilated dogs a significant decrease of PaO₂ after CO₂-insufflation with an intraabdominal pressure of 40 mmHg, much higher than the 13 mmHg used in the present study. The trends of variation in blood gases and acid-base status may, then, have been a response to the capnoperitoneum and were very similar between the dorsal and lateral recumbencies.

CO₂ pneumoperitoneum in the Trendelenburg position may enhance the haemodynamic responses to the head-down position, since there was a trend in the arterial blood pressures to continue to elevate. Moreover, the heart rate also increased accentually. These findings differ from others experimental studies with pregnant sheep, horizontally positioned, where haemodynamic changes were not observed (HUNTER et al., 1995; CRUZ et al., 1996; CURET et al., 1996). Furthermore, in standing horses (LATIMER et al., 2003; CRUZ et al., 2004) and in halothane-anaesthetised ponies (DUKE et al., 2002) as well as in dogs (IVANKOVICH et al., 1975), which were horizontally positioned, these haemodynamic changes were not observed. GALUPPO et al. (1996) described in horses in the head-down position, at an inclination of 30 to 45°, the same haemodynamic variations as those reported in the present study.

In llamas, the arterial blood pressures tend to decrease after insufflation, regardless of the position of the animal – dorsal, right of left recumbencies (LIN et al., 1997).

All these findings and the fact that CURET et al. (2001) have found an increase in the heart rate in pregnant ewes with helium insufflation may indicate that these haemodynamic alterations - increase of the heart rate and arterial blood pressures - are influenced by the increase of the abdominal pressure due to the cranial dislocation of the viscera, and not by the CO₂ absorption.

All curves of variation from the parameters measured were similar in both groups, which indicates that the position (dorsal or lateral) leads to no difference in the blood gas, acid-base status and haemodynamics, although LIN et al. (1997) in the study of llamas in dorsal, right and left recumbencies found lower mean, systolic and diastolic arterial pressures in lateral left position, when compared to right and dorsal positions, although with no significance.
5.3. Daily and Laparoscopic Control

The fourteen days after surgery were useful in the present study to recognise some possible deleterious effects of the surgery in the homeostasis of the animals. As described in our results, the animals recovered immediately from the surgery and showed no signs of disease thereafter.

During the 14 days after surgery, there were no clinically relevant differences between the groups. The alterations found in the urine, ended after the removal of the catheter and with spontaneous micturition, just as in the study of FRANZ et al. (2008). This may suggest that the urine collected from the catheter may be contaminated with fibrin and blood clots, and not represent the condition of the bladder.

RAKESTRAW et al. (1995) recommend to maintain the catheter 7 to 10 days before removal, at least 24 hours after a steady stream is observed (after clamping the catheter). In these authors’ study, the mean time until a steady stream of urine was voided from the penis in 12 patients that were successfully treated with tube cystotomy was 11.5 days; and the mean time until catheter removal was 14.4 days.

The importance of a good execution of the Chinese fingertrap ligature is emphasised, since it can strangle the catheter, in turn hindering the surgical work; as well as the importance of keeping the animal in a box with no other animals, avoiding the chewing of the catheter by another sheep. Making use of an Elizabethan collar in order to prevent the self-chewing of the catheter is also a good measure, as was suggested by RAKESTRAW et al. (1995).

The blood cell count showed trends of increased total leukocytes and polymorphonuclear neutrophils one day after surgery, which returned to pre-operative values two weeks after surgery, as described by FRANZ et al. (2008).

The antibiotherapy was administered for a long period because it was used as a prophylactic measure for cystitis, and afterwards as a preventive therapy before the laparoscopic control.

The findings from the second laparoscopy, 14 days after the cystostomy and catheter implantation showed that the laparoscopic technique had no negative implications in the health of the abdominal cavity, which is in good agreement with the findings of the study of FRANZ et al. (2008).
5.4. Clinical and Scientific Relevance

Tube cystotomy has shown to be the elective treatment of urolithiasis in small ruminants intended to be kept as breeding animals or pets, since it has good rates of success, specifically low reobstruction rate, and appears to be the most appropriate approach for obstructive urolithiasis in small ruminants for use as breeding animals or pets (RAKESTRAW et al., 1995; ISELIN et al., 2001; STREETER et al., 2002; PEARCE et al., 2003; EWOLDT et al., 2006; VAN METRE et al., 2006). Laparoscopy is a valid choice for the treatment of urolithiasis, but the risks of general anaesthesia, added to the Trendelenburg position and capnoperitoneum should be managed with caution in those patients with cardiorespiratory and metabolic instabilities.

Surgery in the lateral position is less comfortable for the operator, and showed no advantages for the blood gas, acid-base status and cardiovascular system in sheep, compared to dorsal recumbency, although more studies, using a larger sample and/or patients, should be carried out.

The implantation of the urinary catheter can precede the cystostomy (taking care not to perforate the catheter’s balloon) in left lateral recumbent sheep, with the advantage of reducing the time needed for surgery, and should be attempted in dorsal recumbent animals.

Pigtail catheters are a good choice for tube cystotomy.

The necessity to place the patients in the Trendelenburg position is obvious in several laparoscopic procedures in the reproductive apparatus, colon and urinary bladder. Sheep do not share their characteristics with horses, dogs, or humans and, therefore, this investigation was useful to show some differences between the species and contributed to the, until now nearly inexistent, values of blood gas, acid-base status and haemodynamic parameters, during laparoscopic surgery in sheep.

Further studies on patients need to be conducted in order to reveal the real risks of this procedure in animals suffering from obstructive urolithiasis.
6. SUMMARY

Urolithiasis is a common disease of male sheep, with significant losses and that concerns the everyday increasing pet-sheep owners as well as producers from fattening units. Treatment continues to challenge clinicians, due to the numerous cases of postoperative complications and reobstruction. Tube cystotomy has been reported as the most efficient procedure to manage the problem. It can be performed with laparoscopic guidance, with the animal in Trendelenburg position and capnoperitoneum settled.

In this study the metabolic and haemodynamic responses to the Trendelenburg position and capnoperitoneum were investigated and compared in anaesthetized animals in dorsal and left lateral recumbency. Afterwards, a laparoscopic-assisted cystostomy and implantation of a urinary catheter were performed.

There were haemodynamic alterations in all animals after the Trendelenburg position, aggravated after the insufflation in both groups. Capnoperitoneum also led to changes in the blood gas and acid-base balance. Cystostomy and implantation of the urinary catheter was feasible in all animals from both groups. In the following days after intervention, some animals showed few alterations during physical examination; and a laparoscopic control on the fourteenth day after surgery documented good signs of healing of the urinary bladder and trocarization and mini-laparotomy sites, in all sheep. Laparoscopic-assisted cystostomy in combination with implantation of a urinary catheter can be a valid choice for the correction of urolithiasis in rams and it is feasible in left lateral recumbent animals. The minimal invasive procedure should be used carefully in patients with haemodynamic and metabolic imbalances due to the risks of general anaesthesia, added to the Trendelenburg position and capnoperitoneum.

Keywords: urolithiasis, sheep, tube cystotomy, laparoscopy, Trendelenburg position, capnoperitoneum, lateral recumbency
7. ZUSAMENFASSUNG


Keywords: Urolithiasis, Schaf, Zystotomie, Laparoskopie, Trendelenburg Position, Kapnoperitoneum, Seitenlage
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