UNIVERSIDADE DE LISBOA
FACULDADE DE MEDICINA VETERINÁRIA

RECURRENT NEPHROSPLENIC ENTRAPMENT: A REVIEW OF CASES, SHORTERM AND LONGTERM OUTCOME AFTER LAPAROSCOPIC NEPHROSPLENIC SPACE CLOSURE WITH BARBED KNOTLESS SUTURE IN HORSES

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Abstract

Left colon displacement and nephrosplenic space entrapment (NSE) is a pathology affecting 6-20,3% of horses suffering from colic and has a reported recurrence of 8-23%. Therefore owners of horses having this type of colic should be warned about its recurrence and advised to perform preventive procedures. Among all the procedures available the one showing better prognosis relies on the closure of the nephrosplenic space. This can be performed through a flank laparotomy, though laparoscopic procedures are nowadays widely used. When entrapment is present by the time of closure most authors describe the need of converting into a hand assisted procedure or deviation of the colon with the aid of instruments. The aim of this study was to present a novel technique, were dorsal abdominal insufflation plays a key role in deviating the entrapped colon and allowing good visualization and closure of the nephrosplenic space. We aimed to assess the short and long term outcomes for horses undergoing this procedure. Data from 28 horses who underwent nephrosplenic space closure with barbed knotless suture were collected. Short term follow up was achieved by rectal palpation 15 days post-surgery and long term follow up was achieved by telephone questionnaire to the owners. Results from horses with NSE at the time of surgery were compared with those where the colon was not entrapped at the beginning of surgery. Total number of episodes of NSE before surgery and number of colic episodes (and diagnosis) after surgery were registered. No differences were found regarding time of surgery and time of closure of the space which suggests there is no increased difficulties or complications when NSE is present by the time of surgery. Adherence of the displaced colon was feared in horses with NSE at time of surgery but short term and long term outcome was positive in every horse. None of the horses had recurrence of NSE after the surgery. Some horses had other colic episodes after the surgery but all were not related to NSE or the surgery itself. As so, these results indicate this procedure to be a time saving and safe technique to perform when the colon is displaced, therefore increasing the advantages of this minimally invasive procedure.

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Keywords: Horses, Surgery, Nephrosplenic Space Entrapment, Nephrosplenic Space Closure, Barbed Suture

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Resumo

O deslocamento do cólon á esquerda e o encarceramento no espaço nefrosplénico (EEN) é uma patologia que afeta 6-20,3% dos cavalos que sofrem de cólica e tem uma recorrência relatada de 8-23%. Dessa forma, os proprietários de cavalos que apresentam esse tipo de cólica devem ser alertados sobre sua recorrência e orientados a realizar procedimentos preventivos. Dentre todos os procedimentos disponíveis, o que apresenta melhor prognóstico é o encerramento do espaço nefrosplénico. Pode ser realizado por meio de uma laparotomia de flanco, embora os procedimentos laparoscópicos sejam hoje em dia mais amplamente usados. Quando o encarceramento está presente no momento do encerramento, a maioria dos autores descreve a necessidade de conversão para um procedimento assistido pela mão ou desvio do cólon com auxílio de instrumentos. O objetivo deste estudo foi apresentar uma nova técnica, onde a insuflação dorsal abdominal desempenha o papel principal desviando o cólon deslocado e permitindo boa visualização e encerramento do espaço nefrosplénico. Pretendeu-se avaliar o resultado a curto e a longo prazo em cavalos submetidos ao procedimento. Dados de 28 cavalos submetidos ao encerramento do espaço nefrosplénico com sutura barbada sem nós foram recolhidos. O acompanhamento a curto prazo foi realizado por palpação retal 15 dias após a cirurgia e o acompanhamento a longo prazo foi realizado através de um questionário por telefonema para os proprietários. Resultados de cavalos com EEN na cirurgia foram comparados com resultados dos que não apresentavam o colon encarcerado no momento da cirurgia. O número total de episódios de EEN antes da cirurgia e o número de cólicas (e o seu diagnóstico) após a cirurgia foram registados. Não foram encontradas diferenças em relação ao tempo de cirurgia e tempo de encerramento do espaço, o que sugere que não há aumento de dificuldades ou complicações quando o EEN está presente no momento da cirurgia. A aderência do cólon deslocado foi temida em cavalos com EEN no momento da cirurgia, mas o resultado a curto e longo prazo foi positivo em todos os cavalos. Nenhum dos cavalos teve recorrência de EEN após a cirurgia. Alguns cavalos tiveram outros episódios de cólica após a cirurgia, mas nenhum estava relacionado com EEN ou com a cirurgia em si. Sendo assim, este procedimento pode ser uma técnica segura que economiza tempo quando o cólon está deslocado, aumentado assim as vantagens deste procedimento minimamente invasivo.

Palavras-chave: Cavalos, Cirurgia, Encarceramento do Espaço Nefrosplénico, Encerramento do Espaço Nefrosplénico, Sutura Barbada

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Abbreviations

A.D.	Anno Domini
NSAIDS	Nonsteroidal Anti-inflammatory Drugs
BID	*Bis in die* (twice a day)
BPM	Beats per minute
Ca^{2+}	Calcium
CO^2	Carbon Dioxide
cm	Centimeters
CRI	Continuous Rate Infusion
GGT	Gamma glutamyl transferase
HCO_3	Bicarbonate
HR	Heart rate
ICS	Intercostal Space
IM	Intramuscular administration
IV	Intravenous administration
IQR	Inter Quartil Range
K^+	Potassium
Kg	Kilogram
L	Litre
m	meteres
Mg	Milligram
Min	Minute
mL	Millilitre
mm	Milimeters
mmHg	Milimetre of Mercury
mmol	Millimoles
Na^+	Sodium
NaCl	Sodium Chloride
NS	Nephrosplenic Space
NSC	Nephrosplenic Space Closure
NSE	Nephrosplenic Space Entrappment
PCV	Packed Cell Volume
PCO^2	Carbon Dioxide Pressure
PO	*Per os*

RPM	Respirations per minute
sec	*Second*
SC	Subcutaneous
SCUE	Serviço de Cirurgia e Urgência de Equinos
SD	Standard deviation
SID	*Semel in die* (once a day)
SIRS	*Systemic Inflammatory Response Syndrome*
TP	Total protein
µg	Microgram
UI	International units
>	More than
<	Less than
º	Degrees

1. Externships and Curricular Clinical Training Report

As part of the clinical training of the Integrated Masters in Veterinary Medicine, a two month externship was undertaken in the Faculty of Veterinary Medicine of Lisbon. In this externship consisted in close follow up of the daily work in the Service of Equine Medicine and Surgery (SCUE). SCUE is a refence hospital and has an emergency service, open not only during daily time, but also during the night and weekends. As an extern it was mainly during out-of-our duties there was opportunity of following the admission of emergencies and to learn more about intensive care. As a reference service, there it was also possible to follow many cases of internal medicine, surgery and sports medicine. As a university hospital every case allowed a profound theoretical study with multiple questions and teaching moments provided by the senior veterinarians, either after the admission of the case or during the morning rounds.

Alongside all the theoretical knowledge, practical clinical training was also accomplished. I was possible to perform: physical exams, drug preparation and administration, admission of emergencies, placement of intravenous catheters, nasogastric intubation, abdominocentesis, ultrasound examination, radiography examination, lameness examination, placing bandages, dentistry procedures. During surgery, it was possible to assist the intern during induction, anaesthesia, clipping and scrubbing, placement of the urinary catheter and placement of the arterial catheter. Regarding the surgical cases, it was given the opportunity of being present in multiple surgeries such as colic surgery, diagnostic arthroscopy and tenoscopy, enucleation of the eye globe, castration, melanoma excision and articular lavage. Considering internal medicine caseload it was possible to assist in gastroscopy, upper airway endoscopy, collecting tracheal lavage samples, examination of guttural pouchs, abdominal and thoracic ultrasound, interpretation of blood analysis. As part of the sports medicine cases many lameness and ataxy cases were assisted.

To complete further clinical training an externship in Clinique Equine de Meslay in France was undertaken from 28 of August 2020 to 5 of October 2020. Clinique Equine de Meslay has a main caseload of race horses, offering a great contrast with the externship in SCUE, were the case load is strictly base on sports horses (dressage, show jumping, leisure). In this clinic, the theoretical knowledge was deepen through morning rounds, case discussion and weekly quizzes and case presentations. It was also possible to perform multiple practical procedures such as general anaesthesia, abdominal ultrasound, admission of emergencies and consults, placement of intravenous catheters, nasogastric intubation, drug preparation and administration, placement of bandages and periocular nerve blocks. It was also possible to assist and scrub in in various surgeries such as colic surgery, arthroscopy, tenoscopy, herniorrhaphy, castration, enucleation. It was possible to assist and follow most of the cases throughout admission and treatment.

2. Introduction

2.1. Anatomy and Physiology of the Gastrointestinal Tract of the Horse

Equids are monogastric herbivores with a specially developed hindgut/large intestine.(G. Klein 2013)

Following the pathway of all the ingested material, the equine mouth has many singularities, such as very sensible lips which promote high selectivity of food and also hypsodont teeth, with continuous growth of the teeth as the horse ages (O. Reece 2015). The next structure is the oropharynx with the entry of the oesophagus dorsal to the trachea. The oeshophagus goes until the stomach, dorsal to the trachea and slightly deviated to the left side and its mainly composed by striated skeletal muscle and smooth muscle in the distal part (G. Klein 2013). The oesophagus entries the stomach in the cardia and the stomach is positioned in the left side of the abdomen. The cardia and pylorus lie closer together united by the lesser curvature. The stomachs capacity is around 5-15 litres (L) (Budras et al. 2005) or 10-15L (Moore et al. 2007) depending on the author, and when moderately filled it lies from the 9th to the 14th intercostal space (ICS), contained by the rib cage. The cardia is fixed to the diaphragm by the oesophageal hiatus and its thickness and oblique position is what prevents reflux from the stomach to the oesophagus. Dorsally to the cardia there is a blind sac called the fundus, from where the body follows, as the largest portion of the stomach, until the pyloric region. The stomach is constituted by a non-glandular part that extends from the fundus to a part of the body and a glandular part which occupies most of the body and the pyloric portion. These parts are divided by the margus pelicatus. The non-glandular mucosa does not secret any enzymes and its function is yet unknow. On the other hand, the glandular mucosa contains parietal and secreting zymogen cells which maintain the acidity of the stomach. To balance this, the pyloric region contains cells that secret gastrin and somatostatin to reduce the acid. As to its curvatures: the lesser curvature extends from the cardia to the pylorus and the greater curvature runs dorsally from the cardia to the left continuing ventrally and running back to the pylorus (Moore et al. 2007). From each curvature a omentum arises, respectively the lesser and greater omentum, having the function of attaching the stomach to its surroundings. Between the stomach and omentum there is a cavity that forms the called omental bursa. This vestibule communicates with the abdominal cavity through a canal: the epiploic foramen, delimitated by the right lobe of the liver, caudal vena cava, portal vein and duodenum (Budras et al. 2005). Two important attachments are the gastrosplenic ligament that connects the greater curvature of the stomach to the hilus of the spleen and the gastrofrenic ligament connecting the greater curvature of the stomach to the diaphragm. From the pylorus, ingesta entries the duodenum.

The duodenum with 1 m of length is attached to the dorsal body wall on the right side by its short mesentery and it runs this direction until the horse's flank, where it changes to the left entering the jejunum. Its beginning is formed by a large ampule followed by a cranial flexure, where the pancreas lies and where the duodenal papilla opens with drainage of the pancreatic and bile ducts. The duodenum has also the caudal duodenal flexure, that runs along the cecum, attaching itself to the descending and transverse colon by the duodenocolic fold, and from there it continues as jejunum. It is in the small intestine, especially the proximal part, where the ingesta suffers most action of the enzymatic digestion by pancreatic and biliar enzymes. In the duodenum bicarbonate is also secreted to increase the pH and therefore solubility of bile and fatty acids. Many pancreatic enzymes are released such as amylase, lipase, trypsin, chymotrypsin, carboxypeptidase and elastase. It is also in the microvilli that specific transport systems are placed. The jejunum follows and has around 17 to 28 meters (m) of length and at its end there is the ileum, as a more muscular part, with 0,7 m of length. The main anion in the small intestine is the chloride and this anion switches with the bicarbonate at the end of the ileum, thus bicarbonate entering the cecum in a larger amount and aiding fermentation. It is as well in the third distal end of the small intestine that occurs most water and Na^+ absorption, though the large intestine plays a much more marked role in water and ion flux (Freeman 2019). All the small intestine has a mesenteric support.

The ingesta then moves from the ileum to the cecum through the ileocecal valve, which is a one-way valve. The cecum forms as a large comma shape and the ingesta moves from the body to the apex then returning to the base where it leaves through the cecocolic orifice to the right ventral colon. The cecum occupies a right flank position with approximately 1 m of length and 30 L of capacity. Its base is positioned dorsally in the abdomen and attached to the body wall in the dorsal right iliac and paralumbar fossa regions. The body contains two curvatures: the greater placed dorsally and the lesser, ventrally and its apex is directed cranioventrally. Four taeniae can be found in the cecum: a dorsal and a medial that continue until the apex, a ventral that normally unites with the medial and a lateral that has a variable length. It is in the cecum and colon that most of the fermentation process takes place, being the cecum the portion of the large intestine the most colonised by specialized microbiota. Bacteria, fungi and protozoa are responsible for digesting hydrolysable nutrients and indigestible complex molecules such as insoluble carbohydrates. This digestion leads to the production of fatty acids, mainly the acetic, but as well the propionic and butyric, that are posteriorly used as energy source (Sherlock 2019). It is also in the cecum and colon that most of the water is reabsorbed (G. Klein 2013) and where major electrolyte flux takes place (Sherlock 2019). Ingesta leaves the cecum through the cecocolic orifice, placed caudal and lateral to the ileocecal orifice. (Sherlock 2019)

The large colon may be divided in four parts based in their location: right ventral colon, left ventral colon, left dorsal colon and right dorsal colon. This portions of the colon and changes in direction promote the formation of three flexures: the sternal flexure between the right ventral colon and the left ventral colon; the pelvic flexure between the left ventral colon and the left dorsal colon and finally the diaphragmatic flexure between the left dorsal colon and the right dorsal colon (Southwood 2019). The pelvic flexure is a place where there is differentiation between the flow of solids and liquids, predisposing it to impaction (G. Klein 2013). It is also a place with changes of diameter: the left ventral colon presents a diameter of 20-25 cm whilst in the left dorsal colon this is reduced to 8-9 cm. The dorsal and ventral colon are united by the mesocolon, which consists in two layers of peritoneum containing connective and fatty tissue in between. Other important features are that the ventral colon presents sacullations and the dorsal does not. The large colon also contains taeniae: the ventral one presents four: a lateral and a medial free and a lateral and a medial mesenteric band. The pelvic flexure and the following left dorsal colon only present a mesenteric band and the right dorsal colon presents 3 taeniae. The right ventral colon is connected to the cecum by the cecocolic fold. In the large colon, hydrolysis of structural carbohydrates takes place, giving origin to soluble sugars that enter the fermentation process. From there fatty acids are generated and utilised as energy source. (Southwood 2019)

From there the transverse colon, a short segment of the large intestine follows and finally the small colon ending in the rectum. The small colon has a size of 3,5 m and 7-10 cm diameter. It's mainly placed in the left caudodorsal quadrant and it is sustained by a descending mesocolon. It contains 2 taeniae, one mesenteric and the other anti-mesenteric. The longitudinal and circular contractions of the small colon form sacullations along all its length and this movements are responsible for the formation of the faecal balls. (Prange et al. 2019)

Other important organs that affect the functioning of the gastrointestinal tract are the liver, kidneys, pancreas, spleen and some peritoneal folds and ligaments. Knowing its position is of most importance to identify abnormalities and displacements of the gastrointestinal tract. The liver is placed craniodorsally between the stomach and diaphragm, closely to the pancreas, which is also side by side to the start of the duodenum. The spleen is placed in the left side of the abdomen, adjacent to the left abdominal wall and it is linked to the left kidney through the nephrosplenic or renosplenic ligament. The right kidney is situated on the right side, further cranially than the left kidney. (Moore et al. 2007)

2.2. Equine Colic: The Acute Abdomen Syndrome

Colic have been described as one of the most common emergencies treated by veterinarians.(Archer 2004)

Most of equine colics are of mild severity and resolve with medical treatment. Approximately 20% may become critical, requiring reference to a hospital facility, surgery, or euthanasia (Barker and Freeman 2019).

A study of the main causes of out-of-hours calls performed by veterinarians described colics as being 35% of the calls. (Bowden et al. 2020)

Generally, arriving to a definitive diagnosis can be very hard so there are some parameters are described to help determine if surgery is necessary or if medical treatment is the ideal course. These parameters include the comfort of the horse: violent colics, not controlled with the aid of painkillers and sedation usually require surgery. A high blood lactate together with a high peritoneal lactate and serosanguinolent peritoneal sample can also determine surgery is necessary. (Blikslager and Marshal 2019)

2.3. Main Causes

Regarding the main causes of colic, a division can be made accordingly to the organ of the gastrointestinal tract affected. Regarding the intestine Blikslager and Marshal 2019 suggested a classification of the lesions as simple obstructions, strangulating obstructions and non-strangulating infarctions. These can happen either in the small intestine or large intestine. The simple obstructions are usually caused by an intraluminal impaction which might eventually compromise the intestinal wall viability by compromising its blood supply, although not being as severe as the strangulating obstructions. In these last ones, the blood supply and intestinal lumen are both compromised, starting by an occlusion of the veins, which are more complying and forming a haemorrhagic strangulating obstruction. Afterwards, if the origin of the problem is not resolved, an ischaemic strangulating obstruction may prevail, when arteries also become occluded. Examples of this type of obstruction are large colon volvulus, entrapment of small intestine through hernias, pedunculated lipomas. Finally, non-strangulating infarction is caused by occlusion of blood supply by a thrombus or embolus originated from diverse causes such as parasites, salmonella, thromboembolic disease or dental disease. (Blikslager and Marshal 2019)

2.3.1. Oesophagus

Oesophageal impaction by food or bedding is the most frequent condition affecting horses with origin in the oesophagus. Treatment consists in relaxation of the oesophagus with resource to sedatives, tranquilizers or oxytocin. Afterwards the impaction may be softened by nasogastric intubation associated with warm water lavage. This procedure should be made very carefully since it may lead to reflux of the impactions content to the pharynx. This might

lead to aspiration pneumonia. In order to prevent it, a nasogastric cuffed tube may be used. External massage also helps softening the impaction and it might be necessary to wait if the treatment does not work right away, since the impaction can take some time to soften. (Fubini 2019)

2.3.2. Stomach

There are three main identities that can be in the origin of a colic implying the stomach: ulceration, distention and impaction. Stomach ulceration is often associated with different degrees of pain being most of the foals and adult horses asymptomatic (Moore et al. 2007). The ones who show signs usually have slight pain and behaviours such as pawing, stretching, low appetite, weight loss or back rolling in foals. Generally, the prognostic is good after treatment with medication to reduce gastric acidity. Gastric distention or dilation can occur when there is accumulation of either excessive fluid or gas. Excessive gas builds up usually happens after consumption of high fermentable feed. When the problem is the excessive fluid, the so called gastric reflux, there might be an obstruction to the stomach outflow secondary to obstruction or strangulation of small intestine or a problem in small intestine motility (Moore et al. 2007; Sanchez 2018; Blikslager and Wilson 2019). Severe inflammation of the duodenum and proximal enteritis also causes high amounts of gastric reflux and great discomfort. Finally gastric impaction is described as a rare cause of colic (Moore et al. 2007) and is caused by accumulation of food badly masticated and dry that might move the spleen caudally in extreme cases. The treatment might require surgery, but stomach lavages are usually the first choice.

2.3.3. Small Intestine

The small intestine might be affect by spasmodic colics, simple obstructions, strangulating obstructions, infarctions, enteritis. (Moore et al. 2007)

The spasmodic colic has so far, unknown origin since there are no proofs of its connection to any cause, only suspicions, of alterations in nerve supply or as a response to undigested feed. It happens in the form of a cramp or spasm of the intestinal musculature, causing moderate pain. Spasmolytic and sedative agents usually resolve this type of colic. (Moore et al. 2007)

Simple obstructions are normally intraluminal obstructions being the most common one the ileal impaction. Ileal impactions happen when ingesta in unable to pass the ileocecal orifice, getting bigger as the ingesta continues to pass from the jejunum to the ileum. This promotes intestinal distention that is aggravated by the fluid build-up caused by the passage of fluid to the intestinal lumen secondary to the impaction. This pathology is associated with certain geographical points and with the ingestion of certain feeds as the Bermuda hay (high fibber content). It has also been linked to tape warm infestation provoking dysfunction of the ileocecal valve. If the distention is not to severe, medical treatment with parenteral and enteral fluid

therapy, oral mineral oil might be attempted. If the distention is already to severe, surgery might be necessary with intraoperative massage of the impaction to the cecum (Moore et al. 2007).

Strangulating obstructions happen when the blood and lymphatic flow are compromised. The first vessels to collapse are the veins due to its more compliant wall, so usually this kind of lesion starts as a congestive lesion because the blood outflow is not possible. Because arteries keep supplying blood there is also rupture of the capillaries in the mesentery. Afterwards, the arteries might be compressed as well, and the ischaemic lesion becomes imminent. After oedema, the lack of blood supply might lead to necrosis of the strangulated segment, and as the lumen is also obstructed, a distention with gas and fluid starts building up proximal to the strangulation point (Blikslager and Marshal 2019). Strangulating lesions can happen in various parts of the small intestine due to different causes. For instance, if there is a mesenteric rent, small intestine, most commonly jejunum and ileum, can pass through it and become entrapped. Epiploic foramen entrapment is another diagnosis of strangulating colic defined by the entrapment of distal jejunum and ileum, with tearing of omentum in the epiploic foramen, which is limited by the caudate lobe of the liver, portal vein, pancreas and caudal vena cava (Moore et al. 2007). This appears to happen in older horses (>8 years) and can be correlated with a certain behaviour of crib biting and windsucking (Archer et al. 2008). Other pathology that can cause small intestine strangulation are pedunculated lipomas, masses of fatty tissue that normally form in older horses and sometimes its pedicle enfolds a segment of small intestine including its mesentery, thus provoking a strangulating lesion. Hernias might as well be problematic: habitually the inguinal hernias are most frequently in the origin of strangulation of small intestine, as the inguinal rings are a very small passage. This condition happens most commonly in stallions and is more frequent after breeding or intense exercise. Other hernias such as umbilical and abdominal hernias are not so alarming though the hernia ring can always set off the formation of a strangulating lesion(Moore et al. 2007). The small intestinal volvulus occurs when a normal motile segment of intestine moves around an immotile segment, rotating the mesentery and ultimately twisting it and inciting a strangulating lesion (Moore et al. 2007). Lastly, ileocecal intussusceptions also cause strangulating obstructions. Its origin is connected with mucosal irritation and changes in motility due to parasitic infestation. The changes in motility incite the invagination of the ileum in the cecum through the ileocecal valve. With the continuous motile waves the ileum and jejunum entry the cecum having its blood flow compromised and becoming strangulated. Small intestine intussusceptions also happen, being the jejuno-jejunal the most frequent in foals, and can sometimes be asymptomatic, as it was found in a study by (Abraham et al. 2014).

Enteritis is a condition that is also in the origin of colic episodes. The proximal small intestine is the most affected, involving duodenum and jejunum, being also called proximal enteritis. This condition doesn’t imply a physical obstruction of the lumen of the intestine, but

a distention with gas and fluid starts, ending with a generalized distention of several intestinal loops. Horses with enteritis present large amounts of gastric reflux caused by ileus, and a higher risk of endotoxemia and laminitis. Its origin is not clarified but there are suspicions of the roll some bacteria play in this pathology (Moore et al. 2007).

Non-strangulating infarction is a condition where the blood flow is compromised either by a thrombus, embolus or a low flow state, such as severe hypovolemia or haemorrhage. It affects mainly the cranial mesenteric artery, and any segment supplied by this artery can be affected though it is described the distal small intestine and the large colon are the most severely affected. Intestine appears with lesions of necrosis or degeneration without obvious obstruction. This pathology has been correlated to arteritis caused by migration of *strongylus vulgaris*, salmonella, dental disease or thromboembolic conditions (Blikslager and Marshal 2019).

2.3.4. Large intestine

The main pathologies affecting the cecum are distention (normally secondary to large colon obstruction or distention), impaction and intussusception. Cecal distention with gassy contents may be secondary to colon displacements, torsions and obstructions of both small colon and large colon. If the condition appears as a primary problem of the cecum it can be related with over fermentation of some types of feed. It might be identified during rectal palpation and if severe, these horses present intense abdominal distention. (Moore et al. 2007)

Caecal impactions are more frequent in the base of the cecum since they are originated from changes in the pattern of caecal motility. Therefore, an accumulation of feed in the base of the cecum happens, followed by dehydration and formation of an impaction. The progression of the intestinal contents promotes further impaction of the caecal body and apex. The main causes linked to caecal impactions are the ingestion of certain feeds, the reduction in water intake, or bad dental conditions. It can also be associated with general anaesthesia, hospitalization and the use of NSAIDS. (Southwood 2019)

Finally, caecal intussusceptions are rare but incite a severe strangulating colic. Unveiling what occurs: the caecal apex enters the body, and as the invagination process occurs, the caecal apex and body pass through the cecocolic valve into the lumen of the right ventral colon. As the intussusception of small intestine into the cecum is associated with parasitism, so is this one. It might also happen after administration of certain drugs (organophosphates and parasympathomimetic drugs). (Moore et al. 2007)

The singular strangulating lesion affecting the large colon has usually only one cause: colon torsion. The severity is determined by the degree of torsion, varying from 180º to 720º (Moore et al. 2007). Risk factors that predispose to colon torsion are age and broodmares foaling in the past 90 days (Leahy et al. 2018). Volvulus or torsion of the large colon promotes a strangulating lesion and also a luminal obstruction, depending on the degree. Large amounts

of gas accumulate, thus promoting distention and the concurrent ischaemia leads to potential wall permeability defects and endotoxemia. Surgery is usually necessary. (Moore et al. 2007)

There are three identities that lead to obstruction of large colon: feed impactions, sand impactions and enterolithiasis. Feed impactions are more frequent in the pelvic flexure due to the change in the lumen diameter from the ventral colon to the dorsal colon. If indigested material with large particles of feed is unable to pass the pelvic flexure, and as the water from this material is reabsorbed, a large impaction starts to form. As more food progresses to the ventral colon the impaction's size enlarges. Treatment involves hydration of this feed mass, either resourcing to parenteral or enteral fluid therapy or both combined. Sand impactions are more frequent in the right dorsal colon affecting the connection between the right dorsal colon and the transverse colon. Horses fed in the soil, especially in soils containing lots of sand, are predisposed. The sand accumulation promotes a mucosal irritation and as it is a heavy impaction, the colonic sacullations disappear. These horses might present diarrhoea, mild pain and intermittent colic (Sanchez 2018). The treatment consists in removing the sand with oral administration of psyllium and fluid therapy, enteral and parenteral combined, if necessary. Lastly, enteroliths may also be the origin of luminal colonic obstruction. They are formed by concretions of magnesium ammonium phosphate and if their size is considerable, they affect the ascending colon, causing obstruction. In the USA it is described that this kind of obstruction is associated with the consumption of alfalfa hay, which contains high values of magnesium. (Moore et al. 2007; Sanchez 2018)

Other affection that can lead to some degree of obstruction of the intestinal lumen is the colon displacement. As described in a previous chapter, the lack of attachments of the colon to the abdomen wall makes it especially predisposed to displacements (Mair and Hardy 2014). The two most frequent displacements are the right dorsal displacement and the left dorsal displacement. The right dorsal displacement occurs when the colon displaces between the cecum and the right wall of the abdomen, due to impaction of the pelvic flexure and its movement cranially in the abdomen. Sometimes, torsion of the colon accordingly to its long axis might also occur. This condition can be managed medically or surgically. Left colon displacements happen when the colon moves between the spleen and left abdominal wall. A most severe condition might happen if the colon also becomes entrapped in the nephrosplenic ligament, lodging itself between the left kidney and spleen. This condition will be further developed in the next chapter. (Moore et al. 2007; Sanchez 2018)

Colitis consists in an inflammation of the colonic wall, thus causing fever, diarrhoea and endotoxemia signs such as tachycardia, prolonged capillary refill time and changes in the colour of mucous membranes. It may be caused by sand, bacteria or certain drugs. (Moore et al. 2007)

Enterolithiasis consists in the formation of enteroliths in the small colon. As described before, the constitution of enteroliths is based on magnesium ammonium phosphate crystals, that usually congregates around a nidus (metal or stone). This normally leads to obstructive disease, although if the prolonged excessive pressure is placed in the intestinal wall, an ischaemic lesion may appear. (Moore et al. 2007; Prange et al. 2019)

Impactions can also cause obstruction of the small colon and consists in excessive accumulation of dehydrated food in the small colon. This leads to moderate pain and might implicate the large colon, cecum and eventually ileum, causing gas accumulation.(Moore et al. 2007)

Hepatolithiasis can also cause colic and affects horses normally older than 3 years old and symptoms consist in fever, icteric mucous membranes and episodes of mild abdominal pain. It might be provoked by a single cholelith but frequently is caused by multiple small cholelithes. (Moore et al. 2007)

2.4. Diagnostic methods

When approaching a horse in colic the first step after gathering a fast past history is to evaluate right away the cardiovascular and metabolic function because the compromise of these during the colic episode might lead to sepsis and endotoxemia (Sanchez 2018). In order to obtain more information, a thorough physical examination should be conducted collecting information about mucous membrane coloration and hydration, capillary refill time, general hydration, heart rate, gut sounds, temperature, respiratory rate, digital pulse. (Southwood and Walton 2012)

When the first approach to the horse is made, its behaviour should be observed, in order to determine if there are evidence of pain, such as violent behaviour, rolling, kicking the abdomen, or even abrasions that might mean the existing of this violent behaviour before this observation. Body condition can also be determined and the horse´s attitude (bright and alert, dull or very painful). If the horse is sweating it can also indicate pain and shock. The abdominal distention might be difficult to determine by the veterinarian if he has not seen the horse before. (Southwood and Walton 2012)

Physical examination should be accessed by the following order: firstly the cardiovascular status as said before, followed by an evaluation of the gastrointestinal system, rectal temperature and finally respiratory rate and evaluation of the respiratory system. To evaluate the cardiovascular status the heart should be auscultated, and the heart rate obtained. Horses have normally a heart rate of 28-36 beats per minute (32-44), and tachycardia means usually that the horse is in pain and in some degree of shock if higher than 70 beats per minute. When the heart rate is higher than 60 bpm nasogastric intubation and

gastric decompression should be performed immediately since there is imminent risk of gastric rupture due to gastric distention (Southwood and Walton 2012). Oral mucous membranes should also be observed in order to access the cardiovascular function. Normal mucous membranes are moist and pale pink with a capillary refill time of <2sec. When there is gastrointestinal disease and endotoxemia the colour of the mucous membranes tends to change to a darker pink to red to purple colour and a toxic line may appear around the teeth. When there is hypovolemia and tissue perfusion is compromised, the CRT is augmented and dry mucous might be a signal of dehydration. Pulse quality can also be evaluated by palpation of the pulse on the facial artery for example. If pulse is not easily palpated and regular, hypovolemia might be imminent. Evaluation of the gastrointestinal tract follows with auscultation of the borborygmi of the 4 quadrants. If borborygmi are reduced or absent motility is reduced, which can happen if the horse was prevented from feeding or can be related with a gastrointestinal disease or the cause of colic. Hypermotility and increased gut sounds are present in spasmodic colics or colitis/enteritis. If reduction of motility is localized to one quadrant it might help the veterinarian have a clue where the problem is located. Rectal temperature should also be assessed and normally ranges from 37,2ºC to 38,3ºC. Pyrexia might be present when an infectious or inflammatory process is present. Horses with colitis, peritonitis, enteritis usually present with pyrexia. Finally, respiratory tract evaluation should be performed. Normal respiratory rate ranges from 8 to 12 RPM and is not markedly evident through thorax and nostrils. In horses with colic, tachypnoea may be present due to pain, shock, or fever. If marked abdominal distention is present, ventilation might be compromised resulting in tachypnoea. Respiratory tract disease is also another differential diagnosis though less likely to be considered when an episode of colic is present. Accessing the digital pulse is a very important step of the physical exam since some types of colic and post-operative complications will leave the patient more prone to develop laminitis. (Southwood and Walton 2012).

Some additional exams are also crucial such as transrectal palpation, nasogastric intubation and abdominal ultrasound. (Southwood and Walton 2012).

Transrectal palpation is a very important step during a colic examination. According to Sanchez 2018, it is “the most specific technique for evaluating intestinal disease” mentioning also its importance to diagnose obstructive conditions. Firstly physical restrain of the horse is very important (Sanchez 2018; Blikslager and Marshal 2019)and chemical control can also be used in difficult horses (sedation). It’s also described that lidocaine per rectum or endovenous administration of butylscopolamine can aid with relaxation and prevent rectal tears (Blikslager and Marshal 2019). Two parameters can be evaluated while palpating: position and size of viscera and its content (gas, fluid or ingesta)(Sanchez 2018). A systematic rectal exam is important in order not to miss any structure: after emptying the rectum, the first step is to

advance into the centre of the abdomen; from there the examiner can advance to the left dorsal quadrant where the caudal edge of the spleen can be palpated, and sometimes, depending on the size of the horse, advancing further and slightly medially might allow the palpation of the caudal pole of the kidney and nephrosplenic ligament. Nextly, if the examiner moves dorsally, the aorta and its pulse can be palpated in the dorsal midline and advancing further cranially, the mesenteric root and its vessels. From there the right dorsal quadrant follows with palpation of the base of the cecum and a thin fibrous band: its ventral taenia. Lastly, the left ventral quadrant can be palpated where the pelvic flexure should be placed. If moved to cranially the pelvic flexure might not be palpated. The small colon can be also be palpated in the left ventral quadrant filled with formed faeces and sometimes in the other quadrants also. As described by several autors (Moore et al. 2007; Sanchez 2018; Blikslager and Marshal 2019) palpating small intestine is rarely a normal finding, since it is almost always empty. Before exiting the rectum the bladder should also be palpated as well as the inguinal canals in stallions and the uterus in mares. (Moore et al. 2007)

Another important step while evaluating a horse in colic is nasogastric intubation. It allows decompression of the stomach and in some cases might prevent stomach rupture. Nasogastric intubation is performed by passing a nasogastric tube from the nose to the stomach and siphoning the stomach contents and lavage (Blikslager and Marshal 2019). The contents recovered from the stomach should be evaluated in colour, odour and amount, being normal to recover between 2 (Blikslager and Marshal 2019) to 4L (Sanchez 2018) of green fluid, non-odorous with saliva. Usually recovering more than this means the horse has gastric reflux, that can be due to a functional or mechanical outflow obstruction (Sanchez 2018; Blikslager and Marshal 2019) or decreased small intestine motility (Blikslager and Marshal 2019). Usually horses with a strangulating or intraluminal obstruction produce smaller amounts of reflux then horses with a proximal enteritis and in the case of the last ones generally an orange to yellow malodorous fluid is present. Post-operative ileus also generates large amounts of reflux. Other findings such as great amounts of food might indicate gastric impaction (Blikslager and Marshal 2019) or bloody fluid might indicate necrotic small intestine, stomach wall or severe ulceration (Sanchez 2018). The tube can be kept in place to transport to a surgical facility or during surgery, aiding with decompression and preventing fluid aspiration (Blikslager and Marshal 2019).

Ultrasound is also very important during the evaluation, treatment and also follow up during recovery of the equine colic. Usually it is performed percutaneously with alcohol or gel and clipping if necessary. The transducer should be low frequency, 2,5-5 MHz and might be linear, curvilinear or sector, being the curvilinear preferred (Sanchez 2018). The most described ultrasound technique to access colic is the FLASH ultrasound which includes specific points of evaluation which was developed after some reviews and based on a

ultrasound technique used in human medicine - the FAST ULTRASOUND, focused on locations in trauma patients to faster evaluation (Busoni et al. 2011). This technique has its advantages such as a good predictive value of the need of surgery, it can be performed in 15 min and it does not require a very experienced technician. It includes 7 to 8 key spots of the abdomen, turning the abdominal ultrasound into a systematic technique (table 1).

Table 1 – Key points to perform Fast Ultrasound. Adapted from (Busoni et al. 2011)

Side	Site	Scanning Procedure
Left	Ventral Abdomen	Place the probe just caudal to the sternum and move caudally to assess the most gravity dependent area of the abdomen
	Gastric Window	Visualise the stomach at the level of the 10th left ICS in the middle third (dorso-ventrally) of the abdomen and then move the probe in the 2-3 ICSs cranial and caudal to the 10th
	Spleno-renal Window	Place the probe between dorsal and middle third of the abdomen
	Left middle third of the abdomen	Freely move the probe around in the middle third of the abdomen
Right	Duodenal window	Place the probe in the 14-15th right ICS in the dorsal part f the middle third (dorso-ventrally) of the abdomen
	Right middle third of the abdomen	Freely move the probe around in the middle third of the abdomen
	Cranial ventral thorax	Place the probe on the cranial ventral thorax just caudal to the tríceps muscle

Using ultrasound the stomach may be scanned between the 11th and 13th ICS in the left cranial abdomen. Its volume may be calculated by measuring the height of the wall at the 12th ICS. Small intestine is usually evaluated in the cranial ventral abdomen and its wall thickness should be less than 3 mm. Its motility and diameter should also be evaluated (Blikslager and Marshal 2019). According to Busoni et al. 2011, the finding of dilated small intestine loops has high correlation with presence of obstructive disease. Wall thickness and motility are parameters evaluated in the colon as well in the ventral abdominal midline and thickness should not exceed 5 mm. Normally sacullations present in the ventral colon can be identified in this window, and if not, there can be a suspicion of torsion, since the dorsal colon, non sacullated, may be identified as ventral. The wall thickness greater than 9 mm can also aid this diagnosis. If mesenteric blood vessels are scanned between the 12th and 17th ICS in

the costochondral junction of the right abdomen, there might be a right dorsal displacement or a 180º torsion. In the case of a right dorsal colitis a thickened wall and a submucosal layer of oedema and inflammatory infiltrate may be observed. In case of a left dorsal displacement of the large colon, this portion of the large intestine is scanned lateral or dorsal to the spleen by the 17th ICS. Sand may also be distinguished when ultrasounding, as a hyperechoic signal and acoustic shadowing, though the best method to diagnose sand impactions is radiography. (Blikslager and Marshal 2019)

Blood analysis is very important as well either to help determine the hydration status of the horse using the packed cell volume and total protein and also to determine the state of metabolic acidosis and sepsis with resource of blood lactate, pH, ions and cell count (Sanchez 2018; Blikslager and Marshal 2019). According to Sanchez 2018 when there are great changes in the hemogram during an acute disease there are already associated with severe dehydration, septicaemia/SIRS and endotoxemia, thus being reinforced by Blikslager and Marshal 2019 that the more severe these alterations are, poorer is the prognosis. For instance a very high PCV and a very low TP are both associated with a poor prognosis reflecting respectively a status of severe dehydration and endotoxemia and a great protein loss into the abdominal cavity (Blikslager and Marshal 2019). Southwood and Walton 2012 also described a high PCV is associated with dehydration or splenic contraction mediated by epinephrine released in situations of excitement or pain. Though some studies described heart rate as the most predicting factor to a poor outcome in surgical colics (Ihler et al. 2004) others refer the PCV associated with the analysis of the other clinical findings to be the most used prognostic indicator (Southwood and Walton 2012). Leukogram might be used to aid in treatment choice. Biochemistry analysis is also very useful to determine therapeutics, help diagnosis and prognosis. For example, acid-base evaluation can be made assessing blood pH, base excess, bicarbonate, PCO^2, or analysing the strong ion difference, which consists in analysing anions as the acids (chloride and proteins) and cations as bases (sodium, ionized calcium and potassium). Most studies describe a metabolic acidosis in cases of colic with a decreased pH and bicarbonate and increase PCO^2 though these values depend also in the type of colic occurring. Blood lactate is also a very import parameter, and its increasing means there is hypoperfusion and hypoxia of tissues thus occurring anaerobic glycosis. There are also other options to consider when blood lactate is increased such as severe alkalosis, sepsis, endotoxemia, glucose administration or liver disease. Normal values of lactate are <2mmol/L in blood though in a well hydrated horse <1mmol/L should be the ideal value and <1mmol/L in abdominal fluid (Southwood and Walton 2012). Though measuring blood lactate is very important to determine prognostic and therapeutics, peritoneal lactate is considered to be more specific determining if intestinal ischaemia is present or not, thus aiding in the decision if a case is surgical or not (Southwood 2019). Though both measurements are of great importance

Blikslager and Marshal 2019 describes blood lactates higher than 6mmol/\L associated with a diagnosis of colon volvulus are associated with poor prognosis and Southwood and Walton 2012 describes blood lactates higher then 7mmol/L have been correlated with non-survival in several studies. Anion gap can also be used to determine lactate indirectly. It is very important to measure blood electrolytes to provide balanced fluid therapy and correct imbalances. Horses with gastric reflux or diarrhoea tend to present loss of Na^{+}, K^{+}, Ca^{2+} and HCO^{3-}. (Blikslager and Marshal 2019)

High GGT values have been associated with colon dorsal right displacement because there might be compression of the bile duct and obstruction. (Blikslager and Marshal 2019)

Abdominocentesis is another important diagnostic procedure that can aid differentiating strangulating lesions from non-strangulating lesions of the small intestine (Sanchez 2018; Blikslager and Marshal 2019) and can also help determining the prognosis (Blikslager and Marshal 2019), thus aiding as well to determine if the course of treatment should be surgical or not (Sanchez 2018; Blikslager and Marshal 2019).Its described as the act of collecting a small sample of peritoneal fluid and evaluating several characteristics such as its colour and transparency, lactate, total proteins and cellularity (white and red blood cells) and also glucose (Sanchez 2018; Blikslager and Marshal 2019). The ideal place to perform the abdominocentesis is the most pendent part of the abdomen, slightly to the right side of the midline, to avoid puncturing the spleen. Ultrasound can be used to aid find a good place to puncture. There are several techniques described as the use of an 18 gauge needle or a teat cannula, in this last case, after a small incision with a 15 blade. The collection should be made into a dry tube and EDTA tube. The first step is evaluating the appearance of the fluid, meaning its colour and transparency. Normal fluid should look clear and light yellow with less than 2g/dl of protein, low lactate and some red blood cells may appear in case of iatrogenic contamination. When there is a strangulating lesion there is translocation of protein into the peritoneal fluid followed by erythrocytes and finally leukocytes (Blikslager and Marshal 2019). When the barrier function of the intestinal wall is completely lost there can also be translocation of bacteria. Glucose is a measurement that can be performed to verify if septic peritonitis is imminent, since differences greater than 50mg/dL between the serum glucose and peritoneal glucose or a peritoneal glucose lower than 30mg/dL associated with a pH lower than 7.3 are good indicators of septic peritonitis.(Southwood 2019)

2.5. Left Colon Displacement and Nephrosplenic Entrapment

The colon of the horse lacks mesenteric attachments (Mair and Hardy 2014) except the right ventral and dorsal colon and due to its freedom to move in the abdomen, it has a specially high tendency to displacements and torsions.

Predisposition has been associated with geldings and warmbloods(Burke and Parente 2016). Though Röcken et al. 2005 linked the depth of the nephrosplenic space with the probability of entrapment, Burke and Parente 2016 could not find this connection in his study.

Left colon displacement occurs when the left colon moves between the spleen and the left body wall. Then, it may become entrapped in the nephrosplenic space, passing dorsally to the nephrosplenic ligament, consequently provoking a nephrosplenic entrapment (Southwood 2019). This results in a non-strangulating obstruction though a torsion of the colon may be associated, turning the condition into a strangulating obstruction (Sanchez 2018).

The aetiology of the displacement of the colon has been associated to colonic motility dysfunction, accumulation of gas, depth of the nephrosplenic space (Arévalo Rodríguez et al. 2019). Sanchez 2018 refers as well that gastric distention may lead to a medial deviation of the spleen, allowing an easier left displacement. The gas accumulation can happen due to excessive fermentation and gas production that might be a result of ingestion of high values of soluble carbohydrates. Everything starts when a high amount of concentrate is fed to the horse which will lead to a higher percentage of soluble carbohydrates in the colon. This will increase the production of gas and fatty acids, leading to an excessive gas accumulation and excessive passage of fluid to the colon promoted by the high levels of intraluminal fatty acids. (Sanchez 2018) It can also happen due to rolling episodes and alteration of motility patterns caused by excess feeding (Southwood and Walton 2012; Sanchez 2018)

There is a tendency to associate these two identities as one becoming the consequence of the other, leading to the idea that only the left colon may provoke a nephrosplenic entrapment. Recently, the definition of nephrosplenic entrapment has been enlarged by Munsterman 2020, describing several case reports and articles where many parts of the intestine, other than the large colon, became entrapped in this space. (Munsterman 2020)

Displacement of the colon most often happens in a cranial to caudal way, but the opposite can also appear, and in this last case the pelvic flexure will be found near the diaphragm.

Left colon displacement has a reported incidence of 6-20,3% (Arévalo Rodríguez et al. 2019) and the nephrosplenic entrapment of 9% (Southwood 2019). Geldings and warmbloods are thought to be predisposed (Southwood 2019).

2.5.1. Diagnosing a Left Colon Displacement and Entrapment

Horses with left colon displacement normally present a mildly painful colic, but when entrapment is present, different degrees of pain have been described, since entrapment has been identified in horses with chronic weight loss, inappetence, and one case with high GGT

values (Southwood 2019). Very painful presentations may occur as well (Sanchez 2018). Cardiovascular state of these horses is usually stable and gut sound might be diminished in the left abdomen, but the situation changes if colon torsion is associated. Reflux is described in 30 to 40% of the horses (Southwood 2019).

The usual methods to diagnose a left colon displacement or entrapment are rectal palpation and ultrasonography (Arévalo Rodríguez et al. 2019). In rectal palpation the left colon can be felt over the nephrosplenic ligament if entrapment is imminent or between the spleen and left body wall. Medial deviation of the spleen can also be identified (Hardy et al. 2000). In more detail, (Southwood 2019) describes the palpation of the left colon running in the left dorsal quadrant of the abdomen, sometimes presenting gas distention. If entrapped the colon presents lateral to the left kidney and medial or dorsal to the caudodorsal limit of the spleen, and the spleen might be deviated medially or/and ventrally. The palpation of the left kidney might be impossible due to gas distended intestine (Sanchez 2018).

Ultrasound can also be an excellent mean to aid identification of this condition, though it should not be used alone (Moore et al. 2007). When performing imaging all the left flank should be examined, limited cranially by the 17th ICS, caudally by the cranial thigh muscles and dorsally by the ventral lumbar muscles. Normally a gas filled colon can be identified near the spleen preventing the left kidney from appearing. The typical image consists in absence of the left kidney and dorsal border of the spleen, appearing a gas distended colon and a spleen deviated medially and into the right ventral abdomen. (Southwood 2019)

2.5.2. Treatment

Medical management is often effective to treat left colon displacement and nephrosplenic entrapment (Sanchez 2018; Southwood 2019). Medical management implemented consists in withholding food and providing enteral and or parenteral fluid therapy. In cases where entrapment is present phenylephrine can also be associated in a rate of 3μg/kg/min over 15 minutes or 20 mg over 15 min (Southwood 2019). Sanchez 2018 describes a rate of 3-6 μg/kg/min over 15 minutes. Medical treatment has around 75% success rate (Southwood 2019). Sanchez 2018 details that a medical management with phenylephrine plus rolling has shown to be more effective than the concomitant use of phenylephrine and exercise with respective success rates of 84% and 63,2%. Phenylephrine is a α1- adrenergic receptor agonist causing peripheral vasoconstriction and splenic contraction. Studies report decreases in the splenic area of 28% when phenylephrine was administered at a rate of 3μg/kg/min (Fultz et al. 2013). The use of phenylephrine has some disadvantages such as the 64 times higher risk of provoking internal haemorrhage in older horses (>15 years) (Southwood 2019) due to the rupture of large splenic vessels (Sanchez 2018). It can also lead to severe bradycardia

after an initial phase of tachycardia, due to the activation of baroreceptors provoked by the increased blood pressure. As so accessing the heart rate is of great importance during administration. Nelson et al. 2015 also refers that when there is only displacement of the colon, withholding food and fluid therapy may be enough to resolve the colic episode.

The rolling technique is described as an attempt to replace the colon to its normal position. It consists in placing the horse under general anaesthesia, moving then from right lateral recumbency to dorsal recumbency. After, the hindlimbs are elevated at least 30 to 40º and the abdomen is shaken. Hoisting of the hindlimbs progresses until 80º is achieved, continuing the percussion and shaking of the abdomen. It finishes with the horse being placed in left lateral recumbency and checking the effectiveness of the procedure through rectal palpation (Southwood 2019). Another recent technique has been described where the horse is also placed under general anaesthesia and placed in left lateral recumbency, following a placement under dorsal recumbency with the aid of a hoist, placing the left side of the horse at a distance of 0,75 m from the wall. This technique requires two assistants to keep the horse in dorsal recumbency since the limbs are relaxed: one placed in the neck and fore limbs and another in the hindlimbs. After, other two assistants' seat on the floor with the back against the wall at the distance of 0,75 m to the left side of the horse. These assistants will place their feet in the horses left side, one in the paralumbar fossa and the other in the caudal ribcage, with their knees resting in a position of 90º. The procedure follows with pistol-like movements performed by these two assistants in the left abdomen of the recumbent horse, performing 7-10 repetitions of 30 compression per 5 minutes. Afterwards the horse is placed under lateral recumbency and an additional cycle of pistol-like compressions is performed for 5 minutes. The procedure finalizes with the rotation of the horse from left recumbency to lateral recumbency 3 to 4 times. The horse is then left in right lateral recumbency and effectiveness of the procedure is verified with ultrasound of the left paralumbar fossa (Fultz et al. 2013). When performing any of these medical treatments it is important to keep in mind that the horse might have another lesion thus the medical procedure may not be effective (Fultz et al. 2013). Southwood 2019 describes that 7,5% of the horses with nephrosplenic entrapment presented a concurrent lesion such as small intestinal strangulation, gastric rupture, intestinal infarction or large colon volvulus. In light of these findings a thorough examination must be carried out in order to determine if another lesion is present.

Surgery might be recommended in left colon displacement with or without entrapment either if the medical treatment or rolling are not effective or if evidence of a colic in need of surgery are imminent. These evidences are: continuous presence of gastric reflux, inability to control pain, hypomotile small intestine, serosanguinous peritoneal fluid with increased total protein and white cell count, deterioration of physical parameters, severe abdominal distention (Blikslager and Marshal 2019; Southwood 2019).

There are several surgical techniques available: midline laparotomy, left flank laparotomy or laparoscopy (Arévalo Rodríguez et al. 2019; Southwood 2019). Flank laparotomy or laparoscopy to correct the displacement or entrapment are only advised in horses with mild pain and not too distended (Southwood 2019). Midline celiotomy requires the horse to be under general anaesthesia and dorsal recumbency. After the incision on the midline, the surgeon, standing on the right side of the horse, finds the spleen across the abdomen, and carefully pushes it ventrally and medially in order to allow the colon to pass and return to its normal position. Intra surgical use of phenylephrine may aid this procedure and if not effective, a case report from Loomes and Anderson 2020 described the successful use of intra-operative intrasplenic administration of phenylephrine to induce splenic contraction. When the colon is back in its normal position the rest of the abdomen should be explored to exclude the presence of other lesions.

Other technique described by Muňoz and Bussy 2013 is the standing hand-assisted laparoscopy. This technique combines correction of left colon displacement and ablation of the nephrosplenic space at the same time and its advised when treatment with phenylephrine does not work and when surgical treatment under general anaesthesia is not advised, for example, in mares with advanced pregnancy or heavy horses, or even due to economical restrains. (Burke and Parente 2016)

2.5.3. Prognosis

Prognosis of left colon displacement is said to be good to excellent. A study by Lindegaard et al. 2011, described a short term survival of 91,5%, similar to a study by Hardy et al. 2000 with an overall success rate of 92,5%. More specifically, a survival of 96,5% was reported regarding horses treated medically, and an 80% survival rate for the ones managed surgically.

Southwood 2019 also reported a 90% survival rate after midline celiotomy to correct left colon displacement.

A study by Nelson et al. 2015 associated an increased PCV by the time of admission to a greater odd of non-surviving. It also concluded that horses that underwent laparoscopic closure of the space had fewer episodes of colic.

Farstvedt and Hendrickson 2005 described as well that ablation of the nephrosplenic space lowered the incidence of colic and the need of midline celiotomy.

2.5.4. Preventing the Left Colon Displacement and Its recurrence

Recurrence is reported to be of 8 to 23%. (Southwood 2019)

Preventive procedures are colopexy, resection of the large colon, closure of the nephrosplenic space under general anaesthesia or laparoscopic closure of the nephrosplenic space, which can be hand assisted or not. (Arévalo Rodríguez et al. 2019)

Laparotomy can be used to close the nephrosplenic space under general anaesthesia with the horse placed in right lateral recumbency. An incision is done 2 cm caudal to the last rib starting at the level of the tuber coxae and with 20 cm widen ventrally. Then, the renosplenic fascia is sutured in an interrupted cruciate pattern to the spleen using a no 2 polypropylene suture. The same goal can be achieved laparoscopically. (Southwood 2019)

Colopexy is a procedure where the colon is fixed to the abdominal wall by the means of a focal adhesion between the ventral colon and the ventral body wall, created through a surgical procedure. Its main utilities are the prevention of colon displacements and large colon volvulus. The procedure consists in suturing 20-35 cm of the lateral free taenia band of the left ventral colon to the body wall, 6-10cm to the left and parallel to the laparotomy midline incision. There are several alternatives to perform this procedure such as the incorporation of the ventral colon in the suture of the midline incision, though this requires the laparotomy incision to be done further cranially. It can also be performed through a laparoscopic procedure, with the horse in dorsal recumbency. The suture normally used is polypropylene metric 2 in either a simple continuous pattern or interrupted cruciate suture, being the last one preferred. The intestinal lumen can never be penetrated. Complications of colopexy consist in recurrent colic, either due to gas distention or augmented tension in the adhesion site. Additional formation of adhesions other than the pretended ventral colon adhesion to the body wall are also described and with less frequency, colon rupture and fistulas. (Southwood 2019)

2.6. Minimally Invasive Surgery - Laparoscopic Surgery

Arthroscopies, laparoscopies, upper airway endoscopic surgery and thoracoscopies are some minimally invasive procedures performed in horses frequently. These present many advantages such as smaller incisions which lead to a smaller tissue trauma, less pain and morbidity, and a faster return to normal exercise and function. Since horses present one of the highest anaesthetic risk when it concerns general anaesthesia, reported to vary from 0,96% to 1,4% in a recent study (Laurenza et al. 2020) the possibility of performing this procedure under sedation and local anaesthesia is of great advantage. Walmsley 2007 refers though there are no studies recording surgical site infection following laparoscopy, in his practice, surgical site infection following laparoscopy never occurred. This represents a great advantage compared to laparotomy, with a reported surgical site infection of 40%. It is also referred that in some

cases, minimally invasive surgery provides better visualisation in articulations, abdomen or thorax than open surgery. The main limitations of these techniques are the cost of all the equipment, that sometimes is not available for horses and the specialized training required. (Martens et al. 2019)

According to Walmsley 2007, though many authors refer laparoscopy as a low morbidity procedure, there are no studies confirming this. Several complications are described such as organ punctures, mainly spleen and colon and peritoneal detachments (Desmaizières et al. 2003). Post-surgical pain associated with insufflation was also thought to be a consequence but a study by Devick et al. 2018 demonstrated there is no difference in the horse comfort between actively deflating the abdomen in the end of the procedure or not. Organ puncture can be avoided if blunt instruments are used to penetrate the abdomen (Walmsley 2007).

Laparoscopy is a minimal invasive technique of surgery of which the use of its basic principles had been described since years of 936-1013 A.D. and the first reports of laparoscopy performed in humans are from 1912. The first papers about veterinary laparoscopy performed in horses report back to the year of 1970 and, as in the human medicine, these procedures where very helpful to describe and observe gynaecological events in the mare. Afterwards several papers were published regarding techniques to manipulate instruments and perform procedures such as biopsies, cultures, aspiration of cysts, as various surgical approaches, haemostasis and ligation methods. The main laparoscopic procedures performed nowadays are inguinal herniorrhaphy, urolith removal, cryptorchidectomy, nephrosplenic space ablation, adhesiolysis and incisional hernioplasty (Martens et al. 2019). Several advantages are highlighted such as the fact that it can be performed standing, so general anaesthesia and all its risks can be avoided, it's a minimal invasive technique, with superior visualization and allows tension free haemostasis. The main challenges of equine laparoscopy consist in the fact that the surgeon is visualizing a three-dimensional structure in a two-dimensional screen. This might bring some difficulties handling the instruments and perceiving the depth. It is also very important that the surgeon and assistant both have special training, because the movement of the instruments for this kind of procedure is very specific: there is a fulcrum effect caused by the abdominal wall, which means that if the surgeon wants to move the tip of an instrument to one side of the screen, he should actually move the hold in the opposite direction. The range of movement necessary to move the tip also depends on the amount of the instrument inside the cavity. (Hendrickson 2012)

All laparoscopic procedures are based on a triangulation principle which means that 2 or more portals are placed in order to perform the procedure. If the portals are too close to each order, it will be harder to manipulate the instruments, so they should be placed as separately as possible, in order to converge into the area of interest, with an angle of at least

30º to 60º. Several instruments are necessary to perform laparoscopy: a telescope with two channels included, one for a lenses and another for a light cable, a camera, a light source, a insufflator, trocar's, constituted by the cannula and respective obturator and finally there are various hand instruments that can be selected according to the procedure that will be performed. (Hendrickson 2012)

2.6.1. Laparoscopic Closure of the Nephrosplenic Space

It is advised to perform closure of the nephrosplenic space in horses suffering from recurrence of left dorsal displacement of the large colon and this can be achieved through a left flank laparotomy or laparoscopic surgery which is less invasive (Southwood 2019). Focusing the laparoscopic closure, there are several techniques described using different materials to close the space: 1 monofilament polyester, 0 polyglyconate, 2 braided polyester and polypropylene mesh (Albanese et al. 2016).

Difficulties with each procedure are described but the main reason for failure of the procedure is associated with knot tying and in order to improve this part of the procedure, several devices have been developed to aid knot tying. A new technique has been described with the use of barbed sutures, which contain barbs along all the length of the suture allowing its anchoring in multiple points and dismissing the need of knots to secure the end of the suture. The multiple anchoring points also distribute the pressure of the suture facilitating the union of the tissues and distributing the forces exerted by the suture. This technique culminates in a reduction of the complications described before associated with knot tying being also excellent to reduce surgery time thus facilitating several procedures that require laparoscopic knot tying. (Albanese et al. 2016)

Recently Muňoz and Bussy 2013 described a technique with the use of a single led powered trocar, allowing direct visualization of the space as a 3 dimensional view. This provides a quicker learning process of the technique. Other advantages are the need of a single incision and not requiring insufflation of the abdomen, though it does require acquiring the led powered trocar.

Preparation of the patient starts by withholding the food for at least 12 hours prior to surgery. Sedation may be achieved with detomidine and butorphanol and if necessary, epidural may also be used as additional analgesia. Infiltration of the portal and clamp locations follows with the use of a local anaesthetic such as lidocaine (Southwood 2019).

All the techniques are usually performed with the use of three portals, and this does not vary depending on the technique: a first one caudal to the 18th rib or in the 17th ICS at the level of the tuber coxae to the laparoscope or an instrument, a second one in the paralumbar fossa halfway between the 18th rib and the tuber coxae to the laparoscope or an instrument

and the last one also in the paralumbar fossa, 3 to 5 cm ventral to the second portal. Insufflation of the abdomen follows with the use of carbon dioxide (CO^2), and after the cannula insertion, a fast exploration of the abdomen is accomplished with the use of a rigid laparoscope, providing a view in a 30 degree angle (Southwood 2019). Other study suggested alternative paravertebral blocks instead of local infiltration of portal sites and concluded that it provides the same surgical conditions (Delli-Rocili et al. 2020).

Suturing of the space can be performed using a continuous simple pattern, starting cranially and continuing caudally. The ligament and dorsal splenic border are sutured together in a dorsal to ventral direction. The beginning of the suture line is secured by passing the suture through a loop, and the first stich should be applied in the perirenal fascia and dorsalmedial to the border of the splenic capsule. After completed caudally the suture is then extended cranially, three throws, ending with an extracorporeal knot or modified Roeder knot may be placed with the aid of knot pusher. Alternatively, barbed knotless suture can be used or polypropylene mesh, secured to the perirenal fascia and dorsal aspect of the nephrosplenic ligament and dorsolateral border of the splenic capsule with a tacking device (Southwood 2019).

Another technique was also described with the use of a prosthetic mesh, which is secured to the perirenal fascia and spleen with the aid of titanium helicoidal coils. This technique was developed due to its simplicity and it was also thought it would prevent the risk of incomplete closure or failure that may be associated to the techniques using sutures. This procedure may be also preferred because when the space is closed with sutures, the tissue apposition until adhesion formation will rely upon this sutures, so failure may happen if the adhesion does not form in time and suture integrity is corrupted. (Burke and Parente 2016)

2.6.1.1. Laparoscopy Closure of the Nephrosplenic Space with Barbed Knotless Suture

Barbed knotless sutures are a type of sutures invented in 1964. It has been used in multiple fields of surgery in human medicine and its main interest resides in its barbs, placed normally in the opposite direction of the needle, or in both directions if the suture in bidirectional. These barbs allow the suture to anchor itself along all its length without the need of knots. Knots have been associated with several complications such as infection, being an easy point of breakage, and requiring more time and training skills from the surgeon. (Lin et al. 2016)

Other study in humans found barbed sutures to be associated with higher risk of infection after knee arthroplasty. Disadvantages of these type of suture are the inability to

remove a suture loop in case it is misplaced and the fact of being expensive. (Kümmerle and Fogle 2019)

Several brands and kinds of barbed sutures have been described in human medicine literature such as: the Quill SRS, a bidirectional barbed suture; the V-Loc Absorbable wound closure device, a unidirectional barbed suture with a needle and a loop at the end of the filament; the Stratafix, with the barbs and anchors distributed in a spiral form. (Lin et al. 2016)

The V-loc Absorbable suture device is the most used barbed suture in equine surgery and especially for the closure of the nephrosplenic space. Two authors describe the use of the 0 metric to close the nephrosplenic space (Albanese et al. 2016; Gandini et al. 2017). The procedure is then carried out as preciously described: the space is closed in a cranial to caudal direction, and the first suture byte is secured by the loop in the end of the suture line. One or two needle holders may be used to manipulate the needle. The first bite is placed in the perirenal fascia in a dorsal to ventral way and the second in a ventral to dorsal way on the splenic capsule, being careful to not enter the parenchyma in excess (Gandini et al. 2017). Around ten bytes of suture are placed, and when the end is reached, over-sewing of this suture in a caudal to cranial direction may be performed, around 3 bytes, to secure the previous suture (Albanese et al. 2016). Gandini et al 2017 also described this technique, performing an interlocking suture at the end and two over-sewing bites caudo-cranially to secure the suture. After each bite tension is placed in the suture and completed in the end. After cutting the suture and inspecting of there is no excessive bleeding the subcutaneous tissue is closed with polyglatine 910 and the skin with nylon (Gandini et al. 2017) or polypropylene (Albanese et al. 2016).

3. Aims

This study aims to evaluate the need to replace a displaced colon during laparoscopic closure of the nephrosplenic space when a left dorsal displacement and entrapment is present at time of surgery.

Since this is a novel option for the procedure, this work further aims to assess short- and long-term outcomes for horses undergoing the procedure in this manner and compare these to other techniques as well as in cases where the closure was performed without the presence of a displaced colon during surgery.

As such, the overall goals of this study where defined:

-To compare short- and long-term outcome of horses undergoing laparoscopic NSC with or without a displaced colon at the time of surgery.

-To perceive overall short and long term outcome in horses that underwent closure of the nephrosplenic space;

-To identify long term and short term complications and survival rate.

The working hypothesis for this work is that the presence of a displaced colon during laparoscopic closure of the nephrosplenic space does not affect the short and long term outcome.

4. Methods

All measurements and procedures described in this chapter were optimized and systematically revised in order to minimize inter and intra-assay variability.

4.1. Study design and patient selection

This is a retrospective study that investigates and compares the short and long term outcome of horses undergoing laparoscopic NSC (Nephrosplenic Space Closure) with or without left colon displacement at the time of surgery.

The horses included in the study were referred to the Clinique Equine de Meslay between 2017 and 2020 for Nephrosplenic Space Entrapment (NSE) and laparoscopic NSC.

Treatments and examination at the time of surgery were recorded. This examination focused mainly on transabdominal ultrasound and rectal palpation to identify if the colon was displaced. If NSE was present, medical treatment with phenylephrine and exercise was attempted to correct the NSE prior to surgery, but if it was not successful, surgery with the displaced colon was performed anyway.

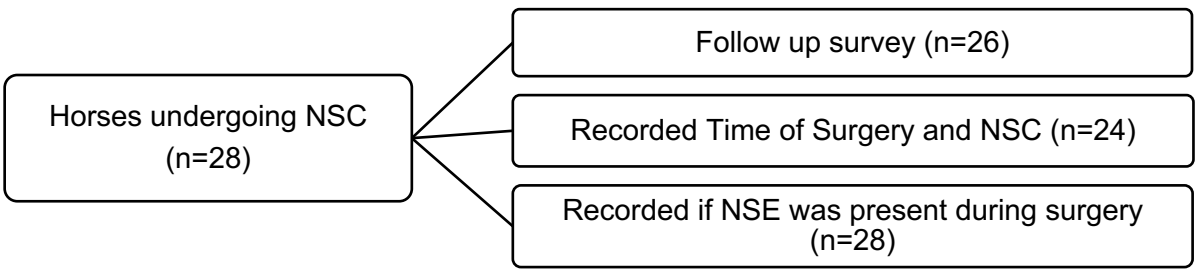
Surgery time and NSC time, post-surgical treatment and management were recorded. Standardized follow up questions were gathered in a survey form, used latter to obtain follow-up by phone call to the owners (see annex 1).

We also investigated if age and number of colic episodes before the intervention affected the outcome.

Total time of surgery and NSC time were also compared between the two groups.

Some data was missing in some cases, so the following scheme (figure 1) summarizes the number of cases gathered in each statistical analysis.

Figure 1- Diagram: summary of the number of results recorded for each parameter.



4.2. Surgery

4.2.1. Patient Preparation

At arrival every patient underwent transabdominal ultrasound and rectal palpation in order to confirm if NSE was present or not.

If NSE was present, treatment with a protocol of phenylephrine and exercise was attempted. When this treatment was not successful, the horse proceeded to surgery with the colon entrapped.

Food was withheld in the first 36 hours in the first 8 cases to perform surgery and then for 12 hours in the rest of the cases.

A jugular catheter was placed, normally on the right jugular vein, before the surgery.

4.2.2. Medication pre-surgery and post-surgery

Tetanus anti-toxin (Inmuser CT, Ovejero, Spain) 3000UI subcutaneously (SC) was given to every horse admitted to surgery.

Antibiotic therapy was performed in every horse according to the hospital's protocols: procaine penicillin (Depocilin, MSD Animal Health, France), 8000UI/Kg IM SID, starting before the surgery, up to a maximum of 3 days post-op, and gentamycin (G4, Virbac, France) 6.6mg/Kg IV SID, also starting before the surgery until 1 day post-op. Anti-inflammatory was also administered: fluinixin meglumine (Antalzen, Virbac, France) at 1,1mg/kg IV before and after surgery and continued at home for 1 day with oral fluinix meglumine (Fynadine Pâte, MSD Animal Health, France).

The left paralumbar fossa was clipped and surgically prepared with a scrub of betadine soap and alcohol.

4.2.3. Neuroleptoanalgesia and Local Anaesthesia Protocol

Horses were restrained in stocks. Sedation was induced with detomidine (0.01 mg/kg IV and butorphanol (Butador, Boehringer Ingelheim Animal Health France SCS) (0.02 mg / kg IV) and maintained with detomidine (Domidine, DECHRA Veterinary Products SAS) (30 µg/ kg /h) and butorphanol (Butador, Boehringer Ingelheim Animal Health France SCS) (0.024 mg/ kg /h) IV CRI.

Local infiltration with lidocaine (Laocine, MSD Animal Health, France) was performed with approximately 15ml of lidocaine per portal site. The points where drape clamps would be placed were also infiltrated.

After local infiltration a last scrub was performed.

4.2.4. Surgical Procedure

All the procedures were performed by the same diplomate ECVS surgeon with the help of a surgical assistant (ECVS resident). The procedure started with a 10mm skin incision performed for the laparoscopic portal 3-4 cm caudal to the last rib at the level of the ventral aspect of the tuber coxae and the trocar and cannula were inserted, following abdomen insufflation with CO^2 (maximum 10 mmHg). Afterwards a 2nd portal (10 mm) was created 8-10 cm ventrally to the 1st one and the 3rd portal (10 mm) was placed cranial to the last rib slightly ventral to the 1st one.

When the colon appeared displaced in the NS space, the laparoscope was placed dorsally to it and abdominal insufflation made the colon move ventrally allowing the NS space to appear. The next 2 portals were then carefully created avoiding the colon. In the first 2 NSE cases, unsuccessful attempts were made to replace the colon with laparoscopic instruments. As this was found to be unfruitful, in the following cases, no attempt was made to replace the colon.

Figure 2 and 3 – Two examples of typical nephrosplenic spaces. In both images the kidney capsule (1) can be seen as well as the spleen (2)

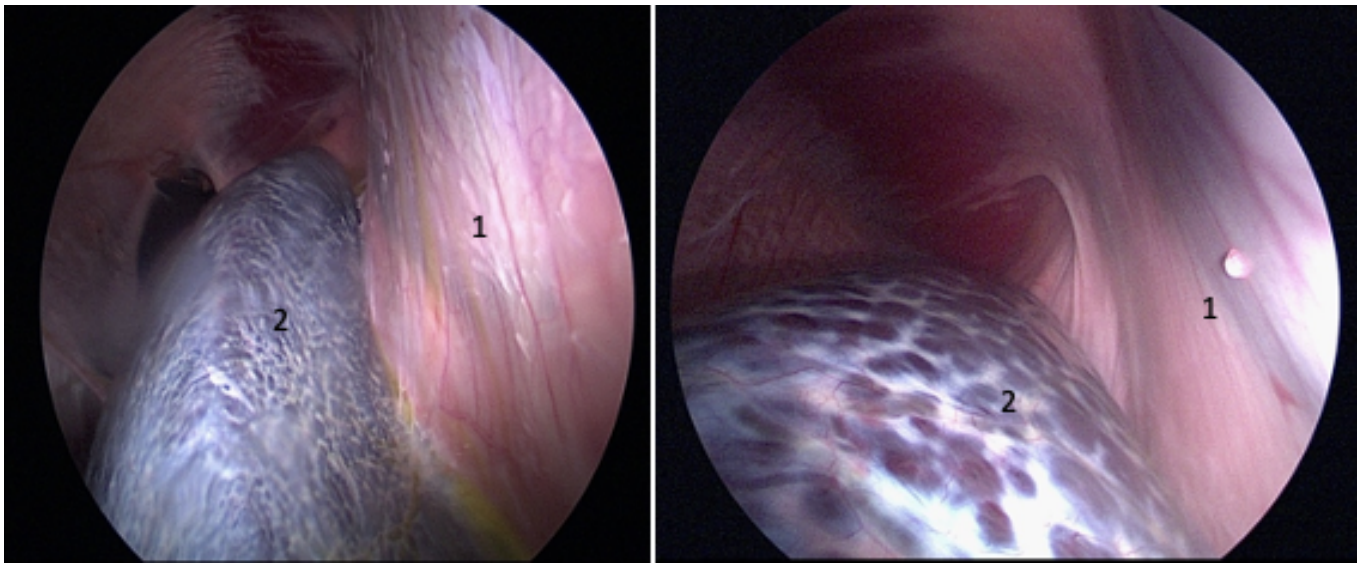


Figure 4 – Example of an atypical nephrosplenic space, with deformation of the spleen due to many episodes of recurrent NSE. The kidney capsule (1) and the spleen (2) are visualized.

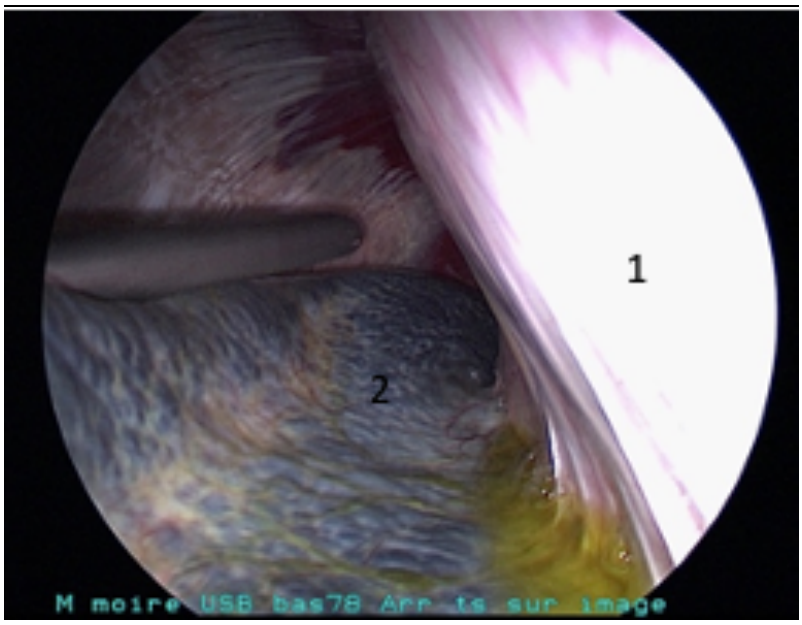
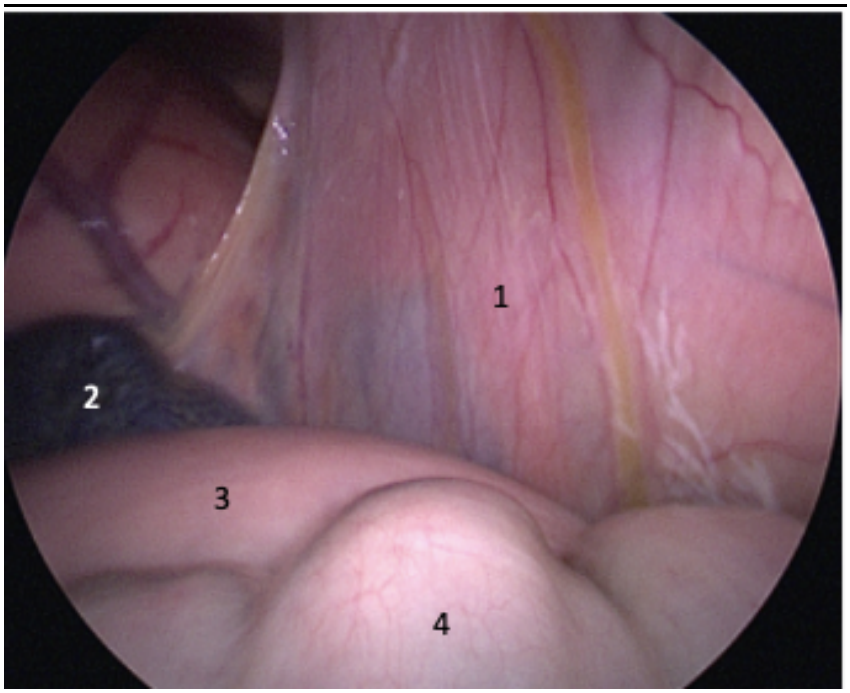


Figure 5 – Nephrosplenic Space with NS entrapment. In the figure we can see the kidney capsule (1), the spleen (2), the left dorsal colon (3) and the left ventral colon (4). The colon presents itself entrapped in the nephrosplenic space.



Regarding insufflation, in non-entrapped horses it was stopped during the procedure and resumed if needed. In horses with NSE, insufflation was maintained to prevent the colon from coming back into the NS space.

Figure 6 – This figure shows the moment after gas insufflation of the abdomen: the colon moves laterally allowing view of the NS, and leaving the space free. In the Picture we can identify the left dorsal colon (3), laterally, the spleen (2) and nephrosplenic ligament (1)

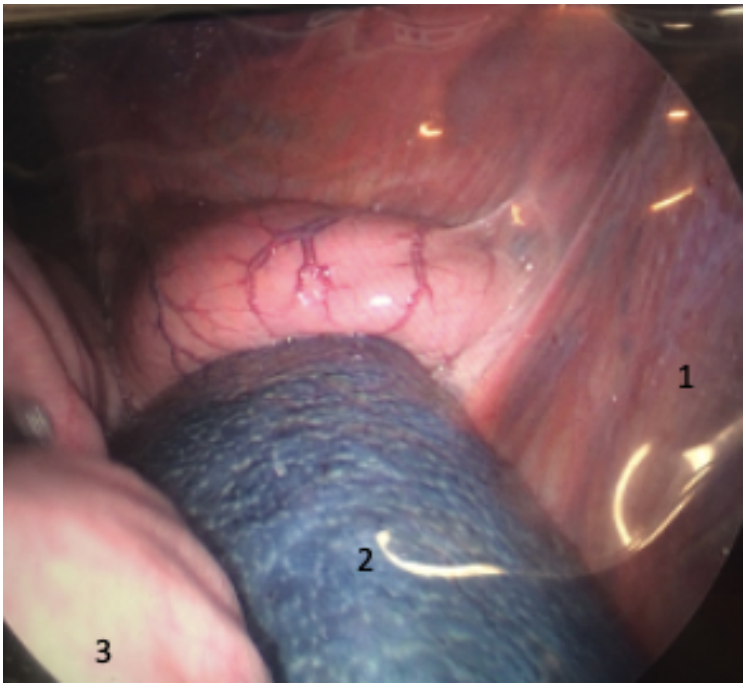
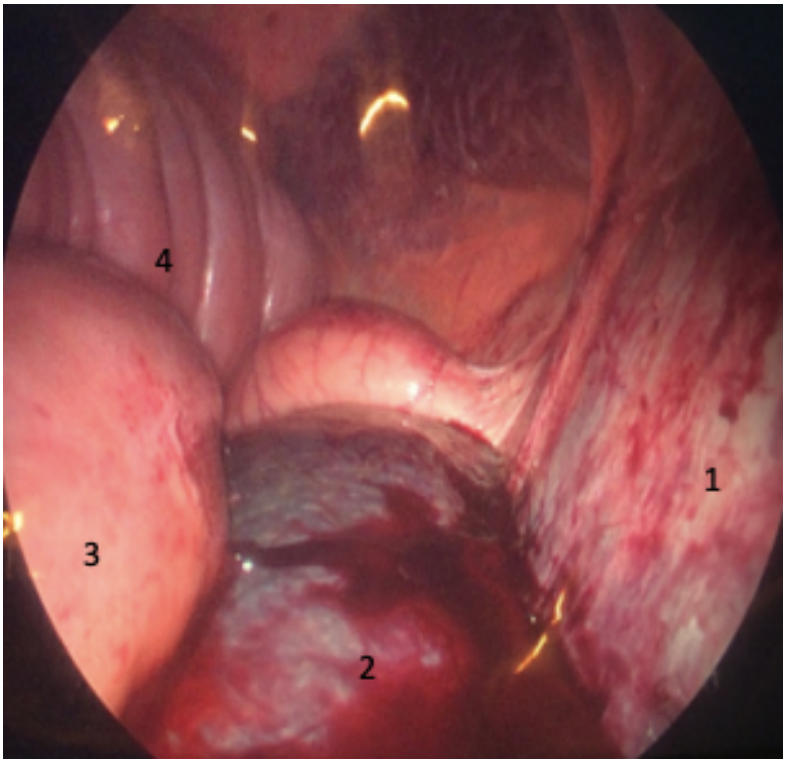
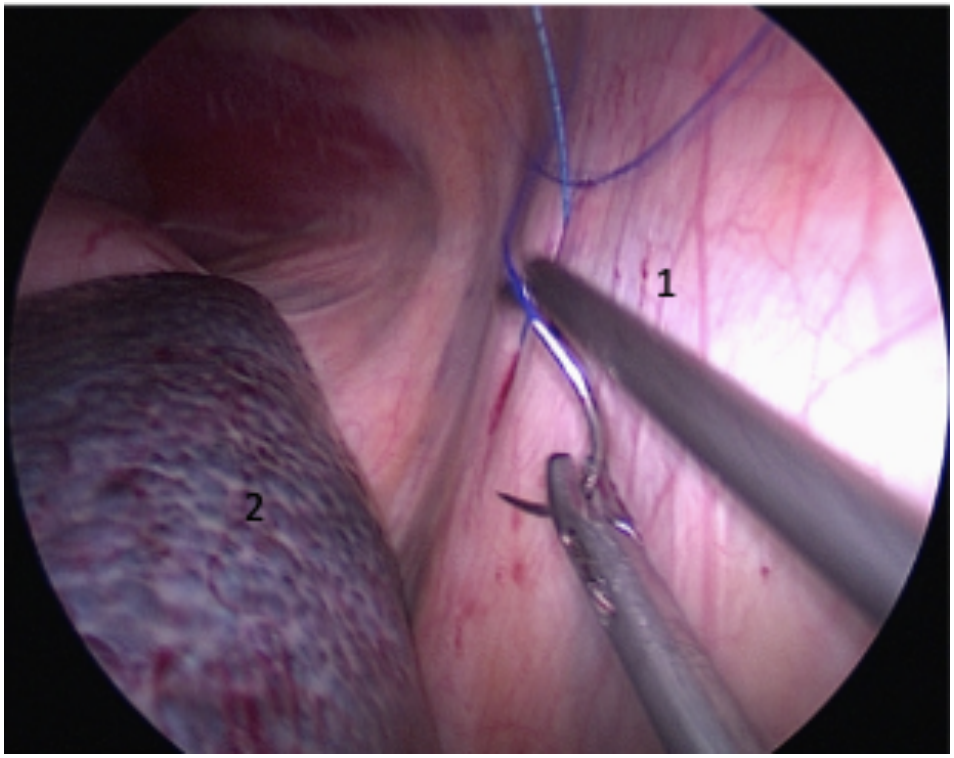


Figure 7 - Aspect of the NS after closure with the colon displaced laterally. The insufflation was maintained during the procedure. The nephrosplenic ligament (1) can be observed as well as the spleen (2), left dorsal colon (3) and left ventral colon (4).



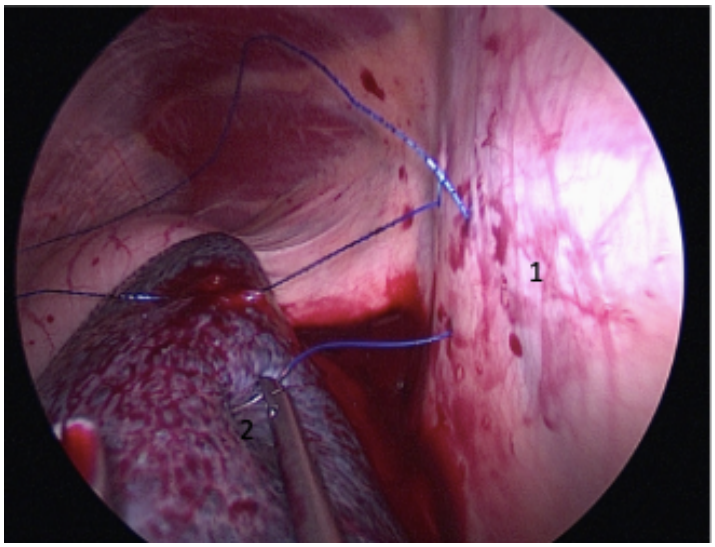
The NS space was then sutured in a cranial to caudal direction with a simple continuous pattern using one barbed, non-absorbable suture (V-LOC ™ Polybutester 0 metric, 45 cm swaged on a ½ circle 27 mm taper needle). After the needle was passed through the cannula, 2 reductors were placed to avoid gas leakage when introducing laparoscopic needle holders. The first byte of the suture was placed in the NS ligament only and then secured by passing the needle through the small preformed loop present at the beginning.

Figure 8 – First suture byte: placed firstly in the nephrosplenic ligament/perirenal fascia, passing the suture line in the preformed loop to secure the beginning of the suture. In the figure we can see the nephrosplenic ligament (1) and the spleen (2).



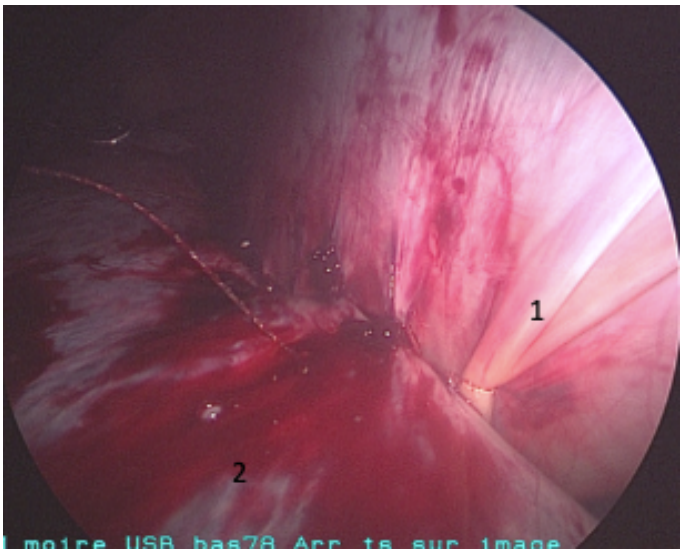
Bites were taken every 2cm (NS ligament and spleen) until the caudal aspect of the spleen was reached.

Figure 9 - Second loop: the suture is passed through the spleen (2) and then through the nephrosplenic ligament (1) again, following this pattern.



At that point, suture was passed twice through the caudal border of the NS ligament and then back twice into the spleen and pulled. Suture was cut leaving 3-4 cm free.

Figure 10 - Last loop: the NS is sutured and closed. The suture is passed twice through the caudal border of the NS ligament and then twice back into the spleen (2), finishing with pulling it. The nephrosplenic ligament (1) is also visualized.



After deflating the abdomen, portals were closed in 2 layers with metric 1 polyglactin 910.

4.2. Follow-up Protocol

After surgery, the protocol varied depending if horses had or had not NSE.

Refeeding was performed after surgery with high quality wet hay in increasing amounts.

Horses without NSE went home the day after surgery. The owners were advised to follow a protocol of 2 weeks box rest and hand walk, followed by 1 week of paddock before resuming exercise.

On the other hand, horses with NSE stayed hospitalised for 48 hours and after were sent home with the same program as the other ones.

Horses were checked by rectal palpation 2 weeks post operatively to verify if the colon was in the correct position and if the NS remained properly closed, thus ensuring short term outcome.

Long term outcome was obtained by phone call to the owners. A survey (see annex 1) was presented during this phone call during which standardized questions were presented to the owners. The intent was to collect information on the main characteristics of the horse (sex, age, breed, weight, use, routine), the place of stabling (outside or inside), the feeding routine and whether there were changes or not when colic episodes were eminent, previous colic episodes, its diagnose and treatment. The main interest was also to know if patients had recurrent colic episodes in the 15 days after the NSC or afterwards, if these were related to the procedure and what treatment implemented. The owners were also asked if the horses had any other problems. Survival was also assessed during this follow up.

4.3. Data and Statistical analysis

The statistical analysis was made using R software with the use of the library R Commander version 2.7-1.

All the electronic reports were analysed. Videos and photos from the surgery were also reviewed to obtain the necessary information.

Firstly, Shapiro-Wilk Test was used to assess normality of the distribution of all the numerical parameters.

Fisher test was used to predict if a horse would have colic after the NSC or not based on the number of NSE episodes the horse had before. For this test 4 categories were made (1-2 episodes; 3-4 episodes; 5-6 episodes; Chronic). Some of the categories had less than 5 cases. It was also used to correlate sex according to the number of NSE episodes; sex according to the number of NSE episodes; being a broodmare and having NSE at time of surgery; number of colic episodes according if the horse had NSE or not at time of surgery; sex according if the horse had colic after NSC or not.

A Wilcoxon Test was performed to test differences in the time of surgery between the two groups: NSE and non NSE at time of surgery. It was also used to compare ages between these groups (NSE and non NSE) and age difference between horses presenting colic or not after the surgery.

A Kruskall Walis test was used to compare the medians of ages according to the number of episodes of NSE before the surgery.

5. Results

None of the variables analysed showed a normal distribution so the median + interquartile range (IQR) values were considered. Significance was considered when the p-value was less than 0.05.

5.1. Patients

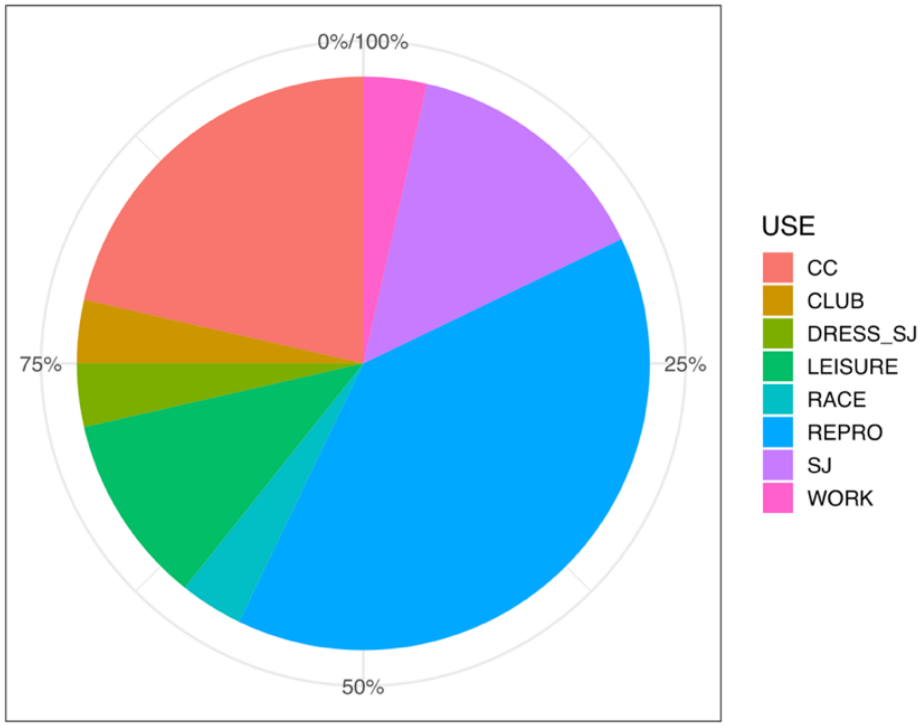
A total of 28 horses met the inclusion criteria for this study, of which 17 were mares, 9 were geldings and 2 were stallions. From the 17 mares included 11 of them were broodmares. The median was 8.5 years + 4.25 (IQR). Most of the horses admitted were French Warmbloods (n=12) and Thoroughbreds (n=9) followed by French chasers (n=3) and Standardbred (n=3) and Anglo European (n=1).

Most of the horses included were living in a stable with daily access to a paddock/meadow (48%). 36% lived exclusively in the exterior (meadow or paddock) and 16% lived in a box without outdoor assess.

The owners described regular feeding of all the horses, normally based on hay and concentrate, adding grass in the horses that had access to a pasture. Only three owners described changes in feeding routine at the time of the colic episode(s).

Most of the horses were broodmares, but other uses were also described: eventing, show jumping, dressage, pony club, work or leisure horses.

Graph 1 - This graph shows the horse's use distribution.



Legend: CC-Eventing; Club- Horse Riding School; Dress_SJ: Dressage and Show Jumping; Leisure: Horse used for leisure, walks; Race: race horse including gallop, trot and obstacles; Repro: Broodmares; SJ: Show Jumping; Work: Draft Horse.

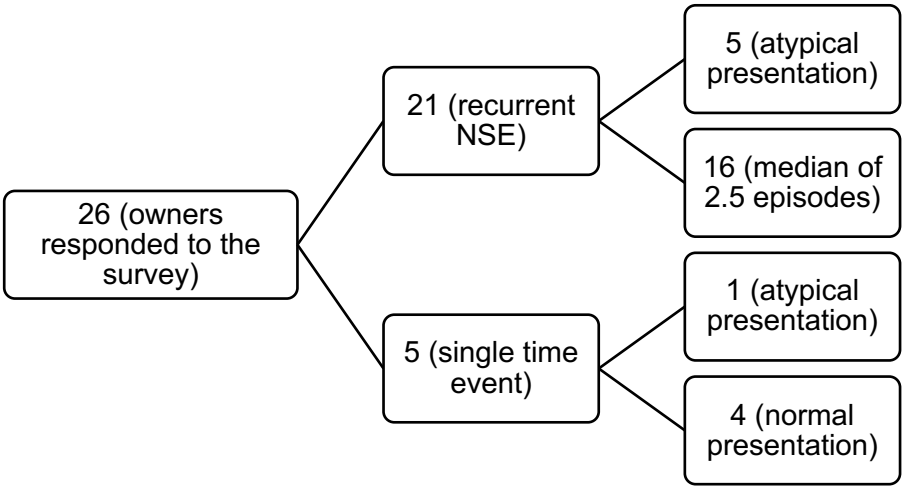
5.2. Before Surgery

Two horses needed emergency celiotomy to correct the NSE: one broodmare had recurrent NSE which didn't resolve with medical treatment (phenylephrine infusion plus up and down walking plus longing), neither with rolling. This mare had laparotomy to replace the colon and was presented 10 days later for NS closure. Colon was re-entrapped without clinical signs. Another broodmare also needed emergency celiotomy to correct the NSE after failure of medical treatment. In this broodmare the colon was not re-entrapped at time of NCS.

A total of 21 horses had recurrent NSE from which 5 had atypical presentation, so the number of episodes was not countable. Regarding the other 16, a median of 2.5 episodes + 2(IQR) was recorded. From all horses with recurrent NSE, only one of the broodmares described before needed surgery and the other were managed medically.

One horse presented mild colic when admitted to NSC and the colic was treated and resolved before NSC.

Figure 11 - Diagram of the horse's owner lead survey. Numbers according to the recurrence and type of the NSE event.



In total, six horses had atypical presentation: one of them showed mild discomfort after feeding and weight loss. He was originally presented for gastroscopy when NSE was discovered. Another showed recurrent tympany and gas expulsion without real colic signs. Four horses presented chronic weight loss. The other one presented abdominal distention without clear signs of colic in a single time event. NSE was resolved in all the cases with medical treatment before NSC and none of these horses were entrapped during surgery.

5.3. Intra-operative

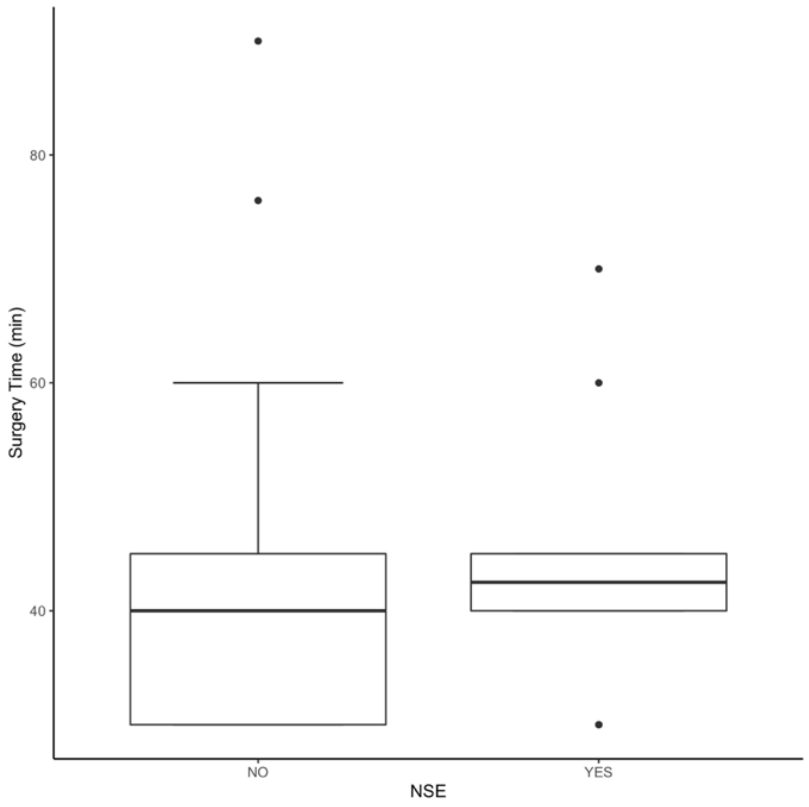
Of the 28 horses who underwent NSC, 17 horses were not entrapped and 11 had NSE at time of surgery.

There were no intraoperative complications. Total surgery time, from skin incision to last skin suture had a median of 40 min + 15 min (IQR) and a mean of 44.4 min ± 16.3 min.

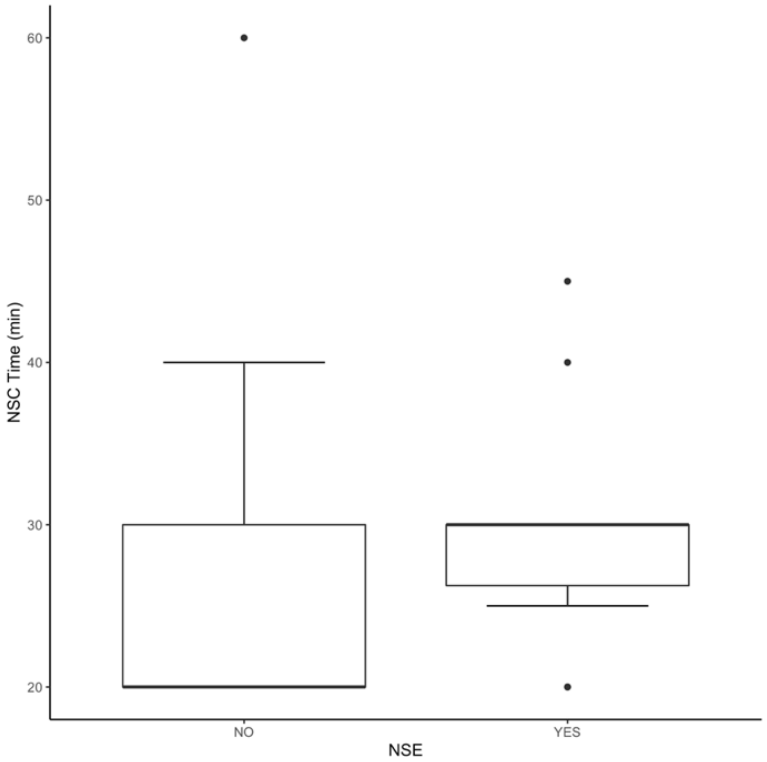
Time for nephrosplenic closure had a median of 30 min + 10 min (IQR) and a mean of 28.8 min ± 10.2 min.

There was no significant surgical time difference between horses with or without NSE at the time of surgery ($p=0.445$). In one of the horses a unilateral ovariectomy was also performed so the time of surgery was not considered for the statistical analysis.

Graph 2 – Total time of surgery according to having NSE during surgery or not



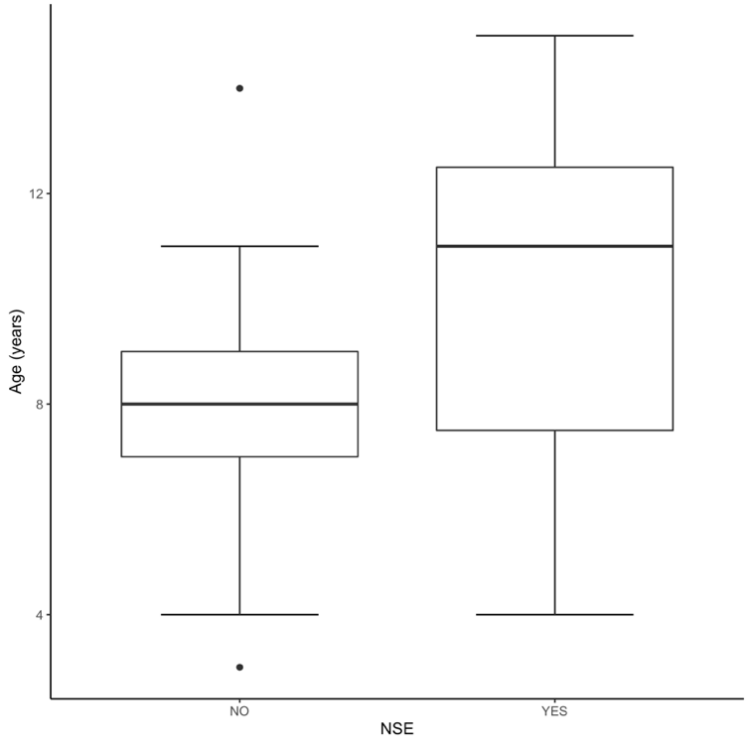
Graph 3 – Total time of surgery according to having NSE during surgery or not and NSC time according to having NSE during surgery or not.



There was also no significant difference in nephrosplenic space closure time difference between horses with NSE or without at the time of surgery (p=0.2639).

Though the group of horses with NSE at the time of surgery was slightly older, no significant difference was found between the medians of the two groups (p=0.2548).

Graph 4 - Age according to having NSE during surgery or not



Of horses with NSE during surgery, 81.8% were mares. We also found that when considering the group of horses who had higher number of accountable colic episodes (class of 5-6 episodes), most of them were mares (66.7%). Though these results are not significant (respectively p=0.08439 and p=0.9048) this lack of difference is likely to be a reflection of the low sample number.

Table 2 – Contingency table with distribution of sex according to NSE at time of surgery or not, results in percentage.

	NSE at time of surgery	
Sex	No	Yes
Female	47.1	81.8
Gelding	47.1	9.1
Male	5.9	9.1
Total	100	100

Table 3 – Contingency table with distribution of sex according to the number of NSE episodes, results in percentage.

	Sex			
Nº of NSE episodes	Female	Gelding	Male	Total
1-2	63.6	27.3	9.1	100
3-4	57.1	28.6	14.3	100
5-6	66.7	33.3	0.0	100
Chronic	40.0	60.0	0.0	100

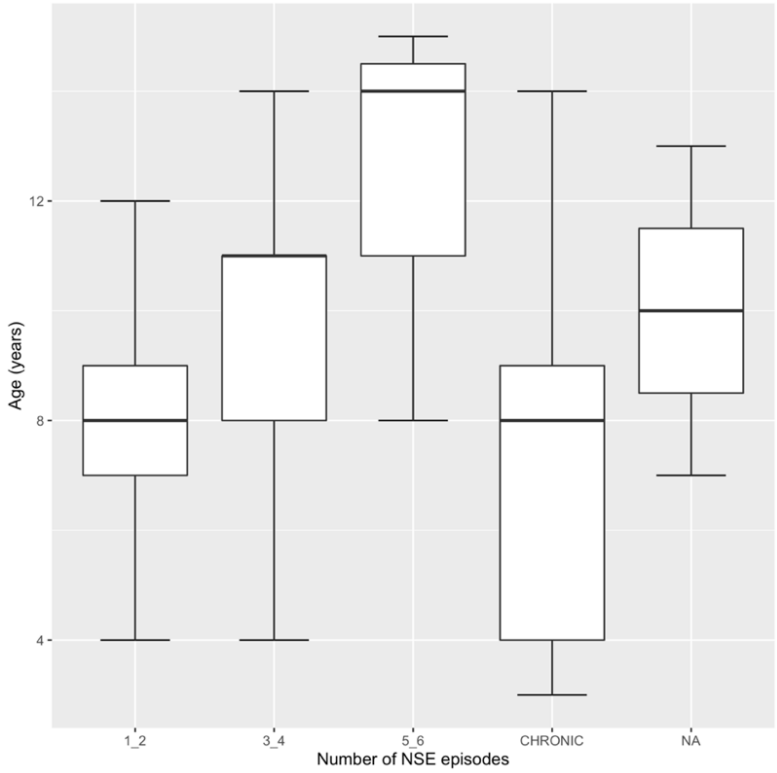
Furthermore, regarding sex differences, of the group of mares in the NSE group, most of them were broodmares. But again, the result was not significant. (P=1)

Table 4 – Contingency table to investigate relation between being a broodmare and having NSE at time of surgery, results in percentage.

	NSE at time of surgery	
Broodmare	No	Yes
No	37.5	33.3
Yes	62.5	66.7
Total	100	100

We also investigated if there was a difference in the median age according to the number of NSE episodes and no significant relation was found (p=0.2963).

Graph 5 – Age according to the number of NSE episodes



When regarding the number of colic episodes and its relation to the presence of entrapment during surgery, a significant correlation (p=0.03772) between these two variables was found: most of the horses with NSE at time of surgery had around 1-2 episodes of NSE before surgery. None of the horses with chronic symptoms were entrapped during surgery.

Table 5 – Contingency table with distribution of number of colic episodes according if the horse had NSE or not at time of surgery, results in percentage.

	NSE during surgery	
Nº of NSE episodes	No	Yes
1-2	37.5	50
3-4	31.2	20
5-6	0.0	30
CHRONIC	31.2	0
Total	100	100

5.4. Short Term Follow Up

In 17 of the horses without NSE at surgery, no post-operative complications were recorded and horses were discharged within 24 hours.

From the 11 horses with NSE at surgery: 1 showed mild colic and ileus for 24 hours after surgery which resolved with IV fluid therapy with Ringers Lactate Solution and continuous rate infusion with of lidocaine. One showed mild discomfort at 48h post op which resolved with of the administration of metamizole (20mg/kg, IV).

Short term follow up was obtained in every horse with transrectal palpation 15 days post-op. In every horse the colon was in a normal position and the nephrosplenic space was free and correctly closed. In all horses with NSE at time of NSC the colon was back in the normal position and the nephrosplenic space was free and correctly closed.

5.5. Long Term Follow Up

Long term follow up was achieved in 26 of the horses and ranged from 4 to 35 month (median 21+ 12.25(IQR)).

8 horses had colic episodes after leaving the hospital, requiring veterinary intervention. None of these episodes appeared to be related to NSE: 4 had gas colic, one had a left displacement of the large colon without NSE, the other had a right displacement of the large colon and one had proximal enteritis. The broodmare which had laparotomy before NSC also had several episodes of mild colic that resolved with metamizole but was never re-entrapped.

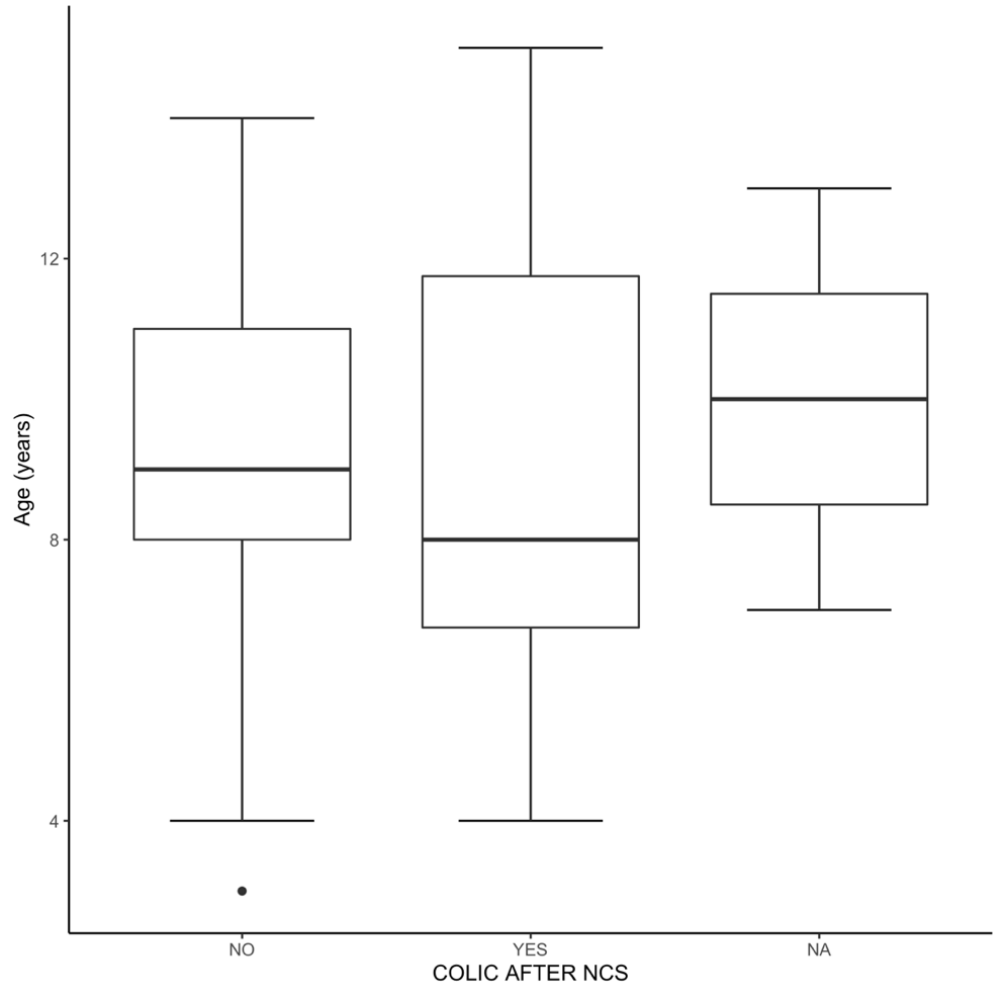
Of the 8 horses with colic symptoms after NSC, one of them had chronic weight loss and the other had a median of 5 episodes of colic before surgery (2-6).

Of the 11 horses with NSE present in surgery only 5 of them presented colic after surgery. Again, none of these cases appeared to be related to NSE and had different colic diagnosis.

Two horses were euthanized. One horse was euthanized 2 years after nephrosplenic space ablation due to colic with a diagnosed colon torsion and small intestine volvulus during exploratory celiotomy. The other horse was euthanized due to poor condition, though NSE was not identified again.

There was no significant difference in ages between horses who had or had no colic after NCS, after leaving the hospital (p=0.8663).

Graph 6 – Age according to having colic after the NSC or not.



When looking at the correlation between horses with colic episodes after surgery and pre-operative NSE episodes these were not significant (p value=0.3872), however a trend of positive correlation appears to be presence which is not highlighted statistically due to low sample numbers.

Table 6– Contingency table with distribution of number of colic episodes according if the horse had colic after NSC or not, results in percentage.

	Colic After NSC		
Nº NSE episodes	NO	YES	TOTAL
1-2	80	20.0	100
3-4	57.1	42.9	100
5-6	33.3	66.7	100
CHRONIC	80.0	20.0	100

No difference was found between the median follow up times of the horses with NSE at time of surgery and without (p=0.1648).

Lastly, when analysing sex predisposing factor for post-operative colic. Most of those with a post-op colic were mares (87.5%), though these results were not identified as significant (p=0.1969) and the fact of being a broodmare also did not influence having post-operative colic episodes since there was no significant relation found.

Table 7 – Contingency table with distribution of sex according if the horse had colic after NSC or not, results in percentage.

	Colic After NSC	
Sex	No	Yes
Female	44.4	87.5
Gelding	44.4	12.5
Male	11.1	0.0
Total	100	100

The owners were also asked if the horses had other problems. 10 owners complained of other problems such as piroplamosis, osteocondrosis lesions, pleuropneumonia, lameness, myositis, sarcoids, laryngeal hemyplagia, gastric ulcers, inferior motoneuron disease. None of these appeared to be related to the surgery or recurrence of nephrosplenic entrapment.

Generally, the colic episodes reduced after surgery with a median of 2.5 episodes + 2 (IQR) before surgery and a median of 0 episodes + 1(IQR) after surgery.

All the horses had a good long term prognosis considering there was never recurrence of NSE.

6. Discussion

Nephrosplenic space closure is advised by several authors to prevent recurrent NSE episodes. Surgery should be performed immediately after the first episode of NSE or after the second episode according to Nelson et al. 2015. NSC can be performed with the colon displaced. The Described techniques when this is the case include hand assisted techniques (Muñoz and Bussy 2013) and the use of instruments to deviate the dislocated colon (Burke and Parente 2016). In this study investigated the success of a technique using barbed suture to close the space and whether the prognosis changed if the colon was entrapped or not at time of surgery. In this technique, when NSE was present, the colon was not deviated with hand assistance or with the aid of instruments.

Average age of affected cases from another studies has a mean of 8.5 years ranging from 2 to 12 years (Albanese et al. 2016), or 8,9 years (Burke and Parente 2016). Though the number of cases was small, the median age in this study is similar.

Affected breeds include warmbloods, thoroughbreds and quarter horses, though some authors refer this to be highly related to the hospital caseload (Hardy et al. 2000). The hospital case load of Clinique Equine de Meslay has 70% of racing breeds, therefore French Warmbloods might be overrepresented but Thoroughbreds are in proportion to the hospital's population.

This study suggests that mares might be predisposed to this condition. Mares were in greater number, specifically broodmares, which has not been reported in other studies were geldings and warmbloods constituted the main population (Arévalo Rodríguez et al. 2019). This might be explained as being in line with the hospitals case load: mostly race horses and many broodmares. But it can also reflect that these are valuable broodmares, which might explain the additional investment made by the owner to prevent any further episodes of colic that might disturb the reproductive ability of these mares.

Four horses in this study presented chronic weight loss without clear signs of colic. One horse presented simultaneously with chronic discomfort and another presented a single episode of gas tympany. Another study by Burke and Parente in 2016 also reported one horse presenting for NSC with chronic weight loss and intermittent anorexia. Rocken et al. 2005 also reports cases of NSE with mild or even no clinical signs. These findings suggest that in horses presenting chronic gas tympany, weight loss and discomfort, NSE should be considered as a differential diagnosis.

We found that eight horses still presented colic episodes post operatively. Other authors such as Farstvedt and Hendrickson 2005 state that NSC will prevent NSE but will not prevent other colonic displacements. This work appears to support this, since 2 of these 8 horses had other types of colon displacements diagnosed: one had a left colon displacement without NSE and other had a right colon displacement. However, even considering these

horses still had colic episodes after NSC we found a reduction in their number. This is also supported by the study of Farstvedt and Hendrickson 2005.

The number of colic episodes before surgery seemed to influence the probability of a horse having colic after surgery. One explanation for this finding might reside in the fact that some horses may be predisposed to colic due to underlying mild and occult conditions such as gastric ulcers or gas tympany. All the diagnosis of colic after the NSC reside in gas colics, right displacements of the colon and enteritis indicating that these colics were not related to the procedure neither to recurrence of NSE.

Albanese et al in 2016, reported a technique with barbed sutures and described a mean time of surgery of 89.6 ± 22.6 and mean NS suturing of 40.4 ± 16.3. In our study these times were shorter. This could be due to the surgeon's experience: in the study by Albanese et al. 2016, two surgical residents performed all the procedures while in our study the entire procedure was performed by an experienced diplomate surgeon with the assistance of a resident. It is also a shorter surgery time when compared with other techniques such as mesh implantation (104 minutes) (Albanese et al. 2016). The self-anchoring design has several advantages such as: not requiring knots at the end or beginning of the suture and aiding to keep the suture strand taut during the procedure. All these advantages make this technique less time consuming.

Regarding the time of surgery and NSC it is also important to note that there was no significant difference between horses who had NSE and horses who did not. This suggests that the presence of NSE does not bring additional difficulties to the procedure. It highlights another benefit of this procedure: other studies describe the need of converting into hand assisted procedures, which is more time consuming.(Muňoz and Bussy 2013)

Other procedures describe that insufflation of the abdomen was not needed for good visualization (Albanese et al. 2016), but in this study insufflation was essential specially in horses with NSE at time of surgery, to promote deviation of the colon from the space and good visualisation.

There were no intra-operative complications or increased difficulties when the colon was displaced during the procedure. Some studies describe the conversion of the procedure into a hand assisted technique, but in this case this was never necessary (Muñoz and Bussy 2013).

Most of the horses who had NSE at time of surgery were mares and brood mares. Broodmares are recognised as being predisposed to colon displacements and torsions (Leahy et al. 2018), probably due to more pendant abdomens and less developed abdominal musculature, however, a specific association to NSE has not been made, we believe that further work to understand this might be of merit.

Two horses demonstrated colic after the procedure in our study (during the 48h after the surgery). This mild discomfort was resolved with administration of either metamizole or lidocaine and perfusion. Abdominal discomfort post-surgery may be related to: chemical peritonitis due to the CO^2 insufflation, stretching of abdominal muscle fibers during insufflation or discomfort related with the suture and tension of soft tissues (Burke and Parente 2016) . In a study by Burke and Parente 2016, 3 horses had abdominal discomfort 6 hours after. In other study by Albanese et al. 2016 one horse had mild colic in the 24 hours post-surgery and other severe colic 69 days post-surgery and was euthanised. None were related to recurrence of NSE.

Though in our study none of the horses suffered from recurrence, another group led by Wilderjans in 2016, reported 3 cases of recurrence after laparoscopic closure mainly related to surgeons inexperience within appropriate closure of the space related with insufficient pulling out or closing of the suture. (Wilderjans 2016)

Even though 8 horses presented colic after NSC the median episodes of colic was reduced. Nelson et al. in 2015 also reported a reduction in the number of colic episodes after closure of the nephrosplenic space. Burke and Parente in 2016 found 38% of horses showed colic signs after mesh obliteration not related to NSE recurrence. The procedure performed in our study is a different technique but none the less our percentage of horses showing colic after the procedure is slightly lower.

The same study by Burke and Parente in 2016 also refers a survival rate of 84% which is also lower than our survival rate (92.9%). All these findings and comparisons could have suggested the technique performed in our study to be more successful, however, it is important to note that in the study by Burke and Parente in 2016 the reasons why some horses did not survive were not related to the surgical procedure of NSC neither to recurrence of NSE.

A significant relation was found between the number of colic episodes and having NSE at time of surgery or not. This finding may lead to the assumption that if the number of episodes is higher, the more likely it is to find the ascending colon entrapped at time of surgery. On the other hand, we should take into account that as the number of episodes is higher, the easier it is for the colon to get either re-entrapped or back to its normal position. It is important to note that in this work took when counting the number of NSE episodes only episodes with colic manifestation were considered, meaning the horse was symptomatic. The horses who had asymptomatic manifestation and multiple episodes of NSE without clinical signs were considered as chronic presentations of NSE. There are several studies that refer asymptomatic horses, and in fact in the present study most of the horses presented for NSC with NSE without clinical signs. Arévalo Rodríguez et al. 2019 highlights that the recurrence rate of NSE episodes may be much higher than reported. These results should be interpreted carefully.

As other authors described (Gandini et al. 2017) VLOC size 1 is normally not available so in this study metric 0 was used. This size may appear small when compared to the metric 2 normally used in regular sutures, but because of the properties of barbed sutures, it is appropriate for this procedure. Barbed sutures have small anchors along its length, and this self-anchoring design applied in a simple continuous pattern distributes tension along the suture line. This prevents suture pull out and dismisses the need of knots.

One of the reasons for this study was to answer one of the concerns identified for this technique: that, since the colon is not relocated, there might be a risk of adhesion formation of the colon to the suture line of the closure of the NS as the fibrin clot forms around it. The concerns are supported in a study by Garcia-Calvo et al. 2015 where a splenectomy was performed in five horses, which described adhesions of the abdominal organs to the nephrosplenic ligament stump. We believe the findings in the present work, disprove this as a concern and therefore this simplifies the procedure reducing skin incision size (tissue damage and invasiveness) as well as surgery time. To further prove this, it would have been helpful to have done second surgeries and performed a post mortem exam of the horses that died to due unrelated reasons. However, this is not practical to achieve in client owned horses so, it is reasonable to assume, that if these adhesions were to occur as a complication that post operative colics with a diagnosis of NSE would have been common in these horses.

Also, time of follow up did not influence the number of colic episodes. This is important since it at least indicates that long and short term colic episodes do not differ as the follow up time did not seem to influence if an owner would report an episode of colic or not (median of 21.5 in both groups).

In more detail, most of the horses who had colic after were mares. No other explanation besides mares being overrepresented in this study is found.

Though some authors describe the use of a modified syringe barrel (Albanese et al. 2016) to pass the needle, in our study regular laparoscopic cannulas were used (10mm) and there was no need of a modified cannula to get the needle inside the abdomen.

Finally, the most important goal of this study was to evaluate if when NSE was present during surgery, the overall prognosis would differ. We therefore conclude that the findings of this work support that the presence of NSE at the time of surgery does not affect outcome or increase complications of this procedure therefore the technique described simplifies the procedure and reduces complications.

7. Conclusions

The study presented in this thesis has significant importance when considering NSC in horses with NSE present at time of surgery. Regarding the results and discussion of the present work, the technique described can be performed when NSE is present without increased difficulty or complications.

The main limitation is a small sample but despite this, similar results to other studies were obtained, regarding the reduction of colic episodes, survival rates and outcome. The procedure of NSC is a very specific surgery, for a very specific pathology, and although the caseload of Clinique Equine de Meslay is high, acquiring a larger sample was not possible.

As it occurred in other studies, atypical presentation of NSE was present in this work. In horses with recurrent colic or chronic weight loss and tympany, NSE should be considered as a diagnosis.

Regarding the use of barbed sutures, we can conclude that the laparoscopic closure of the nephrosplenic space with these is a time saving procedure when compared to other techniques.

We also verified this procedure has an excellent prognosis, without any complications during surgery: a low percentage of horses showed mild discomfort after surgery, and despite 8 horses having colic episodes after surgery, there was never recurrence of NSE and there was an evident reduction in the number of colic episodes after NSC.

The comparison between the group of horses with NSE at time of surgery and the group without showed no differences between the two groups, neither in time nor prognosis. This leads to the conclusion that there are no significant complications caused by not replacing the colon during the procedure.

Finally, the deviation of the entrapped colon promoted by dorsal insufflation of the abdomen seems to be enough to allow good visualisation of the nephrosplenic space, also allowing its closure without any complications or recurrence. Consequently, when the colon is entrapped at time of laparoscopy, we do not find any benefit in either attempting to displace the colon with the aid of surgical instruments or the need of conversion of the laparoscopic procedure into a hand assisted laparotomy.

8. Future Work

The main limitation of this study was the sample's size. This procedure is very specific and though its use has been increasing, it is difficult to find larger samples.

The owners were asked about events that happened long ago, in most cases, so the results obtained in survey were not always very clear, or the owner could not remember. There were also some incomplete medical records. This led to a reduction of information and as the sample was already small, sometimes no statistical significance was found. Nevertheless, some interesting associations were made which leads us to think about the future of this study.

Mares, especially broodmares are overrepresented in this study and although we are not considering all the horses that arrived at the clinic with NSE, we expected to see more geldings and males, as in other studies. It would be interesting to study if broodmares could have also a predisposition to this disease, or if these results are somehow related to the value broodmares may have over geldings or even stallions.

Possibility of future work reside in increasing the sample of the study, hoping to have more significant results. It could also be interesting to perform a longer follow up, assessing if time affects the adhesion formed after the closure of the NS.

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Annexes – Follow up survey presented to owners during phone call

QUESTIONNAIRE FERMETURE ESPACE NEFROSPLENIC/SURVEY CLOSURE OF THE NEPHROSPLENIC SPACE

Cheval/Horse :

Propriétaire/Owner :

Age/age :

Sex/sex :

Si femelle, femelle de reproduction? A déjà pouliner?/ Broodmare?Already foaled?

Race/breed :

Poids/weight :

Utilisation/Use :

Activité et routine normaux et pendant la colique?/ Activity and routine during the colic episode?

Le cheval était au praire, box?/The horse lived in the pasture/box?

Alimentation, changes pendant las coliques?/Feeding and changed during the colics?

Colique avant fermeture?/Colic before NSC?

Combien de colique, tipe de colique?/ How many? Diagnosis?

Colique récurrent? Recurrent colic?

Colique avec entrapment ou seulement déplacement? Colic with entrapment or only displacement?

Traitement de la colique/Treatment?

Chirurgie avant fermeture?/Surgery before NSC?

Intestin éntrape pendant fermeture?/ NSE when NSC?

Colique pendant l'hospitalisation pour fermeture?/ Colicduring hospitalisation when NSC?

Colique après fermeture?/ Colic after NSC?

Combien de colique, tipe de colique? How many? Diagnosis?

Colique récurrent? Recurrent colic?

Si déplacement a gauche, colique avec entrappment ou seulement déplacement? If left displacement NSE was presente or not?

Traitement de la colique/Treatment

Autres problèmes? Other problems

Autres chirurgies?Other surgeries