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Original Article

Strangulating lesions of the small intestine associated with the greater omentum in horses: 32 cases

***N. Storms*[†,*], *A. Salciccia*[†], *S. Grulke*[†], *P. Barbazanges*[†], *J. Detilleux*[‡] and *G. de la Rebière*[†]**

[†]Clinical Department of Equids, Faculty of Veterinary Medicine, University of Liège, Liège; and [‡]Department of Animal Resource Management, Faculty of Veterinary Medicine, University of Liège, Liège, Belgium
**Corresponding author email: nazarestorms@hotmail.com, nazare.storms@uliege.be*

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Summary

Background: Strangulating lesions of the small intestine involving the greater omentum (SSIGOs) have only rarely been reported. Furthermore, information pertaining to clinical descriptions, surgical findings and outcome is lacking.
Objectives: The objective of this study was to describe the prevalence, clinical presentation, surgical findings, postoperative outcome and risk factors associated with SSIGOs.
Study design: This is a retrospective case series of 32 horses with a diagnosis of SSIGOs.
Methods: Data from hospital records of horses identified with SSIGOs between 2005 and 2020 including signalment, clinical findings at presentation, initial laboratory results, surgical findings, surgical procedures performed and postoperative survival were analysed. The prevalence of SSIGOs was determined. SSIGO was compared with small intestinal strangulating and nonstrangulating lesions and other types of colic to identify potential risk factors among signalment data and to determine outcome, using multiple logistic regression models.
Results: SSIGOs were present in 2.3% (32/1413) of all horses undergoing exploratory laparotomy for colic, 4.7% of all horses with primary small intestinal lesions (32/683) and 5.6% of strangulating small intestinal lesions (32/570). Surgical findings included primary strangulation by the greater omentum with or without involvement of a lipoma-like mass originating from the greater omentum (15/32 [47%]), adhesions involving the greater omentum leading to strangulation of the small intestine (14/32 [44%]) and small intestine incarceration through an omental rent (3/32 [9%]). The short-term survival rate defined as survival until discharge was 53% (17/32) considering all SSIGO cases, and 85% (17/20) for SSIGO cases recovered from anaesthesia. Risk factors identified were increasing age and year of surgery.
Main limitations: The limitations of this study are retrospective study design and the limited number of SSIGO cases reflecting the rarity of this condition.
Conclusions: Numerous anatomical configurations of SSIGO exist, but clinical presentation is similar to other strangulating small intestinal lesions. Although uncommon, SSIGOs should be considered a potential cause of small intestine strangulation.

Clinical relevance

- Strangulating small intestinal lesions associated with the greater omentum are a rare but life-threatening condition that can only be diagnosed during exploratory laparotomy.
- These lesions have variable configurations, including primary strangulation by the greater omentum with or without involvement of a lipoma-like mass, adhesions and omental rents.
- Short-term survival rates, defined as survival until discharge, of horses recovered from anaesthesia, are comparable with those of other strangulating small intestinal lesions. Omentectomy could be considered a preventive measure to reduce the risk of adhesions and other types of lesions described in this article.

Introduction

Colic, defined as pain originating from the abdomen, is a common condition in horses (Hillyer et al., 2010). Pathology involving the small intestine reportedly occurs in 25 to 64% of all colic cases treated at equine veterinary hospitals (Edwards, 1981; Kersjes et al., 1988; Morris et al., 1989; Phillips & Walmsley, 1993; Vachon & Fischer, 1995; Vatistas et al., 1996), and the majority (58%–85%) are caused by strangulating obstructions (Freeman, 2019; Freeman et al., 2000; Kersjes et al., 1988; Phillips & Walmsley, 1993). Strangulating obstructions are characterised by interruption of the intestinal blood supply with simultaneous occlusion of the intestinal lumen (Cook et al., 2019). Previously described causes of small intestinal strangulation include pedunculated lipoma, epiploic foramen entrapment, herniation (diaphragmatic, inguinal or umbilical), incarceration within a mesenteric or omental rent, gastrosplenic ligament entrapment, volvulus and adhesions (Freeman, 2019; Mair & Edwards, 2003).

However, strangulating lesions of the small intestine associated with the greater omentum (SSIGOs) have only rarely been reported (Blikslager et al., 1992; Boom & Velden, 2001; Kelmer et al., 2008). Anatomically, the omentum is divided into the greater omentum (omentum majus) and lesser omentum (omentum minus). The greater omentum originates from the greater curvature of the stomach and forms an omental bursa that opens into the abdominal cavity through the omental vestibule and epiploic foramen. The lesser omentum courses from the lesser curvature of the stomach and the cranial part of the duodenum to the visceral surface of the liver (Barone, 1997).

Small intestinal entrapment within the epiploic foramen has been extensively described (Archer et al., 2008; van Bergen et al., 2016; Engelbert et al., 1993; Grulke et al., 2020; Vachon & Fischer, 1995) and is beyond the scope of the current article. Few studies have provided a thorough description of adhesions of the greater omentum as a cause of surgical colic (Gorvy et al., 2008; Mair & Smith, 2005a; Mair & Smith, 2005b; Phillips & Walmsley, 1993). Two cases of omental herniation have been mentioned briefly in a series of 224 horses undergoing colic surgery for small intestinal strangulating obstructions (Boom & Velden, 2001), and one report describes a horse with small intestinal herniation and strangulation through a rent in the greater omentum (Kelmer et al., 2008). Only one report cites a pedunculated lipoma associated with the greater omentum (Blikslager et al., 1992).

The objectives of this study are to describe the prevalence, presenting clinical signs, surgical findings and survival outcome and finally to identify potential risk factors for SSIGO.

Materials and methods

Medical records of horses that underwent exploratory laparotomy for abdominal pain at the Equine Teaching Hospital of Liège between January 2005 and May 2020 were reviewed, following informed owner consent.

Data extracted for all exploratory laparotomy cases operated on during this period included breed, sex, age, weight, number of previous exploratory laparotomies, season and year of surgery, euthanasia during or after surgery and discharge. Further data specifically pertaining to horses identified as SSIGO cases included initial physical examination findings (heart rate and respiratory rate), initial laboratory values, presence or absence of nasogastric reflux, transabdominal ultrasonography, abdominocentesis and rectal palpation findings. These data were reviewed in detail to form the basis of the descriptive part of the study.

The prevalence of SSIGO cases was determined threefold: as the proportion of all the strangulating small intestinal cases (y1), as the proportion of all small intestinal pathology cases (strangulating and non-strangulating lesions) (y2) and as the proportion of all horses that underwent exploratory laparotomy for colic during the study period (y3).

Similarly, risk factors for SSIGO and survival outcome were statistically compared across the same three comparison groups using multiple logistic regression testing.

Horses with nonstrangulating lesions of the small intestine related to the greater omentum were excluded from the descriptive study and considered as nonstrangulating lesions of the small intestine for the second part of the study.

For horses that underwent surgery, preoperative medication included intravenous (i.v.) administration of 22,000 IU/kg bwt sodium benzylpenicillin (Penicillin 5.000.000 IE/IU, Kela Pharma, Sint-Nilkaas, Belgium), 6.6 mg/kg bwt gentamicin (Genta-Equine 100 mg/mL, Dechra, Oudewater, The Netherlands) and 1.1 mg/kg bwt flunixin meglumine (Meganyl 50 mg/mL, Fendigo, Brussels, Belgium). Horses were premedicated i.v. with 0.6 mg/kg bwt xylazine (Proxylaz 2%, Prodivet Pharmaceuticals, Eynatten, Belgium) and induced with a combination of 0.06 mg/kg bwt midazolam (Midazolam 5 mg/mL, Mylan, Hoeilaart, Belgium) and 2.2 mg/kg bwt ketamine (Ketamidor 100 mg/mL, Ecuphar, Oostkamp, Belgium). Anaesthesia was maintained with isoflurane (Isoflo, Zoetis, Zaventem, Belgium) in oxygen or oxygen/air mixture.

Intraoperative data recorded included the type of lesion, the affected segment of the small intestine (jejunum, ileum or both) and its length, surgical procedure undertaken and the length of any resected intestine.

Postoperative treatment of all cases included i.v. administration of 22,000 IU/kg bwt sodium benzylpenicillin four times daily, 6.6 mg/kg bwt gentamicin once daily and 1.1 mg/kg bwt flunixin meglumine twice daily, all administered for 5–7 days. Horses received 0.35 mg/kg bwt low-molecular weight heparin subcutaneously (s.c.) once daily (Clexane 150 mg, Sanofi, Amsterdam, The Netherlands) for 3 days. The treatment was adjusted according to clinical evolution when indicated. Fluid therapy was administered according to hydration, acid-base and electrolyte balance and prokinetic agents (lidocaine – laocaine [Schering Plough Santé Animale, Sergé, France] loading dose 1.3 mg/kg bwt i.v. followed by an infusion rate of 0.05 mg/kg bwt/min i.v., and/or erythromycin – erythromycin [Famar, Saint-Rémy-sur-Avre, France] 0.5 mg/kg bwt in 1 L of saline i.v. over 60 min three times daily, and/or metoclopramide – Vomend [Dechra, Lille, Belgium] 0.25 mg/kg bwt s.c. four times daily or 0.04 mg/kg bwt/h i.v.) to prevent ileus. Clinical examinations were completed every 2 hours, and gastric decompression was performed, where necessary, for refluxing horses. An abdominal bandage was placed for the recovery and then changed every 2–3 days.

Postoperative complications of SSIGO cases were recorded and categorised as none, ileus, postoperative abdominal pain, hyperlipaemia, incisional infection, diarrhoea, septic peritonitis or phlebitis. Ileus was defined as the presence of more than 20 L of nasogastric reflux in 24 hours or 8 L in a single sampling (Roussel et al., 2001). Signs of abdominal pain included lying down for excessive periods, inappetence, restlessness, flank-watching, repeated stretching as if to urinate, kicking at the abdomen, sweating, pawing and rolling (Mair & Smith, 2005b). Hyperlipemia was defined as triglyceride concentration above 5.65 mmol/L (Dunkel & McKenzie, 2003). Incisional infection was defined as purulent secretion, irrespective of duration, in the presence or absence of positive bacterial culture (Salciccia et al., 2020). Jugular vein thrombophlebitis was diagnosed based on clinical signs such as swelling over the affected vein and ultrasonographic evaluation, with or without occlusion of the vein (Mair & Smith, 2005b). Diarrhoea was defined as persistent watery or loose faeces for >24-hour duration (Ellis et al., 2008). Septic peritonitis was diagnosed on the basis of a combination of clinical signs of depression, pyrexia and variable abdominal pain, in conjunction with abnormal peritoneal fluid (total nucleated cell count $>100 \times 10^9$/L) or post-mortem evidence of significant fibrin deposition. Outcome was categorised as subjected to euthanasia at the time of surgery or survival to hospital discharge.

Statistical analysis

Horses were classified according to their lesion type into the following categories: SSIGOs, strangulating small intestinal lesions not involving the greater omentum (A), nonstrangulating small intestinal lesions (B) and colic due to pathologies other than small intestinal lesions (C).

Independent variables included breed (Warmblood type horses, ponies, donkeys or draught horses), sex (male, female or gelding), weight (≤250 kg, 251–450 kg, 451–600 kg or >600 kg), age (≤2, >2–15, >15–20 or > 20 years old), number of previous exploratory laparotomies (0 or more), season (January–March, April–June, July–September or October–December) and year of surgery (2005–2010, 2011–2015 or 2016–2020).

Five logistic regression models were used in total. The first three models were used to evaluate the odds between independent variables and the probability of each horse to suffer from SSIGOs compared with having a strangulating small intestinal lesion unrelated to the greater omentum (y1), compared with having a strangulating or non-strangulating small intestinal lesion (y2) and compared with having an exploratory laparotomy for any other type of colic during the same time period (y3). Two further models were used to evaluate the odds of euthanasia at surgery and survival until discharge in horses suffering from the different categories (SSIGO, A, B or C).

Backward and forward stepwise selection procedures were used to identify models that maximise the model R^2 ($p \leq 0.15$ for entry and $p \geq 0.10$ for removal). SAS (V.9.3) software was used for all statistical analyses. For all statistical analysis, the significance level was set at $p < 0.05$. C-Statistic was used to assess the goodness of fit for the different models.

Descriptive statistics were expressed in terms of percentage, mean ± standard deviation, median and interquartile range. Distribution of this data was assessed using a Kolmogorov–Smirnov test, and the data appeared to be normally distributed.

Results

Prevalence

A total of 1413 horses underwent exploratory laparotomy for colic between January 2005 and May 2020. A small intestinal lesion (strangulating or nonstrangulating) was present in 48.3% (683/1413) of the cases. The prevalence of strangulating lesions of the small intestine was 40.3% (570/1413) of all exploratory laparotomies performed and 83.5% (570/683) of small intestinal pathologies. The prevalence of SSIGO was 2.3% (32/1413) of all horses undergoing exploratory laparotomy and represented 4.7% (32/683) of all horses with primary small intestinal lesions and 5.6% (32/570) of all strangulating lesions of the small intestine.

Signalment and history

The mean age of the 32 SSIGO horses was 15 ± 6.7 years (range: 2–27 years, median 15.5 years, interquartile range 10.8–20.3 years), with 16 females, 15 geldings and one stallion. There were 22 Warmblood type horses, 9 ponies and 1 draught horse. The mean weight was 487.5 ± 64.2 kg (range: 340–635 kg, median 480 kg, interquartile range 450–521.5 kg). The exploratory laparotomy performed for the SSIGO was the first abdominal surgery for 30 horses, the second for one horse and the fourth for one horse.

Clinical examination and laboratory findings

The clinicopathological parameters obtained at admission were normally distributed and are shown in **Table 1**. A peritoneal fluid sample was obtained in 13 cases and appeared macroscopically normal in 4/13 and serosanguineous in 9/13 samples. The total protein concentration exceeded the upper reference limit (20.0 g/L) in 3/4 samples. The total nucleated cell count of the peritoneal fluid was greater than the upper reference limit (5×10^9 cells/L) in 1/3 cases (27.83×10^9/L). The distended small intestine was palpated per rectum in 24/30 (80%) horses. Transabdominal ultrasonographic evaluation revealed small intestinal distension (>5 cm diameter) in 25/29 (86.2%) horses. In some cases, rectal palpation or transabdominal ultrasound was not performed for safety reasons because of the presence of clinical signs of severe and violent colic.

Surgical findings

Strangulation of the small intestine by the greater omentum was only diagnosed at the time of surgery in all cases. Surgical findings included the omentum encircling a length of the small intestine with or without involvement of a lipoma-like mass originating from the greater omentum (15/32 [47%]), adhesions of the greater omentum leading to strangulation of the small intestine (14/32 [44%]) and incarceration of small intestine through an omental rent (3/32 [9%]).

Of the 15 cases where the omentum was found to encircle the small intestine with or without involvement of a lipoma-like mass originating from the greater omentum, the strangulating lesions were located at the jejunum (9/15), ileum (3/15) or both ileum and jejunum (3/15) (**Fig 1**). The mean length of the strangulated portion was 2.2 ± 3.0 m (range: 0.2 to 7.0 m, n = 7). Four horses were subjected to euthanasia during surgery. For the remaining 11 horses, the selected surgical procedure included decompression of the small intestine with repositioning (2/11), and resection and anastomosis (9/11) using the following techniques: jejunojejunostomy (4/9), jejunoileostomy (2/9) and jejunocaecostomy (3/9). Histopathology of the masses was performed in three horses which revealed steatonecrosis.

Fourteen horses were identified as having adhesions originating from the greater omentum. Adhesions occurred between the omentum and different structures in the abdominal cavity, namely, the small intestine and associated mesentery (10/14), the small colon (1/14), the caecum (1/14) or the vaginal ring (2/14). Surgical exploration revealed the aetiology of these adhesions between the omentum and these diverse structures to include pre-existing peritonitis due to severe proximal enteritis in one case and an intra-abdominal abscess to which the adhesions were attached in two cases. In the two horses that had had a previous exploratory laparotomy, one had an adhesion between the previous anastomosis site and the omentum, and the other one had an omental adhesion connected to a mesenteric lipoma. Interestingly, three other horses that had not previously undergone an exploratory laparotomy also had an adhesion between the omentum and a mesenteric lipoma (**Fig 2**). Three horses had concurrent retroflexion of the pelvic flexure, without signs of chronic displacements or peritoneal inflammation and in the remaining cases the aetiology was unknown. The adhesions showed complex configurations. In some cases, they engineered primary strangulation of the small intestine. In others, omental adhesions had served as a rotational axis facilitating the development of a volvulus of the small intestine around this axis. Finally, omental adhesions forming a loop structure causing incarceration of the small intestine were also recorded (**Fig 3**). The portion of the

TABLE 1: Details of the clinical examination and laboratory findings at admission of horses with strangulating small intestinal lesions related to the greater omentum

Parameter	Mean ± standard deviation	Median (interquartile range)	Range	Number of cases
Heart rate (beats/min)	62 ± 16	64 (48–72)	36–100	32
Respiratory rate (breaths/min)	27 ± 10	24 (20–32)	12–52	32
Gastric reflux (L)	7.7 ± 6.0	6.0 (4.5–8.75)	2.0–20.0	7
Packed cell volume (%)	42.0 ± 8.9	40.0 (36.0–45.0)	28.0–60.0	32
Plasma total protein concentration (g/L)	69.0 ± 7.0	68.0 (66.0–74.0)	54.0–80.0	32
Blood lactate (mmol/L)	4.2 ± 3.8	3.4 (1.9–5.1)	0–12.0	26
Peritoneal fluid total protein concentration (g/L)	44.0 ± 26.0	45.0 (26.0–62.5)	14.0–70.0	4
Peritoneal fluid lactate (mmol/L)	6.1 ± 4.0	8.0 (1.8–8.9)	1.0–12.0	9

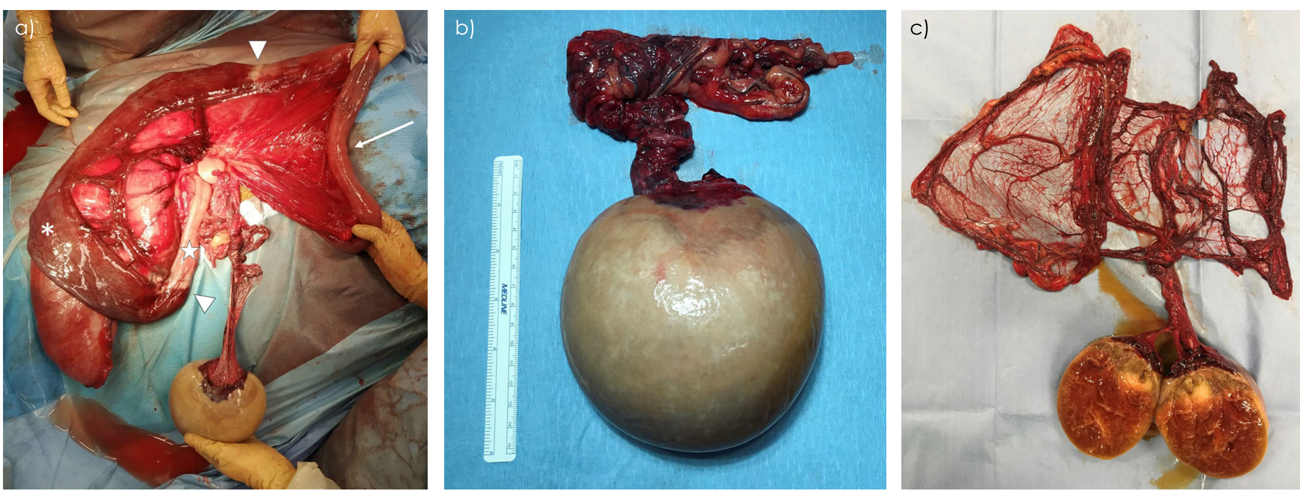

Fig 1: (a) Lipoma-like mass originating from the greater omentum, proximal congested jejunum (arrow), constriction ring (arrowheads), strangulated part of the jejunum (asterisk) and distal part of the jejunum with a normal pink colour (star). (b) Same lipoma-like mass after removal from the abdomen and omentectomy. (c) Transection of the same lipoma-like mass. The omentum is hyperaemic, and the mass has a gelatinous content and a thick capsule.

involved intestine was recorded in 14/15 cases and included both jejunum and ileum in most cases (8/14), only jejunum (4/14) or ileum (1/14). The mean length of involved intestine was 4.8 ± 3.7 m (range: 0.5 to 12.0 m, n = 11). Seven horses were subjected to euthanasia during surgery, and four horses required resection and anastomosis techniques—jejunojejunostomy (3/4), jejunoileostomy (1/4). Two horses did not require a resection and anastomosis procedure.

Incarceration through an omental rent was identified as the cause of small intestine strangulation in three horses. The portion of the incarcerated small intestine was recorded in two cases: one was the jejunum (the incarcerated length was not recorded) and the other was the ileum (0.4 m). One horse was subjected to euthanasia at surgery, one did not need resection and anastomosis and one had a jejunojejunostomy procedure performed.

Of the 20 horses that recovered from general anaesthesia, omentectomy was recorded in the surgical report of 17 cases. This information was not recorded in the three remaining cases.

Outcome and postoperative complications

Euthanasia was elected during surgery in 12 cases. Reasons included severe lesions precluding the possibility of resection and creation of a viable anastomosis (5/12), a requirement to perform a jejunocaecostomy in horses with severe shock and extensive small intestine lesions (involvement of several metres of the small intestine and severe necrosis) (4/12), financial limitations (2/12) and the presence of pre-existing severe peritonitis (1/12).

Detailed results of all univariable and multivariable models for outcomes are summarised in **Table 2** and **Table 3**, respectively. Only cases for which information was available for all variables were retained in the multivariable models. For 2/1413 horses, it was not recorded whether the horses died during surgery or in the postoperative period; therefore, they were not included in the ‘euthanasia at surgery’ model, leaving 1411 included horses (**Table 3**). In the same way, for a few horses, mainly weight or breed were missing (**Table 2**); these cases were also removed from the multivariable models (**Table 3**). The age of the horse and type of lesion (A,

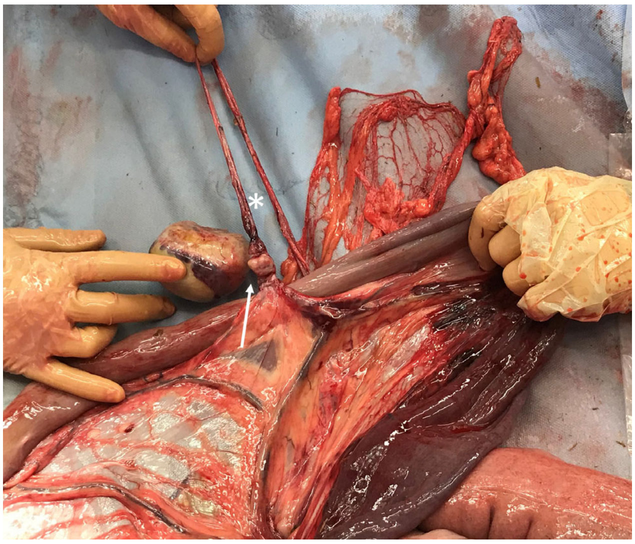

***Fig 2:** Adhesion between the greater omentum and the pedicle of a lipoma originating from the mesentery (arrow) creating a loop that caused strangulation of a segment of the jejunum (asterisk). The pedicle of the lipoma broke during manipulation.*

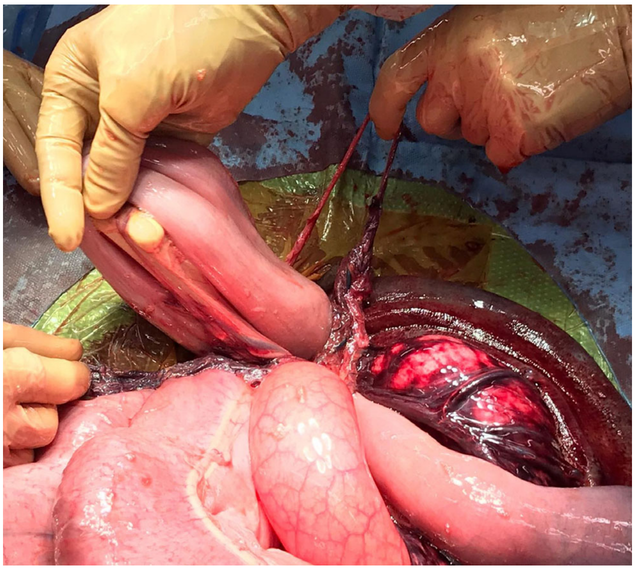

***Fig 3:** Adhesion originating from the greater omentum creating a loop in which a portion of the small intestine was incarcerated.*

B, C or SSIGO) were significantly associated with the odds of euthanasia at surgery. More specifically, the odds ratio of euthanasia at surgery, considering the whole colic population, was significantly lower for horses younger than 15 years than for horses of more than 20 years (**Table 3**). The odds ratio of euthanasia at surgery was significantly lower for horses with nonstrangulating small intestinal pathology (type B) than with SSIGO (**Table 3**).

The short-term survival rate, defined as survival until discharge, was 53% (17/32) considering all SSIGO cases, and 85% (17/20) for SSIGO cases recovered from anaesthesia, with a mean of 15 days of hospitalisation (range: 7–49 days). Specific short-term survival rate presented per SSIGO type is shown in **Table 4**. The odds of short-term survival of horses with SSIGO were not different from the odds of short-term survival of horses with other types of lesions (types A, B and C, **Table 3**). Furthermore, considering the whole colic population, the odds of survival were significantly lower in the years before 2015 than after 2015, and the odds ratio of nonsurvival was significantly lower for horses younger than 15 years than for horses older than 20 years (**Table 3**).

In the three horses that recovered from anaesthesia and did not survive until hospital discharge, severe recurrent colic occurred during the postoperative period. For two of them, a second exploratory laparotomy was not an option, and they were subjected to euthanasia, respectively, on Day 1 and Day 8 after surgery. No necropsy was performed. The third horse underwent a relaparotomy on Day 7 and was subjected to euthanasia at surgery due to the presence of extensive lesions precluding a complete resection (very thickened and congested small intestine extending from the existing anastomosis site to the duodenum; the anastomosis site itself was macroscopically normal).

Seventeen horses developed postoperative complications including ileus (n = 14), postoperative colic (n = 5), diarrhoea (n = 3), hyperlipaemia (n = 5), phlebitis (n = 2) and incisional infection (n = 2). All complications were managed successfully, except in the three horses described before.

Risk factors

Results of univariable and multivariable models for risk factors are presented in **Tables 2** and **3**, respectively. The odds of SSIGO diagnosis were significantly lower for horses operated on before 2015 than after 2015 (**Table 3**). Furthermore, the odds of having SSIGO compared with the other types of colic were significantly lower when the horse was 2–15 years old than older than 20 years (**Table 3**).

Discussion

This article is the first to describe the prevalence, clinical presentation, surgical findings, risk factors and outcome of strangulating lesions of the small intestine associated with the greater omentum.

Although the prevalence of these lesions is low (2.3% of all exploratory laparotomies), this condition is probably underdiagnosed and/or under-reported. This may be because of the fragility of the omentum, adhesions and pedicles of lipoma-like masses that easily break during surgical manipulation. In our study, SSIGO lesions were diagnosed with significantly greater frequency in recent years. This can be explained by increased awareness of the condition among the surgeons or by the increased population of older horses operated in the previous years.

This study showed that SSIGOs lack defining clinical findings to facilitate a preoperative diagnosis, other than clinical signs suggestive of a strangulating obstruction of the small intestine (Mair & Edwards, 2003; Marshall & Blikslager, 2019). Nasogastric reflux was not obtained from all horses, likely reflecting the presence of lesions involving the distal section of the small intestine, a short duration of intestinal strangulation or recent gastric decompression (e.g. prior to referral). Consequently, the definitive diagnosis of a SSIGO is only possible during exploratory laparotomy.

TABLE 2: Results of univariable analysis: Total number of records (n), number of cases (percentages) per category and significance level (*p*)

	y1		y2		y3		Euthanasia at surgery		Short-term survival	
	SSIGO	A	SSIGO	AB	SSIGO	ABC	Euthanasia	No euthanasia	Survival	Non-survival
Year										
≤2010	3 (1.64)	180 (98.36)	3 (1.44)	205 (98.56)	3 (0.71)	421 (99.29)	115 (27.25)	307 (72.75)	217 (51.18)	207 (48.82)
2011–2015	9 (3.90)	222 (96.10)	9 (3.35)	260 (96.65)	9 (1.65)	535 (98.35)	148 (27.21)	396 (72.79)	295 (54.23)	249 (45.77)
>2015	20 (10.64)	168 (89.36)	20 (8.40)	218 (91.60)	20 (4.49)	425 (95.51)	123 (27.64)	322 (72.36)	257 (57.75)	188 (42.25)
	(n = 602; $p < 0.01$)		(n = 715; $p < 0.01$)		(n = 1413; $p < 0.01$)		(n = 1411; $p = 0.99$)		(n = 1413; $p = 0.15$)	
Gender										
Female	15 (6.47)	217 (93.53)	15 (5.38)	264 (94.62)	15 (2.53)	578 (97.47)	176 (29.73)	416 (70.27)	323 (54.47)	270 (45.53)
Gelding	15 (5.23)	272 (94.77)	15 (4.37)	328 (95.63)	15 (2.25)	651 (97.75)	163 (24.51)	502 (75.49)	369 (55.41)	297 (44.59)
Male	2 (2.41)	81 (97.59)	2 (2.17)	90 (97.83)	2 (1.31)	151 (98.69)	47 (30.72)	106 (69.28)	77 (50.33)	76 (49.67)
	(n = 602; $p = 0.37$)		(n = 714; $p = 0.43$)		(n = 1412; $p = 0.66$)		(n = 1410; $p = 0.07$)		(n = 1412; $p = 0.52$)	
Number of surgery										
1 surgery	31 (5.60)	523 (94.40)	31 (4.78)	618 (95.22)	31 (2.37)	1279 (97.63)	353 (26.97)	956 (73.03)	723 (55.19)	587 (44.81)
>1 surgery	1 (2.08)	47 (97.92)	1 (1.52)	65 (98.48)	1 (0.97)	102 (99.03)	33 (32.35)	69 (67.65)	46 (44.66)	57 (55.34)
	(n = 602; $p = 0.30$)		(n = 715; $p = 0.22$)		(n = 1413; $p = 0.36$)		(n = 1411; $p = 0.24$)		(n = 1413; $p = 0.04$)	
Season										
January – March	11 (7.10)	144 (92.90)	11 (6.15)	168 (93.85)	11 (3.11)	343 (96.89)	96 (27.20)	257 (72.80)	205 (57.91)	149 (42.09)
April - June	11 (6.47)	159 (93.53)	11 (5.47)	190 (94.53)	11 (2.78)	385 (97.22)	113 (28.54)	283 (71.46)	207 (52.27)	189 (47.73)
July - September	4 (2.78)	140 (97.22)	4 (2.19)	179 (97.81)	4 (1.18)	336 (98.82)	83 (24.41)	257 (75.59)	176 (51.76)	164 (48.24)
October - December	6 (4.51)	127 (95.49)	6 (3.95)	146 (96.05)	6 (1.86)	317 (98.14)	94 (29.19)	228 (70.81)	181 (56.04)	142 (43.96)
	(n = 602; $p = 0.33$)		(n = 715; $p = 0.26$)		(n = 1413; $p = 0.30$)		(n = 1411;$p = 0.51$)		(n = 1413; $p = 0.29$)	
Age (years)										
≤2	1 (2.33)	42 (97.67)	1 (1.92)	51 (98.08)	1 (1.05)	94 (98.95)	25 (26.32)	70 (73.68)	59 (62.11)	36 (37.89)
>2–15	15 (4.01)	359 (95.99)	15 (3.32)	437 (96.68)	15 (1.54)	957 (98.46)	230 (23.71)	740 (76.29)	555 (57.10)	417 (42.90)
>15–20	7 (6.14)	107 (93.86)	7 (5.34)	124 (94.66)	7 (3.04)	223 (96.96)	78 (33.91)	152 (66.09)	109 (47.39)	121 (52.61)
>20	9 (12.68)	62 (87.32)	9 (11.25)	71 (88.75)	9 (7.76)	107 (92.24)	53 (45.69)	63 (54.31)	46 (39.66)	70 (60.34)
	(n = 602; $p = 0.02$)		(n = 715; $p = 0.01$)		(n = 1413; $p < 0.01$)		(n = 1411; $p < 0.01$)		(n = 1413; $p < 0.01$)	
Weight (kg)										
≤250	0 (0.00)	27 (100.00)	0 (0.00)	32 (100.00)	0 (0.00)	84 (100.00)	23 (27.38)	61 (72.62)	51 (60.71)	33 (39.29)
>250–450	9 (7.63)	109 (92.37)	9 (6.34)	133 (93.66)	9 (3.27)	266 (96.73)	86 (31.39)	188 (68.61)	158 (57.45)	117 (42.55)
>450–600	22 (6.16)	335 (93.84)	22 (5.21)	400 (94.79)	22 (2.72)	788 (97.28)	200 (24.72)	609 (75.28)	450 (55.56)	360 (44.44)
>600	1 (1.32)	75 (98.68)	1 (1.14)	87 (98.86)	1 (0.50)	198 (99.50)	51 (25.63)	148 (74.37)	100 (50.25)	99 (49.75)
	(n = 578; $p = 0.14$)		(n = 684; $p = 0.16$)		(n = 1368; $p = 0.09$)		(n = 1366; $p = 0.19$)		(n = 1368; $p = 0.31$)	
Breed										
Warmblood type	22 (4.47)	470 (95.53)	22 (3.76)	563 (96.24)	22 (1.90)	1137 (98.10)	304 (26.25)	854 (73.75)	631 (54.44)	528 (45.56)
Pony	9 (10.84)	74 (89.16)	9 (9.18)	89 (90.82)	9 (4.55)	189 (95.45)	63 (31.98)	134 (68.02)	114 (57.58)	84 (42.42)
Donkey	0 (0.00)	2 (100.00)	0 (0.00)	4 (100.00)	0 (0.00)	13 (100.00)	4 (30.77)	9 (69.23)	5 (38.46)	8 (61.54)
Draught horse	1 (5.26)	18 (94.74)	1 (4.76)	20 (95.24)	1 (3.03)	32 (96.97)	11 (33.33)	22 (66.67)	13 (39.39)	20 (60.61)
	(n = 596; $p = 0.12$)		(n = 708; $p = 0.12$)		(n = 1403; $p = 0.13$)		(n = 1401; $p = 0.32$)		(n = 1403; $p = 0.16$)	
Type of lesion										
A							195 (34.21)	375 (65.79)	261 (45.79)	309 (54.21)
B							19 (16.96)	93 (83.04)	70 (61.95)	43 (38.05)
C							160 (22.96)	537 (77.04)	421 (60.32)	277 (39.68)
SSIGO							12 (37.50)	20 (62.50)	17 (53.13)	15 (46.88)
							(n = 1411; $p < 0.01$)		(n = 1413; $p < 0.01$)	

SSIGO, strangulating small intestinal lesions involving the greater omentum. A: strangulating small intestinal lesions not involving the greater omentum; B: nonstrangulating small intestinal lesions; C: colic due to pathologies other than small intestinal strangulating or non-strangulating lesions

TABLE 3: Results of multivariable models: Estimates of odds ratios (95% CI) obtained from the different logistic regression models

	y1 SSIGO vs A	y2 SSIGO vs AB	y3 SSIGO vs ABC	Euthanasia at surgery	Short-term survival
n	572	677	1358	1356	1358
C-Statistic	0.71	0.70	0.73	0.61	0.62
Year					
≤2010	0.12 (0.04–0.41)*	0.14 (0.04–0.46)*	0.17 (0.05–0.58)*		0.63 (0.47–0.84)**
2011–2015	0.29 (0.13–0.65)*	0.32 (0.14–0.71)*	0.35 (0.15–0.77)*		0.75 (0.57–0.98)*
>2015	1	1	1		1
Age (years)					
≤2			0.19 (0.02–1.55)	0.45 (0.24–0.84)*	3.07 (1.68–5.62)**
>2–15			0.24 (0.10–0.56)*	0.43 (0.28–0.65)**	2.09 (1.37–3.17)**
>15–20			0.43 (0.15–1.20)	0.69 (0.43–1.12)	1.30 (0.81–2.08)
>20			1	1	1
Type of lesion					
A				0.97 (0.46–2.06)	0.79 (0.38–1.64)
B				0.39 (0.16–0.97)*	1.47 (0.65–3.33)
C				0.59 (0.28–1.25)	1.33 (0.64–2.76)
SSIGO				1	1
Breed					
Warmblood-like horse					1.97 (0.93–4.16)
Pony					2.37 (1.06–5.26)*
Donkey					0.66 (0.17–2.61)
Draught horse					1

N, number of records, SSIGO, strangulating small intestinal lesions involving the greater omentum. A: strangulating small intestinal lesions not involving the greater omentum; B: nonstrangulating small intestinal lesions; C: colic due to pathologies other than small intestinal strangulating or non-strangulating lesions, $*p < 0.05$, $**p < 0.01$.

TABLE 4: SSIGO types and their specific short-term survival rates

SSIGO type	Number of horses per category	Subjected to euthanasia at surgery	Subjected to euthanasia after surgery	Survived to hospital discharge
Direct strangulation by the omentum with or without involvement of a lipoma-like mass	15	4 (27%)	3 (20%)	8 (53%)
Omental rent	3	1 (33%)	0 (0%)	2 (67%)
Omental adhesion	14	7 (50%)	0 (0%)	7 (50%)
Total	32	12 (37%)	3 (10%)	17 (53%)

Varying forms of strangulating lesions of the small intestine involving the greater omentum were encountered. The omentum encircling a length of the small intestine with or without involvement of a lipoma-like mass originating from the greater omentum accounted for 47% of the SSIGO cases. Macroscopically the lipoma-like masses were yellow, round to oval in shape and of varying sizes. The lipoma-like mass did not have a proper pedicle attached to the omentum, but it was the omentum itself that acted as one. The term ‘lipoma-like mass’ was preferred in this article because histopathological examination concluded steatonecrosis in all examined cases. Although abdominal lipomas can occasionally be necrotic or calcified (Kilcoyne & Nieto, 2020), they are usually formed by hyperplastic growth of adipocytes originating from mesenteric tissues (Hargis & Myers, 2017).

Infrequently, calcified masses embedded in the omentum are encountered during exploratory laparotomy (**Fig. 4**) without any clinical relevance. Their appearance differs from lipoma-like masses in that they are of light weight, present a very firm capsule and contain a dry substance that is often dark brown-coloured. They also lack a clear pedicle and are readily detached from the omentum without needing sharp transection.

Omental adhesions have been poorly described, and they may cause signs of abdominal pain by creating abnormal tension on the mesentery, large colon or reproductive tract, or serve as a focus for intestinal obstruction or strangulation (Butson et al., 1996; Gandini et al., 2005; Gorvy et al., 2008; Mair & Smith, 2005a). In our study, intra-abdominal adhesions accounted for 44% of lesions related to the greater omentum and caused strangulation in a variety of ways.

The aetiology of omental adhesions was not apparent following surgical exploration in all cases. Adhesions generally develop to either increase the vascular supply to an organ or to enclose contamination (Butson et al., 1996; Dart & Pascoe, 1994). One horse had severe pre-existing peritonitis and was therefore predisposed to adhesion formation. In horses, adhesions formed in response to chronic low-grade peritonitis commonly become restrictive as they mature, resulting in obstruction of the intestine and development of colic signs. Horses appear to be at increased risk of developing peritonitis, potentially due to the relatively small size of their omentum, decreasing their ability to contain peritoneal contamination (Lores et al., 2011; Mair et al., 1990). Adhesions also seem to occur more frequently after abdominal surgery,

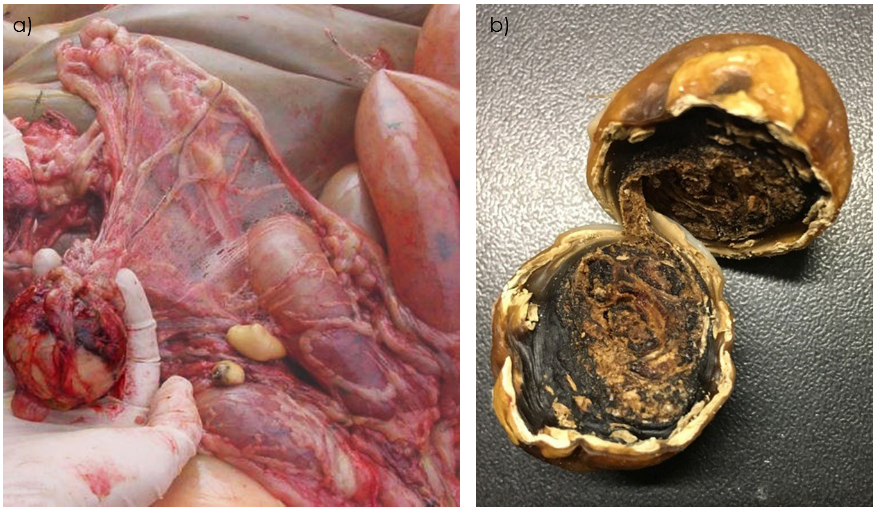

***Fig 4:** (a) Calcified omental mass without clinical relevance in situ. (b) Same mass after removal and section. A thick capsule is visible as well as a dry, dark content.*

as in two of our horses, probably due to intestinal inflammation (Mair & Edwards, 2003). Pathological adhesions were the most common diagnosis at repeat laparotomy following both large and small intestinal lesions (28%) in one study, but omental involvement was uncommon (Gorvy et al., 2008). Interestingly, the two horses presenting with an omental adhesion to the vaginal ring were castrated males, and one of them had a history of a cryptorchid testicle on the side of the adhesion. Velden and Rutgers (1990) report evisceration of the omentum as a postcastration complication and suggest that in such cases, the prolapsed omentum, depending on the correction technique, may serve as a site for adhesions and intestinal strangulation. Unfortunately, no information was available on the castration technique or development of complications in our cases.

Incarceration of the small intestine through an omental rent was reported in only three cases. Mesenteric rents can develop acutely or chronically (typically at the duodenojejunal mesentery) (Lawless et al., 2017). Causes are multiple and include congenital rents or traumatic rents that can develop, for example, peripartum following vigorous foetal movements, after a volvulus nodosus or another small intestinal disorder and after small intestinal surgery (Dart & Pascoe, 1994; Gayle et al., 2000; Lawless et al., 2017). Those mechanisms might be transposed for the omentum but are not applicable in our cases because of the absence of previous abdominal surgery, the incarceration in the omental rent being identified as the primary lesion and the three horses being geldings. As previously mentioned, the omentum is a friable tissue so that spontaneous opening may occur secondary to clinical or subclinical previous intestinal displacements or disorders. Also, a congenital origin cannot be excluded in our cases.

As shown in this study, the omentum seems to be responsible for a wide variety of strangulating lesions. Omentectomy has previously been described as an effective means of reducing postoperative adhesion formation after exploratory laparotomy (Kuebelbeck et al., 1998). Additionally, omentectomy might prevent the occurrence and recurrence of colic due to omental masses and omental rents. However, in human medicine, omentectomy was shown to increase the incidence of postoperative sepsis and the need for a second surgery, highlighting its immunologic role (Ambroze et al., 1991). Compared to humans, the omentum is less developed in the horse and therefore may play a correspondingly modest role in the immune protection. To the authors' knowledge, no studies investigating the relationship between omentectomy and postoperative sepsis in horses have been published. Omentectomy is routinely performed by the equine surgeons in our hospital, with no apparent increase in the incidence of sepsis.

The prognosis for SSIGO seems to be comparable with the prognosis of other strangulating small intestinal lesions. The short-term survival rate of horses with SSIGO was 53% (17/32), which is comparable with the reported short-term survival rates for small intestinal surgery, ranging from 50% to 55% (Boom & Velden, 2001; Mair & Smith, 2005a; Phillips & Walmsley, 1993). Numerous factors may influence these recovery rates, making it difficult to compare the results between different studies. Our short-term survival rate probably reflects the severity and extensiveness of the lesions seen in most cases, which precluded the creation of a viable anastomosis and triggered the decision for euthanasia during surgery. Horses with SSIGO had increased odds of euthanasia during surgery when compared with horses with a nonstrangulating lesion of the small intestine (type B). Furthermore, 50% of horses with omental adhesions were subjected to euthanasia during surgery. Additionally, SSIGO horses presented a high rate of postoperative reflux (14/20, [70%]), attributed to the extensive and complex lesions and the severe intestinal distention over a large portion of the small intestine. Together, these findings demonstrate the significant pathological capacity of SSIGO.

Multivariable analysis showed that survival to discharge of the whole colic population was lower before 2015 than after 2015, likely explained by the development of surgical techniques and experience in managing these cases over the years. Furthermore, survival was higher for horses younger than 15 years than for horses older than 20 years. This can in part be explained by the reluctance of owners of older horses to commit to complex surgical procedures with potential for postoperative complications.

Limitations of this study include its retrospective nature and the small number of SSIGO cases, reflecting the rarity of the condition. As a consequence, risk factor analysis should be interpreted with caution. Furthermore, interactions between variables were not evaluated. Finally, the investigated population consisted of horses referred to the hospital and may therefore not accurately reflect the total population of horses. Further research, using a larger sample size of SSIGO cases to further investigate risk factors and the effect of omentectomy is warranted.

In conclusion, this study is the first to report a series of strangulating lesions of the small intestine associated with the greater omentum in horses. It highlights how omental pathologies can precipitate diverse forms of small intestinal strangulation. Furthermore, although the condition is rare, it is life-threatening in horses, necessitating emergency exploratory laparotomy. Omental pathology should be considered a differential diagnosis in colic cases, with clinical findings suggestive of small intestine strangulation. Omentectomy could be considered a preventive measure.

Authors' declarations of interest

No conflicts of interest have been declared.

Ethical animal research

As this study is retrospective in nature, ethical approval is not necessary.

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N. Storms contributed to study design, study execution, data analysis and interpretation. A. Salciccia, S. Grulke, P. Barbazanges, J. Detilleux and G. de la Rebière contributed to study design, data analysis and interpretation. All authors contributed to the preparation of the manuscript and gave their final approval of the manuscript.

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