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Original Article

Enterolithiasis in horses: analysis of 15 cases treated surgically in Saudi Arabia

Turek, B.[1, 2*]; Witkowski, M.[2, 3] and Drewnowska, O.[1]

[1]Department of Large Animals with Clinic, Faculty of Veterinary Medicine, Warsaw University of Life Sciences, Nowoursynowska 100, 02-797 Warsaw, Poland; [2]Al Khalediah Equine Hospital, Tebrak, Saudi Arabia; [3]University Centre of Veterinary Medicine UJ-UR, Mickiewicza 24/28, 30-059 Kraków, Poland

[*]***Correspondence:*** *B. Turek, Jutrzenki 6, Ustanów, 05-540 Zalesie Górne, Poland. E-mail: bernardturek@gmail.com*

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Abstract

Background: The equine colic, which is caused by the presence of enteroliths that are most often found in the small or large colon, is typical for certain geographical regions (dry and hot climate). A diet rich in alfalfa is one of the highest risk factors. The earliest symptoms include weight loss and repeated episodes of colic pain. **Aims:** To present the results of operative treatment of 15 horses with enteroliths in Saudi Arabia. **Methods**: Fifteen purebred Arabian horses in Saudi Arabia, aged between 2 and 18 years, were treated. Decision about the surgery was based on clinical exam, ultrasound and rectal examination. The surgery was done on recumbent position in every case, under general inhalation anesthesia performed with izofluran. **Results:** Midline laparotomy was performed in all cases. Additional left flank laparotomy was performed in one horse, in which the stone was located in the proximal part of the small colon and parainguinal laparotomy was performed in 1 horse, in which the stone was located distally in the small colon. In each case, pelvic flexure enterotomy was performed in order to empty the large colon. Additionally, four horses underwent ventral colon enterotomy due to the presence of large stones. Small colon enterotomy was performed in 9 horses. In 12 cases treatment outcome was good and in 3 - poor. Chemical analysis of the stones showed similar results: calcium, calcium oxalate, ammonium, phosphates, and magnesium (Mg) were obtained in all these cases but there were quantitative differences accounting for 15 to 30%, 10 to 20%, 10%, 20 to 40%, and 10 to 15%, respectively. **Conclusion:** The results of surgery are generally good if stones are located in the large colon, but the prognosis is worse if they are located in the small colon, particularly in its proximal part. There is a huge importance of X-ray examination, which allows accurate diagnosis for locating the enteroliths and making a decision about surgery.

Key words: Enterolithiasis, Equine colic, Laparotomy

Introduction

The equine colic, which is caused by the presence of intestinal stones (lat. enterolithiasis) that are most often found in the small or large colon, is typical for certain geographical regions (Hassel *et al*., 1999; Cohen *et al*., 2000; Hassel *et al*., 2004; Pierce, 2009; House *et al*., 2016). The presence of such stones often result in a complete obstruction of the intestines, mainly of the small colon, rarely of the large one. Such situation requires a surgical intervention. In other cases, the presence of enteroliths may be the cause of periodic colic pain. Certain food types are one of the factors predisposed to stone formation. They can lead to an increased concentration of minerals and elevation of the pH in the colon which in turn leads to intestinal malfunction and decrease in intestinal motility (Hassel *et al*., 1999; Cohen *et al*., 2000; Hassel *et al*., 2004; Jones *et al*., 2004; Dallap Schaer *et al*., 2008; Pierce, 2009; House *et al*., 2016). Attention is also paid to environmental and genetic factors (Jones *et al*., 2004; Dallap Schaer *et al*., 2008; Pierce, 2009).

Intestinal stones (enteroliths) most often consist of magnesium (Mg) or calcium ions, and Mg ammonium phosphates (struvite) precipitated around a nidus, such as a stone, a piece of wire (Fig. 1). They do not necessarily cause clinical symptoms until they completely block the intestinal lumen. Intestinal stones may occur individually. In that case their shape is most often spherical (Fig. 2), but if they occur in a larger number, they are polyhedral (Fig. 3). Sometimes their shape may be rather unique (Fig. 4). The nature of regions in which intestinal stone formation cases have been reported indicates the relationship of this disease with the composition of soil and water for example, in California, Texas, Florida, Indiana (US), colic caused by intestinal stones accounts for as much as 15% of all colic cases (Hassel *et al*., 1999). The stones most often develop in horses aged 5 to 10 years old. The highest number of cases is reported in Arabian horses and ponies (Hassel *et al*., 1999).

A diet rich in alfalfa is one of the highest risk factors. Horses that were fed with a diet which consisted of over 70% of this plant were most likely to develop intestinal stones, because the concentration of minerals with such feeding was 1.5 times higher than in horses fed differently, leading to a significant increase in the colonic pH (Hassel *et al*., 1999; Hassel *et al*., 2004;

Pierce, 2009; House *et al*., 2016).

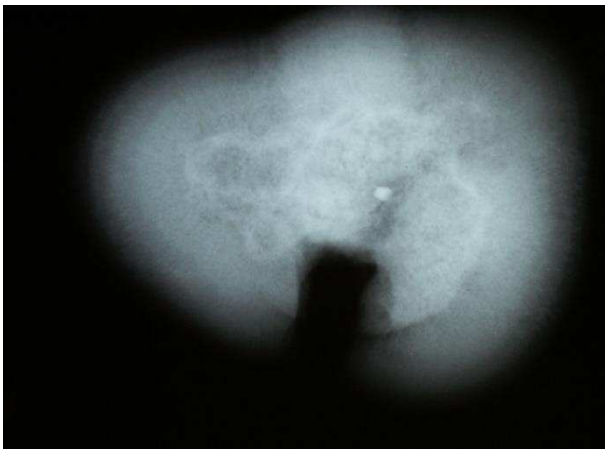

Fig. 1: Radiological image of the intestinal stone with a visible nucleus (horse No. 1, Table 1)

Fig. 2: Spherical stones removed from the large colon [horse No. 12 (two stones at the top), and horse No. 1 (at the bottom) in Table 1]

Fig. 3: Polyhedral stones found in the large colon (horse No. 11, Table 1)

Fig. 4: An unusually shaped stone removed from the large colon (horse No. 10, Table 1)

The earliest symptoms include weight loss and repeated episodes of colic pain. If the intestine is completely obstructed, pain is very severe and heart rate and respiratory rate are significantly elevated (Schumacher *et al*., 2002). Rectal examination rarely reveals stones. However sometimes it is possible to find them that way if stones are in the small colon. X-ray examinations are useful while establishing diagnosis as some of them visualize stone shades in the intestinal lumen (Ruohoniemi *et al*., 2001). Ultrasound examination, which should be an obligatory procedure in the case of colic, may also be helpful. Sometimes it can be used to visualise large hyperechoic masses seen as large acoustic shadowing and thickening of the intestinal wall. However, it is usually not possible due to the large amount of gas in the intestines (Schumacher *et al*., 2002; Jones *et al*., 2004; Dallap Schaer *et al*., 2008).

Materials and Methods

Fifteen client-owned purebred Arabian horses aged between 2 and 18 years were treated in the AL Khalediah Equine Hospital between 2006-2008 and 2013-2015. Eleven cases were mares and the remaining four were stallions. All horses came from Saudi Arabia mainly from the west part of the country (the Red Sea region close to Jeddah) and from the area located close to Dammam (Persian Gulf). They were brought to the hospital because of colic symptoms. Pain intensity and onset varied depending on the existing problem. If a stone was or stones were located in small colon, the complete intestinal obstruction was noted and pain symptoms were severe. In horses, in which the stones were found in large colon, pain was light, lasted for a long time and sometimes it was recurring for several weeks. Upon admission basic vital parameters, such as temperature, heart rate, mucous membrane status and dehydration level were noted. Samples were collected from all horses in order to carry out a complete blood count and biochemical analysis. Subsequently, their abdominal cavity was auscultated and rectal examination was performed. In some cases, a nasogastric tube was passed through to the stomach to decompress it by flushing. All horses underwent ultrasound examination

of the abdominal cavity. In each case, intravenous fluid therapy with lactated Ringer's solution was administered.

Decisions about surgeries were made on the basis of various indicators. In some cases, stones were revealed in rectal examination (some of them were located in small colon). Ultrasound examination did not show stones in any case. In most cases, a decision about surgery was made on the basis of persistent pain and no satisfactory improvement after conservative treatment.

In all cases, the horses were operated under general anaesthesia and in dorsal recumbent position. The horses were put into the recovery box, where they were given the premedication. The intravenous catheter was inserted into the jugular vein left or right. As sedation detomidine (0.02 mg/kg; Domosedan, Orion Pharma, Finland) and butorphanol (0.01 mg/kg; Torbugesic-SA, USA) were administered. After the effective sedation, the induction was administered using diazepam (0.1 mg/kg; Diazepam, USP, USA) and ketamine (2.2 mg/kg; Ketalar inj. 100 mg/ml, Pfizer, USA) as one intravenous bolus. The horses were laid down with assistance on the side and then 400 ml of 5% guaiaphenesin (Myolaxin 15%, Vetquinol, France) was given as intravenous fast bolus up to the full miorelaxation, that allowed safe intubation with the endotracheal tube, diameter 24-26 mm. After intubation the patient was moved into the surgery theater and put on dorsal recumbency. The maintenance of general anesthesia was kept by the inhalant isoflurane with medium concentration of 2% in the mixture of oxygen and air (4 L/min to 8 L/min). Moreover, the additional constant rate infusion was administered using lidocaine (6 mg/kg/h; Lidocaine HCL, Hospira INC., USA) and detomidine (0.01 mg/kg/h; Domosedan, Orion Pharma, Finland). The fluid therapy was led constantly during the anesthesia with Ringer's lactate (Ringer lactate, Jeddah, KSA) solution in 3l/h dose. The patient was monitored with the use of vital sign monitor, showing ECG, pulse oximetry, breaths per min and arterial pressure, measured invasively through insertion of cannula to facial artery.

The surgical approach was done along the linea alba. If necessary, additional laparotomy was performed-depending on the stones' location, it was a parainguinal or lateral laparotomy. In order to remove the stones, an appropriate enterotomy was performed, either on the pelvic flexure of the colon, on left ventral colon or along the *Taeniae coli*. Regardless of the previously mentioned enterotomies, in each case an incision was made along the pelvic flexure to remove the residual content from the colon.

After the surgery, all patients had administered the antibiotic therapy. It involved procaine penicillin (Norocillin, Norbrook GB) 22,000 IU/kg and gentamicin (Gentaject 10%, Kepro, Netherland) 6.6 mg/kg once a day for 7-10 days. In post-operative management flunixin meglumine (Finadyne, Schering-Plough, USA) 1.1 mg/kg once daily, fluid therapy with lactated Ringer's solution (Ringer Lactate, Jeddah, KSA) and NaCl 0.9% were administered. If necessary, the nasogastric tube was passed to decompress the stomach or to administer drugs.

Detailed data of the patients treated are presented in Table 1.

Results

Colic caused by enteroliths constituted merely 1.9% of 756 colic patients surgically treated at that time between 2006-2008 and 2013-2015. Sex distribution within the 756 horses were 78% mares and 22% males. All enteroliths were present in the Arabian horses. Only 4 of them were found in stallions and 11 stones were observed in mares. In 12 cases treatment outcome was good, whereas in three cases it was poor. Peritonitis developed in horse No. 3. The stone in the large colon was removed from the pelvic flexure (Fig. 5); the second stone was located proximally in the small colon which was difficult to access (Fig. 6). The colonic wall was partially necrotic, suturing was very difficult and resection was impossible. As a consequence, peritonitis occurred and the horse was euthanized 7 days after the surgery. Necrosis of the colonic wall along with its perforation and peritonitis were observed during the surgery in the next patient (mare No. 5). The horse was euthanized during the procedure. The next case (horse No. 8) with poor treatment outcome was a nine-month pregnant mare. The mare had difficulties with standing up after the surgery. She was able to stand up after 12 h. In the following days, abdominal volume became enlarged and lowered. Finally, rectus abdominis muscle ruptured (Fig. 7). The mare was euthanized within 2 weeks after the surgery. In the next case (horse No. 4), the mare recovered well, but we had the problem with the peripheral limb necrosis in the foal. During the surgery, the mare was 2 weeks before delivery, therefore a caesarean section was made to avoid delivery-related problems after the surgery.

Midline laparotomy was performed in all cases. In addition, laparotomy with left-sided approach was performed in two horses, in which the stones were located proximally in the small colon and parainguinal laparotomy was performed in a horse, in which the stone

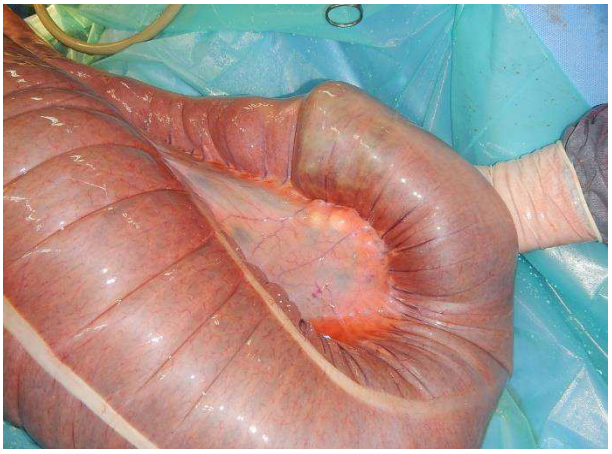

Fig. 5: Intraoperative view of the colon with a stone (horse No. 3, Table 1)

Table 1: Clinical details of horses that underwent surgery due to presence of enteroliths

No.	Breed, sex, age	Selected vital signs of the horse upon admission to the clinic	Duration of the disease	Other factors	Stone location, number, size	Surgery type	Outcome
1	oo, stallion, 16 yo	HR 44, Ht 34, CRT 2 s	Recurrent colic for few months	None	1 stone in ventral transverse large colon, weight: 1600 g	Midline laparotomy, enterotomy of right ventral colon in ½ of its length, enterotomy of pelvic flexure	Good, post-surgical hernia
2	oo, mare, 6 yo	HR 36, Ht 29, CRT 2 s	Colic for few weeks	None	1 stone in ventral large colon, weight: 800 g	Midline laparotomy, enterotomy of pelvic flexure	good
3	oo, stallion, 6 yo	HR 44, Ht 38, CRT 2 s	gradually exacerbating pain, then constant pain	None	1 stone in large colon, 1 stone in small colon	Midline laparotomy enterotomy of pelvic flexure, enterotomy of small colon	poor, peritonitis, euthanasia
4	oo, mare, 3 yo	HR 54, Ht 37, CRT 2 s	gradually exacerbating pain	42nd week of pregnancy	2 stones in small colon	Midline laparotomy, caesarean section, enterotomy of pelvic flexure, enterotomy of small colon	good
5	oo, mare, 6 yo	HR 80, Ht 67, CRT 3 s	Recurrent pain, exacerbating gradually	46th week of pregnancy	1 stone in small colon, intestinal necrosis and perforation	Delivery induction, midline laparotomy enterotomy of pelvic flexure, enterotomy of small colon	poor, euthanasia during surgery
6	oo, mare, 2.5 yo	HR 68, Ht 40, CRT 2 s	Recurrent pain for 2 days	None	1 small stone in large colon, 1 stone bigger in small colon	Midline laparotomy, enterotomy of pelvic flexure, enterotomy of small colon	good
7	oo, mare, 3 yo	HR 78, Ht 40, CRT 2 s	Colic for 2 days	8th month pregnancy	1 small pyramidal stone in large colon, 1 bigger stone in small colon	Midline laparotomy, enterotomy of pelvic flexure, enterotomy of small colon	good, delivery up to date, healthy foal
8	oo, mare, 9 yo	HR 80, Ht 56, CRT 4 s	Colic for 2 days, gradually exacerbating	9th month pregnancy	Huge stone (1533 g) in ventral transverse large colon	Midline laparotomy, enterotomy of pelvic flexure, enterotomy of ventral large colon	poor
9	oo, mare, 4 yo	HR 46, Ht 36, CRT 2 s	Colic for few days, recurrent clinical signs	None	2-kg stone in ventral large colon	Midline laparotomy, enterotomy of pelvic flexure, enterotomy of large ventral colon	good
10	oo, mare, 3 yo	HR 40, Ht 40, CRT 3 s	Recurrent colics	None	1 stone in small colon, 1 stone in large colon	Midline laparotomy, lateral laparotomy, enterotomy of pelvic flexure, enterotomy of small colon	good
11	oo, mare, 4 yo	HR 40, Ht 28, CRT 2s	Colic for approx. 2 weeks	None	4 pyramidal stones in large colon	Midline laparotomy, enterotomy of pelvic flexure	good
12	oo, stallion, 12 yo	HR 36, Ht 34, CRT 2 s	Recurrent colic for approx. a month	None	2 huge stones in large colon - 900 g and 1200 g	Midline laparotomy, enterotomy of pelvic flexure, enterotomy of large ventral colon	good
13	oo, mare, 2 yo	HR 36, Ht 28, CRT 2 s	Colic for 5 days	None	2 stones in small colon	Midline laparotomy, enterotomy of pelvic flexure, enterotomy of small colon	good
14	oo, mare, 2.5 yo	HR 40, Ht 36, CRT 2 s	Colic for 5 days	5th month pregnancy	1 stone in small colon	Midline laparotomy, enterotomy of pelvic flexure, enterotomy of small colon	good
15.	oo, stallion, 15 yo	HR 44, Ht 36, CRT 2 s	Colic for 5 days	none	1 stone in small colon, close to rectum	Midline laparotomy, parainguinal laparotomy, enterotomy of pelvic flexure, enterotomy of small colon	good

CRT: Capillary refill time, Ht: Haematocrit, and HR: Heart rate

Fig. 6: Stone removal from the proximal small colon (horse No. 14, Table 1)

Fig. 7: Rupture of the rectus abdominis, 10 days after the stone removal surgery (horse No. 5, Table 1)

was located distally in the small colon. In each case, pelvic flexure enterotomy was performed in order to empty the large colon. Four horses also underwent ventral colon enterotomy due to the presence of large stones that could not be moved to the pelvic flexure region. Small colon enterotomy was performed in nine horses.

In six cases the stones were subjected to chemical analysis. Similar results were obtained in all these cases according to their composition but there were quantitative differences. Calcium, calcium oxalate, ammonium, phosphates and Mg accounted from 15 to 30%, 10 to 20%, 10%, 20 to 40%, and 10 to 15%, respectively.

Discussion

Most cases described in the literature include the Arabian horses living in regions with a hot and dry climate (Hassel *et al*., 1999; Kelleher *et al*., 2014). In our study, all horses were purebred and came from the Red Sea region (the area of Jeddah) and the Persian Gulf (Dammam). The climate in these two areas is hot and dry. However, it is difficult to determine whether the breed correlation results from the fact that purebred horses are more often kept in conditions that foster the formation of enteroliths (own observations).

According to some authors, stones are mainly reported in purebred horses (Hassel *et al*., 1999; Hassel *et al*., 2004; House *et al*., 2016). In our case, it is difficult to confirm this fact, because all discussed cases were purebred Arabian horses. In our opinion, the above-mentioned conclusion results from the fact that Arabian horses are the most common breed in dry and desert areas.

Intestinal stones are most common in older horses and they occur in horses aged less than 2 years only occasionally. In our case, stones were found in young horses aged around 2 years. The oldest horse was 18 years old. The fact that enteroliths are less frequently observed in young animals results from the time needed for their formation. Nevertheless, literature refers to cases involving stone formation in 1-year-old horses (Cohen *et al*., 2000).

It is assumed that feeding with high-protein feed (alfalfa) is a promoting factor, because it increases intestinal pH (Cohen *et al*., 2000; Hassel *et al*., 2004; House *et al*., 2016). In addition, alfalfa contains significantly more minerals, such as calcium (1.5% dry mass), Mg, ammonium Mg sulphate, phosphates, which are mainly alkaline element and/or crystallize more easily at higher pH. Alfalfa is an easily digested feed that contains a small amount of fibre, which may slow down peristalsis. Feeding with larger amounts of concentrated feed may be a good solution, but may also pose a problem if it significantly reduces pH (Cohen *et al*., 2000; Hassel *et al*., 2004). Some authors also mention lack of access to pasture as a predisposing factor (Cohen *et al*., 2000). No horse of the 15 cases analysed in this paper had access to pasture. This hypothesis is, however, challenged by the fact that no enteroliths were observed in about 1500 horses fed with alfalfa without access to pasture (own observations). It seems that the quality and composition of water may also have impact on enterolith formation. The stable with 1500 horses has access to water obtained from deep wells from a depth of 600-800 m. Horses with enteroliths drank desalinated sea water (author observations). A more detailed research in this area is necessary. The authors of article published in 2018 suggest that the water and quality of the food play an important role in the process of formation of the enteroliths (Rouff *et al*., 2018). In our study we have quite similar observations mainly concerning the quality of water.

It is important, however, to consider the amount of fibre in the feed ration. Horses that consume larger amounts of hay have a lower intestinal pH and are thus less susceptible to formation of enteroliths (Hassel *et al*., 1999; Hassel *et al*., 2004). The same author believes that feeding with bran, which contains large amounts of phosphate salts, Mg and protein, promotes the formation of enteroliths. Generally speaking, enteroliths are found more frequently in horses, given feed which contained

more magnesium, phosphorus, calcium and potassium (Rouff *et al*., 2018).

Of all colics treated surgically, stones accounted for only 1.9%, constituting a small percentage if compared with data provided by Hasell *et al*. (1999) who reported that stones accounted for 27.5% of all surgical cases.

Clinical symptoms depend on stone location. If they are located in the large colon, the clinical symptoms are not pronounced and the heart rate usually remains within normal range. Symptoms usually result from chronic intestinal inflammation. Single stones, which are most often spherical, can sometimes be of impressive sizes and weight. In our case, the heaviest stone weighted over 2 kg. Such stones may cause complete obstruction of the large colon in the pelvic flexure. In such cases pain will be rather pronounced. Numerous polyhedral stones may cause similar symptoms. If stones are located in small colon and completely obstruct its lumen, symptoms are more severe and include elevated heart rate, severe pain and intestinal distension. Precise diagnosis is not always possible. Sometimes, a rectal examination may reveal a stone located in small colon, but an X-ray examination would be very helpful in confirming the presence of a stone, thus complete intestinal obstruction could be avoided in some cases. It would also be easier to identify the problem in case of recurrent colic. In such cases, horses are operated very often on a base of suspicions rather than typical clinical signs. For these reasons, an X-ray examination should be obligatory in the regions where intestinal stones occur (Maher *et al*., 2011; Kelleher *et al*., 2014).

The authors of one of the articles observed intestinal stones in 29.4% of 238 horses that had abdominal X-ray (Kelleher *et al*., 2014). In another study (Maher *et al*., 2011) in 58. 4% of cases, enterolithiasis was confirmed by radiography. Sensitivity of the X-ray examination for detection of stones located in small colon was lower than that for large colon (Maher *et al*., 2011; Kelleher *et al*., 2014).

Good treatment results were most often achieved if stones were located in large colon. Routine large colon enterotomy at the pelvic flexure allows intestinal content and some stones to be removed. Sometimes, additional enterotomy of the left ventral colon was necessary to remove a large stone (Fig. 8). Such enterotomy entails the risk of contamination and infection, which may significantly affect treatment results. In our observations additional enterotomy of large colon was performed only in 4 of 15 horses and none of them developed any complications. Pierce and co-authors analysed the postoperative complications after enterolith removal from the ascending and descending colon and they stated that number and location do not have the influence, although more horses with the enteroliths in the small colon were euthanized intraoperatively (Pierce *et al*., 2010).

As far as stones located in small colon are concerned, enterotomy was always performed along the long axis of the *T. coli*. In cases with stones in small colon, the results were good if no necrosis of the intestinal wall developed due to compression by a stone. The results were poorer if the stone was in the proximal small colon with difficult surgical access. In one case, additional lateral laparotomy allowed to remove the stone. The surgery lasted for a longer time, but it was easier to suture the intestinal wall. If access to the stone was more difficult, additional access in the proximal or distal part of small colon, depending on stone location, is recommended (Anderson *et al*., 2011; Barrett and Munsterman, 2012; Klohnen, 2013). In described cases, one parainguinal laparotomy was performed in order to remove a stone from distal small colon. Before stone removal, pelvic flexure enterotomy was performed at first and then small colon enterotomy was conducted at an easily accessible area in order to empty the intestines. Such approach ensured a good treatment result. Despite the advantages gained from the additional access, it is necessary to note difficulties posed by additional incisions of the abdominal wall (Anderson *et al*., 2011).

Fig. 8: A large stone removed from the large colon during left ventral colon enterotomy (horse No. 8, Table 1)

In one case it was necessary to perform two small colon enterotomies, because it was not possible to move the second stone to the incision site (Fig. 9). Some authors suggest that teniotomy should be performed in order to move the stone (Hassel *et al*., 1999). In our observations, teniotomy was not performed in any case, because the distance between the stones was rather large or the stones varied in terms of their size rather significantly. Usually late pregnancy had an adverse impact on the treatment outcome. In one case, difficulties in getting up were observed and as a consequence the rectus abdominis muscle was ruptured a few days later. The results are generally good if stones are located in the large colon, but the prognosis is worse if they are located in the small colon, in particular in its proximal part with more difficult access. If the peristalsis stops and the intestinal content is obstructed, the intestinal wall necrosis and perforation may occur, in particular if the colic lasts for a longer period of time. Most cases suffer from colic lasting from several days to several weeks, sometimes even months. At this point, we would like to emphasize the importance of X-ray examination, which

allows accurate diagnosis for locating the enteroliths and making a decision about surgery (Maher *et al*., 2011; Kelleher *et al*., 2014).

Chemical analysis of the stones performed by us in six cases showed the similar results of the components presented by others authors (Cohen *et al*., 2000; Hassel *et al*., 2004; House *et al*., 2016; Rouff *et al*., 2018). Rouff *et al*. (2018) presents a quite interesting analysis of the intestinal stones performed by powder X-ray diffraction (XRD) and Fourier transform infrared (FTIR) spectroscopy. Elemental analysis confirmed concentrations of phosphorus (P), magnesium (Mg) and nitrogen (N) consistent with the struvite composition, and detected trace elements ferrum (Fe), manganese (Mn), and zinc (Zn).

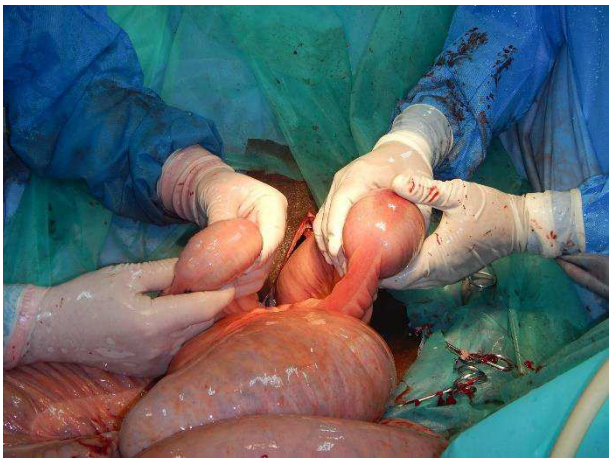

Fig. 9: Two stones in the small colon. It was necessary to perform two enterotomies (horse No. 13, Table 1)

In summary, intestinal stones are a problem typical for certain geographical regions. In our case, all horses came from desert areas located near the sea. The course of disease was rather typical. At the beginning pain was not severe and disappeared for some time after administration of analgesics and spasmolytics. Pain recurs, other symptoms exacerbate and patient's general condition deteriorates in the case of complete intestinal obstruction. Such course of a disease and concomitant lack of typical changes in the intestinal topography should point us towards stones' presence. In such case X-ray examination would confirm the diagnosis. It should be noted that other problems, such as intestinal displacement, strains, sanding or uterine torsion, may be faced at the same time. More than one stone was observed in many cases. Therefore, it is necessary to examine the entire gastrointestinal tract to avoid overlooking the additional problems.

Conflict of interest

There is no conflict of interest.

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