The incidence of post-operative colic in adult equine patients undergoing elective non-abdominal surgery at SLU and potential risk factors

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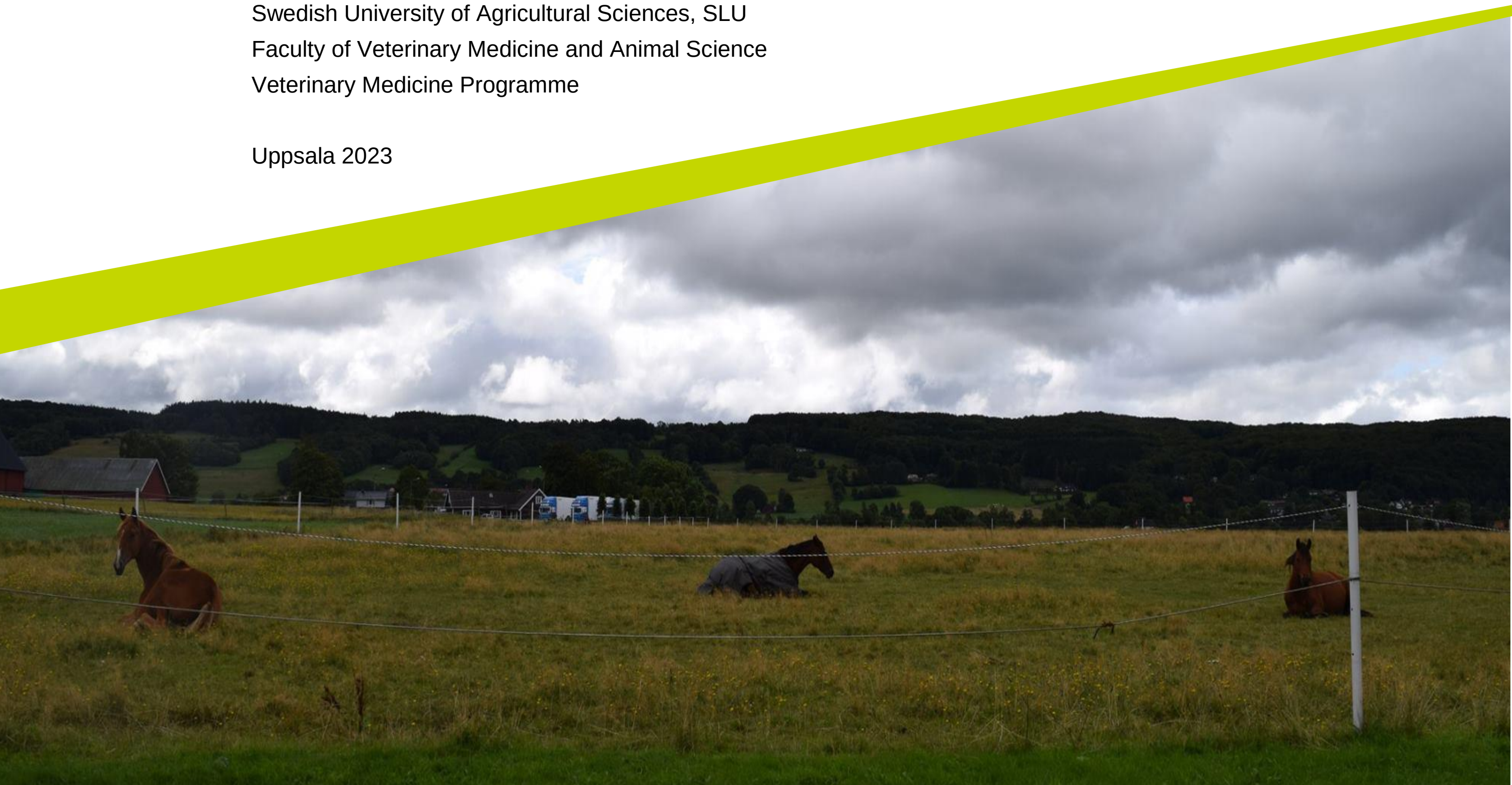

The incidence of post-operative colic in adult equine patients undergoing elective non-abdominal surgery at SLU and potential risk factors

Incidensen av postoperativ kolik hos vuxna hästar efter icke-abdominell elektiv kirurgi på SLU och potentiella riskfaktorer

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Abstract

Post-operative colic (POC) is a well-recognised complication in horses undergoing abdominal surgery but there are few studies describing the prevalence and incidence of colic in horses after non-abdominal surgery. Recently, the benefits of fasting horses pre-operatively have been questioned. A future randomised prospective study is planned to investigate the beneficial or negative effects of fasting horses prior to surgery. This retrospective pilot study was performed to evaluate the incidence of post-operative colic after non- abdominal elective surgery, with the current feeding regimen at SLU. Is there a problem that needs further investigation? Are specific procedures associated with increased risk of POC? Can we identify any common risk factors that should be included and separately studied in a prospective larger case-controlled study? Can we identify possible risk factors in the management pre- and post-surgery that can be applied and changed to decrease the risk of colic post-surgery?

We performed a retrospective study including elective non-abdominal procedures performed at SLU between October 2021 and October 2022. The inclusion criteria were: all adult horses >1 year of age, monitored in the hospital for a minimum of 24h following anesthesia, starved before the surgery according to the pre-surgery feeding regimen at SLU, and not known to have a medical history of colic within 6 months before surgery. In addition, we briefly investigated the incidence of post-operative colic following surgical procedures performed under standing sedation and when two procedures were performed in close succession. Data was analysed using descriptive statistics, hypothetical association tests and binary logistic regression analysis.

297 horses were included in the main study. We found an incidence of POC after non-abdominal surgery of 13.5% (40/297) within 3 days post general anesthesia. The incidence of POC within 7 days post general anesthesia was 14.5% ((43/297). These results are markedly higher compared to the previous described incidence of 2.5% (Bailey *et al.*2016) to 10.5% (Jago *et al.*2015). The incidence of colic following standing surgery during CRI-sedation was 14.5% (10/69) within 3 days post-operative. The incidence of colic following two separate anesthesia events performed close to each other was 10.7% (3/28) within 3 days post the second surgical event.

The results indicate that pre- and especially post-operative management of the horse may alter the risk of POC. We found that hand-walked exercise during hospitalization decreased the odds of development of POC within our study population, an event to our knowledge not described before. Our result also indicates that systemically administration of morphine given either intravenously or intramuscularly during anesthesia may increase the risk to develop of POC. As previous reported by Ekstrand *et al.* (2022), atropine treatment was associated with higher risk of colic. Higher age was found associated with higher risk to develop POC. Comparing orthopaedical and non-orthopaedical procedures, no association was found between procedure and increased risk for POC within our study population. Neither did we find any association with breed type nor positioning during surgery nor lidocaine constant rate infusion during anesthesia. We conclude that a larger prospective study under controlled conditions needs to be performed, to further investigate if it is possible to decrease the risk of POC following the finding of an uncommon high incidence. The result of literature review in combination with the results from our pilot study indicates that different pre- and post-operative feeding regimens should be included and evaluated.

Keywords: post-operative colic, fasting, starvation, risk factors colic

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Abbreviations

SLU	Swedish University of Agricultural Sciences
G. I	Gastro-intestinal
ICC	Interstitial Cells of Cajal
I.V	Intravenous
I.M	Intramuscularly
CRI	Constant Rate Infusion
POC	Post-operative colic

1. Introduction

Post-operative colic (POC) is a well-recognised and reported complication in horses undergoing abdominal surgery, but there are few studies describing the prevalence of colic in horses after non-abdominal surgery. Previous reports have shown that 2.5 % (Bailey *et al.* 2016) to 10.5% (Jago *et al.* 2015) of horses undergoing general anesthesia develop POC after non-abdominal surgical procedures with the most common diagnosis being impaction of the large intestine or caecum (Senior *et al.* 2004; Bailey *et al.* 2016). Studies on the prevalence of colic in non-hospitalized equid populations show a prevalence ranging from 3.5% (Kaneene *et al.* 1997) to 10.5% (Traub-Dargatz *et al.* 2001) .

The benefit of withholding feed before surgery is questionable and has not been fully investigated. Traditionally, the withdrawal of feed for 6-12 hours pre-operatively has been routinely performed. Some hospitals do not fast horses preoperatively anymore although there is no clinical evidence to support this change (Klingler 2012). In textbooks for veterinary anesthesia we still find recommendations to withhold food for 6-12 hours (Dugdale 2010). Doherty & Valverde (2012) on the other hand states that for most cases fasting is not necessary. Pre-operative fasting is supported by early studies that showed a high prevalence of colic after general anesthesia of 30 - 40% in non-fasted horses (Heath 1981; Jones *et al*. 1991). In my literature search, no other publications investigating and supporting preoperatively fasting of the horse was found. Instead, however, preoperatively fasting of the horse can be questioned following the recent publication by Bailey *et al*. (2016) which showed a low colic prevalence of 2.5% for non-fasted horses, compared to 10.5% in fasted horses, after non-abdominal surgery (Jago *et al.* 2015).

The objective of this retrospective pilot study was to evaluate the incidence of POC at SLU equine hospital after elective non-abdominal procedures, with the current fasting regime. In addition, we wished to identify any possible risk factors in the management pre- and post-surgery that may predispose horses to colic. If the patient develops POC, it not only decreases the patient's welfare, it is also a possible life-threatening condition.

2. Literature review

2.1 Recognised risk factors for colic

2.1.1 Starvation

Recently the benefit of starvation pre-surgery has been questioned following the published prevalence of POC of 2.5% (30/1200) for non-fasted horses in the first 6 days after elective non-abdominal surgery (Bailey *et al*. 2016). Earlier described prevalence of POC in the first 7 days post-surgery for fasted horses after non-abdominal surgery has ranged from 2.8% to 10.5% (Senior *et al.* 2004; Jago *et al*. 2015). This suggests that pre-operative starvation could be a risk factor. At Swedish equine hospitals, feed withdrawal is routinely performed for adult horses for 6 -12 hours pre-operatively, with exceptions and adjustments for specific procedures (Lillkull & Williamsson 2020).

To the author´s knowledge there are no studies published that fully investigate how starvation alters the equine gastrointestinal tract (GI). To elucidate this, we first need to understand the physiology of the equine gastrointestinal tract. Sympathetic and parasympathetic branches influence the GI function, but basic functions such as peristalsis, secretion and blood flow are primary regulated locally (Wong *et al*. 2011). Myenteric plexuses located between the two layers of smooth muscle cells and submucosal plexuses within the submucosal layer in the GI tract are responsible for coordinating peristaltic contractions to move the luminal contents along the tract (Wong *et al*. 2011); (Komuro 2012b). Intrinsic pacemaker cells called Interstitial Cells of Cajal (ICC) are a part of the GI tracts local neurologic regulation and are found at intrinsic pacemaker sites. These are responsible for transmitted pacemaker-evoked slow waves that force ingesta from dominant sites toward the distal intestine, resulting in aboral movement. The highest density of ICC:s is found in the ileum, caecal body and pelvic flexure, suggesting that pacemaker activity arises at these sites (Hudson *et al*. 1999). A reduction in ICC density has been found in horses with large intestinal disorders and this further indicates the importance of these cells for normal intestinal motility (Fintl *et al*. 2004). A working hypothesis regarding the possible function of these pacemaker cells is that mechanical circumferential expansion of the lumen activates the network of ICC:s and stimulates contraction of smooth muscle cells by acting as stretch receptors (Komuro 2012a).

Mitchell *et al*. (2005) demonstrated that in fasted horses after sedation, jejunal, caecal, and colonic activity is decreased significantly compared to non-fasted horses. A recent study performed by Di Filippo *et al.* (2021) investigated the effects of feed deprivation on healthy horses kept outdoors under natural conditions and the results showed that food deprivation alone reduced intestinal motility by 90%.

Decreased water intake in healthy horses is a well-known risk factor for colic (Archer & Proudman 2006; Mehdi & Mohammad 2006). Food withdrawal alone has been shown to decrease water intake by 16 - 27%. This results in changes in intestinal water, and along with decreased colon motility, may cause colonic impactions (Freeman 2021; Freeman *et al*. 2021).

The majority of post-operative colic cases remain undiagnosed (Senior *et al*. 2006; Bailey *et al.* 2016). It has been shown that in horses with colic, the composition of gut bacteria differs from healthy horses (Lara *et al*. 2022). Changes in diet, management, supplements, anesthesia, medications, obesity and exercise have also been shown to affect the equid gastrointestinal microbiota (Garber *et al*. 2020). A recent study showed an association between withholding feed for 24 hours and distinct changes in equine faecal microbiota in healthy mares (Willette *et al*. 2021).

Feed withdrawal alone has also been shown to increase the acidity of stomach contents. Besides the significant changes in gastric pH, one of totally six horses involved in a study by Husted *et al*. (2009) developed mild gastric lesions after only 12 hours of starvation. There is evidence that increased stomach acidity can cause ulcers in the gastric squamous epithelium. Gastric ulcers in turn are associated with an increased incidence of colic. If the ulcers directly cause colic or if the presence of equine glandular gastric disease may predispose horses to altered gastrointestinal motility and subsequently cause colic is unclear (Sykes *et al*. 2015).

Due to a lack of evidence, there is no clear recommendation whether to fast horses pre-operatively. Fasting the horse prior to general anesthesia may be beneficial since reduced gastrointestinal volume will improve ventilation and oxygenation in response to the reduced pressure from organs on the lungs in recumbency. In addition, there may be a lower the risk of regurgitation and/or aspiration pneumonia (Bailey *et al*. 2016). These benefits of fasting over the negative influence on gastrointestinal motility, have been discussed (Mama 2019). A recent paper on pre-operative non-fasted horses by Bailey *et al.* (2016) showed that none of the 1200 horses included in the study showed signs of regurgitation or developed post-operative aspiration pneumonia. Blood gas analysis was not performed on these horses and therefore any negative effect of non-fasting on ventilation was not detected.

2.1.2 Anesthesia

Volatile anesthetic agents may suppress intestinal motility by suppression of the migrating myoelectric complex (Durongphongtorn *et al*. 2006), with the effect persisting for up to nine hours (Lester *et al*. 1992). There have been conflicting reports on the choice of anesthetic agent and the risk of developing POC. Andersen *et al.* (2006) found that isoflurane was associated with an increased risk, compared to sevoflurane or halothane, however Senior *et al.* (2004) on the other hand did not find any relationship between choice of volatile anesthetic agents and colic risk.

Longer duration of anesthesia has been suggested as an increased risk factor for POC or ileus in horses, but it is unclear if this association is due to increased exposure to anesthetic agents or due to more protracted surgeries with greater noxious stimuli or both (Lisowski *et al*. 2018).

Positioning of the horse during surgery has been shown to be a possible risk factor for gastrointestinal dysfunction. Nelson *et al.* (2013) showed an increased risk for horses positioned in right lateral recumbency during surgery. Why this position is a risk factor or if this finding is of clinical relevance is unknown.

2.1.3 Pain

Gastrointestinal motility is regulated by the autonomic nervous system and it has been shown that pain decreases gastrointestinal motility in healthy humans and slows down mean transit time (Hasuo *et al*. 2017). Epidural anesthesia after abdominal surgery has been shown in various species to reduce the risk of ileus and promoted colonic transition time (Steinbrook 1998). It has been suggested that pain and noxious stimuli alone can alter the function of the gastrointestinal tract, thereby contributing to development of POC in horses by increased sympathetic tone and increased endogenous catecholamine concentrations (Nelson *et al*. 2013).

Quantifying pain in horses can be difficult, with numerous pain measuring scales described, that include the assessment of behavioural changes (Price *et al*. 2003). Some of the behavioural changes found to be associated with orthopaedic pain are the reluctance to move, spending less time foraging/decreased appetite, decreased exploratory behaviour, spending more time lying down, and less interrogating behaviour. Alongside the well-known physiological changes such as elevation of heart rate and respiratory rate, decreased digestive sounds/decreased gut motility has been described as an indicator of pain (Wagner 2010).

Price *et al.* (2003) studied the behaviour changes after arthroscopic surgery in horses that had been starved for 12 hours prior to anesthesia. They found that in the first six hours after surgery, horses showed signs of anesthetic hangover and showed hunger related activity following starvation such as changes in head position, restlessness and frequent foraging. These patients then became less active than control horses and showed the typical behavioural changes related to pain, described above, despite postoperative analgesia with phenylbutazone (4.4mg/kg^{-1}). This implies the negative effects of inadequate analgesia on gastrointestinal motility.

2.1.4 Peri-anesthetic drug administration

Drugs administered in the peri-anesthetic period may directly affect the motility of the gastrointestinal system or indirectly by effects on the cardiopulmonary system. Several drugs have been investigated for their potential negative effect on gastrointestinal motility. Since in this study we included only the use of morphine and lidocaine CRI, this review is limited to these two drugs.

Morphine

The negative side effects of opiate administration are well documented in the literature (Bennett & Steffey 2002). Opiates mediate their effect on opioid receptors which are found throughout both the central and the peripheral nervous system. The stimulation of CNS opioid receptors induce analgesia, but stimulation of peripheral receptors in the gastrointestinal tract alters gut motility (Lisowski *et al*. 2018). Morphine provides potent analgesia in the horse but because of reported adverse side effects, its use has remained controversial.

Roger *et al*. (1985) demonstrated that a single I.V (intravenous) administrated dose of morphine at (0.5mg/kg to 1mg/kg) inhibited the overall colonic activity, with the effect lasting from 0.5 to 3 hours. Similar effects have been seen after I.M (intramuscular) administration of morphine (0.4mg/kg and 1.0mg/kg) with reduced intestinal sounds, delayed defecation and faecal drying. The negative effect lasted for 7.5 to 18 hours after injection. The higher dose also produced abdominal discomfort (Roberts & Argenzio 1986). A more recent study investigated the adverse side effects of morphine in conscious horses without pain following either IV or IM administration. It was found that a lower dose (0.05–0.1mg/kg) given intramuscularly gave the same detectable decrease in gastrointestinal motility 1 to 2 hours after administration as a higher dose (0.1mg/kg) given intravenously. The conclusion was that clinically relevant doses of morphine only give a minimal and short-term adverse effect when administered to healthy horses with no signs of pain (Figueiredo *et al*. 2012).

In a study in conscious clinically healthy horses, the IV administration of 0.5 mg/kg morphine every 12 hours for 6 days resulted in a decrease in the number of bowel movements and borborygmus, seen 4-6 hours after administration. After the last injection, the gastrointestinal transition time was reduced for a period of 24 hours. Effects seen, such as a decrease in the weight of faeces produced and faecal drying, lasted for three days from the last injection (Boscan *et al*. 2006). Tessier *et al.* (2019) performed a similar study and investigated the effect of three doses of 0,1mg/kg IV morphine 4 hours apart. Using ultrasonographic examination, the authors found that the number of contractions of the duodenum, caecum, left and right ventral colon decreased and that the size of the stomach and water consumption increased, with a cumulative effect after repeated doses of morphine. The parameters returned to normal 16 hours after the last injection of morphine.

A dose-related negative effect of morphine on the gastrointestinal tract has been suggested (Roberts & Argenzio 1986; Boscan *et al.* 2006). In man the dose that produces constipation is generally only 25% of that required to provide adequate analgesia (Ketwaroo *et al.* 2013).

Despite several studies showing an increased risk of post-operative colic in horses with the use of morphine, such as that reported by Senior *et al.* (2004), other publications have not confirmed this association (Mircica *et al.* 2003; Andersen *et al.* 2006; Nelson *et al.* 2013). Mircica *et al.* (2003) discuss the probability that the risk of adverse side effects is lower when given to animals in pain, rather than when given to pain free animals. In addition, it may be important if the drug is administered preoperatively and that the risk of adverse side effects may depend on the surgery itself.

Lidocaine CRI

Lidocaine is widely used as a component in the multimodal approach to analgesia and is used as a prokinetic and anti-inflammatory drug in managing horses after intestinal and colic surgery (Freeman 2019). It also has the effect of decreasing the minimum alveolar concentration in a dose-dependent fashion for volatile inhalation agents. It is therefore used to reduce the cardiovascular depressant effects of inhalation agents on anesthetized horses (Freeman 2019). It has been suggested that the analgesic action of the drug is the key to its benefit on intestinal motility, by blocking the sympathetic efferent response that decreases intestinal motility after abdominal surgery (Fukuda *et al.* 2007). The use of lidocaine perioperatively for non-abdominal surgery has not been fully investigated. In addition, despite the widespread use of lidocaine as a prokinetic agent, there is controversial evidence for this effect (Milligan *et al.* 2007). It has been shown that lidocaine infusion at recommended doses can delay faecal transition time in healthy horses and have a potential for exacerbating those effects when combined with other drugs that decrease motility (Rusiecki *et al.* 2008). An in-vitro study showed that the coordinated pressure peaks in the equine colon can be reduced by slow topical application around the colic arteries (Sellers *et al.* 1979). Freeman (2019) suggested that if this response seen during topical application on colic arteries, is also induced by systemic lidocaine, lidocaine infusion could interfere and reduce normal colonic motility.

2.1.5 Exercise

It is generally accepted that exercise is beneficial for the gastrointestinal tract, with a supposed pro-motility effect and reduction in the risk for colic, despite the lack of evidence from scientific studies. Walking the horse by hand is performed with the aim of preventing and treating colic in horses and minimising the risk of post-operative ileus (Lefebvre *et al.* 2016). The perception and experience is that walking the horse can assist moving gas through the gut and that mild colic can clear after a brisk walk (Redback 2019). The few studies published have con-founding factors such as dietary changes and husbandry factors. Pagan *et al.* (1998) studied the effect of different amounts of exercise on the gastrointestinal tract and recorded feed and faecal analysis and the rate of passage. It was a small study, with only four thoroughbred geldings aged 3–8 years, but resulted in a small but significant decrease in mean retention time and that the exercised horses consumed more water.

A study in healthy horses showed that stabling reduces large intestinal motility and the pattern of motility across different regions of the intestine was altered (Williams *et al.* 2011). Horses with no pasture time or a recent decrease in acreage or pasture time were shown to have a threefold increased risk of developing colic (Hudson *et al.* 2001). Williams *et al.* (2015) showed that transition from pasture to stabling reduced colonic motility, increased water intake dramatically and that the stabled horses produced significantly drier and a lower output of faeces despite increased water intake. Whether the change in activity, the change in feed dry matter or the change in feed pattern is responsible remains unclear. Further studies need to be performed to discover why stabling results in a decreased output and drying of ingesta.

It has been discussed that walking and exercise mentally stimulates the horse and improves welfare. Sarrafchi & Blokhuis (2013) summarized several studies in their review article and showed that stabling, lack of social contact and no daily turnout is correlated with the evolvement of stereotypical behaviours and thus decreased welfare. Dr Eric Mueller stated in an interview that his perception is that the effect of walking a colic horse is mainly on the mental status and by diverting the focus from the pain in the abdomen, it may break the ongoing sympathetic nerve stimulation on the gut and hence give relief (Lamb Stew Ink 2016).

The evidence of the effect of hand walking exercise of the horse versus stall rest and its effects on gastrointestinal motility remains unclear.

2.1.6 Transportation

Transportation may trigger an innate fear in horses and activate the sympathetic system. It can be a stressful event for the horse that can lead to metabolic, electrolyte and body temperature changes (Padalino *et al.* 2016). The transportation of course also limits normal locomotion. These changes may contribute to dehydration and an interruption to normal ingestion, thereby contributing to an increased risk of colic (Weeks *et al.* 2012). The common recommendation seems to be to avoid transportation very close to surgery. Hubbell (2014) suggests that the horse should be given time to acclimate to the environment before the anesthetic event if possible. Simple colonic obstruction and distention have been found to been associated with a history of travel, with a higher risk of colic remaining 24 hours after transportation (Hillyer *et al.* 2002).

Senior *et al.* (2004) found that horses undergoing out-of-hours procedures carried an increased risk of developing post anesthetic colic, and then subsequently discussed if this was correlated with the failure to fast before surgery (Senior *et al.* 2006). However, the horses involved may have been transported close to the surgery, a confounding factor not included in the statistical analysis in that study.

On the other hand, a retrospective cohort study of 273 horses after elective arthroscopy compared the complications between patients that went home the same day as the surgery (outpatients) and for patients staying at the hospital at least one night (inpatients) (Secor *et al.* 2018). This showed that 1.5% of the inpatients developed colic whilst none of the outpatients that were transported relatively soon after surgery developed colic. Anesthesia and surgery time were significantly longer for the inpatient group and could therefore explain the difference. The recommendation for the outpatients concerning box rest and medical treatment was similar to the inpatient group. The author draws the conclusion that management factors pre- and post-surgery may be of importance with one important factor being transport after surgery.

2.1.7 Change of routines & Stress

Changes in feed and management has been identified as risk factors for colic in multiple studies (Curtis *et al.* 2019). Horses are creatures of habit and an elective surgery in a hospital involves many changes in a short time.

The review article by Nellist (2017) summarizes the studies regarding equine stress during the hospitalisation. The horse will be exposed to a variety of stressors which can accumulate and distress the horse. Isolation from familiar companions, novel experiences, painful procedures, prevention from performing innate social and foraging behaviour and restriction of forage are examples of stressors identified. The appearance of stress and distress in the horse varies, and is dependent on individual coping ability, genetics, earlier experiences, the animal's usual management and training experiences, eventually chronic stress, and the horse's ability to respond to and control these stressors. The ability to prevent stressors during veterinary intervention relate to the horsemanship of the veterinary team and the team's skill to identify stressed horses and perform low stress handling and management techniques. Stress can lead to an increased sympathetic tone and the physiological changes associated. The stressed horse can show behavioural changes and become introvert or extrovert, which can lead to changes in feed and water intake.

The hospitalization of the horse can also alter the sleeping pattern and lead to further alterations in the horse's emotional and physiological state (Greening *et al.* 2021; Oliveira *et al.* 2022).

2.1.8 Temperature, Weather and Season

There are few studies that have investigated the effect of temperature, weather, or season on the incidence of colic. In the UK, a seasonal increase in the incidence of colic has been seen during the spring and autumn (Hillyer *et al.* 2002). High mean temperatures have been found to be associated with the arrival of colic horses to an equine hospital in Austria, with mean temperature exceeding 11.92±7.72°C on the day colic horses arrived at the hospital, whereas on days with lower temperatures, no colic horses arrived. They also found that the risk of colic is higher during the summer period (Kaya *et al.* 2009). A Swedish study, using data from the Agria insurance company, found an increase in the proportion of colic cases in the horse population during the winter months (October-March) (Egenvall *et al.* 2008). The seasonality of specific types of colic occurring at a UK referral hospital over a ten year period have been explored and found that the number of large colon impaction cases increased in the autumn and winter months, with a peak in December/January (Archer *et al.* 2006).

It has been suggested that the seasonal changes in colic in the Swedish horse population, is related to a differences in the exercise or feeding regimen (Egenvall *et al.* 2008). Interestingly, a study on total water intake in Shetlands ponies held in paddocks over a 14 month period showed that the water supply and intake is more critical at temperatures below 0°C than in hot summer months because water content of grass is high (Brinkmann *et al.* 2013).

2.1.9 Topical atropine treatment

Atropine is a part of the treatment protocol for equine uveitis for its mydriatic effect. Topical administration has been associated with decreased gastrointestinal motility and colic in horses (Ekstrand *et al.* 2022). For equids treated at a hospital for ocular disease; age, hospitalization time and the topical use of atropine were significantly associated with colic (Patipa *et al.* 2012).

2.1.10 Post-operative feeding

The literature and evidence in this subject is very sparse, and post-operative feeding has not been included or even described in many of studies published on the incidence of post-anesthetic colic after non-abdominal surgery (Nelson *et al.* 2013; Jago *et al.* 2015; Bailey *et al.* 2016). Senior *et al.* (2004) state that the horses included in the study were not fed until gut sounds could be auscultated but did not include this in the analysis, report the time to this event, or describe how the horses were fed post-operatively. Senior *et al.* (2006) included the type of feed for the first meal post-surgery and in their initial statistical analysis found an association with colic, but due to missing data, were not able to include this in the final multivariable analysis.

Post-operative feeding following abdominal surgery has received some attention with regard to the prevention of post-operative ileus (POI), a well-recognized complication. The common feeding regimen following abdominal surgery seems to be early post-operative feeding, starting with trophic feeding (trickle feeding small amounts initially), then grass and soft feeds (bran mash or soaked fibre cubes), followed by the careful introduction of small amounts of good quality roughage at regular intervals (Lisowski *et al.* 2018). The positive effects of sham feeding (gum feeding) on gastrointestinal motility in humans has opened the field of sham feeding in horses and different sham feeding methods have been used. For example, hanging a filled hay net outside the stable within view and bit chewing for 20 minutes has been suggested to stimulate GI motility and be beneficial to perform before and alongside restrictive refeeding (Giusto *et al.* 2014; Lisowski *et al.* 2018).

Decreased water intake has been found to result in changes in intestinal water and along with decreased colon motility, may cause colonic impactions (Freeman 2021; Freeman *et al.* 2021). It has been suggested that one potential method to reduce the incidence of colonic impactions in hospitalized horses is to increase the voluntary water intake. Weak evidence exists that providing a horse with sweet feed-flavoured water or unflavoured electrolyte solutions increases the voluntary water intake (Van Diest *et al.* 2021).

The question remains if post-operative feeding and how it is performed is a potential risk factor for postoperative colic after non-abdominal surgery.

3. Materials & Methods

3.1 Retrospective study

All elective non-abdominal procedures between 1st of October 2021 and 1st of October 2022 were reviewed. Inclusion criteria were as follows: adult horses greater than one year of age, monitored in the hospital for a minimum of 24h following anesthesia, starved before surgery according to the pre-surgery feeding regimen at SLU, and no history of colic within 6 months before the planned surgery or history of general anesthesia 4 weeks before planned surgery. Data was collected using the medical journals. Patients with missing data were excluded from the study.

In addition, to compare with the incidence of colic after general anesthesia, a descriptive study was performed on horses that had standing surgical procedures under CRI (constant rate infusion) sedation.

A few patients underwent more than one anesthetic event during their stay. Another small descriptive study was performed to see if the incidence of post-operative colic was higher if two anesthetic procedures were performed in close succession.

3.2 Literature search

Search for relevant articles were made with the databases PubMed, Web of Science, Google Scholar, Primo and Scopus. Further articles were found using the reference lists.

Search words were used in different combinations: colic, horse, equine, non-abdominal surgery, starvation, physiology of gastrointestinal tract, prevalence, post-operative, complication, lidocaine infusion, feed, recovery, morphine, adverse effects, stereotypic behaviour, intestinal motility, elective, prevalence, exercise, effect, metabolic response, management, risk factors, activity, starvation, pain, POI, water etc.

3.2.1 Inclusion criteria

Main study population:

- Elective non-abdominal procedure performed under general anesthesia at SLU between 1st October 2021 and 1st October 2022
- Adult horses >1 year of age
- Monitored in the hospital for a minimum of 24h following anesthesia
- Fasted before surgery according to pre-surgery feeding regimen at SLU
- Did not undergo surgery/anesthesia during the same stay at the equine hospital before the planned procedure or within 4 weeks before performed surgery
- Not treated by SLU (Hospital or Ambulatory Veterinary practice) or had a known medical history of colic in the 6 months prior to the performed surgery

Multiple procedures

- Patients that had more than one procedure under general anesthesia during their stay at the equine hospital or underwent general anesthesia followed by CRI- sedation
- Elective non-abdominal procedure performed at SLU between 1st October 2021 and 1st October 2022
- Adult horses >1 year of age
- Monitored in the hospital for a minimum of 24h following anesthesia
- Not fasted before surgery according to pre-surgery feeding regimen at SLU
- Not treated by SLU (Hospital or Ambulatory Veterinary practice) or had a known medical history of colic in the 6 months prior to the performed surgery

Standing procedures

- Underwent a standing CRI-anesthesia and non-abdominal procedure performed SLU between 1st October 2021 and 1st October 2022
- Adult horses >1 year of age
- Monitored in the hospital for a minimum of 24h following anesthesia; or came back to the hospital within 72hours because of colic; or reported in the common journal system by SLU ambulatory veterinary practice treated for colic within 72 hours post anesthesia
- Not fasted before surgery according to pre-surgery feeding regimen at SLU

- Not treated by SLU (Hospital or Ambulatory Veterinary practice) or had a known medical history of colic in the 6 months prior to the performed surgery

Horses were excluded if information needed for study was not possible to obtain from the medical journals.

3.2.2 Case definitions

Horses were included in the study if they developed symptoms of colic during their stay at UDS such as: inappetence, gross pain behaviour such as curling of top lip, adopting straining to urinate stance, scraping with forelegs, showing an intent to roll, rolling or throwing itself in an uncontrolled manner and/or a diagnosis of a condition causing abdominal pain by rectal examination, abdominal ultrasound, or gastroscopy. Horses were not categorized as a case if they did not get a rectal examination or treatment for abdominal pain.

3.2.3 Categorizing of colic:

Mild: inappetence, dullness, curling of top lip, adopting straining to urinate stance and/or lying quietly, teeth grinding and/or responds to metamizole treatment.

Moderate: symptoms of mild colic in combination with any of following; scraping with front legs, intent to roll, rolling or throwing itself in an uncontrolled manner and/or diagnosis of abdominal pain confirmed by rectal examination, abdominal ultrasound, or gastroscopy. Responding to pain relief.

Severe: Persistence or recurrence of colic signs despite analgesia.

3.3 Routines and protocols at SLU

Information regarding the routines and protocols were collected from the SLU common database, from medical journals and from interviews with nurses, veterinarians and surgeons working at the equine teaching hospital.

3.3.1 Anesthetic and analgesic protocols at SLU

Anesthetic protocol can vary according to the preference of the personnel handling the case, but the standard protocols are given below:

General anesthesia

Pre-medication with acepromazine 0.03mg/kg intramuscularly, 30 min before induction. Induction with romifidine 0.1mg/kg, midazolam 3mg/100kg IV and ketamine 220mg/100kg intravenously. Selectively, premedication with morphine:

10mg/100kg IV. Maintenance with isoflurane inhalation anesthesia. Before recovery, xylazine 10mg/100kg IV and intranasal phenylephrine administration. Selectively, morphine 10mg/100kg IM.

Standing procedure CRI

Premedication with acepromazine 0.03mg/kg intramuscularly, 30 min before the procedure. Maintenance with romifidine 0.03mg/kg IV bolus dose then CRI 0.05mg/kg/h. If needed, iterating bolus with 0.01mg/kg romifidine. Analgesia with a butorphanol bolus dose 0.02mg/kg IV then CRI 0.04mg/kg/h. Alternatively, analgesia with a morphine bolus dose 0.05mg/kg IV then CRI 0.03mg/kg/h.

Additional medication

If directed by the surgeon, Benzylpenicillin 12mg/kg intravenously maximum 30 minutes before the procedure or Procaine-penicillin 20mg/kg intramuscularly 60 minutes before the procedure. For fracture repair, arthrodesis, septic arthritis, bursitis or similar procedures where infection was suspected or insertion of an implant performed, the horse was also administrated gentamicin 6.6mg/kg intravenously 30 minutes before the procedure. Flunixin-meglumine 1.1mg/kg was given intravenously 30 minutes before the procedure to all horses.

Computed Tomography (CT)

Premedication with acepromazine 0.03mg/kg intramuscularly, 30 minutes before induction. Induction with romifidine 0.1mg/kg midazolam 3mg/100kg IV and ketamine 220mg/100kg IV. Maintenance with Triple-Dip: 250ml myolerax, 500ml Ringer Acetate, 10ml Ketaminol (ketamine 100mg/ml), 25ml Rompun (xylazine 20mg/ml) or 1ml Domosedan (detomodine 10mg/ml).

3.3.2 Current feeding regime at SLU

Horses booked for elective procedures normally arrive the day before surgery between 7pm and 10pm. If arriving the same day, they arrive before 10am and the owners are told to withhold breakfast. All owners receive information that the horse should have been groomed and cleaned before arrival and tetanus vaccination must have been performed within the last two years. If the tetanus vaccination is not up to date, the horse is vaccinated before surgery. The owner is told to check the body temperature of the horse at home and to cancel the surgery if any fever or symptoms of nasal discharge or cough. The owner also receives a form to fill in regarding the diet of the horse; what it is fed at home and what is allowed to be fed during its stay. As far as possible, the horse is fed the same diet as it is used to, using the same make of concentrate and same type of roughage. The type of roughage offered at SLU is small baled hay and hay silage. Hospitalisation involves a change in the roughage fed, unless owners bring their own feed.

The day before elective surgery under general anesthesia, the horse is fed an evening meal at 10pm according to their normal diet. All stables are cleaned between 6am and 8am in the morning and all excessive food taken out. On the surgery day, the first horse in the schedule does not get breakfast and horses with surgery planned in the afternoon get breakfast at 8am including 1-2 kilos of roughage and a watery slobber mash. The horses are therefore starved between 2-8 hours before surgery.

After surgery, when the horse is awake and back in their stable, the horse is fed a small amount of watery slobber mash to encourage water intake. Then it is fed a small amount of hay. The evening meal at 10pm is of normal quantity. During the night and the following day, the horse is repeatedly offered slobber mash. If they had a long anesthesia, this mash is served very watery with the consistence of soup. For short anesthetics, the mash has less water in it and the consistence is more of porridge.

Horses coming for elective standing surgeries are not starved pre-operatively and are fed post-operatively as for horses that underwent general anesthesia.

During the stay, the horses are fed at SLU 4 times a day: 8am roughage and concentrate, 12pm concentrate, 2.30pm roughage and concentrate and 10pm roughage and concentrate. If there are no complications post-surgery or signs of gastro-intestinal problems, the horses are fed roughage ad-lib. Slobbery mash is offered every now and then throughout the day when the nurses check the horses. Water is given ad-lib throughout the stay in water buckets.

Water and feed intake are monitored during the day by the nurses. The nurses working the night shift state in the journal at 7am if the horse has had a normal appetite and water intake during the previous 24 hours.

3.3.3 Exercise routines at SLU

If the horse is allowed to walk post-surgery, the veterinarian prescribes hand walked exercise 3-8 times/day and chooses the duration. The time of the hand walked exercise is divided into the following categories: Micro: 1-2 minutes, Mini: 2-4 minutes, Motion: 10 minutes. Most horses are walked indoors in the large corridor just outside the stables but if weather allows and the horse is safe to handle, the exercise is performed outdoors.

3.4 Data analysis

Data was collected and entered in an excel spreadsheet. Patient information: age, breed, and sex. Information about season: Winter (December-February); Spring (March-May); Summer (June-August); Autumn (September-November). Information about procedure: surgeon, duration of anesthesia from induction to recovery start. Medical treatment during stay: administration and route of morphine during stay and during surgery, administration of CRI lidocaine during surgery, treatment with topical atropine during the stay. Post-anesthetic management: feed post anesthesia, if exercised/walked by hand after surgery. Colic symptoms: whether the horse was developing signs of colic and how long after the anesthesia the signs were first observed, duration of signs of colic/until impaction diagnosed as resolved, and the outcome. Type of surgery was categorized from a model building on the European College of Veterinary Surgeons (ECVS) large animal surgery category list. We altered the list to suit our data and added two categories; non-surgical procedures and two surgical procedures performed during same anesthesia event.

Colic was recorded as a binary (occurrence/non-occurrence) variable for the main statistical analysis. The dependent variable for all analyses was the incidence of colic within 3 days (72 hours) of anesthesia. Following the descriptive analysis, Chi-square tests for association were conducted as first choice and if not possible following too low number within categories Fischer´s exact tests were conducted to access possible associations with post- operative colic. The result from this was used to choose which independent variables of interest to include for further analysis. To be able to perform this, if there was a very low frequency of observations, the categories were grouped. For example, type of surgery was grouped into orthopaedic and non-orthopaedic surgery.

Excel power pivot tools were used for descriptive illustrations and Minitab software was used for computed statistical analysis. For all statistic interpretation a significance alfa level of 0.05 was the choice.

Independent variables, either with a significant association based on statistical analysis or already proven in literature to be related to colic, were then incorporated into a binary logistic regression model. Initial models resulted in non-functional models due to quasi-complete separation of data. This problem was solved by a combination of forwards and backwards stepwise variable selection to identify the troubling variables and then conducting alternations in variable categories or reducing the n-value to get find a functional model. Adjusted deviance R^2, Akaike information criterion (AIC) and Area under the ROC curve value compared between models before choosing a final model. In the final model predictors resulting in a less fitting model was excluded after consideration.

Following the result that systemically administrated morphine during surgery possibly increases the risk for post-operative colic, additional logistic regression analyses were performed with the aim to minimize possible confounding bias. In the second logistic regression analysis with colic 72 hours post anesthesia as a response variable, previously excluded variables were included. To further investigate possible associations between predictors and colic as an event, we, by decreasing the total number of individuals included, excluded observations of low numbers or grouped categories together. A third, logistic regression analysis with a lower number of included individuals was performed, to be able to include post-operative diet in the analysis. Additionally, another binary logistic regression analysis with systemic morphine administration as a dependent variable was performed. The aim was to find possible patterns in the choice of intraoperative administration of morphine to find possible confounders.

For the smaller comparative studies, descriptive statistic was briefly recorded and incidence of post-operative colic within 3 days (72 hours) calculated.

3.5 Reflections

The challenge with this kind of study is the huge risk for confounding bias, due to the multifactorial cause of colic. So many factors can influence gastrointestinal motility and without a standardized study, it is difficult to draw any definitive conclusions. The findings from this study can only suggest possible risk factors of interest to investigate further.

Colic is subjective in its presentation, and there was no standardised method of recording colic signs in the medical journals. In addition, a nervous, unsecure or introvert horse could be mistaken for having mild colic symptoms.

No standardised amount of feed is given following surgery, and so this can lead to a false assumption of the horse’s appetite. The amount of hand walking the horse received post-operatively was also variable.

With the current protocol at SLU, feed withdrawal prior to surgery can vary from 2 hours up to 8 hours. The relevance of this is not possible to determine since the precise time of starvation for each patient was not recorded and therefore could not be included in the statistical analysis.

Repeated sedation following surgery may alter and reduce GI motility and function and could be another risk factor to colic. This could act as a confounding factor in our results.

4. Results

4.1 Study population; descriptive statistic

A total of 297 horses were included. The age ranged from 1 to 26 years with a median of 6 years (Figure 1).

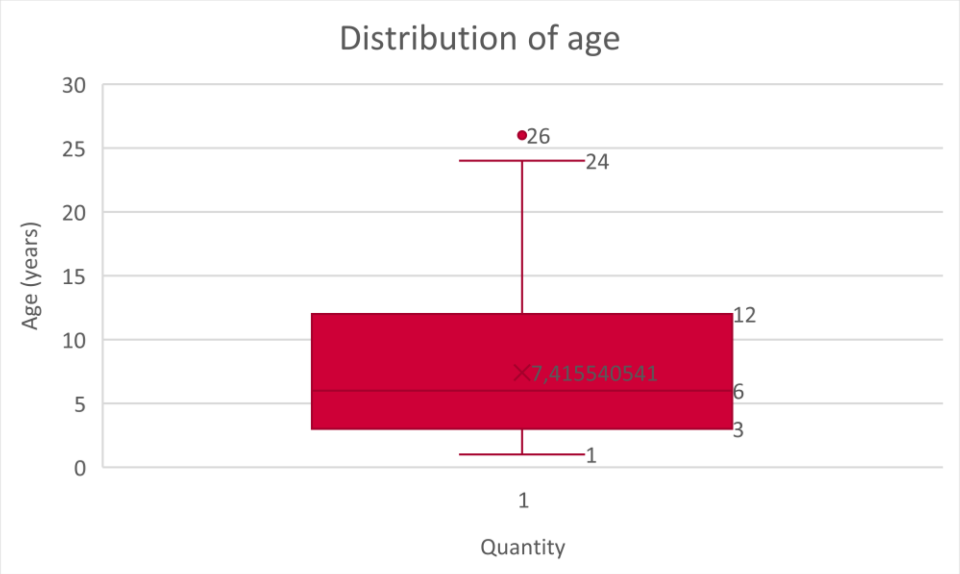


Figure 1. Boxplot illustrating the distribution of age. Lower limit= 1 years age, Lower quartile= 3 years age (25% under 3 years age,) median age= 6 years, upper quartile = 12 years (75% under 12 years age), upper limit = 24 years with the oldest horse included at 26 years (shown like dot following deviation from data). Mean age = 7.4 years of age.

The majority (43.4%) were SWB (Swedish warmblood), 14.1% were warmblood trotters and the third most common breed was Icelandics (8.1%). There was a large distribution of breeds with 40 different breeds represented. 47.4% were mares, 35.1% were geldings, and 16.8% were stallions. Unknown sex was recorded in 2 horses, due to missing data in the records.

The distribution of cases with regards to season was fairly even, with most procedures performed in the autumn and least procedures performed during the summer (Figure 2).

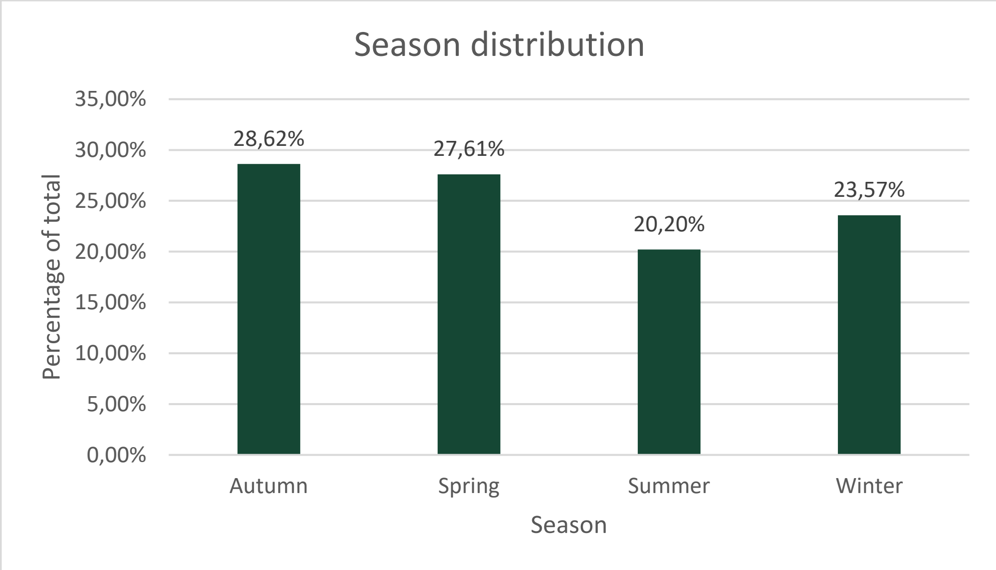


Figure 2. Season distribution.

Procedures were categorized by the ECVS (European College of Veterinary Surgeons) large animal surgery category list. We added two new categories to this list; "non surgery" for patients who underwent general anesthesia during CT (computed tomography) but no surgery was performed and "two different procedures" for patients where two procedures were performed during the same anesthetic event (Table 1).

Table 1. European College of Veterinary Surgeons, Large animal procedure list with added Non surgery category and two procedures category.

Category	**Abbreviation**
Abdominal	AB
Arthroscopy & Tenoscopy	AR
Dental	DE
Fracture Fixation	FF
Laparoscopy & Thoracoscopy	LP
Ophthalmic	OP
Tendon	TEN
Upper Respiratory	UR
Urogenital Surgery	UG
Wounds & Reconstructions	WR
Other (including foot surgery)	OO
Two different procedures	X2
Non-Surgery	NS

The most common procedure performed was arthroscopy and tenoscopy (31.9%), the second most common procedure was wound repair (17.2%), closely followed by urogenital surgery at 13.5% (Figure 3). In figure 3, the raw distribution of procedures is shown and in figure 4 the distribution of the procedures after further categorization.

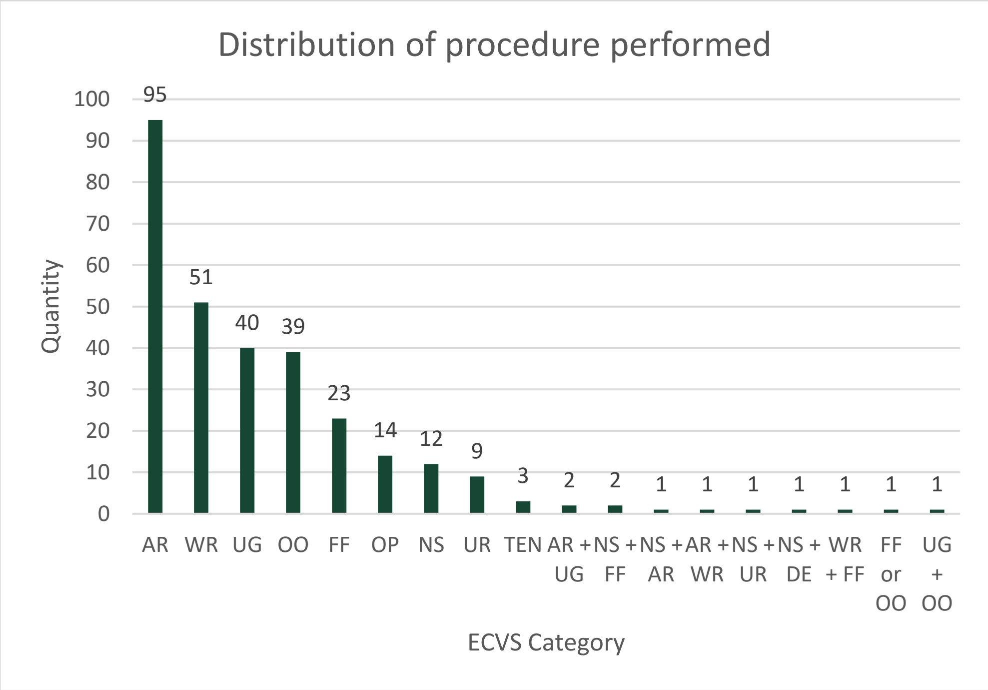


Figure 3. Raw distribution of procedure performed, for abbreviations se list in Table 1.

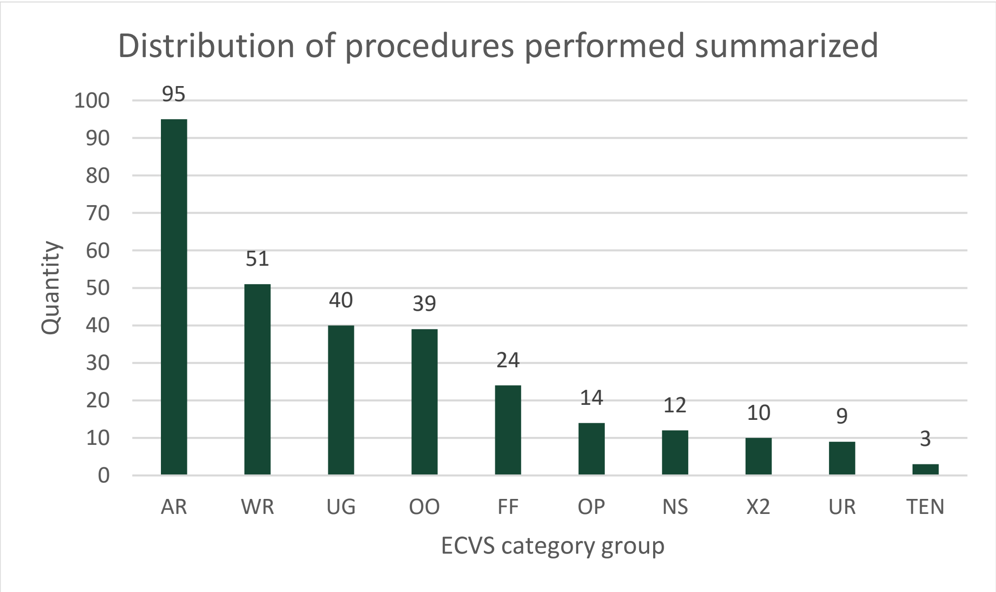
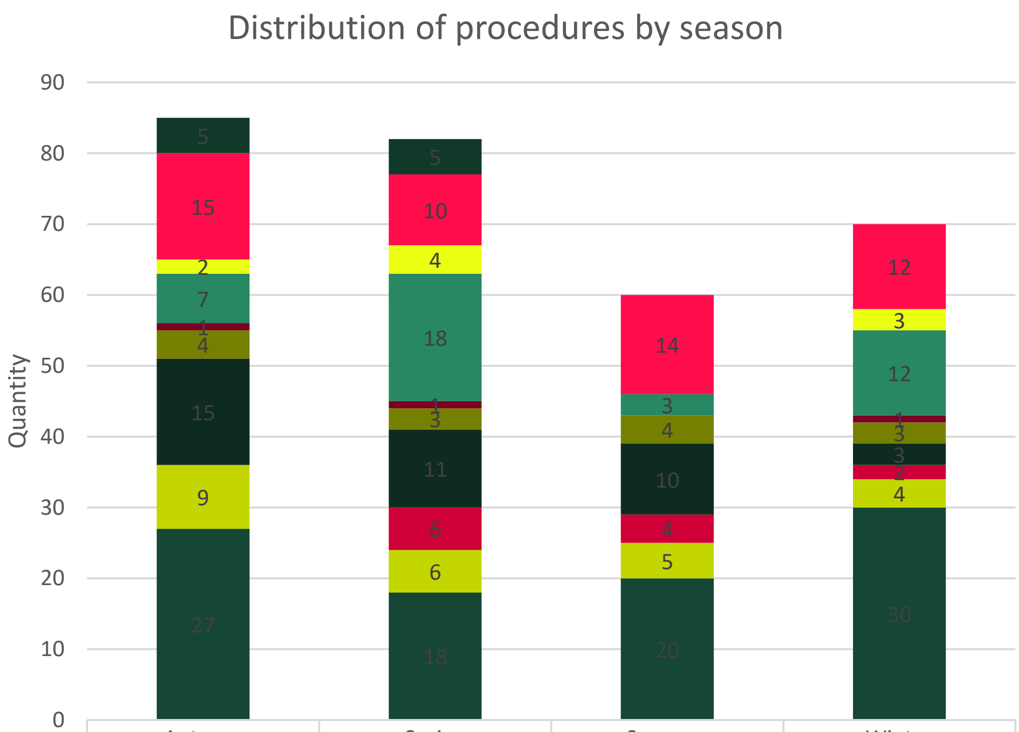


Figure 4. Distribution of procedures performed summarized, for abbreviations se list in Table 1.

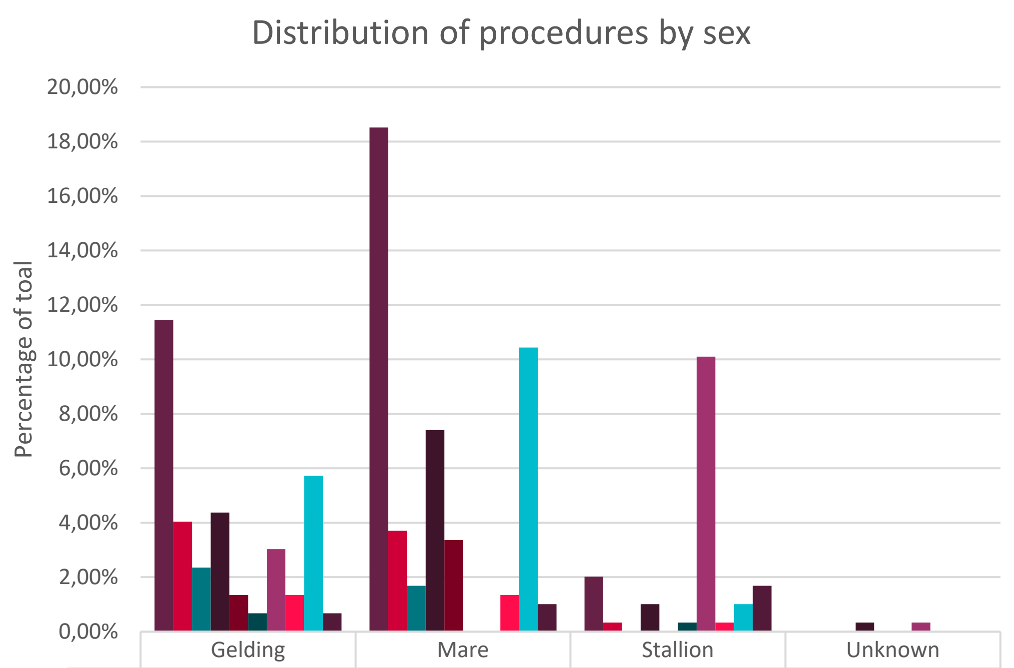
The distribution of procedures performed by season was quite even, with some differences such as more urogenital procedures performed during the spring (Figure 5).



	Autumn	Spring	Summer	Winter
X2	5	5		
WR	15	10	14	12
UR	2	4		3
UG	7	18	3	12
TEN	1	1		1
OP	4	3	4	3
OO	15	11	10	3
NS		6	4	2
FF	9	6	5	4
AR	27	18	20	30

Figure 5. Distribution of procedures by season. For abbreviations se list in Table 1.

There were larger differences when it came to the distribution of procedures by sex, with mares responsible for more of the arthroscopic procedures and wound repairs. In stallions, more urogenital procedures were performed, such as normal castrations (Figure 6).



	Gelding	Mare	Stallion	Unknown
AR	11,45%	18,52%	2,02%	0,00%
FF	4,04%	3,70%	0,34%	0,00%
NS	2,36%	1,68%	0,00%	0,00%
OO	4,38%	7,41%	1,01%	0,34%
OP	1,35%	3,37%	0,00%	0,00%
TEN	0,67%	0,00%	0,34%	0,00%
UG	3,03%	0,00%	10,10%	0,34%
UR	1,35%	1,35%	0,34%	0,00%
WR	5,72%	10,44%	1,01%	0,00%
X2	0,67%	1,01%	1,68%	0,00%

Figure 6. Distribution of procedures by sex. For abbreviations, se list in Table 1.

4.2 Management and medications; descriptive statistics

The majority (71.7%) of the horses were administrated morphine systemically at least once during their stay at the clinic. 53.2% of all horses were administrated morphine systemically pre-operatively at induction (Figure 8). Only 7.1 % received systemic morphine during surgery and 14.8% were administrated systemic morphine in recovery (Figure 9, 10 & 12). During surgery 32.0% of the patients received lidocaine as a constant rate infusion (Figure 11). Only five horses (1.7%) had been treated with morphine in the days before the surgery and 12 horses (4%) were administrated morphine in the days post-surgery (Figure 7 & 13).

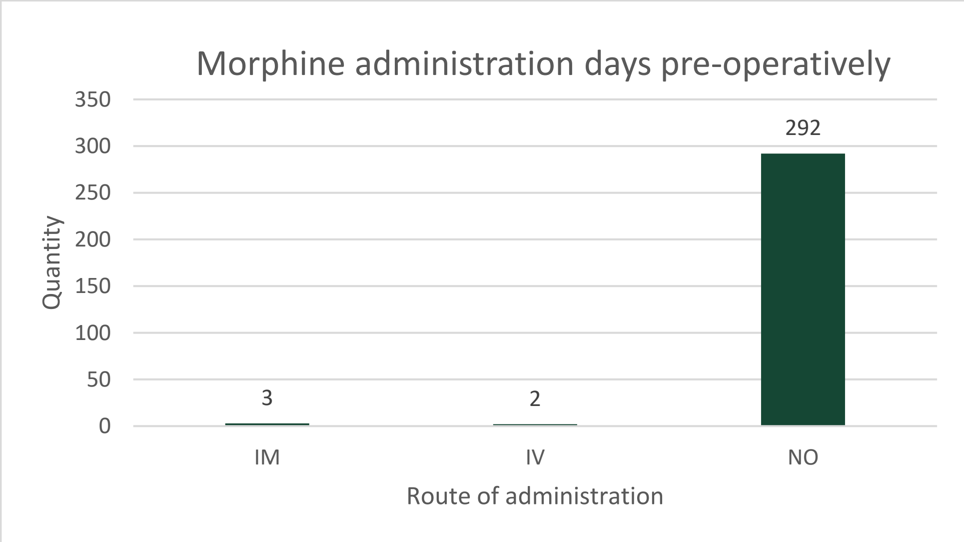


Figure 7. Morphine administrated days before operation day. IM = intramuscularly, IV = intravenous bolus dose, NO = not administrated morphine.

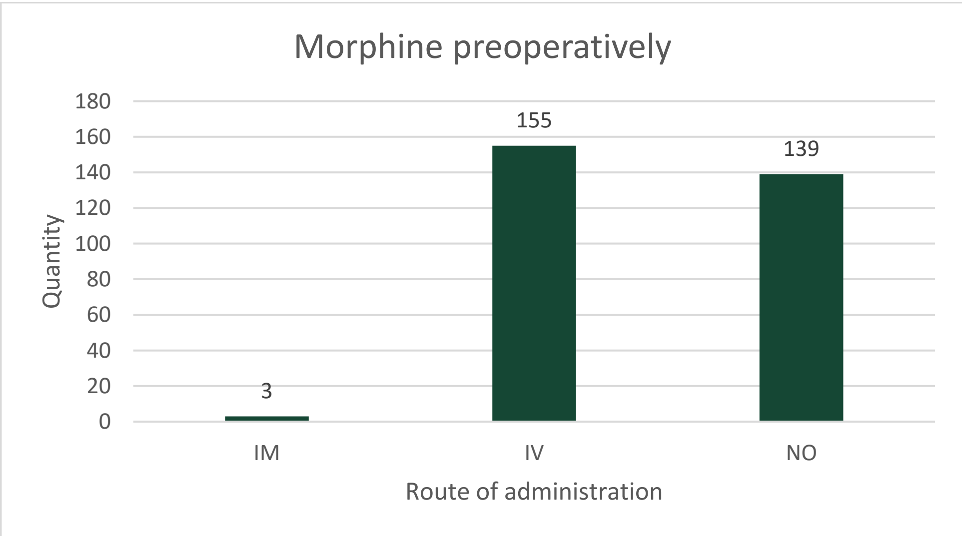


Figure 8. Number of horses administrated morphine preoperatively alongside induction. IM = intramuscularly, IV = intravenous bolus dose, NO = not administrated morphine.

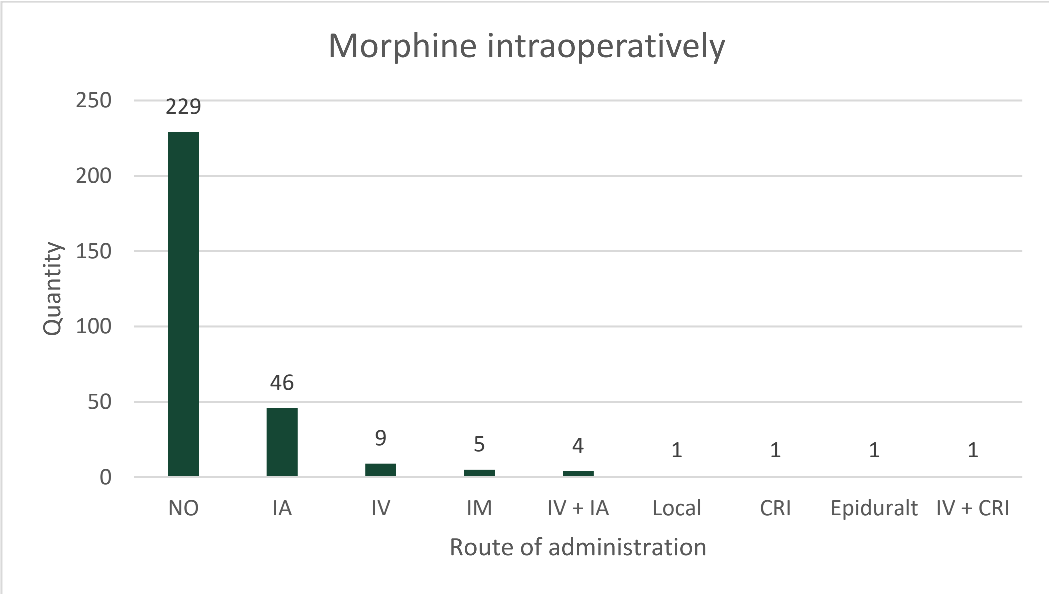


Figure 9. Number of horses administrated morphine intraoperatively. NO= not administrated morphine, IA= administrated intraarticularly, IV= intravenous, IV + IA = intravenous + intraarticularly, Local = given locally other than intraarticularly, CRI = constant rate infusion with morphine, Epidural = administrated buy epidural, IV + CRI = bolus dose given intravenous and by constant rate infusion.

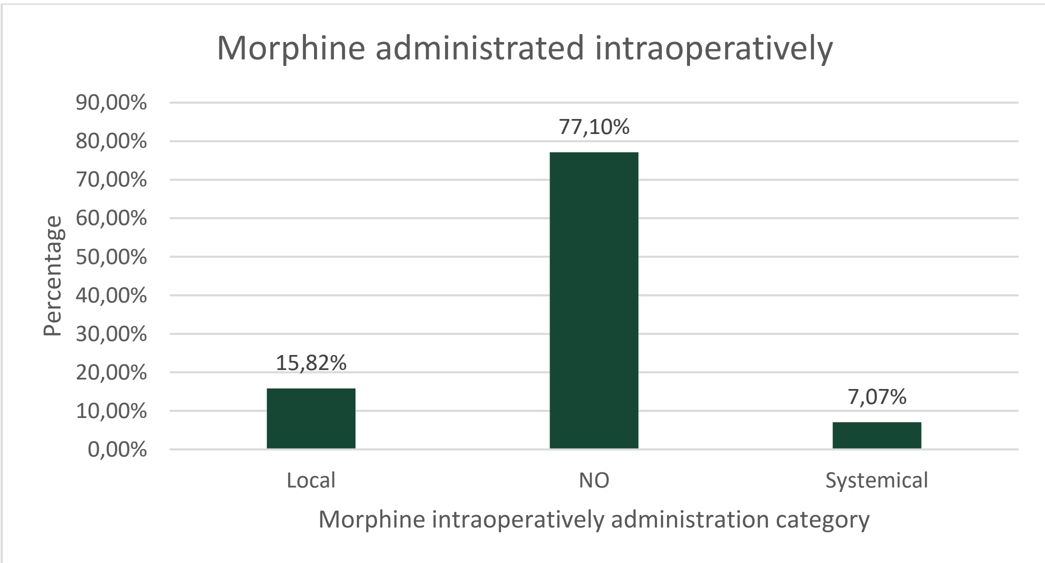


Figure 10. Morphine administration intraoperatively by categories used for statistical analysis. Local = administrated morphine locally, NO = not administrated morphine, YES = administrated morphine intravenous or intramuscularly.

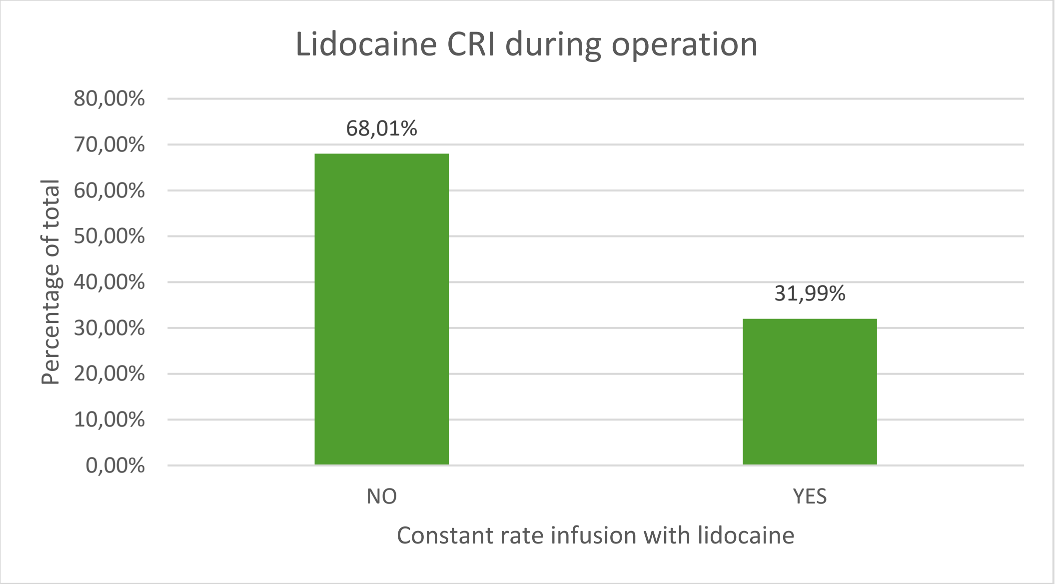


Figure 11. Number of horses treated with lidocaine constant rate infusion during surgery. NO = not received lidocaine infusion during surgery, YES =treated with constant rate infusion with lidocaine during surgery.

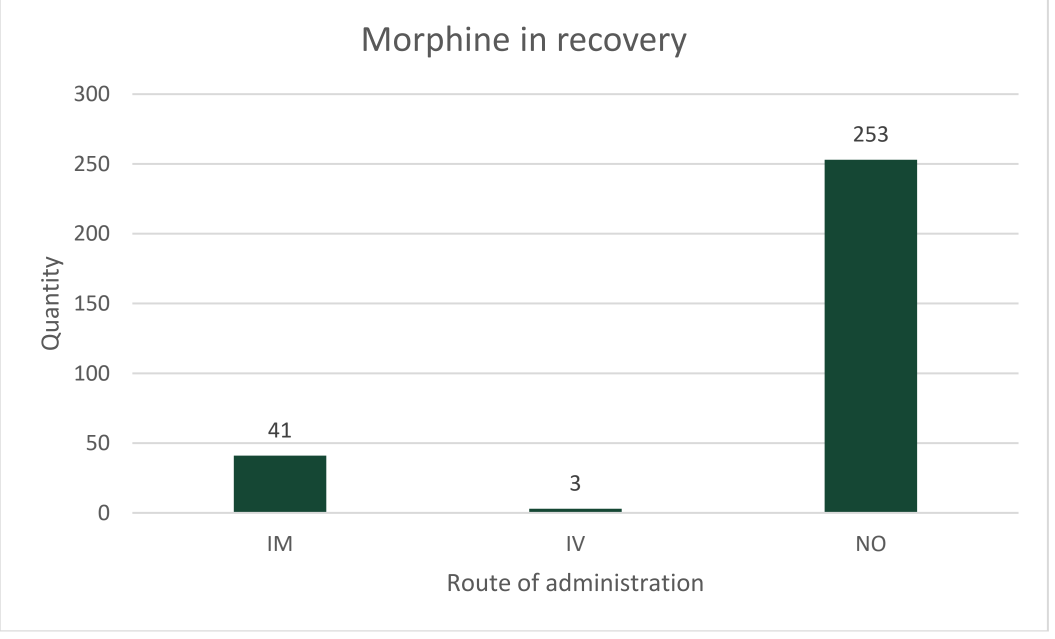


Figure 12. Number of horses administrated morphine in recovery. IM = intramuscularly, IV = intravenous, NO = no morphine administrated.

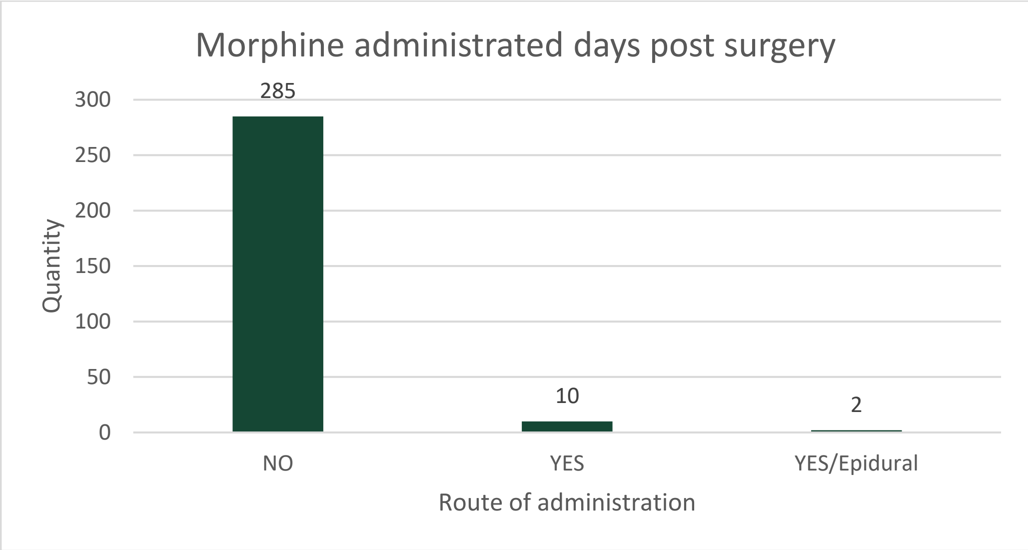
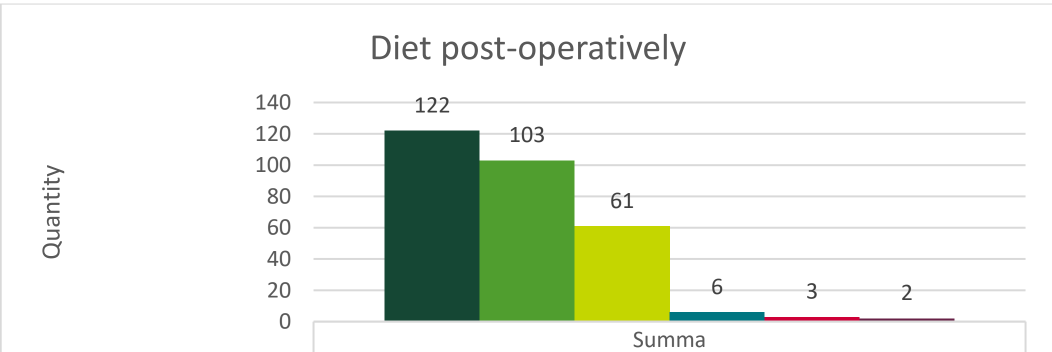


Figure 13. Number of horses administrated Morphine days post-surgery. NO = no morphine administrated, YES = administrated morphine systemically, YES/epidural = morphine administrated by epidural.

4.3 Management post-operatively; descriptive statistics

Diet post-operatively is summarized in figure 14 & 15. For 34.7% of the patients, the journal could not tell the exact diet of the horse post-operatively. Three patients were intubated with water prophylactically post-anesthesia. The term “wet food” included bran mash, pelleted lucerne and/or concentrates mixed with water to a porridge consistency.



	Summa
Ad lib + wet food	122
Unknown	103
Ad lib + Mash Soup	61
Restrictive + wet food	6
NGI + restrictive + mash	3
Only roughage	2

Figure 14. Diet post-operatively in true numbers. NGI = nasogastric intubation, Wet food = bran mash/lucerne pellets/ concentrate mixed with water to porridge consistence, Restrictive = fed small amounts of roughage.

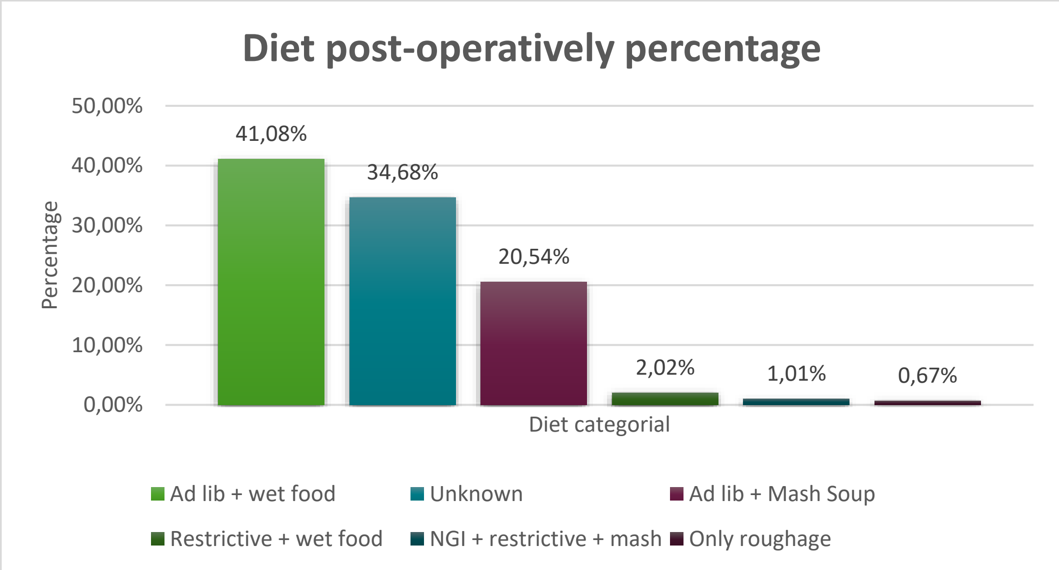


Figure 15. Diet post-operative in percentage. NGI = nasogastric intubation, Wet food = bran mash/lucerne pellets/concentrate mixed with water to porridge consistence, Restrictive = fed small amounts of roughage.

Most of the patients were not hand walked during their stay at the hospital. 178 patients were not exercised, one patient stood in a sling, and 30 patients were on a line in their box. 81 patients received normal hand-walking exercise according to the category 'Normal' as described earlier, 6 patients received 'Mini' exercise and 1 patient received 'Micro' exercise (Figure 16). For the statistical analysis, data was summarized further into three categories shown in Figure 17.

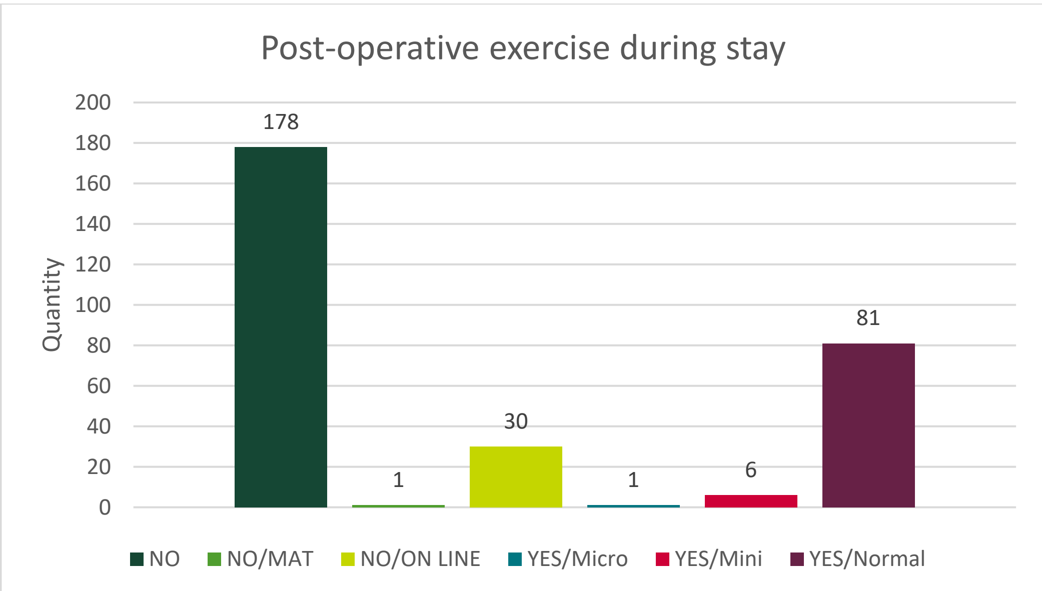


Figure 16. Exercise post-operative in absolute frequencies. Exercise is performed 3-8 times a day. NO = no exercise performed. NO/MAT = not exercised and standing in sling. NO/ON LINE= not exercised and standing on line in their box. Micro = 1-2 minutes, Mini = 2-4 minutes, Motion = 10 minutes.

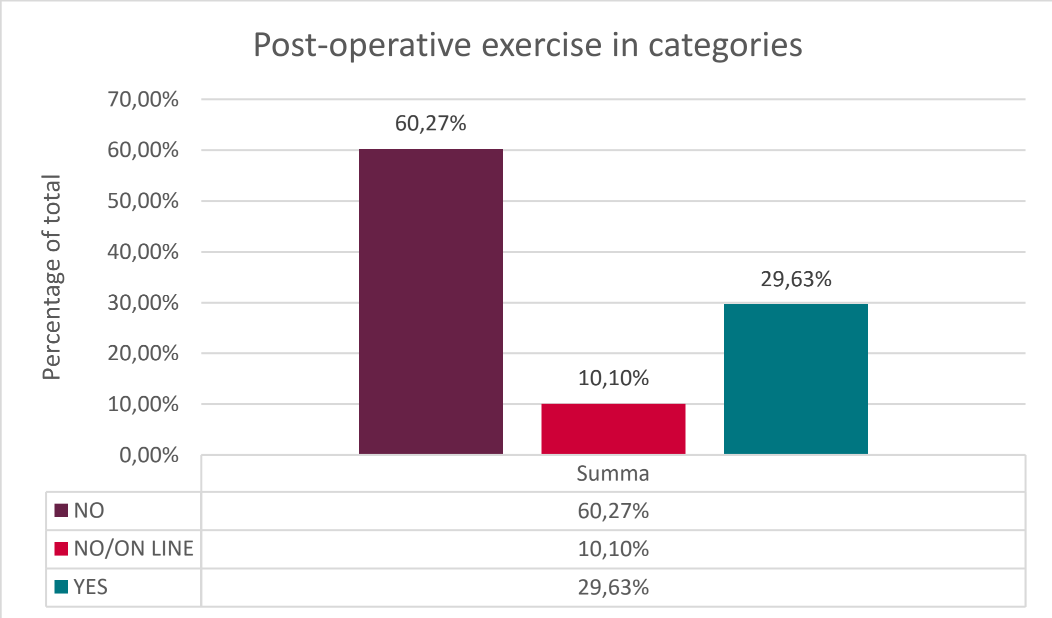


Figure 17. Exercise post-operative categorial. NO= not exercised, NO/ON LINE= not exercised and standing on line in their box. YES: exercised by hand walking.

4.4 Post-operative colic

The incidence of post-operative colic within 3 days post-anesthesia was 13.5% (40/297) (Figure 18). The incidence of colic within 7 days post-anesthesia was 14.5% (43/297). The distribution of colic severity within 3 days post-operatively is shown in Figure 19. Within the fraction of patients that experienced postoperative colic; the majority (75.0% or 30/40) experienced moderate colic, 22.5% (9/40) experienced mild colic and 2.5% (1/40) experienced severe colic. If only moderate and severe colic were included, the incidence of post-operative colic was 10.4% (31/297). The most common diagnosis was impaction, 57.5% (23/40), for a large fraction of the colic cases no diagnosis was confirmed, 40.0% (16/40), and one patient was diagnosed with gastric ulcerations, 2.5% (1/40). Gastroscopic examination only performed on two colic cases, 5% (2/40), and the true number of horses with gastric ulcerations was unknown. One patient that experienced severe colic was diagnosed with impaction of large colon/caecum in combination with gas colic. Description of the site of impaction was not described in a standard way in journals. Specified sites included the caecum, large and small colon, and pelvic flexure. Time from anesthesia to the first symptom of colic is shown in Figure 20. None of the patients needed surgical treatment due to colic and none of the patients were euthanized due to colic.

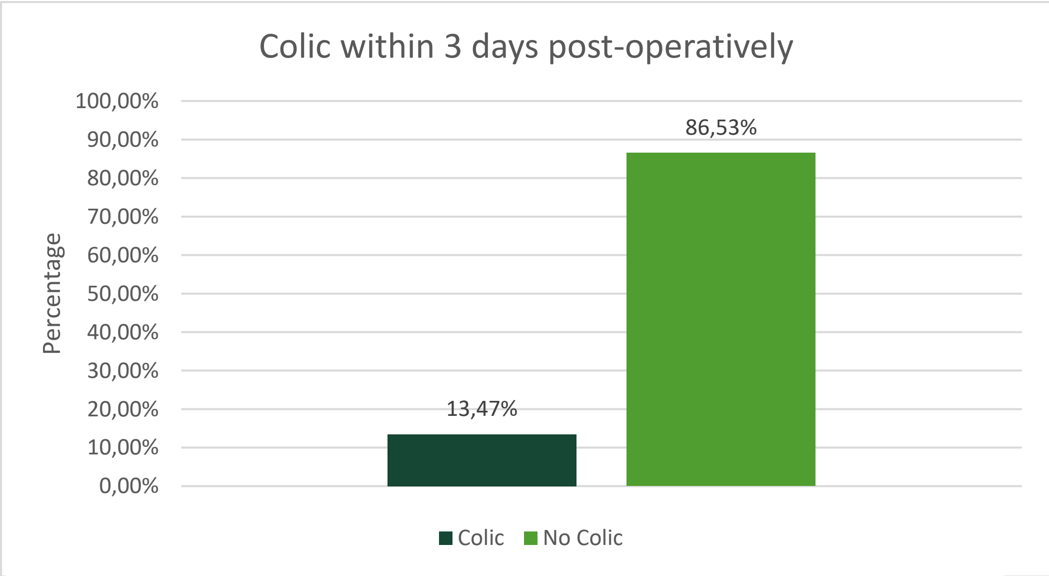


Figure 18. Postoperative colic. Colic = showed symptoms of colic within 72 hours post anesthesia. No Colic = not shown symptoms of colic within 72 hours post anesthesia.

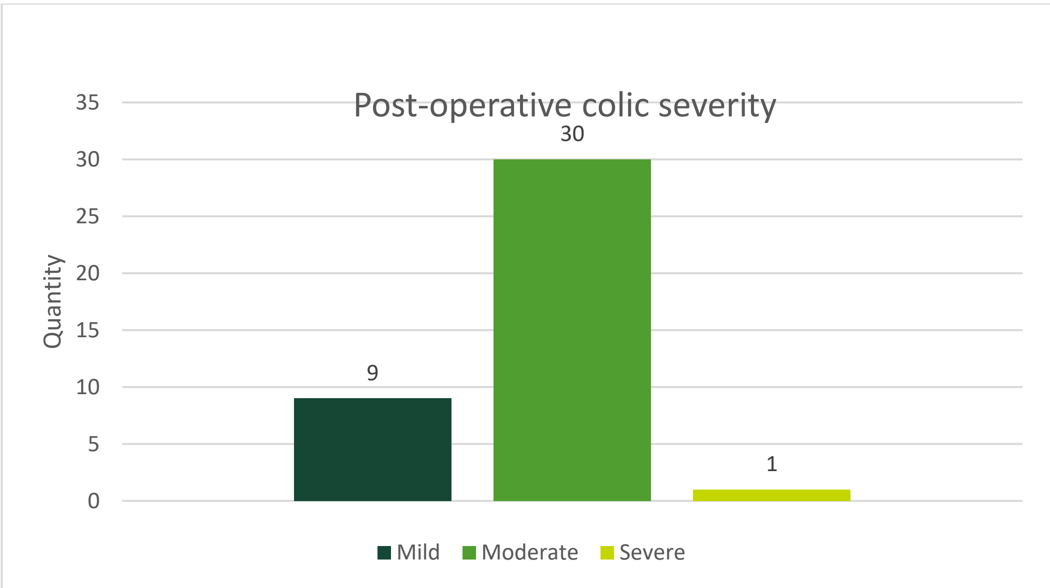


Figure 19. Severity of post-operative colic. Mild: mild symptoms, responds to pain relief, Moderate=/moderate symptoms of colic or mild symptoms of colic in combination with diagnosis of abdominal pain confirmed, responds to pain relief, Severe = persistence or recurrence of colic signs despite analgesia.

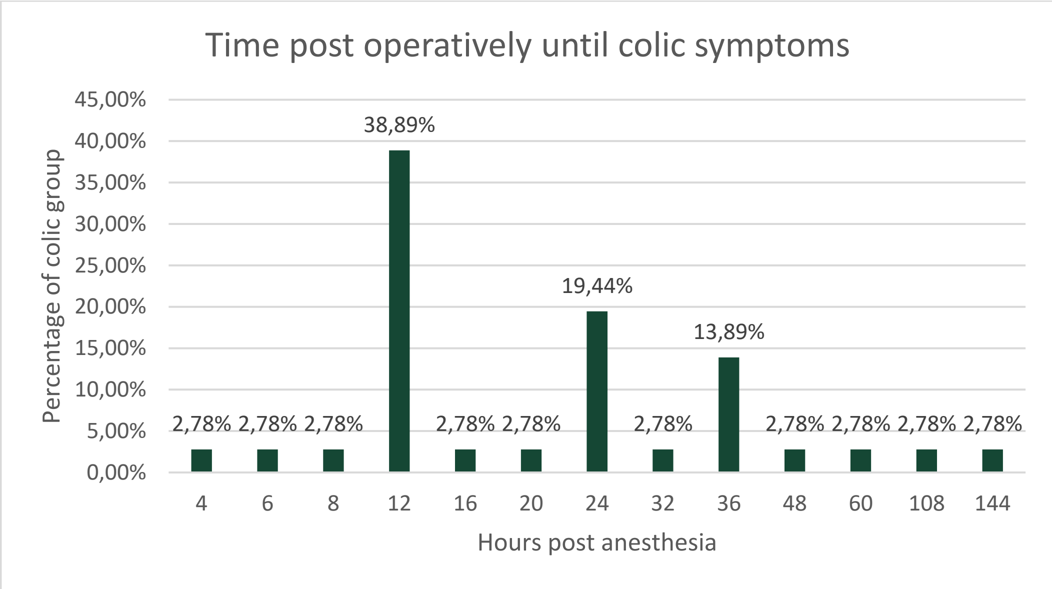


Figure 20. Time from anesthesia to first sign of colic symptom.

4.5 Post-operative colic and potential risk factors; descriptive statistics

16.4% of the patients that were administrated morphine systemically, developed colic, compared to only 9.5% in the non-morphine group (Figure 21).

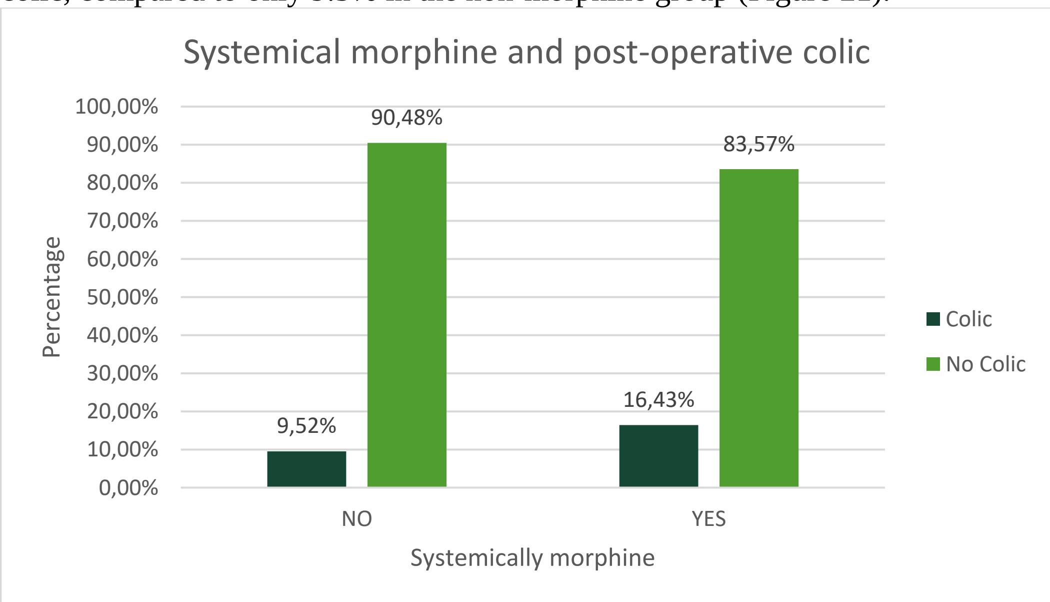


Figure 21. Systemically morphine administration and colic. NO: group not administrated morphine systemically, YES: group administrated morphine systemically.

The descriptive statistics for lidocaine CRI during surgery showed that 15.8% of the patients that received lidocaine CRI during surgery developed postoperative colic and 13.9% of the non-lidocaine group developed colic (Figure 22).

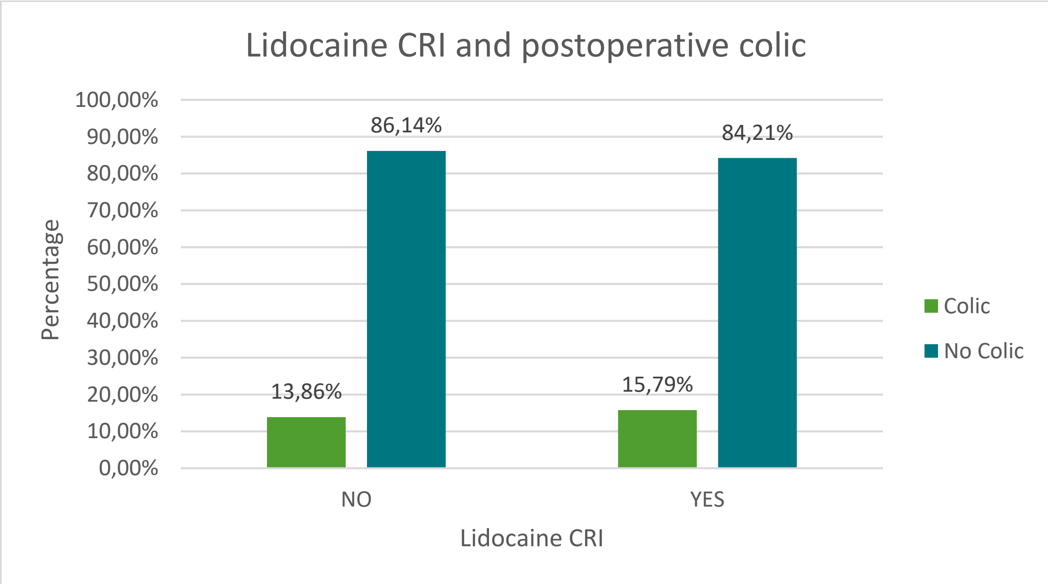


Figure 22. Lidocaine CRI during surgery and post-operative colic. NO = not received lidocaine infusion during surgery, YES =treated with constant rate infusion with lidocaine during surgery.

There was a small increase in colic for horses lying in right lateral recumbency compared to other positions during surgery (Figure 23).

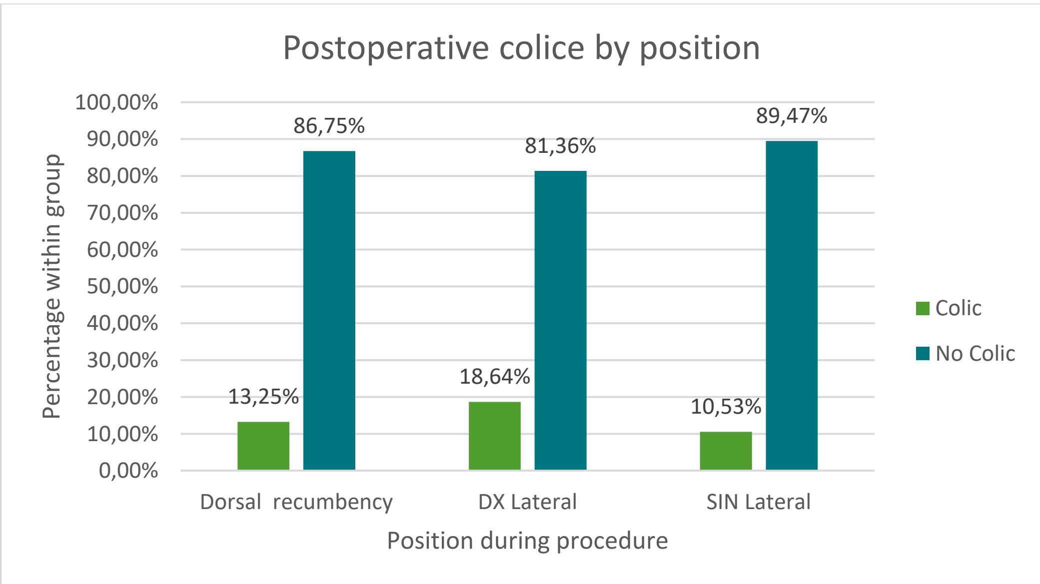


Figure 23. Proportions of patients developed colic regarding to different positions during surgery.

There was a positive trend observed in the risk of developing colic and the duration of anesthesia (Figure 24). The absolute number of observations is presented in Table 2.

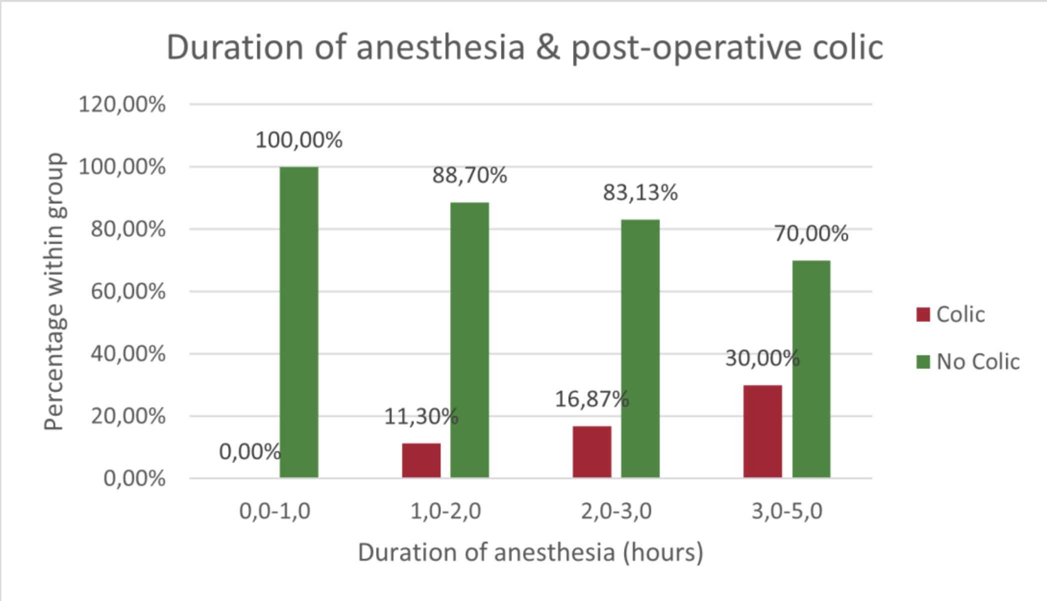


Figure 24. Duration of anesthesia and post-operative colic.

Table 2. Absolute numbers; duration of anesthesia & post-operative colic within 72 hours.

Duration of anesthesia (hours)	**0.0-1.0**	**1.0-2.0**	**2.0-3.0**	**3.0-5.0**
Colic	0	20	14	6
No Colic	17	157	69	14

None of the horses in the non-surgery group developed colic and the proportion of horses that developed post-operative colic did not appear to be greater when two procedures were performed directly following each other (Figure 25). Note that there were large differences in case numbers between different procedure categories, making it easy to misinterpret the descriptive statistics of percentages between and within groups. Absolute numbers are presented in Table 3.

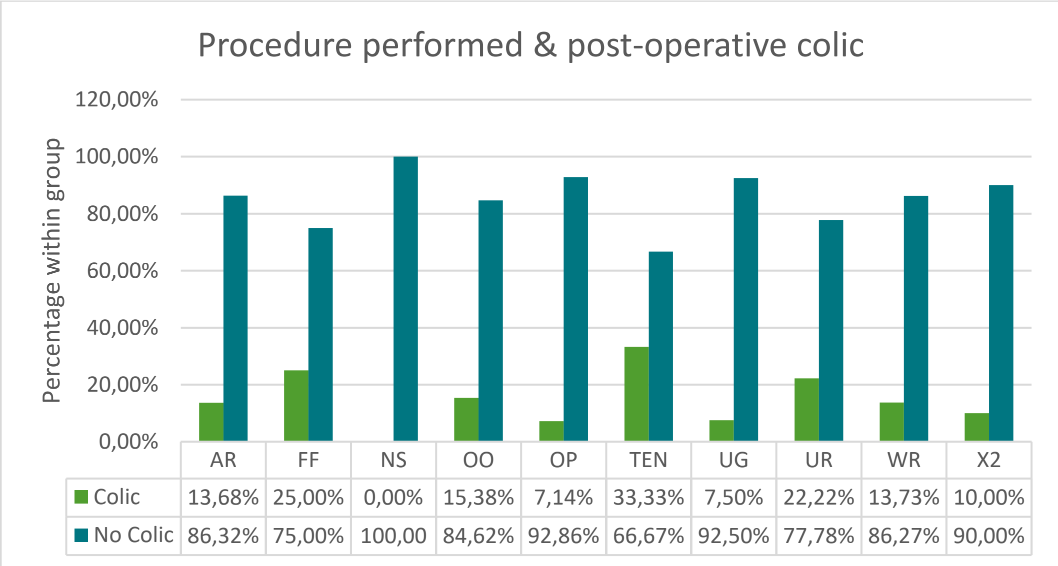


Figure 25. Procedure performed and colic, proportional within groups. For abbreviations see Table 1.

Table 3. Absolute numbers of cases by performed category.

ECVS Category	AR	FF	NS	OO	OP	TEN	UG	UR	WR	X2
Colic n (%)	13	6		6	1	1	3	2	7	1
No Colic n (%)	82	18	12	33	13	2	37	9	44	9

The proportion of patients that developed colic post-operatively was greater for the patients not exercised than for the group of patients that were hand walked during their stay at the hospital (Figure 26). Distribution of the cases is reported in Table 4.

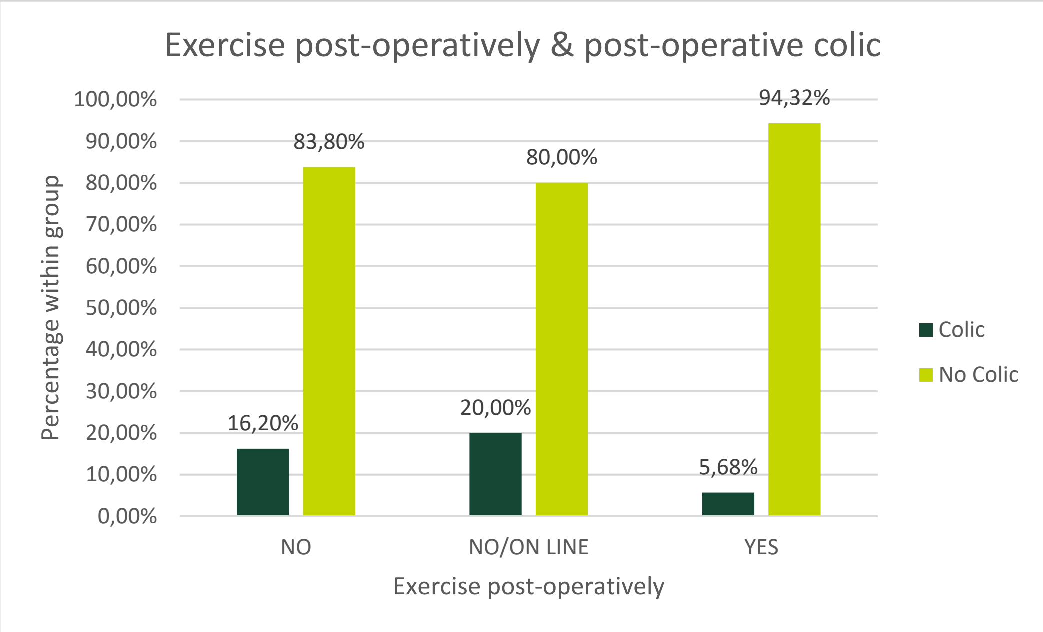


Figure 26. Exercise post-operatively and colic post-operatively within 72 hours. NO= not exercised, NO/ON LINE= not exercised and standing on line in their box. YES: exercised by hand walking.

Table 4. Distribution of cases by exercise category.

Exercise category	**NO exercise**	**NO/on running line**	**YES, exercised**
Colic	29	6	5
No Colic	150	24	83

There was a large distribution in the data for diet post-operatively, with a large percentage of missing values due to diet not being recorded in the patients' journal. The percentage of colic cases within different groups is illustrated in Figure 27 and the number of cases reported in Table 5.

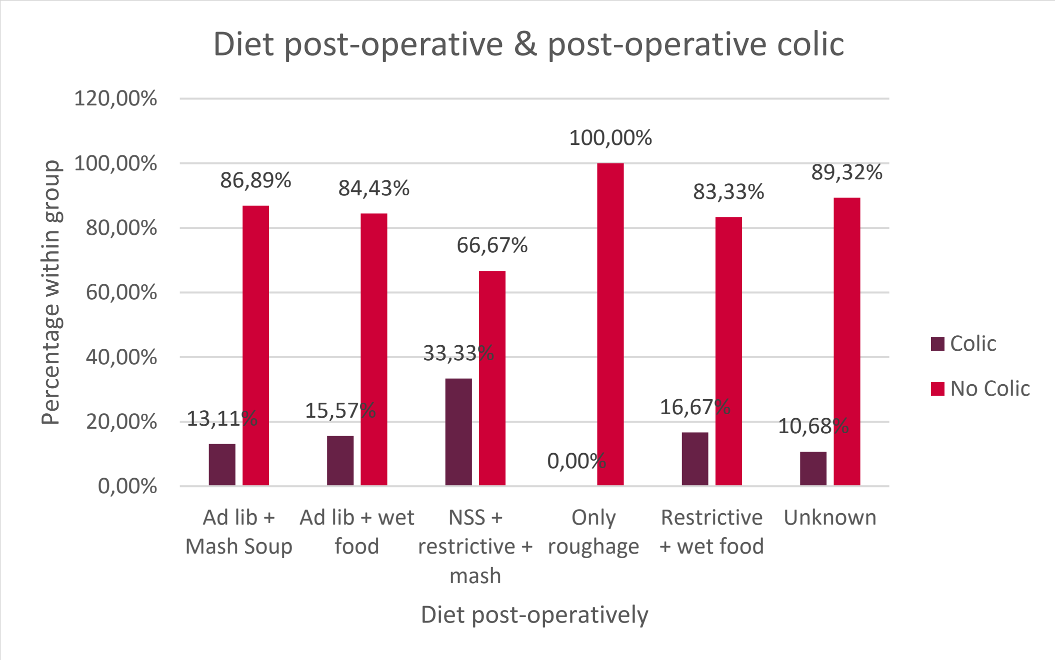


Figure 27. Diet post-operatively correlated to post-operative colic. NGI = nasogastric intubation, Wet food = bran mash/lucerne/concentrate mixed with water to porridge consistence, restrictive = fed small amounts of roughage.

Table 5. Distribution of colic cases correlated with post-operatively diet.

Diet Category	**Ad lib + mash soup**	**Ad lib + wet food**	**NGI + restrictive mash**	**Only roughage**	**Restrictive + wet food**	**Unknown**
Colic	8	19	1		1	11
No colic	53	103	2	2	5	92

4.6 Statistical analysis of possible risk factors

The result of the chi-square test of association of the independent variables, with colic within 72 hours post anesthesia as the response variable, is presented in Table 6. Only one of the tested variables showed a significant association with the outcome of POC within 72 hours post anesthesia, namely post-operative exercise versus strict box-rest.

Table 6. Chi-square test of association; colic within 72h as the response variable.

Variable		Colic n (%)	No Colic n (%)	Total n (%)	p-value for the Pearson´s chi-square test (P) or Fisher´s exact test (F)
Systemical morphine during stay	NO	8 (9,5)	32 (15,0)	40 (13,5)	0,211 (P)
	YES	76 (90,5)	181 (85,0)	257 (86,5)	
Exercise/Motion	NO	35 (87,5)	174 (67,7)	209 (70,4)	0,009 (F)
	YES	5 (12,5)	83 (32,3)	88 (29,6)	
Procedure performed	Orthopeadic	21 (52,5)	136 (56,0)	155 (54,8)	0,319 (P)
	Non-Orthopeadic	19 (47,5)	107 (44,0)	128 (45,2)	
Season	Autumn	18 (45,0)	67 (26,1)	85 (28,6)	0,083 (P)
	Winter	9 (22,5)	61 (23,7)	70 (23,6)	
	Spring	7 (17,5)	75 (29,2)	82 (27,6)	
	Summer	6 (15,0)	54 (21,0)	60 (20,2)	
Lidocaine CRI during surgery	NO	27 (67,5)	175 (68,1)	202 (68,0)	0,940 (P)
	YES	13 (32,5)	82 (31,9)	95 (32,0)	
Sex before surgery ****2 missing values***	Gelding	16 (40,0)	88 (34,5)	104 (35,3)	0,436 (P)
	Mare	20 (50,0)	121 (47,5)	141 (47,8)	
	Stallion	4 (10,0)	46 (18,0)	50 (16,9)	
Topical atropine treatment during stay	NO	39 (97,5)	250 (97,3)	289 (97,3)	1,0 (F)
	YES	1 (2,5)	7 (2,7)	8 (2,7)	

Binary logistic regression analysis was performed, which showed that the risk of colic increases with age and following systemic morphine when administrated during surgery. In the model, colic within 72 hours post-anesthesia was used as response variable and "colic" as event with n= 257 and colic event = 40. Results from the logistic regression model are shown in Table 7. In addition, the probability of colic post-surgery is lower if exercise is performed. For all other independent variables, the results were not significant. The different predictors were low to moderately correlated with each other, with variance inflation factors between 1.15-1.82. Odds ratio for age showed that for each year older, the odds to get colic postoperatively increases about 0.1 times (95% CI 1.0-1.2) (Table 8).

Table 7. Result Coefficients Binary Regression Analysis.

Term	Colic n (%)	No Colic n (%)	Coef	SE Coef	P-Value
Constant			-2,124	0,537	0,000
Age (years)	mean = 9,6 median = 9,5	mean = 7,1 median= 5,0	0,1024	0,0340	0,003
Position during surgery					
DX Lateral	11 (27,5)	48 (18,7)	0,060	0,480	0,901
More than one position	1 (2,5)	7 (2,7)	-0,25	1,19	0,836
SIN Lateral	6 (15,0)	51 (19,8)	-0,845	0,590	0,152
Unknown	1 (2,5)	6 (2,3)	-0,03	1,25	0,981
Morphine day/days before op					
YES	2 (5,0)	3 (1,2)	0,82	1,04	0,434
Morphine preoperatively					
YES	16 (40,0)	24 (60,0))	-0,687	0,449	0,126
Morphine intraoperatively					
NO	24 (60,0)	205 (79,8)	-0,295	0,531	0,579
Systemically	9 (22,5)	12 (4,7)	1,531	0,708	0,031
Morphine postop/in recovery					
YES	11 (27,5)	33 (12,84)	0,858	0,519	0,098
Morphine days post-op					
YES	2 (5,0)	10 (3,9)	-0,441	0,968	0,649
Exercise/motion					
NO/ON LINE	6 (15,0)	24 (9,3)	0,490	0,584	0,401
YES	5 (12,5)	83 (32,3)	-1,475	0,576	0,011

Table 8. Odds ratio for continuous predictor.

	Odds Ratio	95% CI
Age (years)	1,1078	(1,0365; 1,1840)

Table 9. Odds ratios for significant associated categorical variables.

Level A	Level B	Odds Ratio	95% CI
Morphine intraoperatively			
NO	Local	0,7448	(0,2633; 2,1071)
Systemically	Local	4,6239	(1,1536; 18,5339)
Systemically	NO	6,2079	(1,9222; 20,0489)
Exercise categories			
NO/ON LINE	NO	1,6324	(0,5195; 5,1289)
YES	NO	0,2289	(0,0740; 0,7082)
YES	NO/ON LINE	0,1402	(0,0320; 0,6142)

The result indicates that the odds to get colic post-operatively increase about 6.2 times (95% CI 1.9-20.0) with systemically administrated morphine during surgery. Comparing systemically administration of morphine intraoperatively with locally administrated morphine intraoperatively, e.g., intra-articular or in the tendon sheath, the odds to get post-operative colic increases about 4.6 times (95% CI 1.2-18.5). The difference in odds between no morphine administered intraoperatively and locally administrated morphine intraoperatively did not reach statistical significance.

Additionally, exercise of the patient post-operatively during the patients stay at the clinic decreased the odds for post-operative colic, comparing to box-rest (95% CI 0.07-0.7). This was even more pronounced when exercise was compared to box-rest on a line (95% CI 0.03-0.6). The difference between no exercise in combination with standing on a line and box-rest alone was not significant in our study (Table 9).

In the preliminary results, the model explained 17.07% of the total deviance in the response variable. For these data the Deviance R^2- value indicated a poor fit to the data. Nevertheless, the area under curve was considered acceptable and the best fitting model found for this dataset (Table 10). Additionally, the parameters in the goodness-of-fit test, especially the Hosmer-Lemeshow's test, was not significant which indicated that the result was trustworthy (Table 11).

Table 10. Model Summary Binary Logistic Regression Analysis 1.

Deviance R-Sq	Deviance R-Sq(adj)	AIC	AICc	BIC	Area Under ROC Curve
17,07%	11,53%	222,67	224,16	274,38	0,7793

Table 11. Godness-of-fit test Binary logistic Regression analysis 1.

Test	DF	Chi-Square	P-Value
Deviance	283	194,67	1,000
Pearson	283	302,61	0,202
Hosmer-Lemeshow	8	5,02	0,756

The second binary logistic regression analysis with only 243 individuals included and altered grouping of categories within variables showed similar results, with a few new findings (Table 12 & 13). Variance influence factor was still low to moderate between variables, ranging from 1.14 to 1.86. After including possible confounding predictors, systemic morphine during surgery still was significantly associated with higher odds to get colic within 72 hours post anesthesia (95% CI 1.1-14.9). Additionally, topical atropine treatment during stay (95% CI 1.1-209.4) was found to increase the odds to develop colic 15.2 times. If the surgery was performed during the spring, the odds to develop post-operative colic was lower than if performed during autumn (95% CI 0.096- 0.95). The odds to get colic post-operatively if exercised was still lower comparing to box rest (95% CI 0.05-0.7) and compared to box rest on a line (95% CI 0.03-0.7). The other newly added predictors, compared to the first logistic regression, were duration of anesthesia, procedure performed (orthopaedical vs non-orthopaedical) and breed type. These did not alter the result or show any association with development of POC in our study population (Table 14).

This second binary logistic regression model explains 20.79% of the deviance in the response variable (Table 15). The adjusted Deviance R^2 at 11.25% is lower than the first models adjusted Deviance R^2 (11.53%), AIC at 228.64 is higher than first models AIC (222.67) but area under ROC is slightly higher with 0.7851 compared to first model (0.7793). Hosmer-Lemeshow´s test is not significant making this binary model trustworthy (Table 16). The models were quite equal but following higher adjusted Deviance R^2, the first model fitted the data better.

Table 12. Coefficients Binary Regression Analysis 2. N= 243 and event (colic)=40. Breed of horse categorised into three following categories: cold-, hot- and warm-blooded.

Term	Colic n (%)	NO Colic n (%)	Coef	SE Coef	P-Value
Constant			-1,508	0,839	0,072
Age (years)	Mean= 9,6 Median= 9,5	Mean= 7,0 Median=5,0	0,1098	0,0363	0,002
Season					
Spring	7 (17,5)	69 (28,4)	-1,196	0,583	0,040
Summer	6 (15,0)	50 (20,58)	-1,024	0,599	0,087
Winter	9 (22,5)	59 (24,3)	-0,897	0,569	0,115
Surgery categories					
Orthopaedic	21 (52,5)	107 (44,0)	-0,191	0,487	0,695
Breed type					
Hot blooded	2 (5,0)	9 (3,7)	-0,20	1,16	0,864
Warm Blooded	32 (80,0)	204 (84,0)	-0,289	0,596	0,628
Position during surgery					
DX Lateral	11 (27,5)	46 (18,93)	-0,318	0,524	0,544
More than one position	1 (2,5)	(7 (2,88)	-0,04	1,27	0,978
SIN Lateral	6 (15,0)	51 (21,0)	-1,191	0,623	0,056
Unknown	1 (2,5)	6 (2,5)	-1,06	1,36	0,433
Morphine day/days before op (YES/NO)					
YES	2 (5,0)	3 (1,2)	0,92	1,12	0,409
Morphine preop (YES/NO)					
YES	16 (40,0	140 (57,6)	-0,846	0,525	0,107
Lidocaine CRI intraoperatively					
YES	13 (32,5)	80 (32,9)	0,141	0,492	0,775
Morphine in recovery					
YES	11 (27,5)	33 (13,6)	1,088	0,560	0,052
Morphine days post-op					
YES	2 (5,0)	10 (4,1)	-0,437	0,999	0,662
Alternative motion categories					
NO/ON LINE	6 (15,0)	24 (9,9)	0,291	0,647	0,653
YES	5 (12,5)	70 (28,8)	-1,728	0,704	0,014
Duration of anesthesia					
1,5-3 hours	27 (67,5)	155 (63,8)	0,355	0,521	0,495
3-5,5 hours	6 (15,0)	14 (5,8)	1,147	0,827	0,165
Systemically Morphine intraoperatively					
YES	9 (22,5)	12 (4,9)	1,398	0,664	0,035
Topical Atropine Treatment during stay					
YES	1 (2,5)	6 (2,47)	2,72	1,34	0,042

Table 13. Odds ratio continuous predictor binary regression analysis 2

	Odds Ratio	95% CI
Age (years)	1,1161	(1,0395; 1,1983)

Table 14. Odds ratios for categorial predictors binary regression analysis 2.

Level A	Level B	Odds Ratio	95% CI
Season			
Spring	Autumn	0,3023	(0,0964; 0,9486)
Summer	Autumn	0,3592	(0,1111; 1,1614)
Winter	Autumn	0,4077	(0,1337; 1,2427)
Summer	Spring	1,1880	(0,3173; 4,4477)
Winter	Spring	1,3483	(0,4026; 4,5158)
Winter	Summer	1,1350	(0,3100; 4,1558)
Alternative motion categories			
NO/ON LINE	NO	1,3375	(0,3766; 4,7497)
YES	NO	0,1776	(0,0447; 0,7052)
YES	NO/ON LINE	0,1328	(0,0253; 0,6975)
Systemically Morphine intraoperatively			
YES	NO	4,0477	(1,1026; 14,8589)
Topical Atropine Treatment during stay			
YES	NO	15,1643	(1,0983; 209,3661)

Table 15. Model summary binary regression analysis 2.

Deviance R-Sq	Deviance R-Sq(adj)	AIC	AICc	BIC	Area Under ROC Curve
20,79%	11,25%	228,64	232,90	312,48	0,7851

Table 16. Godness-of-Fit tests binary regression analysis 2.

Test	DF	Chi-Square	P-Value
Deviance	260	182,64	1,000
Pearson	260	321,82	0,005
Hosmer-Lemeshow	8	5,93	0,655

4.7 Additional statistical analysis; main study population

4.7.1 Administration of systemic morphine intraoperatively

In order to gain further insight regarding which horses administrated morphine during anesthesia, we performed a logistic regression analysis with systemically morphine administration during surgery as response variable. Firstly, we performed a Fischer´s exact test to re-evaluate the association of systemic morphine administrated intraoperatively and post-operative colic, with the result that the association was significant (Table 17). Secondly, we performed a chi-square of association test between the systemic administration of morphine intraoperatively and post-operative exercise to exclude possible confounding bias between those two. No significant association was found (Table 18). Finally, we performed a binary logistic analysis with morphine administration as event. For this analysis, 283 horses were included and the number of horses that received morphine (event in analysis) was 21. The result of binary logistic regression analysis is presented in Table 19 and Table 20. No multicollinearity among factors was detected, with variance influence factors ranging from 1.04 to 1.94. We found that the odds that the patients would receive morphine systemically during surgery was higher if they got morphine in the days prior to surgery (95% CI 2.7-148.8). The odds that the horse would receive morphine systemically intra-operatively was also higher if the duration of anesthesia was long. We found a significant difference between anesthesia duration of 3-3.5 hours comparing to shorter duration 0-1.5 hours (95% CI 1.0-35.5). It was more likely the horses were treated with morphine systemically intra-operatively if duration of anesthesia was 3-5.5 hours long. When comparing 1.5-3 hours of anesthesia and 3-5.5 hours, no significant difference in the choice of systemically morphine administration during anesthesia was found.

Table 17. Fischer´s exact test systemically administered morphine & post-operative colic within 72 hours

Variable		Colic n (%)	No Colic n (%)	Total n (%)	p-value Fisher´s exact test (F)
Systemically morphine administrated intraoperatively	YES	9 (22,5)	12 (4,9)	21 (7,4)	0,0007 (F)
	NO	31 (77,5)	231 (95,1)	262 (92,6)	

Table 18. Chi-square test of association systemically administrated morphine intraoperatively & post-operative exercise

Variable		Exercise post-operatively n (%)	No exercise post-operatively n (%)	Total n (%)	P-value for Pearson´s Chi-square test (P)
Systemically morphine administrated intra-operatively	YES	5 (6,7)	16 (7,7)	21(7,4)	0,771
	NO	70 (93,3)	192 (92,3)	262 (92,6)	

Table 19. Coefficients morphine binary logistic analysis. Breed of horse categorised into three following categories: cold-, hot- and warm-blooded.

Term	Systemically Morphine n (%)	NO Systemically morphine n (%)	Coef	SE Coef	P-Value
Constant			-2,511	0,823	0,002
Age (years)	Mean= 8,5 Median 5	Mean = 7,2 Median = 6	0,0496	0,0426	0,245
Surgery categories					
Orthopaedic	11 (52,4)	117 (44,7)	0,247	0,528	0,640
Breed type					
Hot blooded	2 (9,5)	9 (3,4)	0,31	1,00	0,760
Warm Blooded	14 (66,7)	222 (84,7)	-1,140	0,621	0,066
Morphine day/days before op					
YES	3 (14,3)	2 (0,76)	3,15	1,05	0,003
Morphine preoperatively					
YES	11 (52,4)	145 (55,3)	-0,885	0,549	0,107
Morphine in recovery					
YES	1 (4,8)	43 (16,4)	-1,41	1,10	0,199
Morphine days post-op (yes/no)					
YES	4 (19,1)	8 (3,1)	1,365	0,765	0,074
Recoded Duration of anesthesia					
1,5-3 hours	13 (61,9)	169 (64,5)	0,656	0,695	0,346
3-5,5 hours	5 (23,8)	15 (5,73	1,793	0,906	0,048

Table 20. Odds ratios for categorial predictors binary regression analysis morphine administration.

Level A	Level B	Odds Ratio	95% CI
Morphine day/days before op (YES/NO)			
YES	NO	23,4000	(2,9629; 184,8093)
Morphine preop (YES/NO)			
YES	NO	0,4127	(0,1407; 1,2104)
Morphine in recovery (YES/NO)			
YES	NO	0,2429	(0,0281; 2,1034)
Duration of anesthesia			
1,5-3 hours	0-1,5 hours	1,9265	(0,4930; 7,5280)
3-5,5 hours	0-1,5 hours	6,0087	(1,0174; 35,4864)
3-5,5 hours	1,5-3 hours	3,1189	(0,7906; 12,3042)

4.7.2 Post-operative bran mash soup & post-operative colic

To evaluate possible associations between post-operative feed and post-operative colic additional analyses were performed. For this analysis we excluded patients with missing values regarding to post-operative feed. We compared ad-lib roughage in combination with bran mash mixed with lots of water (soup) or combined with bran mash with less amount of water (porridge). The sample size for these analyses was 183 horses and 27 horses developed colic post-operatively.

Initial Chi-square test indicated no association between the different feeding regimens and with post-operative colic, with a Pearson´s p-value of 0.658. A binary logistic regression analysis with other predictors included was also performed. The result showed no significant association regarding feed post-operatively ad-lib roughage in combination with bran mash mixed with lots of water (soup) or bran mash with less amount of water (porridge) and development of post-operative colic within 72 hours post anesthesia (Table 21). No multicollinearity was seen among factors, with variance influence factor ranging from 1.03 to 1.74. The model showed an acceptable model summary and goodness-of-fits test (Table 22).

Table 21. Result Coefficients, reduced regression analysis regarding post-operatively diet.

Term	Colic n (%)	No Colic n (%)	Coef	SE Coef	P-Value
Constant			-2,778	0,678	0,000
Age (years)	Mean =9,3 Median =8	Mean =6,5 Median = 6	0,0924	0,0413	0,025
Exercise categories					
NO/ON LINE	5 (18,5)	12 (7,7)	0,493	0,673	0,463
YES	4 (14,8)	53 (34,0)	-1,172	0,627	0,062
Morphine intraoperatively categorial					
NO	17 (63,0	119 (76,3)	0,088	0,635	0,890
Systemically	6 (22,2)	8 (5,1)	1,646	0,821	0,045
Diet post op					
Ad lib + concentrate porridge	19 (70,4)	103 (66,0)	0,398	0,500	0,426

Table 22. Modell summary & goodness-of fit test; binary regression analysis regarding post-operatively diet with reduced sample size.

Deviance R-Sq	Deviance R-Sq(adj)	AIC	AICc	BIC	Area Under ROC Curve
12,02%	8,10%	148,74	149,38	171,20	0,7555

Test	DF	Chi-Square	P-Value
Deviance	176	134,74	0,991
Pearson	176	174,47	0,518
Hosmer-Lemeshow	8	9,29	0,318

4.8 Comparative study group; surgery during standing CRI sedation

For this smaller comparative study, we did not perform any association analyses due to a small study group. Only 69 horses were included. The incidence of colic within 72 hours post-procedure was 14.5% (10/69). If excluding mild colic, the incidence of colic within 72 hours post procedure was 5.8%. No diagnosis was confirmed for 70% of the colic cases (7/10), 10% (1/10) diagnosed with caecum impaction and 20% (2/10) diagnosed with colon impaction. Colic symptoms developed between 12 hours post anesthesia (40% of cases) and 24 hours (50%) and one horse developed colic 36 hours post anesthesia. The study group was similar the main study population regarding both patient factors and management factors. 87.1 % (61/70) of the patients were systemically administrated morphine intraoperatively, either as one single dose I.V or by CRI. Descriptive statistics briefly summarized in Appendix A.

4.9 Comparative study group: two anesthesia events performed close to each other

28 horses were included in this study group of horses with two events of anesthesia performed with 1-7 days in between. The incidence of post-operative colic within 72 hours post anesthesia was 10.7% (3/28). One horse developed colic 12 hours post the second anesthesia event with no diagnosis confirmed. The other two horses developed colic 48h post the second anesthesia event, one had gas colic and one hade impaction in small colon. All horses were treated medically, and colic resolved after 24 hours for the first two, the impaction was resolved after 48 hours.

The most common combination of anesthesia was first general anesthesia with computed tomography and then a standing procedure performed, but 9 (32%) of the horses had two general anesthesia events. Breed distribution and age were similar to the main study group, but more events (32%) were performed during summer season. Age and sex distribution was similar to the main study population as well. The majority of procedures performed were upper respiratory procedures (50.0%), arthroscopy (21.4%) and wound repairs (10.7%), dental procedures (7.1%) and eye procedures (7.1%). Only 54 % (15/28) of the group received systemically morphine intraoperatively. 54.0% of horses were not hand walk exercised, 35.7% were exercised and in 10.7% it was unknown if the horses were exercised or not. Two of the horses that developed colic did not get exercise, whilst in one case it was unknown if the horse was exercised or not.

5. Discussion

Post-operative colic not only decreases the patient’s welfare, it is also a possible life threatening condition. It increases the economic cost due to a prolonged stay at the hospital and the requirement for further diagnostic investigation and treatment. This study demonstrated the prevalence of post-operative colic in horses undergoing elective non-abdominal surgical procedures (standing or under general anesthesia), in our hospital population between 1st of October 2021 and 1st of October 2022. During this period the incidence of post-operative colic was 13.5 % and 14.5%, respectively within 3 and 7 days after general anesthesia. Following standing surgery with CRI-sedation the incidence was 14.5% within 3 days of the procedure.

5.1 Incidence of post-operative colic

The incidence of post-operative colic found in our study is high in comparison with previous reports, where the incidence ranged between 2.5 and 10.5% (Senior *et al.* 2004, 2006; Nelson *et al.* 2013; Jago *et al.* 2015; Bailey *et al.* 2016). Bailey *et al.* (2016) reported an incidence of 2.5 % within 6 days post anesthesia. However, unlike our study none of the patients were fasted before surgery. In our population, a standard feeding program was applied, with all patients fasted pre-operatively between 2 and 8 hours. One of the main reasons to fast horses before surgery is the supposed benefit on ventilation during anesthesia, however there is no prospective clinical study investigating the relationship between ventilation and stomach dimension. The negative effect on ventilation and oxygenation if the horse is not starved remains equivocal. In the study by Bailey *et al.* (2016) for example, the ventilation parameters during anesthesia were not recorded.

Feed withdrawal alone reduces and alters gastrointestinal function and motility (Starvation) and Senior *et al.* (2004) reported that the most common diagnosis of post-operative colic is impaction of the colon and/or caecum, a finding in agreement with our study. The pre-anesthetic feeding program at SLU involves strict fasting for only 2-8 hours. This is shorter than previously described fasting of 8-12 hours before surgery (Senior *et al.* 2004, 2006; Jago *et al.* 2015; Lillkull & Williamsson 2020). We could speculate that even this short fasting period could have a negative effect on gastrointestinal motility. In combination with the additional negative influence on the gastrointestinal tract by anesthetic agents and medication, this could explain the increased incidence of colic in our population compared with the previous study by Bailey *et al.* (2016).

Senior *et al.* (2004) reported a colic incidence of 2.8% but they included only orthopaedic surgeries, elective or emergencies, performed day time or out of hours. The patients were both fasted and not fasted before surgery and may have been transported close to surgery. Post-operative management was not described. Similar to our study, they reported an association between the administration of systemic morphine and post-operative colic, although with a lower incidence.

One difficulty that arises when comparing our study with previously published data, is the difficulty in defining mild colic cases. Mild colic symptoms are diffuse and subjective to the observer. Symptoms of pain not originating from the abdomen and/or psychological stress could be mistaken for colic. Excluding mild colic cases, the incidence of post-operative colic in our population decreased to 10.4%, a value closer to the study by Jago *et al.* (2015) but still higher than most of the previously published literature (Senior *et al.* 2004, 2006; Nelson *et al.* 2013; Bailey *et al.* 2016). The incidence from the study by Jago *et al.* 2015) at 10.5% is similar ours, with pre-operative fastening of patients as a common variable.

In contrast with previous studies, which have chosen to include all cases of colic within 6 or 7 days post-anesthesia (Jago *et al.* 2015; Bailey *et al.* 2016), we decided to only include cases of colic within 3 days post anesthesia, in agreement with Senior *et al.* (2004 and 2006). Based on colic's multifactorial aetiology, it is less likely that colic occurring later would be clearly associated to the anesthetic event, with more confounding bias existing with a longer time span.

It would have been of interest to compare the post-operative incidence of colic with the total incidence of colic during hospitalization. A prospective study with colic as a complication to hospitalization, comparing post-operative colic with non-post-operative colic and associated risk factors would be of interest. Such control groups might give further insight as to which risk factors for colic are more important and if the incidence could be reduced.

5.2 Identified predictors to post-operative colic

One possible risk factor identified in our study was the systemic administration of morphine during surgery, given either I.V or I.M intra-operatively. The result using two different analysis models, showed that the odds to get colic post-operatively within 3 days increases 4.6 to 6.2 times, when morphine is administrated systemically during surgery.

Results from previous studies on the association between the use of morphine and post-operative colic differ. Senior *et al.* (2004) agreed with our finding, with a four-fold increased risk of colic, but this association was not confirmed by others (Mircica *et al.* 2003; Andersen *et al.* 2006; Nelson *et al.* 2013). In our initial analysis, when we looked at the effect of systemic administration of morphine during the entire hospital stay, we did not find any association. Interestingly, when we looked at when in relation to the anesthetic event the morphine was administrated, a significant association was found. It appears therefore that it may matter when the morphine is administered, not only if the horse received morphine or not. This finding has not previously been described in the literature, although Mircica *et al.* (2003) discussed the possibility that such a difference may exist.

There is however the possibility that confounding bias exists in our result. Systemic administration of morphine during surgery was associated with a longer duration of anesthesia and with the administration of morphine systemically in the days before surgery. A longer duration of anesthesia may be associated with the procedure performed and more protracted noxious stimuli perioperatively, which may in turn reduce gastrointestinal motility (Hasuo *et al.* 2017).

Comparing our incidence in the general anesthesia group with the standing surgery CRI group, the incidence of post-operative colic was descriptively similar at 14.5%. The majority (87.1%) of the patients that underwent standing sedation received systemic morphine. This, in combination with the result from the regression analysis where no association between anesthesia duration and post-operatively colic was found, may indicate that it is not the duration of anesthesia in terms of exposure to inhalation anesthesia agents or the longer duration in recumbency that is responsible for the increased colic risk.

Inadequate pain management can result in changes in appetite, reduced voluntary movement (Price *et al.* 2003), and increased sympathetic tone. This could therefore contribute to alterations in gastrointestinal motility and predispose the horse to POC (Nelson *et al.* 2013). Post-operative pain could be a confounding factor for the increased risk of colic, since the horse was given morphine intraoperatively.

Additionally, we did find an association between the administration of morphine in the days before surgery and systemic administration of morphine during anesthesia. Both Boscan *et al.* (2006) and Tessier *et al.* (2019) demonstrated a cumulative effect of morphine's negative effect on the gastrointestinal tract of the horse. Perhaps a cumulative effect of morphine can explain our finding. Further investigation therefore is needed before a definitive correlation between systemic administration of morphine during anesthesia and postoperative colic can be made.

Topical Atropine administration has been associated with decreased gastro-intestinal motility and colic in horses (Ekstrand *et al.* 2022). For equids treated at a hospital for ocular disease; age, hospitalization time and the topical use of atropine were significantly associated with colic (Patipa *et al.* 2012). The results in our study agree with the previously described findings. Topical atropine treatment during the stay at the clinic was found to increase the odds of developing post-operative colic 15.2 times.

The odds ratio at 1.1 for age showed that for each year older, the risk of post-operative colic increased about 10%.

A very interesting finding in our study was that hand walking horses after surgery was found to be associated with a decreased risk of developing POC. This implies that decreased exercise is a risk factor. To our knowledge, no comparative study has looked at the effect of post-operative exercise. Pagan *et al.* (1998) showed that exercised horses consumed more water and Sarrafchi (2012) described how stabling can alter the horse mental welfare. The positive effect with hand walked exercise seen in our study could be related to an overall increased mental welfare or with a physiologically effect on gastrointestinal function. If the positive effect is due to an improvement in mental welfare, perhaps we can find other methods to stimulate horses that have forced restricted movement during hospitalisation.

The most common diagnosis of post-operative colic after non-abdominal surgery is impaction of the large colon and caecum (Senior *et al.* 2004; Bailey *et al.* 2016). The pathophysiology of POI differs from the pathophysiology of post-operative colic after non-abdominal surgery, but slowly refeeding is practiced in in order to minimise POI. Feed recommendations in general after even mild colic symptoms, impactions and any disturbance in the gastrointestinal tract is to restrict feeding, and when symptoms are resolved to slowly introduce feed again (Pratt-Phillips & Geor 2017). There is strong evidence that pre-operative feed withdrawal together with anesthesia and the surgical event has a negative effect on the gastrointestinal tract (2.1.1 Starvation). According to this, a slow introduction of feed as for any other disturbance within the gastrointestinal tract is recommended after surgery to minimize the risk for post-anesthetic impaction and colic.

6. Conclusion

This pilot study has shown that post-operative colic is a multifactorial event correlated with pre- and post-operative management. We found that post-operative colic is less likely to be related to the anesthesia and surgery itself and more likely related to the overall management of the hospitalized horse, including analgesia.

A future prospective cohort study with controls to evaluate both pre-operative fasting, restrictive post-operative feeding, use of analgesia and post-operative exercise would be helpful to better understand and evaluate all the risk factors involved. The aim would be to reduce the incidence of post-operative colic using evidence-based best practice.

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Popular science summary

Abdominal discomfort, colic, is a well-recognised problem after surgical events in horses. If the horse develops colic during its stay at the hospital this will result in a decreased welfare for the horse, an increased cost for the owner and in some cases become life-threatening for the horse. If we identify why horses develop colic, we may prevent it from happening. Few studies have been performed trying to identify risk factors for colic, especially after non-abdominal planned surgeries. The studies that have been made have reported that 2.8% to 10.5% of the horses develop colic after non abdominal surgeries. In 2016 a study was published where only 2.5% of the horses developed colic. In that study none of the horses were fasted before the anesthesia and surgery, which is quite novel. Not fasting the horses was presented as a possible reason for the lower percentage of post-operative colic cases.

For decades, horses have been fasted 8-12 hours before anesthesia, with the aim to improve the horses' breathing and blood circulation during anesthesia. A horse is a big animal and mostly they are positioned lying on their back during anesthesia and surgery. When they are lying on their back their intestines by gravity are falling downwards and in a forward direction and put pressure on the lungs and the blood flow. Studies from 30-40 years ago stated that it is better to fast the horses prior to surgery and this has routinely been performed ever since. The evidence from the study from 2016 on non-fasted horses with a lower percentage of post-operative colic cases stimulated a renewed interest to investigate which is most beneficial, fasting, or non-fasting of the horse prior to surgery. Before such a study can be performed, we needed to evaluate the percentage of horses developing colic at our equine hospital with the current feeding regimen. Of interest was also to review and investigate if we could find any common factors for horses developing colic post-operatively. We wanted to investigate if colic is an actual problem at our equine hospital or not and if a future study would be of any interest.

The study was performed by a review of publicised scientific studies within the subject and a brief summary of findings. Previous studies have shown that fasting the horse alters the gastrointestinal function in a negative way. Medications and anesthesia during surgery can also affect the gastrointestinal negatively. Stress, pain, and decreased water intake can predispose the horse for colic. Abdominal discomfort can arise from many different causes; ulcerations in the stomach, constipation in the intestines and following accumulation of gas in the intestines. When the horse experiences colic you can diagnose the cause by per rectal palpation. This can be an uncertain diagnostic method since you cannot palpate more than a small proportion of the equine abdomen. You can also ultrasound the abdomen, or go down with a camera through the nose and look at the stomach, or by different blood tests and tests on abdominal fluids. After anesthesia the most common cause of abdominal discomfort remains undiagnosed. The most common diagnosed cause is impaction/constipation.

Earlier studies have focused on differences during the actual anesthesia, different medications, different procedures, and different anesthesia methods used, and reported common factors for horses developing colic. The reports from different studies are sometimes giving opposite findings, making it difficult to draw conclusions. In my thesis, these findings are summarized. In our study we included aspects before and after anesthesia not taken in account previously. For example, we looked at whether the horse got exercise during their stay at the hospital. Hand walking exercise of the horse has been used to treat and prevent colic in horses, but there is limited evidence for this.

The study we performed included adult patients who went through anesthetic events and non-abdominal surgeries over a one-year period. Abdominal surgeries were excluded because if performing surgeries in the abdomen, abdominal discomfort is more likely to occur. Horses with a history of previous colic were excluded, because horses that have had colic before, are more likely to get colic again, according to literature. We collected information about the patient, medications, procedures performed, diet and exercise post-operatively. We compared horses anesthetized with the horse lying down on their back or on their side. We compared horses only sedated and still standing up during surgery and if two or more procedures performed close together seemed to increase the risk to develop colic. Limitations in our study were the small number of horses, compared to other studies and problems when collecting information from the past, missing data and non-standardised recordings in the journals.

Our result showed that exercise during hospitalization post-anesthesia decreased the risk of colic. Old age was associated with a higher risk to develop colic post-anesthesia. Pain management with morphine during anesthesia was found to be related to the development of colic. However, more studies need to be done before determining if it is the opioid that is responsible or if other factors are important. We had a high percentage of colic post-operatively compared to earlier reported numbers, but it is not possible to directly compare numbers because our study included a smaller number of horses, and the studies were designed in different ways.

Both the literature and the results in our study showed a high percentage of colic cases following non-abdominal surgery. It would therefore be of interest to perform a more controlled investigation. Possibly the feeding post-operatively can alter the percentage of horses developing post-operative colic. If the horse is fed smaller amounts after the surgery, perhaps the risk of colic is lower. If not fasted before surgery, maybe the negative influence on the gastrointestinal tract is minimized. We do not know the answer to these questions, and more studies need to be done to evaluate this and many more aspects. Previous results at least do not show an increased risk with not fasting the horse before surgery, making a future trial study ethical to perform.

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Appendix 1

Tabell 1. Summary standing CRI surgeries

Season	Count	Percent
Autumn	16	23,19
Spring	19	27,54
Summer	13	18,84
Winter	21	30,43
N=	69	

Sex (before surgery)	Count	Percent
H	6	8,70
S	27	39,13
V	36	52,17
N=	69	

ECVS categorie	Count	Percent
FF	6	8,70
OO	16	23,19
OP	25	36,23
UG	5	7,25
UR	9	13,04
WR	7	10,14
WR + FF	1	1,45
N=	69	

Systemical Morphine intraoperatively	Count	Percent
NO	9	13,04
YES	60	86,96
N=	69	

Morfin preop	Count	Percent
IV	15	21,74
NO	54	78,26
N=	69	

Motion post op category	Count	Percent
NO	21	30,43
NO/MAT	2	2,90
NO/on line	5	7,25
Unknown	18	26,09
YES	23	33,33
N=	69	

Age (years)	Count	Percent
1	3	4,35
2	2	2,90
3	2	2,90
4	7	10,14
5	4	5,80
6	3	4,35
7	1	1,45
8	3	4,35
9	2	2,90
10	4	5,80
11	5	7,25
12	7	10,14

Breed	Count	Percent
Arabian Thoroughbred	1	1,45
Ardenner	1	1,45
Belgian half-blood	1	1,45
Connemara	5	7,25
English Thoroughbred	2	2,90
Friesian	1	1,45
Holsteiner	1	1,45
Irish Cob/Irish sportpony	1	1,45
Irish Sporthorse	2	2,90
Islandic horse	4	5,80
Coldblooded trotter	3	4,35
Knabstrup	1	1,45
Crossbred horse	4	5,80
Crossbred pony	3	4,35
KWPN	1	1,45
Lusitano	1	1,45
Polo pony	1	1,45
Quarter horse	1	1,45
Shetland pony	1	1,45

13	4	5,80
14	6	8,70
15	1	1,45
16	2	2,90
17	1	1,45
18	2	2,90
19	3	4,35
20	1	1,45
22	1	1,45
23	2	2,90
27	2	2,90
28	1	1,45
N=	69	

SWB	21	30,43
Tinker	1	1,45
Warm-blooded trotter	9	13,04
Welsh Cob	1	1,45
Welsh Pony	2	2,90
N=	69	

Colic within 72 hours	**Count**	**Percent**
Mild	6	8,70
Moderate	4	5,80
NO	59	85,51
N=	69	

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