Factors Associated with Surgical Site Infections in Horses A Retrospective Study

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ABSTRACT

Post-operative surgical site infection (SSI) is a significant complication in equine surgery. This demonstrates an urgent need to broaden our knowledge and capabilities regarding SSIs. The current study evaluates the incidence, the bacteria involved and possible risk factors for equine surgery SSIs in our hospital (Koret School of Veterinary medicine, Department of Large Animal Medicine and Surgery). All 198 surgical procedures performed in 167 horses between November 2011 and February 2013, were included in the study. The parameters evaluated were: type of surgery, the surgeons involved, age, weight, sex, breed of the animal, duration of the procedure, time of day the procedure was performed, season and duration of hospitalization. The general incidence of infection during the study period was 16.7%. Risk factors were: type of surgery, repeat surgery, sex, and weight. Abdominal procedures had a higher risk of developing SSI than other procedures. Pregnant mares had higher risk of developing an infection than others. Heavier body weight increased the risk for the development of SSIs as well. Nineteen samples were sent for culture and sensitivity, and the most common bacteria isolated were Methicillin resistant *Staphylococcus aureus* (MRSA) and *Pseudomonas aeroginosa.*

According to the uni-variable analysis, the factors that were found to have an association with SSI, were the weight of the patient, the type of surgery, repeat surgery, sex and reproductive state and hospitalization time. The logistic regression test found that the patient's weight, repeat surgery, type of surgery and sex and reproductive state of the patient had a direct effect on the development of SSI.

INTRODUCTION

Post-operative surgical site infections (SSIs) are a common problem in equine surgery and can cause considerable complications during recovery, raise morbidity and mortality of the patients, lengthen duration of hospitalization, delay return to function and increase client costs. Furthermore, infections involving drug resistant pathogens can make treatment quite challenging (1). The effects of these infections can be devastating. For example, in orthopedic procedures infections can cause fatal complications such as contra-lateral-limb-laminitis, even after seemingly successful internal fixation, and in celiotomies SSI markedly increase the risk for incisional hernia and can even lead to fatal evisceration (1, 2, 3). In some studies, horses suffering from incisional complications during recovery from celiotomies were up to 62 times more likely to develop incisional hernias, which have been reported to decrease patient survival (4, 5, 6). When looking at long-term complications after colic surgery, horses which suffered from incisional complications were more likely to develop adhesions (7). In addition to purely clinical considerations, the financial implications associated with an extended period of hospitalization and additional specific treatments that include abdominal bandages can also negatively affect the fate of the patient (8). All this demonstrates a dire need to broaden our knowledge regarding the development of post-operative SSIs, in order to find ways to avoid them as much as possible.

Although there is a theory that the most effective window of opportunity to prevent infections is during the actual surgery (9), several equine studies suggest that the period for acquiring infections occurs after abdominal closure. One study found that infections tended to occur in horses which had significant bacterial growth after recovery and 24 hours post-surgery (8). In an equine prospective study bacterial culture of the incision during surgery was not predictive of SSI (10). Furthermore, bacterial contamination during recovery from anesthesia was found to increase the risk for SSI. Horses who did not recover well from anesthesia were 4 times more likely to develop infections than horses with a good quality of anesthesia recovery (1, 11).

The incidence of post-operative infections is also dependent on the type of surgical procedure. Previous studies in horses found that the incidence of infection in arthroscopic surgery is 0.9%, while in abdominal procedures it is between 7.4-37% and 0-17% in laryngoplasty procedures (2, 12, 13). Furthermore, different factors were found to affect the incidence of infection that was observed for each type of procedure. In arthroscopies, the breed of the horse, the removed fragment size and the joint involved in the procedure were found to be the only significant risk factors (14, 15). In general, for orthopedic procedures, an overall frequency of infections of 10% was reported. Clean-contaminated procedures increased the risk for infection by 24 times than clean procedures, and females were twice more likely to develop infection than males (16)PB Fretz </author></subsidiary-authors></contributors><titles><title>An examination of the occurrence of surgical wound infection following equine orthopedic surgery (1981-1990. Another study found more incisional complications in emergency procedures compared to elective ones (17). In abdominal procedures, horses that had a repeat laparotomy had twice higher incidence of incisional complications than those that underwent one laparotomy (18). Both enterotomy or resection & anastomosis procedures, which increase the risk for bacterial contamination, surprisingly did not increase the risk for SSI (4, 17). Nonetheless, not all risk factors are consistent between studies, highlighting the need for individual hospitals to study their own surgical populations (1).

While the major bacterial populations in post-operative SSIs can differ for every individual hospital, these include *Enterobacteriaceae*, *Streptococcus* spp., *Staphylococcus* spp., *Pseudomonas* spp., and anaerobes such as *Bacteroides* spp. *Staphylococcus aureus,* that is the most common musculoskeletal pathogen of human beings and animals, has been reported to be responsible for almost 20% of equine orthopedic infections (19). The involvement of multi-drug-resistant (MDR) bacterial species such as Methicillin Resistant *Staphylococcus Aureus* (MRSA) has become more common over the past years, and as such sampling SSI for culture and sensitivity has become more crucial than before (19, 20).

There is a dearth of studies evaluating SSI at the hospital level, not limited to a specific type of procedure, actually most of the relevant studies have specifically reported on abdominal procedures alone (1, 2, 4, 5, 7, 8,10, 11, 17, 21, 22,).

The present study was aimed to prospectively evaluate the post-operative SSI incidence that occurred in a large equine population in a veterinary teaching hospital in order to find possible risk factors involved in the development of these infections along with determining the common bacterial species involved.

RESEARCH METHODS AND DESIGN

The study was designed as a retrospective study in a referral hospital population (Koret School of Veterinary medicine, Department of Large Animal Medicine and Surgery). The sample size that underwent the surgical procedures included 196 surgical procedures carried out on 167 equids, between November 2011 and February 2013.

Procedures that ended or terminated with the death of the patient less than a week after surgery and did not show any signs of SSI were excluded from the study. This criterion was decided based on the assumption that early clinical signs of SSI may take a week to appear.

Infections were diagnosed based on the following parameters – swelling, heat, pain, drainage and in some cases positive culture.

The following parameters were analyzed as potential risk factors for SSI – type of surgery, procedures performed on an infected structure, the surgeon performing the procedure, age, weight, sex and breed of the animal, duration of the surgery, time of day and the season in which the surgery was performed, duration of hospitalization before and after the surgery and the bacterial population cultured from the infections. All procedures were divided into 3 categories: orthopedic, abdominal, and other.

In horses over a year old, the sex of the animal was divided into 4 categories of reproductive state: stallion, gelding, female, and pregnant female.

The season was defined by the month in which the procedure took place. Winter included December – February, spring included March – May, summer was defined as June – August, and fall as September – November. Regarding abdominal surgeries, no distinction was made between enterotomies, resection and anastomosis.

Data collected from the medical records of all horses that were included in this study. A repeat surgery was defined as a consecutive surgery carried out on the same patient 6 months or less from the previous surgery, using the same incision or a nearby approach to the previous incision.

Surgeries performed between 8:00 in the morning and 20:00 in the evening were defined as day surgeries. Surgeries performed between 20:00 until 8:00 in the morning were defined as night surgeries. The hospitalization of the patients was divided into two periods: the number of days from admittance to the hospital until the procedure was performed, and the number of days the patient stayed at the hospital after the procedure. The main team of veterinary surgeons in the large animal department includes a certified specialist of equine surgery (surgeon 1), and 3 residents specializing in equine surgery (surgeons 2-4). A few of the emergency procedures at night were performed by a certified specialist of small animal surgery (surgeon 5). For most procedures, 2-3 surgeons were present. At night, procedures were usually performed by one surgeon.

Statistical Methods

Fisher's exact test was used to test the relations between the categorical variables. T test was used to compare quantitative variable groups. Mann–Whitney test was used when the group size was too small. A logistic regression model was used to simultaneously test the effect of individual variables found to influence SSI rate. The model was carried out in the step-wise method and from this model the significance, odds ratio and its confidence interval were calculated. All the statistical tests were bidirectional and a P value of 0.05 or less was considered statistically significant.

Since the study was a retrospective in nature and no interventions other than the routine surgeries as clinically indicated, no owner's permission was granted for inclusion in the study.

RESULTS

The general incidence of SSI during the study period was 17.86%, as 35 procedures out of the 196 procedures included in this study developed an infection.

Season of Surgery (Supplemental Information Table 1)

No significant association was found between the incidence of SSI during the winter (20%), spring (20%), summer (13.5%), or fall (11.6%) (P = 0.567).

Types of surgery (Table 1)

Abdominal procedures were the most common, and included a total of 78 procedures, 65 orthopedic procedures were carried out, and the other procedures were 55 in total. The incidence of infection was significantly higher in abdominal procedures (28.2%) than in orthopedic (12.3%) and in other (5.5%) procedures, (P = 0.001).

Opening the gastrointestinal (GI) tract (Supplemental Information Table 1)

Most abdominal procedures did include an opening of the GI tract (54 cases, 69%), while in 24 (31%) procedures no entry into the GI tract was made. There was no significant statistical difference between the cases in which the GI tract was opened (29.6%) and the cases in which it was not (25%) (P = 0.761).

Repeat surgeries (Supplemental Information Table 1)

A total of 21 repeat surgeries were performed during the study period. The incidence of infection in repeat surgeries (38.1%) was significantly higher than the incidence of infection in first/single surgeries (14.1%) (P = 0.011).

Emergency and elective surgeries (Supplemental Information Table 1)

Overall, 61 (31%) surgeries were defined as elective procedures, while 136 (69%), were emergencies. No significant difference was found between the incidence of infection in elective procedures (9.8%) and emergency procedures (19.1%) (P = 0.102).

Time of surgery (Supplemental Information Table 1)

Overall, 152 (81.3%) surgeries were performed during the day, while 35 (18.7%) surgeries were performed during the night, there were 11 surgeries for which the documentation of the time of surgery was missing. No significant difference was found between the incidence of infection in day surgeries (16.4%) and the incidence of infection in night surgeries (14.3%) (P = 0.753).

Breed (Supplemental Information Table 1)

One-hundred-and-sixty-three (84.9%) procedures were performed on purebred horses and 31 (15.1%) procedures were performed on mixed breed horses. The most common breeds were Arabians (33.8%), and Quarter horses (16.7%). Other breeds in the study included Tennessee walkers (9.6%), Thoroughbreds (5.1%), Frisians (4.5%), Holsteins (3.5%), Missouri Fox Trotters (2.5%), and Ponies (2.5%).

The incidence of infection in purebred horses (16.6%) and mixed breed horses (16.1%) was almost identical (P = 0.952).

Table 1: Association of categorical variables with surgical site infection.

Variable		Frequency	Incidence of infection	*P* value
Season	Summer	22.7% (45)	13.3% (6)	0.567
	Fall	21.7% (43)	11.6% (5)	
	Winter	37.9% (75)	20% (15)	
	Spring	17.7% (35)	20% (7)	
Surgery Type	Abdominal[(A)]	39.4% (78)	28.2% (22)	**<0.001**
	Orthopaedic[(B)]	32.8% (65)	12.3% (8)	
	Other[(C)]	27.8% (55)	5.5% (3)	
Enterotomy/R&A (abdominal procedures only)	Executed	69.2% (54)	29.6% (16)	0.675
	Not executed	30.8% (24)	25% (6)	
Repeated Procedures	Repeat surgery[(A)]	10.6% (21)	38.1%(8)	**<0.011**
	First/only surgery[(B)]	89.4% (177)	14.1% (25)	
Electivity	Elective	31% (61)	9.8% (6)	0.102
	Emergency	69% (136)	19.1% (26)	
	Missing	1 (197)		
Time	Day	81.3% (152)	16.4% (25)	0.753
	Night	18.7% (35)	14.3% (5)	
	Missing	11 (187)		
Breed	Pure	82.3% (163)	16.6% (27)	0.952
	Mix	17.7% (31)	16.1% (5)	
Common breeds	Arabic	33.8% (67)	16.4% (11)	0.936
	Quarter	16.7% (33)	15.2% (5)	
	Tennessee	9.6% (19)	15.8% (3)	
	Thoroughbred	5.1% (10)	10% (1)	
Sex (1 year and older)	Stallion[(A)]	22.2% (44)	2.3% (1)	**<0.001**
	Castrated male[(B)]	15.6% (31)	16.1% (5)	
	Female[(C)]	38.8% (77)	23.4% (18)	
	Pregnant female[(D)]	5% (10)	50% (5)	
	Total	162		
Anaesthesia	Recumbency	88.4% (175)	17.7% (31)	0.537[(a)]
	Standing	10.1% (20)	10% (2)	
	Missing	3 (195)		
Surgical environment	Infected structure	28.3% (34)	8.8% (3)	0.934
	Clean	71.6% (86)	9.3% (8)	
Total Procedures		100% (198)	16.7% (35)	

The frequencies were calculated using the total procedures of each category, while procedures with missing data were not included.
Quantitative values are presented in parenthesis.
"Missing data" presents the number of missing data items for each category. The total data items recorded for the category are presented in parenthesis.
P ≤ 0.05 is considered as a significant connection and is bolded.
[a] represents P calculated by Fisher's test rather than Pearson's test due to a small sample size.

There was no significant difference in the incidence of infection between the different pure breeds (P = 0.936).

Sex (Supplemental Information Table 1)

Overall, 92 of the procedures were performed on males and 106 were performed on females. Of those, 44 (22.2%) procedures were performed on stallions, 31 (15.6%) on castrated males, 77 (38.8%) on non-pregnant females, and 10 (5%) on pregnant females.

The incidence of infection in stallions (2.3%) was significantly lower than the other sex groups, while pregnant females (50%) had the highest incidence of infection (P < 0.001). The incidence of infection in non-pregnant females (24.3%) was not significantly different from the incidence in castrated males (16.1%) (P = 0.87).

Anesthesia (Supplemental Information Table 1)

Overall, 20 (10.1%) procedures were performed under sedation on a standing horse, and 175 (88.4%) performed under general anesthesia. There was no significant difference in the incidence of infection between procedures performed under sedation (10%) and procedures performed under general anesthesia (17.7%) (P = 0.537).

Infected anatomical structure (Supplemental Information Table 1)

Eighty-six (71.8%) surgeries were considered to be clean or clean-contaminated procedures. Thirty-four (28.3%) procedures were performed on an organ/anatomical-structure that due to medical circumstances (such as a joint-penetrating injury) was considered to be infected, or was proven to be infected after the surgery by a bacterial culture. The incidence of SSI in procedures performed on an infected structure (8.8%) was not significantly different from the incidence of infection in clean procedures (9.3%) (P = 0.934).

Table 1: Significant risk factors by Logistic Regression

This table describes the significant variables that were found to influence the incidence of infection by a logistic regression test.
The logistic regression test included all variables that were found significant by the Pearson's test.

Variable		OR	*P*
Weight		1.04	0.043
Repeat Surgery		5.95	0.005
Sex	Stallion	1	0.008
	Castrated male	3.79	
	Female	3.9	
	Pregnant female	22.5	

OR - Odds Ratio
P ≤ 0.05 was considered significant.

Age (Supplemental Information Table 2)

The patients' ages ranged between a few hours to 21 years. The mean age was 6.4 years old, and the median was 5 years old. No significant difference was found between the average age of horses that developed an infection (7.6 years) and the average age of the horses that did not develop an infection (6.2 years) (P = 0.175). In addition, there was no significant difference between the age medians of the cases that developed an infection (7 years) and the cases that did not (4 years) (P = 0.175).

Weight (Supplemental Information Table 2)

The range of the patients' body weight was wide (30-653 kg). The average weight was 361.9 kg, and the median was 400 kg. The average weight of the cases that developed an infection (427.5 kg) is almost 80 kg higher than the average weight of the cases that did not develop an infection (349.4 kg) (P = 0.021). Accordingly, the medians also show a significant difference, as the median of the cases that developed an infection (430 kg) was 30 kg higher than the median of the cases that did not develop an infection (400 kg) (P = 0.02).

Duration of surgery (Supplemental Information Table 2)

In total, 174 procedures had a record of the duration of the surgery. The range of procedure duration was wide (1-8 hours), while the average was 2.4 hours and the median was 2 hours. The average duration of procedures that did not develop an infection (2.3 hours) was not different than the duration of procedures that did develop an infection (2.7 hours) (P = 0.11). Similarly, the median of procedures with no infection (2 hours) was not different than the median of procedures that developed an infection (2.3 hours) (P = 0.32).

Duration of hospitalization (Supplemental Information Table 2)

There was a wide range of hospitalization days before the surgery (0-91 days) and after the surgery (0-138 days). Generally, patients were hospitalized an average of three days before the procedure and were released an average of 10 days after the procedure.

When observing the average duration of hospitalization before the surgery, no significant difference was found between procedures that did not develop an infection (three days) and procedures that did (2.2 days). Similarly, the medians of pre-surgical hospitalization times were identical between infected and non-infected cases (one day) ($P = 0.62$). The average hospitalization time after the surgery for procedures that developed an infection (21 days) was significantly longer than the average hospitalization time for procedures that did not develop an infection (eight days) ($P = 0.01$). The median of procedures that developed an infection (10 days) was also significantly longer than the median of procedures that did not (six days) ($P = 0.01$).

Surgeons (Supplemental Information Table 3)

There was no significant difference in the incidence of infection found when a particular surgeon was present in the surgery in comparison to when a particular surgeon was absent. There is also no significant difference in the incidence of infection between the different surgeons.

Logistic regression analysis of risk factors (Table 1)

In order to analyze causativeness, a multi-factorial logistic regression test was performed. This test included all the variables with a significant association with SSI (surgery type, weight, repeat surgery and sex).

Repeat surgery and sex were found to be the variables that affect the incidence of SSI. The risk for developing an infection in a repeated surgery was 5.67 times higher than a first/single surgery. The risk for developing an infection is 3.79 times higher for a castrated male than for a stallion, 3.9 times higher for a female, and 22.5 times higher for a pregnant female. The risk for developing an infection increases with the increasing weight of the patients ($P = 0.021$). When all procedures were included, the surgery type was also found to be a variable that affects the incidence of infection

Table 2: Association of continuous variables with surgical site infection.

		Age (years)	Weight$^{(A)}$ (kg)	Duration of surgery (hours)	Hospitalization before (days)	Hospitalization after$^{(B)}$ (days)
Average	General	6.4	361.91	2.39	2.84	10.45
	No infection	6.19	349.4	2.32	2.98	3.38
	Infection	7.63	427.48	2.73	2.16	20.97
Median	General	5	400	2	1	6
	No infection	4	400	2	1	6
	Infection	7	430	2.3	1	10
Standard Deviation	General	5.57	168.13	1.21	8.48	15.74
	No infection	5.64	169.67	1.18	9.18	11.59
	Infection	5.11	145.55	1.35	2.87	26.61
Range	General	0.01-21	30-653	1-8	0-91	0-138
	No infection	0.01-21	30-653	1-8	0-91	0-115
	Infection	0.05-20	40-650	1-7	0-12	2-138
P value		0.175	0.021	0.11	0.62	0.01

$P \leq 0.05$ is considered as a significant correlation (marked in parenthesis).

Table 3: Association of surgeon with surgical site infection.

		Surgeon 1	Surgeon 2	Surgeon 3	Surgeon 4	Surgeon 5	Surgeon 6
General participation		57.1% (113)	56.6% (112)	57.6% (114)	21.2% (42)	6.1% (12)	2% (4)
Incidence of Infection	**Present**	16.8% (19)	16.1% (18)	16.7% (19)	19% (8)	0% (0)	50% (2)
	Absent	15.5% (13)	16.5% (14)	15.7% (13)	15.5% (24)	17.5% (33)	50% (2)
P value		0.8	0.94	0.85	0.58	0.11	0.13

The participation and the incidence of infection is described as a percentage, and the numerical values are written in parenthesis
Two - three surgeons participated in most of the procedures
$P \leq 0.05$ is considered as a significant statistical difference.

(P = 0.001). While orthopedic surgeries are just as likely to develop an infection as other surgeries, abdominal procedures are 3.71 times more likely to develop an infection (P = 0.029).

Bacteria (Supplemental Information Table 4)

Overall, 19 cultures, out of the 35 SSI cases, were sent to a culture and sensitivity test. Due to the small sample size, no statistical analysis was performed, but it should be noted that 15 out of the 19 cultures sent (79%) yielded positive results. The most common bacterial isolate, found in six of the cultures, was MRSA. MRSA cultures were not unique to a particular surgeon, but mostly appeared in procedures in which surgeon two was present (4/6). Other than MRSA, no other resistant bacteria strains were found. The second most common bacterial isolate was Pseudomonas aeruginosa, which appeared in four cultures. The third most common bacteria was *Escherichia coli* (E. *coli*) which appeared in three cultures. The remaining bacterial isolates, most of them appearing in only one culture, are described in aforementioned table. Five of the positive cultures had growth of multiple isolates. In one wound highly resistant *Acinetobacter baumonii* was cultured.

Table 4: The bacteria isolated from the surgical site infection.

Bacteria	Positive Cultures
MRSA	31.6% (6)
Pseudomonas aeroginoasa	21.1% (4)
E. Coli	15.8% (3)
Klebsiella pneumoniae	10.5% (2)
Enetrobacter aerogenes	5.3% (1)
Enterobacter colacae	5.3% (1)
Staphylococcus schleiferischleiferi	5.3% (1)
Gram-negative rod non-fermented species	5.3% (1)
Staphylococcus intermedius	5.3% (1)
Streptococcus equi	5.3% (1)
Cedecealapagei	5.3% (1)
Enterococcus faccium	5.3% (1)
Actinobacillusequulihaemolticusa	5.3% (1)
Actinobacterbaumaniihaemolyticus	5.3% (1)
No growth	21.1% (4)
Total positive cultures	78.9% (15)
Total cultures taken	19

- The frequency of positive cultures for a certain bacteria is described as a percentage.
- The numerical value of the amount of positive cultures is described in parenthesis.

DISCUSSION

This study analyzed a wide range of factors that might be involved in the development of post-operative SSI in horses. According to the univariable analysis, the factors that were found to have an association with SSI, were the weight of the patient, the type of surgery, repeat surgery, sex and reproductive state, and hospitalization time after the surgery. The logistic regression test performed on these factors, found that the patient's weight, repeat surgery, type of surgery, and sex and reproductive state of the patient had a direct effect on the development of SSI.

In the current study, 16.7% of all the procedures developed an SSI. When looking at previous studies on SSI in horses, each study concentrated on one type of surgery. There are multiple studies on SSI of abdominal surgeries, arthroscopies, fracture repair, certain upper airway procedures (1-5, 7, 8, 12, 13, 16, 17, 22). Nevertheless, we could not find a single study that analyzes the general incidence of infection on all procedures that were performed in a specific equine medical center, as in the present study. In light of the significant difference between the incidences of infection of different types of procedures, the general incidence of infection is likely to be affected by the proportion of the different types of procedures performed during the study. If, in a certain time-period, a larger proportion of abdominal procedures were performed, it is likely that the general incidence of infection will be higher, thus giving a misleading impression about the likelihood of occurrence of SSI in that medical institution.

Combining results from different studies concentrating on either abdominal, orthopaedic or laryngoplasty procedures (3, 12, 16, 18, 19, 23, 24), and when the total number of surgeries includes 40% abdominal, 30% orthopaedic and 30% other procedures (as in this study), it is plausible to expect a general SSI of 9-20%. The general incidence of infection in this study (16.7%) falls within this expected range of values.

The fact that no significant association was found between the seasons the surgery was performed and SSI is reasonable given the moderate climate in Israel. In contrast, a recent study from the United Kingdom found SSI to be more prevalent in the winter and summer seasons (6).

Although this study found abdominal procedures to have a higher risk for infections than other types of procedures

(28%), it is well within the reported range of abdominal SSI incidence (7%-37%) (2). Several factors may be contributing to the increased incidence of SSI in abdominal surgeries. In abdominal procedures, the incision carries a lot of weight, and so the tension on the sutures is high, in addition, abdominal incisions are usually long and the length of an incision was found to have an effect on the occurrence of SSI (21). Also, most abdominal procedures are emergency procedures, while the remainder of the surgeries are mostly elective. Although this study did not find emergency procedures to have a significantly higher risk for infections, the rate of SSI in emergency procedures nearly doubled that of routine procedures (19% vs. 10%, P = 0.1). Previous studies did find a significant association between emergency procedures and a higher incidence of infection (17, 25).

Another factor that could potentially raise the risk for an infection in abdominal procedures is performing an enterotomy or a resection and anastomosis, since the procedure is then contaminated. Surprisingly, in this study, and in most previous studies, no significant association was found between these procedures and post-operative SSI (4, 17). It appears that current meticulous surgical techniques used in these types of procedures, provide adequate protection to the incision. In contrast, a recent study by Isgern *et al.* (2016) found association between SSI occurrence and resection and anastomosis (10).

Consistent with previous studies, repeated surgery increased the risk of developing an SSI (4). However, previous studies mostly looked at abdominal procedures performed within approximately 2 weeks from the original surgery, while this study included all types of procedures and within a period of 6 months. Most of the repeated procedures, in the current study, were orthopedic. In any event, when the need arises to perform a repeat procedure 6 months or less from the previous procedure, it must be considered that the possibility for developing an SSI is higher requiring that the owners be informed accordingly.

The time of day in which the surgery was performed is a variable that has not been analyzed in previous studies in horses, and in the current study, it did not have an effect in the rate of SSI. This variable can be specific to each individual medical facility and its method of operation. This parameter if of great practical importance, as a difference between day and night surgeries may indicate a need to change the method of operation in the facility. This study found no difference in the incidence of infections between day and night. Thus, it is reasonable to conclude that the format of operation, such as aseptic preparation by the technicians, proper tissue management by the surgeons and the patient recovery from the anesthesia, is performed in an acceptable manner after hours, and therefore not increasing the risk for SSI.

The breed of the horse did not have a significant association with the incidence of infection, while previous studies show contradictory results regarding this variable. Some studies did not find an association between the breed of the horse and incisional complications, while others found complications that are more incisional in certain breeds such as thoroughbreds and quarter horses (4, 17, 26).

Pregnant mares were found to have the highest incidence of infection, in the current study, while stallions had the lowest, and non-pregnant females had a slightly but significantly higher incidence of infection than geldings. Some studies, consistent with this study, found that the risk for SSI is higher in females (16)PB Fretz </author></subsidiary-authors></contributors><titles><title>An examination of the occurrence of surgical wound infection following equine orthopedic surgery (1981-1990, some found a higher tendency for SSI in geldings (17), while others found no association at all between SSI and gender (22). We found no other study that observed the association between pregnancy and SSI, and there is a slight chance that this difference is not real but influenced by the small number of pregnant mares in the study. However, in this study pregnant mares were highly more likely to suffer from SSI and this difference remained significant using logistic regression as well.

According to the current study, pregnant female is about 5.5 times more likely to suffer from SSI than non-pregnant female. This has several potential explanations: In pregnancy, changes in blood flow distribution occur, which changes the perfusion to different tissues and as such might lead to a lower oxygenation state at the site of the surgery. In addition, hormonal changes, as well as the physiological burden of carrying the fetus, can weaken the immune system and thus lower the bacterial inoculum needed to establish an infection. In addition, the sheer physical load on the abdomen wall can cause more stress on the sutures and incision in abdominal procedures. Thus, whenever possible, elective procedures in pregnant mares, should be postponed until after parturition. Another interesting issue is the low SSI rate in stallions.

Studies in different animals indicate the effect of sex hormones and the differences between males and females in the function of the immune system (24, 27). In addition, there is evidence that testosterone might have a protective role in certain infectious diseases in horses (28).

There was no difference in the incidence of infection between standing procedures performed under sedation and procedures performed under general anesthesia. However, it is quite possible that no significant difference was found, because there were only few standing procedures and a larger sample might have shown significant difference.

Surprisingly, performing a procedure on a clean or infected anatomical structure was not associated with the incidence of infection in this study. When an infected structure is involved in the surgery, it is reasonable to assume that the risk for SSI increases. Some previous studies contradicted these results, and others partially support them (16, 17)PB Fretz </author></subsidiary-authors></contributors><titles><title>An examination of the occurrence of surgical wound infection following equine orthopedic surgery (1981-1990.

No significant association between SSIs and the age of the patient was found. Previous studies, however, did find an association between the patient's age and the likelihood of developing SSI. Foals and younger horses showed less incisional complications than mature and geriatric horses, while no difference was found between mature and geriatric horses (17, 21). It is possible that the small sample size caused the lack of a significant difference in the current study.

Consistent with previous studies, this study found a positive and significant association between the patients' weight and the incidence of infection, with heavier patients exhibiting a higher incidence of infection (17, 21). The body weight was one of the few factors that were not only found significant in the univariable analysis but in the logistic regression as well. Heavier weight means higher stress on the incision in abdominal procedures and it is likely to have a negative effect on healing.

This study did not find a significant association between the duration of the surgery to the incidence of infection, however, longer surgeries did seem to suffer more SSI but that association was not significant (P = 0.11). Previous studies showed contradicting results regarding this variable (10, 16, 17, 21). However, most studies support that procedures lasting over 90-120 minutes have a higher infection rate than shorter procedures. Longer procedure increases the risk of airborne bacterial contamination, as well as contamination from the surgical team and instruments. Additionally, a longer procedure means a longer anesthesia which can cause hypovolemia, hypoxia and an inadequate tissue perfusion, all factors found to support the development of infections (9, 23, 19). Furthermore, longer procedures are usually more complicated, or have to do with a more serious illness, both factors can encourage infection. Even though this study did not find a significant association between surgery duration and infection, it is reasonable to assume that increasing the sample size and the variability of surgery duration (including more short procedures) may lead to finding this association.

Similar to results from a previous study, duration of hospitalization after the surgery had a significant association with SSIs (11), however it is logical to assume that this is because SSIs lengthens the duration of hospitalization. The need to medically treat the infection and accompanied complications, such as dehiscence (5, 10), delay the release from the hospital. This emphasizes another aspect in the importance of the prevention of SSIs, as a longer period of hospitalization and a more complicated treatment means higher financial expenses to the hospital and the owner.

This study did not find an association between the presence of a specific surgeon in the procedure and the incidence of infection. Previous studies show diverse results. Some did not find an association between the veterinary surgeons and their level of expertise to the incidence of infection, while some found that procedures performed by expert surgeons had less SSIs than procedures performed by the residents (17, 22).

Only half of the cases that developed an infection were sampled for culture and sensitivity. The small sample size is due to different reasons including: lack of compliance of the owners, the development of SSI after release from the hospital, budget limitations, or an infection that resolved with an empiric antibiotic treatment.

Eighty percent of the samples (15/19) sent for culture had growth. This result shows a successful recognition of infections, as the described range of positive cultures taken from infected wounds is 44-88% (10, 22). The most common bacteria found was MRSA. In 2010 an outbreak of a specific strain of MRSA was documented in our hospital, affecting both personnel and horses. After taking therapeutic and preventative measures, the outbreak seemed to be under control

(29). The results of this study imply that MRSA is still a clinical problem and continuation of testing and prevention is indicated. Previous studies found hospital environment as the main source of MRSA infection, but it can just as well be from the regular living environment of the animal (20). During the mentioned outbreak, horse ranches were also tested for carriers, and none were found, therefore signifying the need to focus on eliminating MRSA from the hospital personnel and patients. The results of the current study emphasize the importance of investigating this subject further.

This study investigated a wide variety of factors that could influence the incidence of SSI in a variety of different procedures, some were factors that have not been previously investigated. One of the study limitations is the small number of cases in some of these variable categories that makes it difficult to reach conclusions. In order to investigate these associations further, a larger multicentric study needs to be carried out, and as such increase the sample size. Another limitation of the current study is that consistent follow-up on released patients was not performed and documented.

Further larger studies on this subject, will help to deepen the understanding of this important subject in the future. In addition, the study was initiated in 2011 and thus some of the surgical techniques, bacterial population and resistance patterns may have changed since then, and contemporary studies gathering relevant, up to date, information are indicated.

In conclusion, the incidence of SSI in this VTH falls within the expected range, according to previous studies on the subject. The risk for developing an infection is higher in abdominal procedures, repeat surgeries, heavier weight, and especially in pregnant females. In addition, the relative prevalence of MRSA raises questions about contamination in the hospital and implies that there is a need to routinely monitor and take preventative measures to limit the spread of these bacteria.

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