

# Comparison of laparoscopic versus conventional open cryptorchidectomies on intraoperative and postoperative complications and duration of surgery, anesthesia, and hospital stay in horses

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**Objective**—To compare surgical preparation time, surgery and anesthesia times, hospitalization duration, and intra- and postoperative complications between laparoscopic and conventional open cryptorchidectomy in horses.

**Design**—Retrospective cohort study.

**Animals**—60 horses that underwent cryptorchidectomy.

**Procedures**—Medical records were reviewed to identify horses that had undergone cryptorchidectomy from 1991 to 2012. Thirty horses that underwent laparoscopic cryptorchidectomy (case horses) were matched with 30 control horses that had undergone open cryptorchidectomy (ie, inguinal and parainguinal surgical approaches). Horses were matched according to history of previous surgery, testicle location, and type of closure following removal of an undescended unilateral testicle. Duration of surgery, surgical preparation and anesthesia times, hospitalization duration, and number of intra- and postoperative complications were compared between horses that underwent laparoscopic cryptorchidectomy versus open cryptorchidectomy. Comparisons were also made between horses in terms of whether there was a history of previous failed cryptorchidectomy or unknown location of testicle prior to surgery.

**Results**—Horses that underwent laparoscopic cryptorchidectomy had significantly longer surgery and anesthesia times overall, compared with horses that underwent open cryptorchidectomy. No difference in surgery time was found between case and control horses that had a previous surgical attempt to remove an undescended testicle or in which the testicle location was unknown prior to surgery. Overall, horses undergoing laparoscopy had a non-significant increase in intraoperative complications, compared with control horses, and had significantly more postoperative complications.

**Conclusions and Clinical Relevance**—Horses undergoing laparoscopic cryptorchidectomy had increased surgical preparation time, increased surgery and anesthesia times, and more postoperative complications, compared with horses undergoing open cryptorchidectomy. Laparoscopy may be advantageous for a second attempt at cryptorchidectomy or if the testicle location is unknown prior to surgery. (*J Am Vet Med Assoc* 2015;246:885–892)

Laparoscopy, a type of minimally invasive surgery, has been performed by equine surgeons for approximately 15 to 20 years.<sup>1</sup> Proposed advantages of laparoscopy in horses include superior visual field, less surgical morbidity, and shorter convalescence.<sup>2</sup> A number of authors have extolled the benefits of laparoscopy in different surgical situations,<sup>3–6</sup> although intraoperative complications were also reported.<sup>7–9</sup> It has been acknowledged that disadvantages of laparoscopy include expense of equipment and necessity of familiarity with laparoscopic equipment and techniques, and anecdotally such disadvantages outweighed the benefits for some surgeons.<sup>10</sup> We specu-

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## ABBREVIATION

IQR Interquartile range

late that this may particularly be the case in procedures such as cryptorchidectomy, whereby surgeons may consider little need to learn a laparoscopic technique for surgeries that can usually be straightforwardly performed in horses.

Several nonlaparoscopic surgical approaches for cryptorchid castration have been described including noninvasive inguinal and parainguinal approaches as well as invasive suprapubic paramedian or flank approaches.<sup>10</sup> Inguinal and parainguinal approaches have previously been determined to be superior to suprapubic paramedian or flank approaches.<sup>11</sup>

Previous reviews of conventional open cryptorchidectomies have revealed an overall complication rate of 7.55% to 12.3% in horses.<sup>11,12</sup> Laparoscopic surgery has become an accepted method of cryptorchidectomy,<sup>13</sup> and 1 review of laparoscopic cryptorchidectomies

revealed a complication rate of only 1.0%.<sup>14</sup> Comparison of those reports would suggest that laparoscopy might be the safer alternative for cryptorchidectomy in horses. However, a meaningful comparison should only be made when between horses with similar clinical situations. To our knowledge, no previous study has compared intraoperative and postoperative surgical variables between a standard conventional open cryptorchidectomy and its laparoscopic equivalent in horses.

Cryptorchidectomy was considered to be an appropriate surgery to use for a comparison of surgical techniques because cryptorchidism is a common condition,<sup>15</sup> allowing optimal numbers of cases for study, and is an accepted laparoscopic procedure.

Therefore, the objectives of the study reported here were to compare preoperative surgical preparation, surgery, and anesthesia times and duration of hospital stay as well as the occurrence of intra- and postoperative complications between laparoscopic cryptorchidectomy and conventional open cryptorchidectomy in horses and to conduct the comparisons with the data subdivided into categories of first or second surgery as well as known and unknown testicular location prior to surgery. For the purposes of the present study, a conventional surgery was defined as an accepted approach for open surgical removal of an undescended testicle, which included inguinal and parainguinal approaches.<sup>10</sup> We hypothesized that for horses undergoing laparoscopic cryptorchidectomy, the surgery time would be faster, there would be fewer intraoperative and postoperative complications, and the duration of the hospital stay would be shorter, compared with that of horses undergoing conventional cryptorchidectomy.

## Materials and Methods

**Case selection**—A review of the medical records of all horses that underwent a cryptorchidectomy under general anesthesia at the Ontario Veterinary College was conducted. A convenience sample of all horses that had undergone laparoscopic removal of 1 or more undescended testicles was selected. Horses in which the testicle was identified and grasped laparoscopically but removed by extra-abdominal ligation were also included. These case horses were matched according to predetermined criteria with 1 other horse, as a control, that had undergone routine conventional cryptorchidectomy for removal of 1 or more undescended testicles. The period during which case and control horses were admitted to the hospital ranged from January 1, 2000, and January 1, 1991, respectively, to January 1, 2012. The hospital admission dates of the case horses corresponded with the year laparoscopic equipment was first available for cryptorchidectomy in our hospital. The sample size was driven by the number of available records for case horses.

**Medical records review**—In all matched case and control horses, the history of any previous attempt at castration including specifically whether surgery had been performed on the undescended testicle, the presence of information dictating the side on which the undescended testicle was located prior to surgery (including information obtained from history, rectal pal-

pation, preoperative ultrasonographic examination, and presence of scar tissue), the number and location of testicles removed at surgery (abdominal, partial abdominal, inguinal, scrotal), and the type of closure performed on the contralateral descended testicle (primary closure, partial closure, or no closure for second intention healing) were to be the same. Attempts were then made to match horses in the following order: according to age, breed, and whether the same surgeon performed both surgeries in the same year. Horses were excluded if testicular disease was present or if a suitable match between a case horse and control horse could not be made.

An overall comparison between all matched pairs of horses was performed, and a comparison between matched pairs according to whether the surgery was the first or second attempt at cryptorchidectomy and knowledge of location of undescended testicle prior to surgery was performed. Included within the group of pairs that were undergoing an attempt at cryptorchidectomy for a second time were those horses that had been misrepresented as geldings at the time of purchase. The rationale behind this categorization was to determine whether laparoscopy was advantageous overall or only in specific situations determined by history.

Duration of surgery was defined as the time from the first incision to removing the sterile drapes. Duration of anesthesia was defined as the time from anesthetic induction to exit of the horse from the operating room to the recovery stall. Surgical preparation time was counted as time of anesthetic induction to first incision, which would include positioning, surgical skin preparation, and draping. All horses included in the study had hair clipped in the surgical site under general anesthesia and not prior.

All cryptorchidectomies were performed with horses under inhalation anesthesia with isoflurane or halothane. In all control horses that underwent conventional open cryptorchidectomy, an inguinal approach, as described elsewhere,<sup>10</sup> was performed initially to remove the undescended testicle. In brief, the superficial inguinal ring was exposed by a skin incision directly overlying it and blunt dissection of the inguinal fascia. Through this approach, either an inguinal testicle was identified or the inguinal extension of the gubernaculum testis was identified leading to the abdominal testicle. For horses undergoing laparoscopy, retained testicles were removed by extracorporeal ligating loops,<sup>a</sup> a handheld electrosurgery device,<sup>b</sup> extra-abdominal ligation, and bipolar cautery.

Details of surgical approach and intraoperative complications were obtained from the surgical report. An intraoperative complication was defined as a situation in surgery that was not part of the initial surgical plan and was recorded as a dichotomous variable (present vs absent) for statistical analysis. Intraoperative complications included direct surgical complications such as excessive hemorrhage, equipment malfunctions, and poor visual field. Conversion of a laparoscopic surgery to a laparoscopic-assisted surgery with extra-abdominal ligation of the testicle or an open conventional surgery was included as an intraoperative complication. Similarly, for conventionally performed

cryptorchidectomies, the requirement for an additional surgical approach was included as an intraoperative complication. Recovery score as noted in the anesthesia record was recorded for each horse, according to a predetermined scoring system of 1 to 5, where 1 equals the best recovery, and 5 the worst.<sup>16</sup> Postoperative complications were defined as those that arose prior to discharge from the hospital and also were recorded as dichotomous variable (present vs absent) for the statistical analysis. These included surgical-related complications and all other medical complications affecting body systems, regardless of whether they were determined to be related to the cryptorchidectomy.

To estimate the severity of postoperative pain in each horse, the heart rate as noted in the medical record between 12 and 24 hours following surgery, the need for analgesia in addition to the scheduled postoperative administration of NSAIDs, and the total number of times a full dose of NSAIDs was administered after surgery were recorded. Furthermore, the total duration of hospital stay was recorded and was defined as the number of days between hospital admission and discharge from the hospital.

Additional data were collected for horses undergoing laparoscopy. This included the number of years of experience each laparoscopist had obtained since completing an American College of Veterinary Surgeons residency program and the method of removal of the testicle to determine whether they affected any of the variables recorded for horses undergoing laparoscopy.

**Statistical analysis**—The data analysis was conducted with statistical software,<sup>c</sup> and the level of significance was set at  $\alpha = 0.05$ . For continuous variables, the median and IQR were reported and frequency statistics were used to summarize categorical variables.

As a result of the pairing of case horses (ie, those that underwent laparoscopic cryptorchidectomy) with control horses (ie, those that underwent conventional open cryptorchidectomy), comparisons within matched pairs were conducted with nonparametric tests that accounted for the dependency of the data such as signed rank test of the differences of continuous variables or McNemar test for the agreement of dichotomous variables. More conservative nonparametric tests were selected over parametric tests because on visual assessment (ie, histograms and QQ plots) most differences were not normally distributed. Continuous variables between independent groups (eg, the comparison of surgery time between horses undergoing a first or second laparoscopic surgery) were compared by means of either a Mann-Whitney *U* or Kruskal-Wallis test. A  $\chi^2$  test was used for a comparison of categorical variables.

A  $\chi^2$  test was used to evaluate whether the proportion of breeds in the study population was the same as in the general hospital population. Then, the 2-tail *Z* test for proportions was used to identify which breeds were different between the study and the general hospital population.

## Results

Four hundred ten horses underwent surgery for cryptorchidism between January 1, 1991, and January

1, 2012. Of these, 46 horses underwent a laparoscopic approach under general anesthesia for the removal of 1 or more undescended testicles. In the end, 30 pairs, or 60 horses, met the criteria for inclusion in this study. This included 30 horses that had laparoscopic surgery for cryptorchidism and matched control horses that underwent conventional open cryptorchidectomy. Breeds represented in this study included American Quarter Horses ( $n = 16$ ), Thoroughbreds (12), Standardbreds (8), Appaloosas (4), American Paint Horses (3), and other breeds (17). American Quarter Horses ( $P < 0.01$ ), Appaloosas ( $P < 0.01$ ), and American Paint Horses ( $P = 0.02$ ) were all overrepresented in the study population, and Standardbreds ( $P = 0.02$ ) were underrepresented, compared with the general hospital population over the study period. Seventeen surgeons performed the surgeries, with laparoscopies being performed by 7 of those surgeons. All surgeries were performed by American College of Veterinary Surgeons board-certified surgeons, and in 6 pairs of horses, surgeries were performed by the same surgeon in the same year. The median age of the horses undergoing conventional open cryptorchidectomy (median, 2 years old; IQR, 1 to 4 years old) or laparoscopic cryptorchidectomy (median, 2 years old; IQR, 2 to 4 years old) did not differ significantly ( $P = 0.19$ ).

When categorized according to history, 14 pairs of horses underwent cryptorchidectomy where the side of the undescended testicle was known and the horses had no history of prior surgical removal attempts. The other 16 pairs of horses underwent a second surgery in an attempt to remove the undescended testicle. This included horses for which a surgery had to be started without knowing on which side the undescended testicle was located (6 pairs) and 10 pairs with a history of either an attempt (7 pairs) or no attempt at removal of the undescended testicle (3 pairs) by the referring veterinarian. Of the 16 pairs undergoing a second attempt, surgery ultimately revealed that 12 had a testicle removed prior to referral, and 4 pairs still had both testicles at the time of hospital admission.

The position and number of the testicles to be removed was as follows: 12 pairs of horses had only 1 testicle in total that was in the abdomen, which was right sided in 13 of 24 horses; 12 pairs of horses had unilateral cryptorchidism with 1 abdominal testicle, which was right sided in 5 of 24 horses; 3 pairs of horses had unilateral cryptorchidism with 1 inguinal testicle, which was right sided in 3 of 6 horses; 2 pairs of horses had bilateral abdominal cryptorchidism; and 1 pair of horses had 1 inguinal and 1 abdominal testicle, in which the abdominal testicle was right sided in one horse and left sided in another.

Generally, the hospital admission dates for horses undergoing laparoscopy (the middle 50% of admission dates fell between 2001 and 2008 [median, 2003]) were comparable ( $P = 0.1$ ) to those undergoing conventional cryptorchidectomy (the middle 50% of admission dates fell between 1996 and 2007 [median, 2003]). However, the only exception were the horses (7 pairs) that underwent surgery for a second time and where the side of the undescended testicle was not known; here the horses undergoing laparoscopy (the middle 50% of admission dates fell between 2002 and 2008 [median,

2006]) were admitted significantly ( $P = 0.02$ ) more recently than their matched control horses (the middle 50% of admission dates fell between 1991 and 1995 [median, 1993]).

All 30 case horses underwent general anesthesia with isoflurane. Of the 30 control horses, 22 underwent general anesthesia with isoflurane and 8 with halothane. Of the 27 control horses that had an abdominal testicle, the superficial inguinal ring was closed in 17 to prevent evisceration. Its closure was not required in 7 control horses because the vaginal ring had been only minimally dilated for retrieval of the testicle. The surgical records of 3 control horses were inconclusive on whether the superficial inguinal ring had been closed. In all horses undergoing conventional cryptorchidectomy, the deep fascial and subcutaneous tissues on the side of the undescended testicle were closed.

Of the 30 case horses that underwent laparoscopic cryptorchidectomy, retained testicles were removed by extracorporeal ligating loops ( $n = 15$ ), a handheld electrosurgery device (6), extra-abdominal ligation (5), and bipolar cautery (1). In 1 case horse, the method of laparoscopic removal was not recorded, and in 2 case horses, the testicle could not be found and had to be removed in a subsequent surgery.

Surgery, anesthesia, and surgical preparation times for various comparisons were summarized (Table 1). With the exception of the surgical preparation time, the method of removal of the testicle did not affect any other variables. However, the surgical preparation time for extra-abdominal ligation (median, 40 minutes; IQR, 35 to 45 minutes) was shorter than for the handheld electrosurgery device technique (median, 55 minutes; IQR, 45 to 60 minutes;  $P = 0.03$ ). Furthermore, recorded times were generally longer for case horses undergoing laparoscopy than for their matched control horses. This association remained significant, when the analysis was repeated including only horses that underwent cryptorchidectomy for the first time or for which the surgeon knew prior to surgery the side of undescended testicle.

However, no difference in surgery time was found between laparoscopic and conventional surgery in horses that underwent cryptorchidectomy for the second time and in those horses for which the surgeon did not have knowledge of which side the undescended testicle was located prior to surgery. Surgical preparation time and anesthesia time for horses undergoing laparoscopy, however, were significantly longer, compared with those of horses undergoing conventional cryptorchidectomy in these latterly described groups.

Interestingly, the year in which the surgery was performed was positively correlated with the anesthesia time ( $r^2 = 0.13$ ;  $P = 0.05$ ) and surgical preparation time ( $r^2 = 0.2$ ;  $P = 0.01$ ). The more recent the surgery was done, the longer those times were. Furthermore, the number of years of experience of the surgeon since finishing an American College of Veterinary Surgeons residency was also positively correlated with both the duration of the surgery ( $r^2 = 0.30$ ;  $P < 0.01$ ) and anesthesia time ( $r^2 = 0.36$ ;  $P < 0.01$ ). The latter 2 factors were again not correlated with any other variables.

The recovery score was similar between case horses undergoing laparoscopy and their matched control horses even when analyzed within different subgroups (Table 2). Complications were encountered in 10 case horses undergoing laparoscopic cryptorchidectomy and included the need to convert to an open conventional approach in 3 of the 10 horses. In 1 horse, the reason for conversion was a failed attempt to pull an inguinal testicle into the abdomen. In the other 2 case horses, conversion arose as a result of lack of identification of the testicle. In 1 of the 2 horses, it was concluded that the testicle had been already previously removed after an inguinal approach was performed. In the other case horse, the testicle also could not be found on a paramedian approach, but was found on a subsequent laparoscopic approach on a subsequent day. In this case horse, feed was withheld for a longer period prior to the second laparoscopy, the horse's legs were hoisted in addition to the Trendelenburg position, and the laparoscopic portal was

Table 1—Comparison of surgical preparation, anesthesia, and surgery times between horses undergoing conventional (C) and laparoscopic (L) cryptorchidectomy.

Pairs compared	Conventional	Laparoscopy	Difference (L – C)	P value
All horses (n = 30)				
Surgical preparation time (min)	30 (25 to 40)	45 (35 to 55)	10 (0 to 30)	< 0.01
Surgery time (min)	75 (60 to 90)	105 (90 to 120)	30 (0 to 45)	< 0.01
Anesthesia time (min)	115 (90 to 135)	162 (135 to 180)	38 (15 to 75)	< 0.01
First surgery only (n = 14)				
Surgical preparation time (min)	27 (25 to 30)	45 (35 to 45)	12 (0 to 20)	< 0.01
Surgery time (min)	75 (60 to 90)	97 (90 to 120)	30 (30 to 45)	< 0.01
Anesthesia time (min)	105 (90 to 130)	150 (135 to 165)	30 (20 to 75)	< 0.01
Second surgery only (n = 16)				
Surgical preparation time (min)	32 (25 to 42)	50 (43 to 55)	10 (1 to 30)	0.02
Surgery time (min)	87 (67 to 97)	105 (90 to 127)	30 (–25 to 45)	0.30
Anesthesia time (min)	120 (105 to 142)	165 (142 to 187)	42 (–12 to 75)	0.03
Testicle site known (n = 24)				
Surgical preparation time (min)	30 (25 to 40)	45 (35 to 50)	5 (0 to 20)	0.01
Surgery time (min)	75 (60 to 90)	105 (90 to 120)	30 (0 to 45)	< 0.01
Anesthesia time (min)	120 (90 to 135)	150 (135 to 180)	30 (15 to 75)	< 0.01
Testicle site unknown (n = 6)				
Surgical preparation time (min)	20 (15 to 40)	50 (50 to 55)	30 (10 to 40)	0.01
Surgery time (min)	85 (75 to 150)	105 (90 to 120)	30 (–30 to 45)	0.60
Anesthesia time (min)	110 (105 to 180)	175 (165 to 180)	65 (–15 to 75)	0.08

Values are reported as median (IQR).



Table 2—Comparison of indicators of postoperative pain in horses undergoing conventional (C) and laparoscopic (L) cryptorchidectomy.

Pairs compared	Conventional	Laparoscopy	Difference (L – C)	P value
All horses (n = 30)				
Recovery score	2 (1 to 3)	1 (1 to 2)	0 (–2 to 1)	0.17
No. of NSAID doses	2 (1 to 2)	2 (2 to 4)	1 (0 to 2)	0.06
Horses with complications after first surgery (n = 14)				
Recovery score	2 (1 to 2)	2 (1 to 2)	0 (–1 to 1)	> 0.99
No. of NSAID doses	2 (1 to 3)	2 (2 to 3)	1 (–1 to 2)	0.32
Horses with complications after second surgery (n = 6)				
Recovery score	2 (2 to 4)	1 (1 to 2)	–1 (–2 to 0)	0.09
No. of NSAID doses	2 (0 to 2)	2 (2 to 4)	2 (0 to 2)	< 0.01
Testicle site known (n = 24)				
Recovery score	2 (1 to 2)	2 (1 to 2)	1 (0 to 2)	> 0.99
No. of NSAID doses	2 (1 to 3)	2 (2 to 3)	0	0.02
Testicle site unknown (n = 6)				
Recovery score	3.5 (2 to 4)	1 (1 to 2)	–2 (–3 to –1)	0.06
No. of NSAID doses	2 (0 to 2)	2 (2 to 4)	0	0.06

Values are reported as median (IQR).

placed more cranially. These changes aided in finding the testicle where there were adhesions to the surgical site of a previous conventional attempt at cryptorchidectomy by the referring veterinarian.

Other complications encountered during laparoscopy were a poor visual field from excessive small intestinal distension (n = 2) requiring the testicle to be removed during a subsequent laparoscopic surgery under sedation; one horse was standing during surgery because the testicle was found to have adhesions to the spleen, and the other horse underwent extra-abdominal ligation of the testicle. In another horse, portals were placed inappropriately relative to the testicle so it had to be removed extra-abdominally. In another 2 horses, small intestine repeatedly obstructed the visual field, which resulted in severe irritation of the small intestinal serosa in 1 horse from repeated manipulation with instruments. The Semm-Claw forceps broke in one horse during manipulation of the testicle, and another horse developed severe facial edema from the Trendelenburg position.

Intraoperative complications in the horses undergoing a conventional open inguinal approach included the need for a different approach to remove the testicle during surgery (n = 2), difficulties locating an abdominal testicle because of the position of the small intestine (1), excessive intra-abdominal fat obscuring the visual field (1), and adhesion formation from a previous attempt to remove the testicle (1). No significant differences in intraoperative complications were seen when horses were compared within groups according to their history (eg, previous surgery).

Significantly (P = 0.03) more postoperative complications were noted for horses undergoing laparoscopic cryptorchidectomy (n = 10) compared with horses undergoing conventional open cryptorchidectomy (4). In the horses undergoing laparoscopy, 4 horses developed 2 postoperative complications and 6 developed 1 postoperative complication. Complications included diarrhea (n = 5), colic (4), incisional swelling (3), fever (1), and rhabdomyolysis (1). In horses undergoing conventional open cryptorchidectomy, complications included an episode of hyperkalemic periodic paralysis (n = 1) and

generalized myopathy (1), necessitating euthanasia of both these horses; diarrhea (1); and colic (1).

Interestingly, when occurrences of postoperative complications after the laparoscopic and the conventional approaches were compared, where the side of the undescended testicle was known prior to surgery, significantly (P = 0.01) more horses developed postoperative complications after laparoscopy (n = 7/24) than after conventional surgery (1/24).

The heart rate between 12 and 24 hours following surgery was recorded for 29 pairs of matched horses. Heart rate was not significantly (P = 0.5) different for horses undergoing laparoscopic versus conventional cryptorchidectomy (median difference, –4 beats/min; IQR, –8 to 2 beats/min) or when any of the groups were compared according to their history of surgery performed before (median difference in heart rate, –6 beats/min; IQR, –12 to 4 beats/min; P = 0.10) or not performed before (median difference in heart rate, 0 beats/min; IQR, –6 to 12 beats/min; P = 0.4) or location of undescended testicle known (median difference in heart rate, –2 beats/min; IQR, –8 to 8 beats/min; P = 0.64) or unknown (median difference in heart rate, –6 beats/min; IQR, –12 to 10 beats/min; P = 0.68).

The median number of postoperative NSAID doses administered to horses following laparoscopy was comparable to number of doses administered following conventional surgery for all groups that were compared (Table 2). However, 6 case horses (ie, laparoscopic surgery) required postoperative analgesia in addition to the scheduled postoperative NSAIDs, compared with only 1 control horse (P = 0.06). All of these 7 horses were given the first postoperative dose of NSAID earlier than scheduled, and 2 horses that had laparoscopic surgery received  $\alpha_2$ -adrenoceptor agonist drugs for analgesia. The surgical approach or history did not influence the duration of the hospital stay.

## Discussion

This is the first study, to our knowledge, that compared surgical preparation, surgery, and anesthesia

times and duration of hospital stay as well as intra- and postoperative complications, including postoperative pain, between laparoscopic and conventional open cryptorchidectomy in horses. Cryptorchidectomy was chosen as a procedure through which such comparisons could be made because it is a common procedure<sup>15</sup> and the search of medical records yielded a fair number of cases for the present study.

To eliminate bias by the surgeon for selection of the patient for laparoscopy, the case horses were matched with control horses according to history. However, this reduced the number of cases in the laparoscopic cohort, and matching cases for other criteria, including number and location of testicles and type of closure, limited the factors that could be assessed in this analysis. Nevertheless, this study provided new insights to advantages and disadvantages of laparoscopy in horses.

Unfortunately, laparoscopic cryptorchidectomy was associated with several disadvantages, compared with conventional open cryptorchidectomy, in the present study population and the overall anesthesia time was significantly longer for the horses that underwent laparoscopy. There are several likely reasons for this.

Laparoscopy requires additional steps, compared with conventional surgery, and as expected, we found that the surgical preparation time for laparoscopic cryptorchidectomy was longer than that for the conventional procedure. Additional time is used during the surgical preparation for laparoscopy because the area to be prepared for aseptic surgery is larger and more draping and equipment setup is required prior to the start of this approach, compared with conventional open cryptorchidectomy. Interestingly, we observed an increase in surgical preparation time the more recently the surgery was performed. One might speculate that this result may be particular to our institution; in more recent years, modifications were made by some surgeons to positioning to improve the visual field (eg, hoisting the horse's hind legs in addition to the Trendelenburg position), and some surgeons started using electrosurgery equipment for hemostasis instead of commercially made extracorporeal ligating loops. All of these additional steps would add to the setup time.

Instrumentation is required for laparoscopic procedures, increasing the likelihood of adjustments needing to be made intraoperatively, such as with carbon dioxide insufflation or a fogging laparoscope. However, because of the retrospective nature of the present study, such pre- or intraoperative details were not available in the medical records.

Even though the comparison was not significant, numerically more horses undergoing laparoscopy had intraoperative complications than did control horses, which would result in an increased surgery time. The median difference between the laparoscopic and conventional surgery times was 30 minutes, which conceivably could be accounted for by such events.

Laparoscopic surgery is also technically more challenging, and one might speculate that some of the surgeries included in the laparoscopic cohort were part of the learning curve for some surgeons, which potentially also contributed to the greater number of horses with complications. Surprisingly, surgeons with a greater number of

years of experience since completing an American College of Veterinary Surgeons residency program had the longer surgery times in the present study. It could be possible that the surgeons with a greater number of years of surgical experience had to go through a steep learning-curve after the acquisition of new laparoscopic equipment, whereas surgeons in the later years of the present study learned laparoscopic technique as residents and therefore did not experience such a steep learning curve. Furthermore, the surgeons with a greater number of years of experience since completing an American College of Veterinary Surgeons residency program may be more engaged in teaching students and residents during surgery. Therefore, procedure times may be increased because of time spent in teaching or training others.

Longer anesthesia time can be detrimental to horses, although no direct complications were seen in this study. It has been associated with poorer anesthetic recovery and postoperative myopathy previously.<sup>17</sup> For all horses, overall anesthesia time was longer for horses undergoing laparoscopy by a median difference of 38 minutes. It could be argued that this duration of time is enough to dissuade the choice of laparoscopy for anesthetized horses undergoing cryptorchidectomy. Furthermore, longer anesthetic times also translate to increased cost to the owner. However, as with all surgeries, this factor has to be taken into account with other purported advantages of laparoscopy for the individual horse in question, such as faster return to work.<sup>15</sup>

Postoperative complications were significantly more common in horses that underwent laparoscopic cryptorchidectomy. However, although only 4 horses developed complications after conventional cryptorchidectomy, 2 died as the result of complications.

Although there were significantly more postoperative complications associated with laparoscopy, none were specifically associated with some of the main concerns of performing cryptorchidectomy, including postoperative hemorrhage. Instead, diarrhea and colic accounted for most postoperative complications. The diarrhea and colic may have been a result of a prolonged period of food withholding prior to laparoscopic surgery. In general, in our surgical facility, feed is withheld for 24 to 48 hours prior to laparoscopic cryptorchidectomy and 4 to 12 hours prior to conventional cryptorchidectomy. Metabolic effects from prolonged periods of food withholding have been demonstrated,<sup>18,19</sup> and it is suggested that this period of food withholding prior to laparoscopy may be unnecessarily long because of the potential for deleterious clinical consequences.<sup>15</sup> Should this be the case, the incidence of postoperative complications in case horses could be readily decreased. However, this is speculation as no records of food withholding periods were available, and to our knowledge, no other studies concerning laparoscopic surgery in horses have reported complications related to food withholding. Furthermore, although shortening food withholding time may prevent the development of diarrhea and colic, it may increase the risk of a poor visual field during surgery. Regardless, the frequency of each of the different complications was insufficient to associate their frequency with particular surgical approaches or other pre-, intra-, or postsurgical variables.

Incisional swelling accounted for some of the postoperative complications in the present study, and it is possible that this was noted more in case horses because the location of the incisions in the abdominal wall is easier to see than an inguinal incision.

Although the postoperative heart rate was comparable between case and control horses, horses undergoing laparoscopic procedures received more analgesics than control horses. However, because of the retrospective nature of the present study, it was not possible to assess whether a surgeon's bias regarding postoperative pain management after the laparoscopic procedure played a role in the decisions to administer a greater number of, or more profound, analgesics or whether the extra analgesia became necessary as a result of the postoperative complications of diarrhea and colic rather than a direct result of pain from the surgical procedure. A blinded postoperative pain-scale scoring study would be better to fully assess these variables.

The duration of hospital stay was comparable between the 2 groups. This suggests that there were no major differences in postoperative care despite differences in the frequency of intraoperative and postoperative complications.

Despite several apparent disadvantages, the laparoscopic approach also had advantages. Importantly, in horses undergoing a second surgery and where the location of the undescended testicle prior to starting the surgery was unknown, the surgery time of both methods was comparable and the recovery scores were better for case horses.

One could argue that the relative ease of access to the abdomen in a horse that has adhesions at the surgical site from a previous surgery is better with laparoscopy. In addition, the arguably superior visual field provided during laparoscopy allows the surgeon to locate an undescended testicle through small laparoscopic and instrument portals regardless of its location (eg, inguinal or abdominal) rather than the inferior view and palpation gained through potentially 2 inguinal incisions.

Indeed, the better recovery scores in this category of horses undergoing laparoscopy could also be related to the ease of access to the abdomen and a superior visual field to locate a testicle during laparoscopy, compared with conventional surgery. It can be speculated that the conventional surgical approach on a horse that has had surgery before can be significantly more invasive, involving more dissection of tissue related to adhesions and manipulation to locate the testicle. This will likely cause more intraoperative pain and could be associated with a worse recovery. It is also possible that this factor may account for the increased use of NSAIDs in this category of horse. Although some horses that underwent conventional cryptorchidectomy were administered halothane anesthesia, no association has been found between administration of this type of inhalation anesthetic and worsened recovery score.<sup>20-22</sup>

Unfortunately, a limitation of this retrospective study was that we could not compare the longer-term impact of the surgical approaches, which would be an

important factor to consider in the overall advantages of a surgical approach. For example, it is recommended to give horses only 1 to 2 days of box stall rest prior to return to normal activities following laparoscopic cryptorchidectomy,<sup>15</sup> whereas following conventional cryptorchidectomy, between 1 and 3 weeks of box stall rest is recommended depending on the location of the testicle.<sup>18</sup>

Additionally, the study might have had different results if we had included sedated horses that had undescended testicles removed while standing as a comparison. Although laparoscopic cryptorchidectomies in standing sedated horses are performed in our hospital, it was decided not to include them in the present study because it would introduce additional confounders into the analysis. The visual field in standing horses during laparoscopic cryptorchidectomy is generally better because the abdominal contents fall away from the inguinal ring making identification of key structures easier.<sup>10</sup> Indeed, 6 surgeries in the laparoscopic cohort of the present study were subject to intraoperative complications as a result of lack of observation of testicular structures.

A further variable not analyzed as part of the present study was cost of the procedure. In our hospital, it was deemed problematic to determine the true cost of a procedure because of substantial changes in fee structure and billing practices over time. Similar problems have been noted in studies attempting to analyze the cost of laparoscopies in humans.<sup>23</sup> On the basis of the results of our study, it would seem logical, however, that laparoscopic procedures would ultimately cost more because of required specialized equipment, longer anesthesia time, and more complications, which could be offset by shorter recovery times.

The breed distribution of horses in the study herein was not representative of the hospital population. American Quarter Horses were overrepresented and have previously been identified as a breed of horses in which cryptorchidism is common.<sup>24</sup> There is no clear reason for the overrepresentation of American Quarter Horses, Appaloosas, and American Paint Horses and the underrepresentation of Standardbreds, compared with the hospital population, in the present study.<sup>23</sup>

Matching case horses with control horses according to location of testicles reduced the potential bias from case selection by the horse owner or surgeon. As a result of the number of factors that the cases were to be matched by, it did not occur that > 1 case was suitable. The limitations of a retrospective study such as this include that not all cases could be matched according to variables such as surgeon experience, anesthetic protocols, and preoperative and postoperative management. In addition, the number of observations per group of data was limited so it was not sensible to perform a multivariate analysis that would have accounted for multiple predictors. The present study included surgeries performed by surgeons with a range of years of surgical experience, and although attempts were made to match this variable for cases, it was only possible in 6 pairs. One comparative study<sup>23</sup> of laparoscopy ver-

sus open surgery in people found that more experienced laparoscopists had improved patient outcomes, whereas for open repairs, there was no association of experience with patient outcomes. Because of the large number of surgeons included in this study, no attempts to grade surgeon experience or correlate surgeon with outcome were made. However, this limitation may also be advantageous as the study summarizes results of both surgical approaches from surgeons with differing levels of experience rather than a single surgeon.

In conclusion, the combination of increased intraoperative and postoperative complications and increased anesthesia time suggests that laparoscopy under general anesthesia for the purpose of removing undescended testicles in horses may carry disadvantages, compared with open conventional surgery. The current practice by the authors is to perform conventional cryptorchidectomy on horses with a history of no attempt of previous castration, unless it is specifically requested that the horse return to work as soon as possible. However, horses with an uncertain history of castration are worthy of consideration for laparoscopy under general anesthesia because surgery times are comparable to conventional approaches and recovery scores may be improved. Further studies measuring hormonal response, including cortisol levels as a measure of stress,<sup>25</sup> and inflammatory mediators would be necessary to test whether increased surgical and anesthesia time actually makes laparoscopic procedures more invasive and therefore less preferred in horses with cryptorchidism.

- a. Endoloop, Ethicon Inc, Somerville, NJ.
- b. Ligasure, Covidien, Saint-Laurent, QC, Canada.
- c. SAS, version 9.3, SAS Institute Inc, Cary, NC.

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