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Original Research

Decision Making for Cryptorchid Castration; a Retrospective Analysis of 280 Cases

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ABSTRACT

The location of an undescended testicle influences the choice of surgical technique for efficient cryptorchid castration. We review a standardized protocol for preoperative examination to dictate surgical approach to cryptorchidism. Cases are split into two periods: 2004–2006 and 2007–2014. In 2004–2006, conventional cryptorchidectomy and laparoscopic cryptorchid castration (standing) were both offered, but the choice of technique was based primarily on owners' preference for a recumbent or standing procedure. In 2007–2014, ultrasonography was used to locate the testes and dictate the preferred surgical approach; for abdominal testes, laparoscopic intraabdominal spermatic cord ligation without orchidectomy was preferred and for inguinal testes, conventional open orchidectomy. The numbers of animals requiring a second procedure to complete castration were compared between the two periods. In addition, failure rates for individual testes grouped by location were determined separately for the different techniques, and the value of preoperative ultrasonography to locate the retained testes was assessed. In 2004–2006, 15.3% (20/131) of the cryptorchids needed more than one surgery to complete castration, compared to 0.7% (1/144) in 2007–2014. Failure rates for laparoscopic castration were 0/168 (0%) for abdominal, 3/40 (7.5%) for inguinal, and 9/55 (16.4%) for scrotal testes; for conventional castration, failure was recorded for 3/12 (25%) abdominal and 0/92 (0%) inguinal testes. For 94% (156/166) of retained testes, ultrasound-based preoperative advice on surgical approach was correct. Using a standardized preoperative examination to determine choice of surgical technique significantly ($P < .001$) reduced the number of second surgeries needed to complete castration. Preoperative ultrasound is therefore a useful aid to determining the surgical approach to cryptorchid castration.

1. Introduction

Cryptorchidism is the failure of one or both testes to descend into the scrotum and is the most common nonlethal developmental defect of equids [1]. Cryptorchid castration is, therefore, a common procedure in an equine surgical referral practice. Cryptorchid castration involves more risk than castration of normal stallions, and complication rates reported for cryptorchids undergoing castration [2,3] are considerably higher than those reported for normal stallions undergoing routine castration under general anesthesia [4,5]. Unilaterally castrated cryptorchid horses sold to unsuspecting buyers can further complicate decision making regarding surgical approach. Although hormone assays can be used to definitively demonstrate the presence of testicular tissue in suspected cryptorchids [6–9], it can still be a challenge to perform the necessary castration or hemicastration without unnecessary risk or cost when an endocrine test indicates cryptorchidism in a case with an uncertain history. Inguinal and transrectal palpation alone are also not reliable means of confirming

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testicular location, and from an owner's perspective, costs of diagnosis and management of unilaterally castrated cryptorchids are significantly higher than for normal cryptorchids [2,10].

Several conventional and laparoscopic approaches have been described for cryptorchid castration [1]. At Utrecht University's Equine Clinic (UUEC), intraabdominal spermatic cord ligation without orchidectomy performed laparoscopically in the standing horse [11] and conventional open cryptorchidectomy (inguinal or parainguinal approach under general anesthesia) [1] are both used for cryptorchid castration. A retrospective study published in 2006 reviewing laparoscopic castration without orchidectomy in both cryptorchids and normal stallions concluded that this technique was invariably successful for abdominal testes (n = 123), whereas 3.4%–5.6% of normally descended or inguinally retained testes failed to become completely necrotic [12]. Therefore, laparoscopic castration without orchidectomy was concluded to be insufficiently reliable for castration of inguinal cryptorchids and normal stallions [12]. This led to a change in the UUEC protocol for advising owners of cryptorchid stallions with regard to castration methods. During 2004–2006, both the conventional and laparoscopic approaches were used for cryptorchid castration, and after informing the owners about the advantages and disadvantages of the 2 approaches, a decision was reached about which technique was to be used. Owners submitting their horses for laparoscopic castration were always informed that this was a procedure without orchidectomy. Therefore, they were always warned in advance that their horse would only be pronounced a gelding after postoperative testosterone determination and that additional surgery (orchidectomy of normally descended or inguinally retained testes) might be necessary. Although the average mortality risk for elective surgery under general anesthesia is low [13], the desire to eliminate this risk often resulted in owners choosing standing laparoscopy. For most owners, the process was considered satisfactory even if the horse had to return for a second operation; however, the high rate of reoperation (7%–11%) was sufficient reason to want to optimize the decision making process [12]. In 2007, a new protocol was adopted to improve and standardize the procedure for cryptorchid castration. In the new protocol, ultrasonography was used to locate the testes, and the location was used to select the surgical approach. This study reviews the efficacy of the new protocol (2007–2014) compared to the old protocol (2004–2006).

2. Material and Methods

2.1. Patients

All (suspected) cryptorchids that underwent castration, and for which complete records were available (n = 280), at the UUEC between 2004 and 2014 were included in the study.

Data retrieved from case records included preoperative findings (basal plasma testosterone concentration or human chorionic gonadotrophin [hCG] stimulation test at day of surgery [d0], ultrasound examination), surgical procedure and findings (castration technique, location of testes, intraoperative complications), and postoperative findings (basal plasma testosterone concentration or hCG stimulation test 1 week after surgery [d7] and complications).

2.2. Old and New Protocol, Guidelines, and Evaluation

To evaluate the standardized protocol for determining surgical approach to cryptorchidism, animals (n = 280) were split into two periods: 2004–2006 "old protocol" (n = 131) and 2007–2014 "new protocol" (n = 149).

Under the old protocol, the scrotal and inguinal region of each horse was palpated to rule out a missed descended testicle, but no attempt was made to further classify the type of cryptorchidism by transrectal palpation or ultrasonography. Both conventional open cryptorchidectomy (inguinal or parainguinal approach under general anesthesia) and standing laparoscopic cryptorchid castration techniques were offered. The advantages and disadvantages of the two techniques were explained to the owner, and the choice of technique was based on the owner's preference for a recumbent or a standing procedure. The price for cryptorchid castration was fixed and independent of surgical technique, so that finances did not play a role in decision making. After surgery, plasma testosterone assay was used to determine whether complete testicular removal or necrosis had been achieved. If testosterone production continued, a second evaluation and surgery were performed without further charge.

During 2007–2014 (new protocol), a more standardized approach to cryptorchidism was adopted. Equids admitted for castration with known or suspected cryptorchidism were examined to determine the position of the testes. If at least one testis could not be palpated in or close to the scrotum, the scrotum and inguinal area were examined using an ultrasound machine (Mylabs 5, Esaote, Maastricht, the Netherlands) equipped with a 5–7.5 mHz micro-convex probe. If the missing testis was not identified in the inguinal canal, a switch was made to per rectum ultrasound examination with a 7.5-mHz linear array transducer. Transrectal palpation and ultrasound examination were performed with the horse restrained in stocks, and noncooperative horses were sedated with detomidine hydrochloride (0.01 mg/kg bwt detomidine, IV). All ultrasonographic examinations were performed by European College of Animal Reproduction diplomates or residents. Testicular location was then used to determine the surgical approach. For abdominal testes, this was standing laparoscopic intra-abdominal spermatic cord ligation without orchidectomy. For inguinal testes, conventional open orchidectomy under general anesthesia was preferred. For a stallion with one abdominally retained and one normally descended or inguinal testis, a combined procedure was selected, standing laparoscopy followed by conventional orchidectomy of the scrotal/inguinal testis under general anesthesia.

2.3. Surgical Procedures

2.3.1. Laparoscopic Castration

Prior to laparoscopic castration, horses were fasted for 36 hours to reduce intestinal bulk. Horses were restrained in stocks and sedated with detomidine hydrochloride (0.01 mg/kg bwt, IV) and butorphanol tartrate (0.02 mg/kg bwt, IV). Sedation was maintained by continuous rate infusion of detomidine hydrochloride (generally starting at 0.01 mg/kg bwt/h with adjustment based on the level of sedation). The surgical sites were clipped and prepared aseptically. The instrument portal sites in the paralumbar fossae were then infiltrated with local anesthetic (lidocaine was injected both subcutaneously and intramuscularly to a total of approximately 10 mL per portal). Laparoscopic placement and subsequent castration was performed as described by Rijkenhuizen and van Dijk [11]. In the case of abdominally retained testes, all structures proximal to the testis were ligated twice (Polyglactin 910, USP 2), without subsequent resection. For normally descended or inguinally retained testes, after double ligation of the entire spermatic cord, the cord was transected completely.

2.3.2. Conventional Open Cryptorchidectomy

Prior to recumbent castration horses were fasted for 8 hours. After premedication with detomidine hydrochloride (0.01 mg/kg bwt, IV) and butorphanol tartrate (0.02 mg/kg bwt, IV), general anesthesia was induced using ketamine hydrochloride (2 mg/kg btw, IV) and midazolam hydrochloride (0.1 mg/kg bwt, IV) and maintained with isoflurane in oxygen delivered by assisted or controlled ventilation. Horses were placed either in dorsal recumbency or lateral recumbency with the upper hindlimb abducted. For inguinal testes, an inguinal approach and half-closed technique followed by primary closure of the incision was used [1]. Briefly, a skin incision was made directly over the superficial inguinal ring, followed by blunt dissection of the inguinal fascia. The testis was exposed, and after crushing and double ligating the spermatic cord (Polyglactin 910, USP 2), the testes were removed. To remove abdominally retained testes, either an inguinal approach (invasive or noninvasive) including closure of the superficial inguinal ring was used or a parainguinal approach (invasive or noninvasive) with subsequent closure of the fascia and skin [1]. Scrotal testes were removed via an inguinal incision and a closed technique, or a scrotal incision and half-closed technique, depending on the surgeon's preference [1]. The inguinal incisions were closed, whereas scrotal incisions were left to heal by second intention.

2.3.3. Combined Laparoscopy and Conventional Castration

For combined laparoscopic/conventional castration, the preoperative management was as described for laparoscopic castration. Laparoscopic castration of the abdominal testis was performed in the standing animal first, followed by removal of the normally descended or inguinally retained testis under general anesthesia. Standing conventional castration of the scrotal testis was not offered.

All surgeries were performed in an equine hospital environment under strict aseptic conditions, and therefore, prophylactic antibiotics were not administered preoperatively as a standard procedure. All surgeries were performed by European College of Veterinary Surgeons diplomates or residents (n = 19).

For all three surgical approaches, flunixin meglumine (1.1 mg/kg bwt, IV) was administered preoperatively. Additional postoperative analgesia (meloxicam, 0.6 mg/kg bwt, PO) was provided only to horses showing signs of pain, excessive postoperative swelling, or pyrexia.

2.4. Protocol to Evaluate the Success of the Different Castration Techniques and to Identify the Individual Testis Responsible for Failure

For laparoscopic and combined castrations, plasma testosterone concentrations were determined by radioimmunoassay, as described by Verjans [14], immediately before (d0) and 1 week after surgery (d7) to verify complete removal of testicular tissue. Laparoscopic castration was considered successful if the d7 plasma testosterone level was below our laboratory's detection limit of 25 pg/mL [12]. An upper testosterone threshold of 40 pg/mL is reported for geldings, compared to a lower threshold of 100pg/mL for stallions; hCG stimulation tests are helpful in cases that fall in the "gray area" (between 40 and 100 pg/mL) [9]. In our clinic, when testosterone was between 25 and 100 pg/mL, a hCG stimulation test was performed using 6000 iu of hCG (Chorulon) IV [15]. In horses without viable testicular tissue, there should be no significant postchallenge increase in testosterone concentrations [15–18]. Horses were only considered geldings if the 1 hour post-hCG testosterone concentration did not increase above the 100 pg/mL threshold. Because single serum testosterone concentrations are more prone to error when measured in horses under 18 months of age [9], animals under the age of 2 years were only included when a preoperative testosterone concentration was available and exceeded 25 pg/mL. Horses for which a d7 testosterone concentration was not available were only included if information on stallion behavior over the 6 months after surgery (vocalizations, excitement, attempts to mount other horses) was available (n = 15). If laparoscopic castration without orchidectomy failed to reduce the testosterone concentration to less than 25 pg/mL, the horse was readmitted to the hospital for conventional castration to remove the remnants of the inguinal and/or descended (but not abdominal) testis of which the spermatic cord had only been ligated and transected. These excised testes were examined macroscopically. When viable testicular tissue was present (Fig. 1), the original surgical procedure performed on that testis was considered to have been unsuccessful. If the macroscopic appearance was inconclusive, histopathology was performed to allow a final conclusion as to whether a recovered testis was responsible for testosterone production. In the case of unilateral abdominal cryptorchids, after the second surgery, an additional blood sample for testosterone was collected (to prove that the laparoscopically ligated abdominal testis had become necrotic); the horse would only be pronounced a gelding if both testes had been removed during the two surgeries or if d7 plasma testosterone levels were below 25 pg/mL.

Conventional cryptorchid castration was considered successful if two complete testes were removed. If only one testis was removed (assumption of a previous unilateral castration), the horse was only declared a gelding if d7

Fig. 1. Macroscopic appearance of the cut surface of a testis that underwent incomplete necrosis after laparoscopic castration. *Necrotic tissue.

testosterone concentrations were below 25 pg/mL. In the case of an elevated postoperative testosterone concentration, a second surgery was performed to investigate the origin of testosterone production.

The final outcome was recorded for all castrated horses and for individual testes. The number of horses that needed a second surgery for successful completion of castration during the old and new protocols was compared. Based on the outcomes for individual testes, the failure rates were analyzed for the laparoscopic and conventional approaches separately and grouped per testicle location.

2.5. Evaluating Ultrasound Examination to Locate the Retained Testes Preoperatively

For horses admitted after 2007, ultrasound examination was used to locate retained testes. Locations of retained testes determined by the ultrasound were compared to surgical findings, which was used as the gold standard.

To select the best castration technique for horses with a clear castration history and suspected cryptorchidism, it is not always strictly necessary to definitively prove intra-abdominal location of the retained testis [19]. In equids that were too fractious or too small for transrectal palpation and ultrasound, where the history clearly ruled out previous castration (n = 20), establishing that the testis was not located in the inguinal canal was considered sufficient to justify choosing the laparoscopic approach. In these cases, the inability to locate the testis was considered to indicate abdominal retention, and avoiding injury during per rectum examination was considered more important than verifying the intraabdominal location. The success of preoperative ultrasound as a clinical tool for providing adequate information on the most appropriate surgical approach, without necessarily visualizing the testis, was evaluated by determining whether or not the ultrasound-based preoperative advice was correct.

2.6. Statistical Analysis

Fisher's Exact test was used to assess the association between the two protocols and the outcome "second surgery required." Univariable binary logistic regression was used to assess the two protocols for their association with the outcome measure "second surgery required." Associations between the categories (mild and more severe) of postoperative and intraoperative complications and the surgical approach were also assessed using Fisher's exact test. A chi-squared test was used to evaluate whether the proportion of breeds in the study population was similar to the overall hospital population. Sensitivity and specificity were calculated for ultrasound evaluation using the location determined by surgery as a gold standard for comparison. All statistical tests were performed using SPSS statistical software (SPSS 22). Statistical significance was set at $P \leq .05$.

3. Results

3.1. Case Details

The 280 equids included were of various breeds and signalment (mean ± standard deviation [SD] body weight 448.8 ± 123.4 kilograms; mean ± SD age 3.3 ± 2 years); breeds included Dutch Warmbloods (n = 83) and other Warmblood Breeds (e.g., Belgian and German Warmbloods) (n = 17), Friesian Horses (n = 85), Welsh Ponies/Cobs (n = 18), Quarter Horses (n = 12), Icelandic Horses (n = 11), various pony breeds (n = 22), various draft horse breeds [10], Arabians (n = 6), and eight miscellaneous (e.g., Standardbreds, Thoroughbreds, and donkeys). Friesian Horses were (chi-squared test $P < .0001$) overrepresented in the study population (85/280; 30.4%), compared to the general hospital population (3,630/32,551; 11.2%) during the period of the study.

Based on surgical findings, the cryptorchids were classified as: 28 (10%) bilateral abdominal, 76 (27.1%) unilateral abdominal, 5 (1.8%) 1 testis abdominal and 1 inguinal, 47 (16.8%) 1 testis abdominal and 1 previously removed, 7 (2.5%) bilateral inguinal, 109 (38.9%) unilateral inguinal, and 8 (2.9%) 1 testis inguinal and 1 previously removed. In total, 94 of the 184 (51.1%) abdominally retained testes were left sided and 90 (48.9%) right, and 67 of 136 (49.3%) of the inguinally retained testes were left and 69 (50.7%) right; 185 testes were normally descended, and 55 testes were absent as a result of previous castration. Further classification of the testes location of the Friesian Horses revealed 16 (18.8%) bilateral abdominal, 28 (32.9%) unilateral abdominal, 2 (2.4%) 1 testis abdominal and 1 inguinal, 4 (4.7%) 1 testis abdominal and 1 previously removed, 5 (5.9%) bilateral inguinal, 29 (34.1%) unilateral inguinal, and 1 (1.2%) 1 testis inguinal and 1 previously removed.

In total, laparoscopic castration was performed on 145 cryptorchids: 99 underwent conventional open cryptorchidectomy, and 36 horses underwent combined laparoscopic/conventional castration. Surgery was performed on 131 horses during the years 2004–2006 ("old protocol"), comprising 104 laparoscopic castrations and 27 conventional cryptorchid castrations. Under the new protocol, 149 horses were operated: 41 laparoscopies, 72 conventional castrations, and 36 combined surgery.

Complications of the three different approaches are described in Table 1. No significant association was found between the different castration approaches and the occurrence of mild and more severe intraoperative or postoperative complications.

3.2. Evaluating the Need for a Second Surgery Under the Old and New Protocols

Following the old protocol, 15.3% (20/131) of the horses needed a second surgery to complete castration. In 19 horses, surgery was not successful (17 laparoscopies and 2 conventional castrations), and in 1 horse, it was retrospectively concluded that laparoscopic castration had been irrelevant (in a horse previously castrated on one side with an inguinally retained testicle on the other side. As a result of a left-right mix-up, only the spermatic cord on the previously castrated side was ligated, whereas the contralateral side was not checked).

During 2007–2014 (new protocol), in 5 out of 149 cases, the protocol was not followed due to the owners' (n = 2) or surgeon's preference (n = 3) (e.g., because animals were very small or too fractious), and these cases were excluded. Following the new protocol, 1 of 144 (0.7%) horses required a second surgery; in this case, the selected conventional surgery had to be changed to a laparoscopic approach because the testis turned out not to be inguinal. A Fisher's exact test indicated that the percentage of second surgeries was significantly ($P < .001$) lower under the new protocol. Univariable binary logistic regression showed that the odds of needing a second surgery to complete castration were 25 times higher during the old protocol (odds ratio, 25.8; 95% confidence interval = 3.4–194.9) compared to the new protocol. Following the new protocol, surgery was (incorrectly) started laparoscopically in nine cases due to the ultrasound-based presumption that the retained testis was not located inguinally; in one case, the testis, although inguinal, was so small and atrophic that it required histology for identification, in six cases, the testis was not located by ultrasound, and in two, it was incorrectly identified as being abdominal. In these cases, laparoscopy rapidly revealed that the retained testes were in fact inguinal, and surgery was continued conventionally under general anesthesia in the same session. These cases (n = 9) were recorded as a single, but phased surgery.

3.3. Success of the Different Castration Techniques and Failure Rates per Testicular Position

Success rate was determined for 280 horses. In one case (before 2007), a laparoscopic surgery was retrospectively considered irrelevant (the spermatic cord of the previously castrated side was ligated), and in one case (after 2007), the conventional surgery was changed to a laparoscopic approach based on operative findings of testicular position (abdominal instead of inguinal). For all horses in which relevant and complete surgery was performed (n = 278), the overall success rates for the different castration techniques grouped by type of cryptorchid are shown in Table 2.

As shown in Table 2, success rates differed between techniques and types of cryptorchids, and this was investigated further. Castration outcome was determined for all testes individually to examine failure rates of the laparoscopic and conventional approaches separately and the interaction with testicular location. Of 17 unsuccessful laparoscopic castrations, four horses were not readmitted

Table 1
Complications of different castration approaches.

Surgical Approach	Laparoscopic n = 145 (%)	Conventional n = 99 (%)	Combined n = 36 (%)
Intraoperative complications			
Mild			
Splenic injury (cannula insertion)	6 (4.1)	x	x
Mild abdominal wall bleeding (cannula insertion)	5 (3.4)	x	1 (2.8)
Mild peritoneal detachment (cannula insertion)	1 (0.7)	x	1 (2.8)
Excessive bleeding during inguinal incision	x	4 (4)	x
Total	12 (8.3)	4 (4)	2 (5.6)
More severe			
Bowel perforation (cannula insertion)	1 (0.7)	x	x
Bladder puncture (instrument insertion)	1 (0.7)	x	x
Total	2 (1.4)	0	0
Postoperative complications			
Mild			
Fever >38.5	22 (15.2)	1 (1)	4 (11.1)
Mild emphysema at incision site	2 (1.4)	x	x
Surgical site infection	2 (1.4)	3 (3)	x
Preputial/scrotal swelling	1 (0.7)	2 (2)	x
Mild signs of discomfort (fever/dull/decreased appetite)	10 (6.9)	5 (5.1)	2 (5.6)
Fever due to upper respiratory tract infection	4 (2.8)	7 (7.1)	x
Hemorrhage	x	1 (1)	x
Limb trauma during recovery	x	1 (1)	x
Total	41 (27.7)	20 (20.2)	6 (16.7)
More severe			
Colitis	2 (1.4)	x	1 (2.8)
Peritonitis	1 (0.7)	x	x
Colic due to intestinal adhesions	1 (0.7)[a]	x	x
Total	4 (2.7)	0	1 (2.8)

[a] Horse was euthanized.

Table 2
Overall (old and new protocol combined) successful outcome for the different castration techniques, grouped by type of cryptorchidism (position of testes), for all horses in which complete surgery was performed (n = 278).

Castration Technique	Outcome		Total
	Successful	Not Successful	
Laparoscopic			
Position of testes			
Bilateral abdominal	28	0	28
Abdominal and scrotal	23	8	31
Abdominal and inguinal	3	0	3
Abdominal and previously castrated	45	0	45
Bilateral inguinal	3	0	3
Inguinal and scrotal	21	9	30
Inguinal and previously castrated	4	0	4
Total	127	17	144
Conventional			
Position of testes			
Abdominal and scrotal	9	2	11
Abdominal and previously castrated	0	1	1
Bilateral inguinal	4	0	4
Inguinal and scrotal	79	0	79
Inguinal and previously castrated	3	0	3
Total	95	3	98
Laparoscopic/conventional			
Position of testes			
Abdominal and scrotal	34	0	34
Abdominal and inguinal	2	0	2
Total	36	0	36

for a second surgery, and in two horses, the removed testes were not evaluated macroscopically or histologically for viable testicular tissue. In these cases, it remains uncertain which testis was still functional, and these horses were therefore excluded from further analysis of castration failure. Following laparoscopic spermatic cord ligation with or without transection, 0/168 (0%) abdominal, 3/40 (7.5%) inguinal, and 9/55 (16.4%) scrotal testes remained viable. During conventional castration, 3/12 (25%) abdominal and 0/92 (0%) inguinal testes could not be removed. Failure in two cases was due to failure to locate the abdominal testis. In the remaining case (a partial abdominal cryptorchid), only the epididymis was amputated, and as a result, an incomplete castration was erroneously performed. All three testes were successfully ablated laparoscopically during a second surgery.

3.4. Evaluating Preoperative Ultrasound Examination

Of 149 horses admitted for castration after 2007, 148 cases were valid for evaluating the efficacy of a preoperative ultrasound examination to determine the appropriate castration technique (in one horse, the preoperative ultrasound was not performed because the horse was too fractious). Based on surgical findings, 94 testes were abdominally retained, 72 testes were inguinally retained, 102 were scrotal, and 28 were absent due to previous castration. In 14 cases in which the testis was absent, no ultrasound was performed because of the clear history of previous castration. For all suspected cryptorchid testes in which ultrasound was performed, the locations determined by ultrasound and the surgical findings are shown in

Table 3
Locations of retained testes based on surgical findings compared to location indicated by ultrasound (US) examination.

Location Testis as Determined by Surgery	US Location Testis			Total
	Abdominal	Inguinal	Absent/Not Found	
Abdominal	80	1	13	94
Inguinal	2	63	7	72
Previously castrated	0	0	14	14
Total	82	64	34	180

Table 3. Overall, surgery and ultrasound findings for errant testes were the same in 143/166 (86.1%) cases. In 6 out of 13 cases in which an abdominal testis was not located ultrasonographically, it was not possible to safely perform rectal examination because the animals were too small (n = 5) or too fractious (n = 1). Because complete preoperative ultrasound examination was not possible, these cases were excluded from evaluation of the utility of ultrasonography to locate the testis. Sensitivity and specificity of full preoperative ultrasound examination were 91% and 97% for abdominal and 88% and 99% for inguinal testes. For the 13 horses in which the exact location of the abdominal testis could not be determined by ultrasound (including the six in which transrectal ultrasound was not possible), a reliable history that excluded previous castration and an ultrasound examination that excluded an inguinal testis informed the surgeon adequately about the appropriate castration technique. In 94% (156/166) of the retained testes, ultrasound-based preoperative advice about the surgical approach was therefore correct.

4. Discussion

Using the old protocol, an unacceptably high percentage (15.3%) of horses needed a second surgery to complete castration; this was mainly because laparoscopic castration without orchidectomy was used to castrate normal or inguinal testes. The introduction of the new protocol resulted in a significant reduction in second surgeries, and only 1 out of 144 horses needed a second surgery to complete castration. In the one reoperated horse, ultrasound examination had erroneously indicated the testis to be inguinal. No testis was found in the inguinal canal during conventional surgery, and an abdominal position was therefore suspected. Conventional castration was stopped, and successful laparoscopic castration was performed after adequate fasting. Deviating from the protocol and removing the abdominal testis at the initial surgery by use of an open conventional technique could have avoided a second surgery in this case. Subjecting the horse to a delayed standing minimally invasive procedure was preferred by the owner over and above a more invasive procedure during the first surgery.

The introduction of the combined castration technique was driven by the desire to adhere to a standing, minimally invasive technique for abdominal testes. To our knowledge, no other studies describe this combined approach. In unilateral abdominal cryptorchids with one normally descended testis, we recommend conventional orchidectomy in the recumbent position for the normal testis. A standing conventional open castration could also be considered in these cases to eliminate the expense and risk of general anesthesia. A study comparing standing and recumbent castration techniques showed that the incidence of complications was significantly higher in standing castration, with scrotal sepsis accounting for 92% of complications [5]. These results suggest that it is not possible to guarantee asepsis during a standing open procedure. In our clinic, all castrations are performed in an equine hospital environment under strict aseptic conditions, with no routine preoperative antibiotic administration. With respect to antimicrobial usage, our clinic's policy is to avoid standard prophylactic antimicrobials in healthy patients undergoing elective routine surgery like castration. Moreover, we believe that prophylactic antimicrobials should not be seen as a way to compensate for suboptimal asepsis during standing surgery. Performing the castration on the recumbent horse under strict aseptic conditions allowed us to avoid prophylactic use of antibiotics in compliance with best antibiotic use protocols. Therefore, standing conventional castration of the normal testis is not performed in our hospital.

Because a high percentage of normal and inguinal testes (4%–11%) fail to become completely necrotic after laparoscopic castration without orchidectomy [12], this technique was discontinued under the new protocol. For inguinal testes, laparoscopic intraabdominal ligation with removal of the testis following incision of the internal inguinal ring to allow the testis to be pulled back into the abdomen has been described by Fischer et al (1998). Although eventration of intestines did not occur in the nine inguinal testes described in the study by Fischer and Vachon [20], they do report this as a potential cause for concern. Cribb et al [3] reported successful laparoscopic cryptorchidectomy of three out of four inguinal testes, but in one horse (25%), an attempt to pull the inguinal testis into the abdomen failed, forcing the surgeon to convert to an open conventional approach. Based on these findings and anecdotal reports of a higher incidence of inguinal herniation in Dutch Warmbloods, our main hospital population, we prefer not to perform laparoscopic orchidectomy of inguinal testes.

In our new protocol, for equids with one abdominal and one scrotal or inguinal testis, surgery was started as a standing procedure and continued under general anesthesia. Switching from standing to recumbent position and a second aseptic preparation cycle necessitates more time from the operation assistants. Laparoscopic castration of abdominal testes can also be performed under general anesthesia [3,20], and although this would eliminate the need to switch from standing to recumbency, it would increase anesthesia time. In horses, longer time under anesthesia is associated with poorer anesthetic recovery and higher risk of postoperative myopathy [13]. In addition to reducing time under anesthesia, standing laparoscopic castration provides a better field of view because the abdominal contents fall away from the inguinal ring [1]. Cribb et al [3] performed laparoscopic cryptorchidectomy under general anesthesia, but 6 out of 30 cases suffered intraoperative complications as a result of poor visibility of the testicular structures. In our study, conventional castration was unsuccessful for 3 out of 25 abdominal testes. In two cases, failure was due to the abdominal testis not being found using this approach. In the third case, only an epididymis was removed during castration of a partial abdominal cryptorchid. Hartman et al [2] performed conventional open cryptorchidectomy (invasive and noninvasive) on 246 equids with abdominally retained testes and were unable to identify the retained abdominal testis in only one horse. Because the laparoscopic approach is the preferred technique for abdominally retained testes in our hospital, residents are less experienced with conventional (non)invasive techniques. Moreover, they are more inclined to stopping the conventional surgery and switching to a laparoscopic approach. This may have biased the failure rate for conventional surgery of abdominal testes in our study.

Of 160 retained testes for which full preoperative ultrasound was performed, the location was not correctly established by ultrasound for 17 cases (10.6%); this resulted in an incorrect surgical plan in only 10 cases. In nine cases, the incorrect surgical plan resulted in "phased" surgery, in which a "diagnostic" laparoscopy established the correct location, and conventional castration was performed in the same session. In one case, this resulted via the new protocol in a second surgery to complete castration. A previous study using combined inguinal and transrectal ultrasonography in a small group of nine cryptorchids (11 testes) reported a 100% association between testis location diagnosed by ultrasound and as proven by surgery [21]. In another study using inguinal ultrasonography only without transrectal ultrasound, 1 abdominal and 2 inguinal testes out of 44 retained testes (6.8%) were incorrectly located [22]. A recent study reviewing a simplified technique of percutaneous inguinal ultrasound successfully located 98% of the inguinal testes and 97% of the abdominal testes [19]. In the latter study, absence of a testis in the inguinal area was considered to indicate abdominal retention; however, this assumption would not reliable for horses with an uncertain history of previous castration. The higher accuracy of the previous studies compared to our larger survey suggests that there is room for improvement in our ultrasound technique. In this respect, it is our impression that the majority of occasions on which the testis was either not or incorrectly located were performed by residents with relatively little experience in locating a testicle ultrasonographically, indicating that it is a skill that requires practice. Performing a more extensive inguinal examination, as described by Schambourg et al [22], could help reduce the incidence of inconclusive outcomes. Improving the accuracy of preoperative ultrasound examination should more or less eliminate the need for second or "phased" (starting with a "diagnostic" laparoscopy and continuing with a conventional castration in the same session) surgeries in the future.

Complications associated with laparoscopic surgery in horses in general are well documented [23–25]. For standing laparoscopy, intraoperative complications most commonly arise during cannula insertion or gas insufflation; in this respect, several blind and visually controlled cannula insertion techniques have been described [25]. The most serious complication encountered during cannula insertion is bowel perforation [23]. In our study, cannula insertion was carried out "blind" and pneumoperitoneum was induced after laparoscopic visualization to confirm that the laparoscopic sleeve was positioned in the abdominal cavity. Nevertheless, all of the complications encountered during laparoscopic castration were related to cannula or instrument insertion (n = 14; 9.7%). All intraoperative complications could, however, be treated adequately, and the horses recovered without long-term negative consequences. In one horse, although no intraoperative complications were noted during surgery, postoperative abdominal adhesions later developed that necessitated euthanasia. Based on the pathological findings (severe adhesion of small intestine to the lateral side of the cecum), it was presumed that perforation of the cecum during cannula placement was causative. To reduce the risk of bowel perforation during cannula insertion, the use of an optical device to insert the initial cannula may be considered [25].

Seventy-two of the 280 patients (25.7%) developed postoperative complications. A recent retrospective study reported a postoperative complication rate of 25% (postoperative fever included) and 3% (only major complications, postoperative fever not included) for cryptorchidectomy performed with a variety of surgical approaches, but minor complications such as edema and swelling were not recorded [2]. A review comparing laparoscopic and conventional open cryptorchidectomies reported postoperative complication rates of 33.3% and 13.3%, respectively [3].

Fifty-one of 280 patients (18%: 11 conventional, 33 laparoscopic, and 7 combined) exhibited postoperative fever. In 24 cases, fever was simultaneous with, and probably related to, other complications. In 27 cases (1 conventional, 22 laparoscopic, and 4 combined), fever was the only complication noted. For horses castrated using a laparoscopic or combined approach and when no other significant abnormal finding were apparent during clinical examination, we assume that postoperative fever was most likely caused by a chemical peritonitis as a reaction to the CO_2 [11]. Although other alternatives can be used for abdominal insufflation, CO_2 is preferred over oxygen, room air, and nitrous oxide because it is noncombustible, blood soluble, and eliminated via the lungs during expiration [26]. In 2.7% (n = 4) of the laparoscopically castrated horses, severe postoperative complications were recorded, including 1 (0.7%) fatality due to intestinal adhesions. Hartman et al [2] reported 2 out of 346 equids (0.6%) with abdominally retained testes undergoing conventional (non)invasive cryptorchidectomy to have died from complications related to the surgery, and Cribb et al (2015) reported 2 out of 30 horses (6.7%) to have died as a result of complications after conventional cryptorchidectomy.

Several disadvantages of laparoscopy, including the expense of equipment and the necessity of familiarity with the equipment, have been acknowledged. With regard to cryptorchid castration, Hartman et al (2015) reported no difference in postoperative complications for patients castrated laparoscopically versus conventionally. The latter study did report longer hospitalization times for patients undergoing invasive or laparoscopic cryptorchidectomy, but for laparoscopic treatments, this was a result of a longer time of preoperative fasting to empty the gastrointestinal tract [2]. A recent study comparing recumbent laparoscopic and conventional open cryptorchidectomies reported increased surgical preparation time, increased surgical and anesthetic times, and more postoperative complications for horses undergoing recumbent laparoscopic cryptorchidectomy [3]. Under our new protocol, we perform laparoscopy in the standing horse, but exclusively for abdominally retained testes. In our opinion, standing laparoscopic castration without orchidectomy of abdominal testes is a valuable minimally invasive technique allowing easy intraoperative localization of the testis and a 100% success rate.

In our study, although no prophylactic antibiotics were given, two horses developed severe colitis after laparoscopic castration. The increased incidence of severe complications may have resulted from the longer preoperative fasting period increasing the risk of subsequent dysbacteriosis. Reduced intestinal fill is necessary for safe blind cannula insertion and adequate visibility of the cryptorchid testis during laparoscopic castration. This is why a fasting period of 36 hours is recommended [25]. No alternative fasting protocols have been described for equine laparoscopy, but reducing the intake more gradually and keeping the period of complete fasting as short as possible could be considered.

Failure rates for laparoscopic castration of scrotal and inguinal testes were considerably higher than reported in previous publications. In a study on cryptorchid and normal stallions, 5.6% of inguinal testes and 3.4% of scrotal testes failed to become completely necrotic [12]. Another study reported a failure rate of 4 out of 32 (12.5%) horses with bilateral normally descended testes [27]. In our study, only cryptorchid stallions were included, but the failure rate per testis was 7.5% (3/40) for inguinal and 16.4% (9/55) for scrotal testes. The fact that only the descended testes of cryptorchid stallions were included might have contributed to the higher incidence of failed testicular necrosis. In this respect, it is possible that the size and vascularity of a normally descended testis in a unilateral cryptorchid is increased to compensate for the atrophied cryptorchid testis. This might result in better development of the collateral (alternative) blood supply to the descended testis of cryptorchid compared to normal stallions, thereby increasing the risk of the testis retaining viability following spermatic cord ligation and transection. In any case, these results support the recommendation that laparoscopic castration without orchidectomy should not be used for castration of normal stallions or inguinal cryptorchids [12].

Previous surveys of laparoscopic cryptorchid castration report removal of the abdominal testis after double ligation [28–30]. Although it is technically easy to remove the testis, an enlarged incision is necessary and it increases surgery time. In our study, all 168 abdominally retained testes underwent complete necrosis after laparoscopic double ligation of the spermatic cord without orchidectomy. Voermans et al [12] also reported 100% success in 123 abdominal testes, and Rijkenhuizen and Dijk [11] reported 100% success in 24 abdominal cryptorchids. It therefore seems justified to dispense with the routine determination of d7 plasma testosterone concentrations following ligation of the spermatic cord of an abdominal testis. However, all cases with an uncertain history of previous castration still need to be checked to prove that the horse has been successfully castrated. Because this study was retrospective, several limitations such as the lack of complete similarity between the compared groups and the involvement of a large variety of surgeons with different levels of experience were encountered. Moreover, because the study compares an old to a new policy, a sequential rather than a contemporaneous comparison of the approaches was performed. During the studied period (2004–2014), no significant temporal changes in general treatment occurred in our hospital. Even with these limitations, related to the retrospective nature of the study, valuable information was obtained.

5. Conclusion

On the basis of failure rates, for our clinic, a laparoscopic approach is recommended over a conventional open approach for castration of abdominally retained testes. For inguinally retained or normally descended testes, conventional open surgery is the approach of choice.

The use of a standardized preoperative ultrasonographic examination to determine the surgical approach significantly reduced the need for second surgeries required to complete cryptorchid castration. In this respect, the use of preoperative ultrasonography to locate the testis proved to be a valuable means of determining the best surgical approach (sensitivity 94%). All surgical techniques were safe with low rates of serious complications.

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