Cryptorchidectomy in equids: 604 cases (1977–2010)

Richard Hartman, DVM; Jan F. Hawkins, DVM; Stephen B. Adams, DVM; George E. Moore, DVM, PhD; John F. Fessler,† DVM

Objective—To evaluate the management of equids undergoing cryptorchidectomy at a referral hospital.

Design—Retrospective case series.

Animals—604 client-owned equids.

Procedures—Medical records of all equids undergoing surgical treatment of cryptorchidism from 1977 to 2010 were retrospectively reviewed. Analyses of breed, location of retained testes, accuracy of palpation per rectum for determining the location of retained testes, surgical technique, and postoperative complications were performed.

Results—The most frequently affected breed was the Quarter Horse (282/604 [47%]), which was significantly overrepresented. Of the 604 equids, 90 (15%) had undergone previous surgical attempts at castration. Preoperative palpation per rectum was performed in 395/604 (65.4%) patients, and was accurate in predicting the location of the retained testes in 354/395 (89.6%). Surgeons were significantly more likely to be incorrect in determining the location of the retained testis by means of palpation per rectum in patients that had undergone a prior attempt at castration. For equids with abdominal cryptorchidism (360/604 [59.6%]), the most common surgical technique was noninvasive cryptorchidectomy (298/360 [82.8%]). In unilateral cryptorchids (521/604 [86.3%]), the 2 most common sites were left abdominal (184/521 [35.3%]) and right inguinal (148/521 [28.4%]). For bilateral retention (80/604 [13.2%]), abdominal cryptorchidism was most common (48/80 [60%]). Fever was present in 138/324 (43%) equids on the first day after surgery. Postoperative fever was not significantly associated with any variables evaluated. Including postoperative (≤ 24 hours) fever, 150 of 604 (25%) patients developed postoperative complications. Excluding postoperative fever, 18 of 604 (3%) patients developed major postoperative complications; complications in 10 of 604 patients were deemed surgically related, and 3 of 604 patients died.

Conclusions and Clinical Relevance—Results indicated that cryptorchidectomy in equids performed with a variety of surgical approaches was associated with minimal postoperative complications. A history of previous attempts at castration decreased the ability to accurately predict the location of the retained testis. (*J Am Vet Med Assoc* 2015;246:777–784)

Cryptorchidism, a developmental condition, is the failure of a testis to descend into the scrotum. The retained testis can be either inguinally or abdominally retained. Cryptorchidism is one of the most common congenital abnormalities in horses and may be heritable, although evidence for heredity is lacking.[1,2] In horses, retention of testes is approximately equally distributed between left and right, with left abdominal cryptorchidism and right inguinal cryptorchidism being most commonly reported.[3,4] The diagnosis of cryptorchidism is confirmed on the basis of results of physical examination, including palpation per rectum, and, in selected cases, results of hormonal assays. Methods for determining the location of retained testes include external palpation of the scrotum and inguinal region, palpation per rectum, and ultrasonography.[1,5,6] Traditional open surgical approaches for treatment include inguinal, parainguinal, modified parainguinal, suprapubic paramedian, flank, and scrotal as well as laparoscopic surgery.[1,7–15]

A prior retrospective study[3] of 350 horses undergoing cryptorchidectomy at our hospital from 1962 to 1976 concluded that palpation per rectum was a valuable technique for determining the location of the retained testis and that results of noninvasive cryptorchidectomy were superior to those of invasive techniques. In that study,[3] the surgical technique was classified as invasive whenever the surgeon's fingers or entire hand was inserted into the abdominal cavity via the inguinal canal, and as noninvasive if the retained testis was retrieved by means of traction on the gubernaculum,

From the Departments of Veterinary Clinical Sciences (Hartman, Hawkins, Adams, Fessler) and Comparative Pathobiology (Moore), College of Veterinary Medicine, Purdue University, West Lafayette, IN 47907. Dr. Hartman's present address is Mid Rivers Equine Centre, 404 Stable Ln, Wentzville, MO 63385.

Address correspondence to Dr. Hartman (rhartmandvm@gmail.com).

†Deceased.

epididymis, or ductus deferens after rupture of the vaginal process without any manual exploration within the abdominal cavity or insertion of the surgeon's fingers or hand. On the basis of those results and the experience of the clinicians at Purdue University with the treatment of horses with cryptorchidism, the diagnostic method of choice has for many years been palpation per rectum and the preferred surgical technique has been noninvasive cryptorchidectomy as described by Stickle and Fessler in 1978.[3]

Diagnosis and treatment are difficult in horses with cryptorchidism that have a history of attempted castration or that have been unilaterally castrated (ie, hemicastrated) but continue to have stallion-like behavior.[16] In either case, results of abdominal palpation per rectum are frequently misleading and routine cryptorchidectomy may not be surgically feasible. The purpose of the study reported here was to further describe the experience at our hospital with treatment of cryptorchidism in equids. We hypothesized that abdominal palpation per rectum would be an accurate method to determine the location of the retained testis in equids without a history of castration but not in hemicastrated equids, that noninvasive cryptorchidectomy would be associated with less morbidity (ie, fewer complications) than invasive cryptorchidectomy, and that the use of inguinal packing when treating abdominal cryptorchidism would be associated with greater patient morbidity (ie, more complications), compared with equids undergoing surgery by means of inguinal incisions and scrotal ablation without packing.

Materials and Methods

Case selection criteria—Medical records for equids treated for cryptorchidism at the Purdue University Veterinary Teaching Hospital from January 1977 to July 2010 were reviewed. This represented all equids treated for cryptorchidism at our hospital following the 1962 to 1976 series (n = 350) reported by Stickle and Fessler.[3] Equids were included in the study if surgical removal of 1 or more retained testes was performed. True monorchids were excluded from this study.

Medical records review—Data collected from the medical records included signalment, history of previous castration or attempts at castration, results of external palpation of the scrotum and inguinal region, results of palpation per rectum, hormonal assays if performed (including results), location of the testis removed at surgery, surgeon, surgical technique (noninvasive, invasive, or laparoscopic cryptorchidectomy or scrotal ablation), total anesthesia time (from endotracheal intubation to discontinuation of anesthesia), administration of perioperative antimicrobials (yes or no; drug type was not recorded), duration of hospital stay, outpatient versus inpatient surgery, presence of a fever (> 38.3°C [101.0°F]) within 24 hours after surgery, results of histologic evaluation of samples if performed, and any major postoperative complications associated with cryptorchidectomy. Fever was not considered a major postoperative complication. Postoperative complications were considered major if they required specific treatment (eg, administration of antimicrobials or anti-inflammatory medication) or if the procedure resulted in death or euthanasia. Minor documented complications such as edema and swelling were not recorded. A veterinary medical database[a] was searched to determine the breed distribution of equids in the Purdue University Veterinary Medical Teaching Hospital during the time of the study.

Preoperative diagnostic testing—All patients had a complete physical examination. The scrotum and inguinal region of each equid was palpated for evidence of descended or undescended testes. Abdominal palpation per rectum was performed with the patient restrained in stocks to localize the testis prior to general anesthesia and surgery. Patients that were not amenable to restraint were sedated with xylazine hydrochloride (0.3 to 0.6 mg/kg [0.14 to 0.27 mg/lb], IV) or detomidine hydrochloride (0.01 to 0.02 mg/kg [0.009 to 0.018 mg/lb], IV), sometimes in combination with butorphanol tartrate (0.01 to 0.02 mg/kg, IV). Both internal inguinal rings were palpated per rectum to identify the vas deferens. If the vas deferens was palpated entering the inguinal ring in a patient without a history of castration, 1 of 3 diagnoses was made: normally descended testis, inguinal cryptorchidism, or partial abdominal cryptorchidism. In horses with partial abdominal cryptorchidism, the testis is located in the abdomen but the vas deferens and epididymis have entered the inguinal ring.[3] If the vas deferens was not palpated entering the inguinal ring, abdominal cryptorchidism was diagnosed. No effort was made to palpate the testis.

Hormonal assays were performed in some patients that had a history of castration but continued to have stallion-like behavior. A variety of hormonal assays were performed at the discretion of the referring veterinarian or attending clinician. Hormonal assays included measurement of estrone sulfate and basal testosterone concentrations or the human chorionic gonadotrophin stimulation test in patients treated after 1989.[17] Transrectal or transinguinal ultrasonography was performed in a small number of patients examined after 1990, by means of a previously described technique.[5,6]

Surgical technique—Equids with inguinal cryptorchidism (palpable testis) were prepared for standard castration by 1 of 2 techniques. Until 1996, standard castration was performed via a skin incision directly over the descended or retained testis. The testis was exposed, and the spermatic cord was ligated, crushed with an emasculator, or both. The skin incision was left open to heal by second intention. From 1996 on, affected testes were approached via scrotal ablation. Both testes were approached via a single scrotal incision and removed as for standard castration. The scrotal incision was then closed following removal of both testes. With either technique, the inguinal canal was not explored and the abdomen was not entered because the vaginal tunic and testis were palpable in the inguinal region.

Surgical technique was categorized as invasive or noninvasive for abdominal or partial abdominal cryptorchidism, and laparoscopic cryptorchidectomy was categorized separately. Procedures in which > 2 fingers or the entire hand of the surgeon entered the abdominal cavity to manipulate intra-abdominal structures were classified

as invasive. Procedures in which abdominally retained testes were removed through an incision in the vaginal process followed by traction of the gubernaculum, epididymis, or ductus deferens digitally or with surgical instruments were classified as noninvasive.[3]

Equids with either unilateral or bilateral abdominal cryptorchidism were prepared for noninvasive cryptorchidectomy. If the noninvasive approach was not successful in removal of the abdominally retained testis, the external inguinal and internal inguinal rings were digitally dissected or dilated manually to allow partial insertion of the surgeon's hand into the abdominal cavity. On the rare occasions that inguinal exploration did not allow removal of the testis, an 8- to 10-cm parainguinal incision was made adjacent to the external inguinal ring and the surgeon inserted a hand into the abdominal cavity. Following abdominal cryptorchidectomy, the inguinal canal was packed with sterile gauze that was removed the day after surgery.

From 1996 on, most cryptorchidectomies were performed by means of scrotal ablation.[11,12] The skin over the external inguinal ring was retracted with Richardson retractors, Kelly retractors, or both to allow for identification of the vaginal process. Noninvasive cryptorchidectomy was then performed as described. After cryptorchidectomy, the incision was sutured. Packing of the inguinal canal was no longer performed following routine adoption of the scrotal ablation technique.

Equids with a history of attempted castration (in which a surgical incision had been made to remove a descended testis or explore for a retained testis) may have had 1 (ie, hemicastrated) or both testes remaining at the time of referral. Equids with a history of castration were aseptically prepared for surgical exploration of both external inguinal rings and for a parainguinal abdominal incision or, from 1996, for laparoscopic cryptorchidectomy. Following induction of general anesthesia, the inguinal region and scrotum were inspected for incisional scars and the inguinal region was palpated bilaterally. If fibrosis from prior inguinal incisions was judged to be either absent or minimal, noninvasive cryptorchidectomy was attempted; otherwise, a parainguinal incision was made to allow for abdominal exploration and identification of the retained testis. Both sides were explored unless a definitive history of unilateral castration was provided prior to surgery. From 1996 on, laparoscopic cryptorchidectomy under standing sedation or general anesthesia was preferred for abdominal cryptorchidectomy in patients with a history of prior attempts at castration.

Statistical analysis—Associations between categorical data were assessed by means of the Pearson χ^2 test of independence or, when expected frequencies were ≤ 5 in at least 25% of cells, the Fisher exact test. Numeric data (age and anesthesia time) were assessed for normality with the Shapiro-Wilk test. Because of nonparametric distributions, groups of numeric data were compared by means of the Wilcoxon rank sum test (2 groups) or Kruskal-Wallis test (> 2 groups). Forward stepwise multivariable logistic regression analysis, adding variables with values of $P > 0.20$, was used to evaluate for any associations between history of castration, location of the testes at surgery, surgical technique and closure, use of hormonal assays, hospitalization time, antimicrobial use, and postoperative fever (model 1) or complications (model 2). Significance was set at $P \leq 0.05$. Summary statistics for categorical data are presented as proportions, percentages, or both. Summary descriptive statistics for numeric data are presented as median and range. Statistical analyses were performed with commercially available software.[b]

Results

A total of 604 equids underwent cryptorchidectomy during the 33-year study period. Breeds included Quarter Horse (n = 282), Standardbred (62), Paint (49), Appaloosa (38), Thoroughbred (31), Arabian (30), draft (21), Tennessee Walking Horse (12), Pony of the Americas (9), and Saddlebred (7); the remaining 63 equids were of unknown breed or were very uncommon for our hospital population (eg, warmbloods, Morgans, and donkeys). The most common breed affected, Quarter Horses were significantly ($P < 0.001$) overrepresented in the study population (282/604 [47%]), compared with the hospital population (10,002/30,809 [32%]) during the period of the study. Median age was 2 years (range, 6 months to 13 years).

Most patients were referred for surgical removal of at least 1 retained testis, as determined on the basis of results of manual palpation of the scrotum and inguinal region by either the referring veterinarian or owner. Ninety of the 604 (15%) equids had undergone previous attempts at castration. Of the 90 equids that had previous attempts at castration, 85 (94%) had signs of stallion-like behavior, 54 (60%) had a testis removed prior to admission to our hospital, 26 (29%) had hormonal assays performed, and 16 (18%) had been purchased as geldings.

Of the 604 surgeries in this study, more than half (348 [58%]) were performed by 2 of the authors (JFF [196 {32%}] and SBA [152 {25%}]). The remaining surgeries were performed by other faculty surgeons (154 [25%]) or surgery residents (102 [17%]).

Scrotal palpation was performed in 559 of the 604 (93%) equids. Of the 559 equids, 254 (45%) had an undescended left testis, 215 (38%) had an undescended right testis, 80 (14%) had bilateral undescended testes, and 10 (2%) had undergone previous attempts at castration. Results of scrotal palpation could not be determined from the medical record for 45 of the 604 (7%) patients.

Results of abdominal palpation per rectum were available in 395 of 604 (65%) cases. For the remaining patients, results of rectal palpation were not recorded in the medical record or rectal palpation was not performed because animals were too fractious or too small. The location of the retained testis was correctly determined, as confirmed at surgery, in 354 of 395 (90%) cases. Two authors (JFF and SBA) also performed the majority of the preoperative palpations per rectum (298/395 [75%]). These surgeons were correct in determining location of the testes in 279 of 298 (94%) cases. Other surgery faculty (56/395 [14%]) and residents (41/395 [10%]) performed palpation per rectum in the remaining cases and correctly determined the location in 46 of 56 (82%)

and 29 of 41 (71%) of patients, respectively. The surgeons (JFF and SBA) who performed rectal examinations in most patients were significantly ($P < 0.001$) more likely to be correct in determining the location of the retained testis than were the other surgeons or surgical residents performing preoperative rectal examinations.

Hormonal assays were performed in 32 of 604 (5%) patients. In these 32 patients, hormonal assays included human chorionic gonadotrophin stimulation (21 [66%]), measurement of baseline testosterone concentration (4 [13%]), and measurement of estrone sulfate concentration (1 [3%]); in 6 (19%), the type of hormonal assay was not recorded. Of the 32 patients that underwent hormonal assays, 26 (81%) had a history of castration and 6 (19%) had an unknown castration history and signs of stallion-like behavior. Equids with a history of castration were significantly ($P < 0.001$) more likely to have had hormonal testing than those without a history of castration. Hormonal assays performed prior to surgery confirmed the presence of testicular tissue prior to surgery in 22 of the 26 (84.6%) patients with a history of castration. For the remaining 4 (15%) patients, the results of the hormonal assays were absent from the medical record. Hormonal assays were performed after surgery in 7 patients that had been tested prior to surgery and indicated no residual testicular tissue.

Transabdominal or transinguinal ultrasonography, or both, was performed in 5 of the 604 (< 1%) patients. Results correctly determined the location of the retained testis as confirmed at surgery in all 5 patients.

Of the 604 patients, location of retained testes was available for 601 **(Table 1)** and was not recorded for 3. Equids with unilateral cryptorchidism on the left were significantly ($P < 0.001$) more likely to have abdominally retained testes, and those with unilateral cryptorchidism on the right were significantly ($P < 0.001$) more likely to have inguinally retained testes. The number of patients with everted or inverted vaginal processes was not recorded.

Of the 360 equids with abdominally retained testes, 298 (83%) underwent noninvasive cryptorchidectomy, 48 (13%) underwent invasive cryptorchidectomy, and 14 (4%) underwent laparoscopic cryptorchidectomy (under general anesthesia in 11 and standing sedation in 3). Standard castration (testis palpable inguinally and removed) was performed in all 244 patients with an inguinally retained testis.

For the 604 patients, surgical closure technique consisted of packing the inguinal incision for abdominal cryptorchidism in 208 (34%), leaving the inguinal incision open for inguinal cryptorchidism in 199 (33%), scrotal ablation with primary closure for abdominal or inguinal cryptorchidism in 150 (25%), primary inguinal incision closure in 29 (5%), and laparoscopic portal closure in 11 (2%); surgical closure technique was unknown in 7 (1%).

For the 90 patients with a history of prior attempts at castration, 60 (67%) had palpation per rectum. The location of the retained testis was correctly determined, as confirmed at surgery, in 40 of these 60 (67%) patients. Causes for inaccuracy in the remaining 20 patients included previous removal of the descended testis in 17 (85%) and retraction of the vas deferens into the abdomen in 10 (50%). If there was a history of attempted castration, surgeons were significantly ($P < 0.001$) more likely to be incorrect in preoperatively determining the location of the retained testis by means of palpation per rectum. The surgical approach in 90 patients with a history of previous castration included noninvasive (45 [50%]), invasive (20 [22%]), standard (14 [16%]), and laparoscopic (11 [12%]). For the 90 patients with a history of castration, 85 (94%) had unilateral cryptorchidism and 5 (6%) had bilateral cryptorchidism. In the 90 patients, surgical diagnoses included abdominal (56 [62%]), inguinal (15 [17%]), partial abdominal (14 [16%]), bilateral abdominal (4 [4%]), and abdominal and inguinal (1 [1%]) cryptorchidism.

Of the 90 patients with a history of prior attempts at castration, 54 (60%) were hemicastrated (1 testis removed prior to referral) and 36 (40%) had 2 testes at admission. Of the 54 hemicastrated patients, 32 (59%) underwent noninvasive cryptorchidectomy, 9 (17%) underwent standard castration, 8 (15%) underwent invasive cryptorchidectomy, 3 (6%) underwent laparoscopic cryptorchidectomy, and 2 (4%) underwent laparoscopy plus invasive cryptorchidectomy. Rectal examination was performed in 44 of 54 (81%) hemicastrated patients; of these 44 cases, diagnosis was correct for 29 (66%) and incorrect for 15 (34%). Location of the retained testis in the 54 hemicastrated horses was abdominal (35 [65%]), partial abdominal (11 [20%]), and inguinal (8 [15%]). In the 90 patients, surgical closure technique consisted of inguinal packing (36 [40%]), no closure (ie, open inguinal incision and drainage; 20 [22%]), primary closure of the inguinal canal (12 [13%]), scrotal ablation (10 [11%]), and laparoscopic closure (8 [9%]); in 4 (4%) cases, surgical closure technique could not be determined from the record.

Laparoscopic cryptorchidectomy was performed in 11 of 90 (12.2%) patients with a history of previous attempts at castration. Laparoscopic approach included general anesthesia and dorsal recumbency in 6 (55%) patients; general anesthesia, dorsal recumbency, and hand-assisted laparoscopy in 2 (18%); and sedation, local anesthesia, and standing flank laparoscopy in 3 (27%). Laparoscopy under general anesthesia had to be performed in 1 equid in which the invasive approach failed. One equid underwent invasive cryptorchidectomy after the surgeon was unable to identify the retained

Table 1—Location of retained testes in 601 equids undergoing surgical treatment of cryptorchidism from 1977 to 2010.

Location	Left (n = 281)	Right (n = 240)	Bilateral* (n = 80)
Abdominal	184 (66)	60 (25)	48 (60)
Partial abdominal	18 (6)	32 (13)	2 (2.5)
Inguinal	79 (28)	148 (62)	17 (21)

Values are reported as number (%).
*For 13 (16.5%) patients bilaterally retained testes were left abdominal and right inguinal (n = 8), left abdominal and right partial abdominal (2), left inguinal and right partial abdominal (2), and left inguinal and right abdominal (1).

testis with standing laparoscopy because of its location adjacent to the kidney.

Total anesthetic time (defined as time from induction of anesthesia to conclusion of surgery) was available for 601 of 604 patients (3 underwent laparoscopic cryptorchidectomy under standing sedation). Of the 601 patients, 235 (39%) underwent standard castration (median surgery time, 30 minutes [range, 10 to 355 minutes]), 307 (51%) underwent noninvasive cryptorchidectomy (median anesthesia time, 60 minutes [range, 15 to 200 minutes]), 48 (8%) underwent invasive cryptorchidectomy (median anesthesia time, 120 minutes [range, 30 to 260 minutes]), and 11 (2%) underwent laparoscopic cryptorchidectomy (median anesthesia time, 137 minutes [range, 120 to 240 minutes]). Total anesthesia times for surgical wound closure techniques were also compared. Surgical closure technique consisted of open inguinal incision (healing by secondary intention) for 199 of 604 (33%) patients (median anesthesia time, 30 minutes [range, 10 to 180 minutes]), open inguinal incision with inguinal packing for 208 (34%; median anesthesia time, 55 minutes [range, 15 to 200 minutes]), scrotal ablation with primary closure for 150 (25%; median anesthesia time, 75 minutes [range, 22 to 355 minutes]), primary inguinal closure for 29 (5%; median anesthesia time, 97 minutes [range, 20 to 145 minutes]), and laparoscopic portal closure for 11 (2%; median anesthesia time, 137 minutes [range, 120 to 240 minutes]). There was a significant ($P < 0.001$) difference in total anesthesia time for each of the surgical approaches used. Similarly, there was a significant ($P < 0.001$) difference between each of the types of surgical closure techniques and the total anesthesia time.

Histologic evaluation of the testes removed at surgery was performed for 199 of 604 (33%) patients to document the removal of testicular tissue. Fifty of 199 (25%) patients underwent previous attempts at castration. Testicular hypoplasia and atrophy were the most common findings (188/199 [94%]). Testicular abnormalities were found for 8 of 199 (4%) patients for which histologic evaluation was performed. Testicular abnormalities included teratoma (2), testicular torsion (2), testicular ischemia (2), cystic testis (1), and fibrovascular tissue (1). Results for 3 samples were missing from the medical record.

Perioperative antimicrobials were administered to 243 (40%) of the 604 patients. Of those 243 patients, 35 received perioperative antimicrobials prior to 1996. Univariate and multivariate statistical analyses did not reveal any significant associations between the use of antimicrobials (yes or no) and the presence or absence of gauze packing with the occurrence of postoperative fever or complications.

Of 604 patients, 425 (70%) were hospitalized and 179 (30%) were treated on an outpatient basis. Median hospitalization time was 2 days (range, 0 to 22 days). Patients were hospitalized for ≤ 2 days in 250 of 425 (59%) cases and ≥ 3 days in 175 of 425 (41%) cases. Patients that received inguinal packing for surgical closure technique were significantly ($P < 0.001$) more likely to be hospitalized ≥ 3 days, compared with those not receiving inguinal packing. Similarly, patients undergoing invasive or laparoscopic cryptorchidectomy (standing or under general anesthesia) were significantly ($P < 0.001$) more likely to be hospitalized ≥ 3 days, compared with those undergoing noninvasive cryptorchidectomy or standard castration techniques. Equids undergoing laparoscopic cryptorchidectomy were typically hospitalized longer because of the time required for preoperative emptying of the gastrointestinal tract (ie, 24 hours prior to surgery). Equids with a history of prior attempts at castration were significantly ($P < 0.001$) more likely to be hospitalized ≥ 3 days, compared with those without prior attempts. Finally, patients that developed major complications were significantly ($P < 0.001$) more likely to be hospitalized ≥ 3 days.

When a postoperative fever and other complications were considered, 150 of 604 (25%) patients developed complications. Postoperative rectal temperature was available for 324 of 604 (54%) patients. Fever was present in 138 of 324 (43%) patients on the first day after surgery, and fever was the only complication in 130 of 138 (94%). There was no known selection bias (as determined by a review of the medical record) on hospitalizing patients and the risk for those developing a postoperative complication. The remaining 280 of 604 (46%) patients did not have rectal temperature available because temperature was absent from the medical record or they were treated on an outpatient basis or were fractious.

Eighteen of 604 (3%) patients developed major complications, of which 8 also had a fever in the first 24 hours after surgery. Of those 18 patients, 5 had a respiratory infection, and 3 had diarrhea. Of the patients with complications directly related to cryptorchidectomy, 3 died (1 each of hemorrhage from slipped ligature, anesthetic complications, and ruptured colon secondary to iatrogenic trauma to the colon with sponge forceps), 2 had surgical errors that were not fatal (1 each of lacerated caudal epigastric artery and sponge left in surgery site), 2 had seromas, and 1 each had eventration (treated successfully with surgery), hyperkalemic periodic paralysis episode, and rhabdomyolysis. The lacerated caudal epigastric artery was ligated and the surgical sponge removed, and both equids were discharged from the hospital.

Fever (> 38.33°C) in the first 24 hours after surgery was not significantly associated with retained testes in an abdominal or partial abdominal location, compared with an inguinal location. There was no significant association between the surgical approach (noninvasive, invasive, or laparoscopic cryptorchidectomy or standard castration) and the presence of a fever or other complications evaluated. There was no significant association between the type of surgical closure (packing, inguinal closure, scrotal ablation with primary closure, and laparoscopic portals) and fever in the first 24 hours after surgery. Likewise, no significant association was found between the types of closure and complications. The use of inguinal packing was not significantly associated with fever or any complications. Equids undergoing standard castration were significantly ($P < 0.001$) less likely to have major complications, compared with those undergoing invasive, noninvasive, or laparoscopic cryptorchidectomy. No significant association was

found between the use of antimicrobials and a postoperative fever. Furthermore, there was no significant association in multivariable analysis with any variable, other than surgical approach, and the occurrence of postoperative complications.

Discussion

In this large case series, cryptorchidectomy by a variety of approaches performed over a 33-year period from 1977 to 2010 at 1 teaching hospital, mainly by 2 experienced surgeons, was associated with minimal postoperative complications. Preoperative palpation per rectum was highly accurate (354/395 [89.6%]) in predicting the location of the retained testes for patients in which it was performed, and it was not associated with any complications.[1,3] Furthermore, our study indicated that results were more accurate when rectal examination was performed by an experienced clinician. Surgeons experienced in abdominal palpation per rectum can accurately identify the anatomic features of the internal inguinal ring and vas deferens, plan the specific surgical approach (eg, noninvasive vs standard castration; short-duration IV vs inhalation general anesthesia), and discuss the surgical technique with the owner prior to treatment. Preoperative knowledge of location of the testis can also be used to help determine whether the procedure can be performed on an outpatient basis (inguinally retained testis) or will require hospitalization (abdominally retained testis).

If an abdominally retained testis is diagnosed via rectal palpation, the surgeon must be familiar with the necessary surgical techniques, such as noninvasive cryptorchidectomy. Some equine practitioners are not comfortable with removal of abdominally retained testes and subsequently refer these horses to surgical specialty centers staffed by board-certified surgeons. In contrast, inguinal cryptorchidectomy can generally be successfully performed in the field by a veterinarian experienced with equine castration. With preoperative abdominal palpation per rectum, the procedure required can be determined prior to surgery and the veterinarian can aid the owner in deciding how to proceed. Likewise, if abdominal cryptorchidism is diagnosed at the referral center, it allows the surgeon to advise the owner regarding which surgical technique will be used and the likely costs associated with the procedure.

In the present study, less invasive techniques and scrotal ablation for cryptorchidectomy were not associated with fewer complications, compared with invasive techniques. However, this may be explained by a low overall complication rate, with only 3% of patients having a major postoperative complication. Regardless of the surgical technique, we suggest that the expected complication rate for horses undergoing cryptorchidectomy should be low.

On the basis of the results of this study, for equids with abdominal cryptorchidism, the noninvasive technique was associated with minimal complications. It is currently the preferred method for removal of abdominally retained testes at our institution.[1] Noninvasive cryptorchidectomy requires minimal surgical equipment and can be performed rapidly by a competent surgeon. In the present study, patients undergoing noninvasive cryptorchidectomy (307/601 [51%]) had a significantly shorter anesthetic time (median, 60 minutes [range, 15 to 200 minutes]) than those undergoing all other procedures, except standard castration for inguinally retained testes (median, 30 minutes [range, 10 to 355 minutes]).

Adams[1] originally described packing of the inguinal canal with a sterile towel following noninvasive cryptorchidectomy to prevent postoperative eventration from the open vaginal process. Whenever gauze packing was used, it required hospitalization because the pack was removed 24 hours after placement. Palpation per rectum prior to removal was also required to ensure that the gauze was not adhered to the intestine. The elimination of gauze packing has the advantages of decreased postoperative care, elimination of the requirement for a repeated rectal examination, decreased hospitalization time, and elimination of an open draining surgical wound after gauze removal. We hypothesized that gauze packing within the inguinal canal would be the main contributing factor to postoperative fever, but gauze packing was not significantly associated with postoperative fever in this study. With the adoption of the scrotal ablation technique, we eliminated the use of gauze packing in 1996.

The combination of noninvasive cryptorchidectomy and scrotal ablation minimizes the risk of postoperative herniation and eventration because of primary closure of the single scrotal incision. There were no instances of postoperative herniation or evisceration following scrotal ablation in our study. We conclude that the risk of postoperative evisceration following scrotal ablation with noninvasive cryptorchidectomy is minimal and have therefore completely abandoned the use of gauze packing of the inguinal canal. Scrotal ablation has become our preferred technique for surgical approach in horses with cryptorchidism. This technique allows adequate exposure to remove unilateral or bilateral inguinally and abdominally retained testes. However, 1 surgeon (SBA) at our hospital prefers bilateral inguinal incisions versus a scrotal approach for treatment of bilateral abdominal cryptorchidism because of improved access to the inguinal rings. The advantages of scrotal ablation include the absence of draining incisions, closure of a single incision, decreased risk of herniation because of primary closure, elimination of the need to pack the inguinal canal, and obliteration of dead space. The primary disadvantage of scrotal ablation is increased anesthetic time and increased cost, compared with inguinal packing and healing by secondary intention. We feel this disadvantage is negated because of decreased risk of herniation and eventration and the ability to perform the surgery on an outpatient basis. Other potential disadvantages of scrotal ablation can include seroma formation or abscess formation, although this did not occur in any of the patients treated with scrotal ablation in this series.

Laparoscopic cryptorchidectomy has been described as a minimally invasive technique, which may minimize postoperative complications and improve patient outcomes.[13–15,18] Despite the purported benefits, we currently choose to avoid laparoscopy for

routine cryptorchidectomy. In our clinical experience, standard castration techniques for horses with inguinally retained testes and the noninvasive technique for horses with abdominally retained testes are associated with minimal complications, shorter hospitalization time, lower expense, and shorter surgical times, compared with laparoscopy. In this study, laparoscopy was used in 11 patients and was associated with the longest anesthesia times (median, 137 minutes [range, 120 to 240 minutes]). Lack of experience and equipment setup could have contributed to the longer anesthesia times, but we suggest that the longer anesthesia time was more likely secondary to the fact that most cases were explored bilaterally because of a history of previous castration. There was no difference in postoperative complications for patients treated laparoscopically versus with the other surgical techniques; however, postoperative pain scoring was not performed, so the difference in signs of pain between patients being treated with a minimally invasive approach versus with scrotal ablation was not assessed. Of these 14 cases, 11 had previous attempts at castration. Laparoscopic cryptorchidectomy was found to not be significantly different from invasive or noninvasive cryptorchidectomy with regard to postoperative complications; however, laparoscopic and invasive cryptorchidectomy were associated with increased hospitalization times. Currently at our institution, laparoscopic cryptorchidectomy is reserved for cases where there is a history of prior attempts at castration. We have found laparoscopy to be particularly advantageous for removal of abdominally retained testes in horses with previous attempts at castration because fibrosis at the previous surgical site frequently precludes noninvasive cryptorchidectomy. Laparoscopy can allow the surgeon to visually evaluate each internal inguinal ring for the presence of a testis and can improve the surgeon's ability to compensate for the disruption of normal anatomic structures associated with previous attempts at castration.

Fever was the most common complication identified in this study. Our hypothesis was that the presence of gauze packing in the inguinal canal would be the main contributing factor to the development of postoperative fever within the first 24 hours after surgery, but we did not find this to be the case. Results of our analyses suggested that there was not a single factor contributing to the development of postoperative fever. Schumacher et al[19] documented that of 24 clinically normal horses castrated by routine methods, 15 developed nonseptic peritonitis. The only clinical sign of peritonitis for these horses was fever. Peritoneal fluid was not evaluated in in the present study; therefore, development of peritonitis could not be determined. Fortunately, nonseptic peritonitis in most horses following cryptorchidectomy or castration is self-limiting and does not require treatment.

In the present study, only 1 of 18 major complications (respiratory infection) was associated with an inguinally retained testis. Three patients with abdominally retained testes died. Death in 1 patient was attributed to an adverse reaction to general anesthesia. The remaining 2 deaths were due to fatal hemorrhage from a slipped ligature and peritonitis secondary to a perforated colon. The patient that died as a result of hemorrhage underwent noninvasive cryptorchidectomy, and the inguinal incision was partially closed with inguinal packing. The patient that died of peritonitis secondary to a perforated colon underwent noninvasive cryptorchidectomy with scrotal ablation. It was recognized at surgery that the colon was grasped with traumatic forceps; however, the procedure was not converted to an invasive inguinal approach because no perforation was seen on inspection of the colon at surgery. The most likely cause of perforation was secondary to injury caused by use of the traumatic forceps. Surgical errors can occur in any procedure, and 2 resulted in death; however, the remaining surgical errors were manageable and the patients recovered without adverse effects.

Horses with a history of previous attempts at castration or that have been unilaterally castrated can be a challenge for practitioners, and a history of attempts at castration decreases the ability to accurately predict the location of retained testes with palpation per rectum. The most accurate way to confirm the presence of a remaining testis is the human chorionic gonadotrophin stimulation test.[17] Accuracy of palpation per rectum when examining hemicastrated horses is complicated by retraction of the vas deferens into the abdominal cavity after castration on the side of the previously descended testis and scarring in the inguinal region following previous castration or following exploration for the retained testis. The best way to definitively determine the side of the retained testis is to surgically explore each side of the abdomen. For the cases described in this study, most hemicastrated patients had an abdominally retained testis. Most unilaterally castrated patients in this study were approached with traditional surgery techniques, including standard castration and noninvasive and invasive techniques.

In this study, histologic evaluation was used to confirm the removal of testicular tissue and to identify testicular abnormalities. Neoplasia of retained testes is commonly reported in dogs and people but is rarely reported in horses. In this study, only 8 of the 199 (4%) patients with cryptorchidism that underwent histologic evaluation had a testicular abnormality. However, surgeons should be aware that abnormal retained testes do occur and it can be difficult during surgery to be certain that the testis has been completely removed. Histologic evaluation can therefore be useful to identify testicular tissue, even though the structure removed may not appear to be testicular in origin. Finally, human chorionic gonadotrophin stimulation testing following removal of suspected testicular tissue can confirm removal.

Antimicrobial use in healthy patients undergoing elective surgery is a controversial topic. In our study, most patients undergoing general anesthesia prior to 1996 did not receive perioperative antimicrobials. From 1996 on, most patients received some form of perioperative antimicrobial. Prophylactic antimicrobials were administered because primary closure of the scrotum was performed and because of the belief that the rate of postoperative surgical site infection would be decreased.[20] Our data did not indicate that antimicrobial use prevented the devel-

opment of a fever after surgery or had a significant effect on occurrence of postoperative complications. The type of antimicrobial administered was not recorded because our focus was not on specific types of antimicrobials but rather whether their use would decrease the risk of complications.

Limitations of the present study include the retrospective nature, the missing data, the fact that multiple clinicians and residents performed the procedures in the study, and the fact that procedures and tests were often performed on the basis of clinician preference and experience.

a. Veterinary Medical Database [database online]. Urbana, Ill: Association of Veterinary Medical Data Program Participants. Available at: www.vmdb.org. Accessed May 8, 2013.
b. STATA SE, version 12.1, StataCorp, College Station, Tex.

References

1. Adams OR. An improved method of diagnosis and castration of cryptorchid horses. *J Am Vet Med Assoc* 1964;145:439–446.
2. Schumacher J. Testis. In: Auer JA, Stick JA, eds. *Equine surgery*. 4th ed. St Louis: Elsevier; 2012;804–840.
3. Stickle RL, Fessler JF. Retrospective study of 350 cases of equine cryptorchidism. *J Am Vet Med Assoc* 1978;172:343–346.
4. Cox JE, Edwards GB, Neal PA. An analysis of 500 cases of equine cryptorchidism. *Equine Vet J* 1979;11:113–116.
5. Jann HW, Rains JR. Diagnostic ultrasonography for evaluation of cryptorchidism in horses. *J Am Vet Med Assoc* 1990;196:297–300.
6. Schambourg MA, Farley JA, Marcoux M, et al. Use of transabdominal ultrasonography to determine the location of cryptorchid testes in the horse. *Equine Vet J* 2006;38:242–245.
7. Wilson DG, Reinertson EL. A modified parainguinal approach for cryptorchidectomy in horses: an evaluation in 107 horses. *Vet Surg* 1987;16:1–4.
8. Wright J. Laparo-orchidectomy in the horse with abdominal cryptorchidism. *Vet Rec* 1960;72:57–60.
9. Cox JE, Neal PA, Edwards GB. Suprapubic paramedian laparotomy for equine abdominal cryptorchidism. *J Am Vet Med Assoc* 1978;173:680–682.
10. Swift PN. Castration of a stallion with bilateral abdominal cryptorchidism by flank laparotomy. *Aust Vet J* 1972;48:472–473.
11. Barber S. Castration of horses with primary closure and scrotal ablation. *Vet Surg* 1985;14:2–6.
12. Palmer SE, Passmore JL. Midline scrotal ablation technique for unilateral cryptorchid castration in horses. *J Am Vet Med Assoc* 1987;190:283–285.
13. Hendrickson DA, Wilson DG. Laparoscopic cryptorchid castration in standing horses. *Vet Surg* 1997;26:335–339.
14. Davis EW. Laparoscopic cryptorchidectomy in standing horses. *Vet Surg* 1997;26:326–331.
15. Ragle CA, Southwood LL, Howlett MR. Ventral abdominal approach for laparoscopic cryptorchidectomy in horses. *Vet Surg* 1998;27:138–142.
16. Marshall JF, Moorman VJ, Moll HD. Comparison of the diagnosis and management of unilaterally castrated and cryptorchid horses at a referral hospital: 60 cases (2002–2006). *J Am Vet Med Assoc* 2007;231:931–934.
17. Arighi M, Bosu W. Comparison of hormonal methods for diagnosis of cryptorchidism in horses. *J Equine Vet Sci* 1989;9:20–25.
18. Fischer AT, Vachon AM. Laparoscopic intra-abdominal ligation and removal of cryptorchid testes in horses. *Equine Vet J* 1998;30:105–108.
19. Schumacher J, Schumacher J, Spano J, et al. Effects of castration on peritoneal fluid in the horse. *J Vet Intern Med* 1988;2:22–25.
20. Durward-Akhurst SA, Mair TS, Boston R, et al. A comparison of two antimicrobial regimens on the prevalence of incisional infections after colic surgery. *Vet Rec* 2013;172:287–290.