Review Report

Perineal urethrostomy in the male horse: a review of the indications, surgical technique, outcome, and complications

Agustin J. Ruiz,[a] Eduardo Arroyo[b]
[a]Goulburn Valley Equine Hospital, Congupna, Victoria, Australia
[b]College of Veterinary Medicine, Washington State University, Pullman, WA, USA

Abstract

Perineal urethrostomy is a surgical technique performed for temporary or permanent urine diversion from the penile urethra in male patients with obstructive urinary outflow disease, extensive trauma or invasive tumor affecting penis and prepuce, to access the urethra or bladder to remove uroliths, and to treat horses affected with hemospermia or hematuria secondary to urethral rents. Perineal urethrostomy has been advocated as the treatment of choice in geldings where hematuria does not resolve with conservative treatment and in stallions with hemospermia caused by urethral defects. Most cases of geldings with hematuria are resolved with a single perineal urethrostomy surgery; however, stallions with hemospermia might need a second surgery. Perineal urethrostomy also enables access to the urinary bladder in male horses with cystoliths following minimal dissection and without accessing the abdominal cavity. The most common complications directly related to this surgery are hemorrhage, urine scalding, and urethral stricture at the surgical site. The aim of this article is to review comprehensively the indications for perineal urethrostomy surgery, illustrate the surgical technique approach, and discuss outcomes and complications.

Keywords: Perineal urethrostomy, corpus spongiotomy, urethral rent, hemospermia, hematuria

Introduction

Perineal urethrostomy (PU) is a surgical technique that entails the creation of a temporary or permanent opening of the urethral lumen most commonly at the level of the ischial arch in male horses. The surgery is indicated in several disorders of the equine penis, prepuce, urethra, and urinary bladder. The most common indication of PU in male horses is for resolution of hemospermia in the breeding stallion and hematuria in geldings due to urethral rents.

The aim of this article is to review comprehensively the indications for PU surgery, illustrate the surgical technique approach, and discuss outcomes and complications.

Indications

Temporary PU at the level of the ischial arch is indicated for temporary urine diversion from the penile urethra in male patients with obstructive urinary outflow disease, to access the urethra or bladder to remove uroliths, and to treat horses affected with hemospermia or hematuria secondary to urethral rents. Permanent PU is indicated in patients with extensive trauma or invasive squamous cell carcinoma affecting the penis and prepuce requiring permanent urinary diversion.

One of the most common primary lesions of the equine urethra are longitudinally oriented urethral rents that extend from the surface of the urethra to the corpus spongiosum penis (CSP) at the level of the ischial arch.[1,2] Males of any age and breed are affected, although Quarter Horses have been proposed to be more predisposed.[3] A retrospective study evaluated 24 years of clinical cases presented to a referral facility and found that 33 male horses presenting with hematuria or hemospermia were diagnosed with a urethral rent on urethroscopy (0.08% of the total gelding and stallion population admitted during the study).[4] The cause of urethral rents is idiopathic; however, it has been hypothesized to be associated with a combination of factors, occurring simultaneously, favoring the onset of this lesion. These include the abrupt reduction of the urethral diameter (from 3.5–5cm to 1–1.5cm) at the level of the ischial arch and the increased hydrodynamic forces occurring during erection, ejaculation, and final stages of urination that the urethra at the level of the ischial arch is exposed to.[2,5] Commonly, urethral rents clinically present as hemospermia in stallions and terminal hematuria in geldings

CONTACT Agustin J. Ruiz **agustin.ruiz@gvequine.com.au**

Citation line: Clinical Theriogenology 2023, 15, 9641, http://dx.doi.org/10.58292/CT.v15.9641

because of the communication between the CSP and the urethral lumen through the mucosal defect.[6,7] In geldings, presence of bright red blood exiting the urethral process at the end of urination apparently occurs when intraluminal urethral pressure decreases suddenly, secondary to forceful contractions of the bulbospongiosus penis (BSP) muscle while the pressure in the CSP remains high.[2] Dysuria, pollakiuria, or pain are not commonly present. In stallions, hemospermia as a result of hemorrhage during or at the end of ejaculation occurs when contraction of the BSP during ejaculation and coitus causes a 45-fold pressure increase within the CSP.[2,4,8]

Hemospermia can have severe economic impacts in a breeding program mostly associated with variable degrees of fertility reduction in sires. In stallions on live-cover breeding programs, the first indication of hemospermia is reduced fertility rates and possibly evidence of blood on the mare's perineal region or stallion's glans penis following dismount. In stallions that are collected with an artificial vagina, hemospermia will be observed with a variable degree of blood-tinged ejaculate (Figure 1). The presence of significant amount of blood in the ejaculate (>50% of whole blood) is associated with severe sperm damage due to the extensive peroxidative damage induced on sperm membranes as a consequence of the iron released by the red blood cells.[9,10] A lower degree of blood contamination on the ejaculate (between 5–20% of whole blood per volume) has been associated with decrease in fertility[11] and no effect on fertility,[10] respectively.

In some geldings, hematuria resolves spontaneously. While sexual rest alone seems not to resolve hemospermia in stallions, it is imperative to alleviate the severity of the clinical signs as an adjunct to non-invasive treatment.[1,3] A variety of medical treatments have been attempted on affected horses. They are aimed to stop the bleeding and promote healing. These include intravenous administration of formaldehyde solution, oral administration of methenamine, systemic administration of antimicrobial drugs and more recently topical treatment with 4% Policresulen solution.[12–14] On the other hand, surgical treatment is aimed at decreasing pressure within the CSP to minimize or prevent hemorrhage through the rent so that it can heal.[1] The most common surgical approaches include PU and corpus spongiotomy (CS). Alternative surgical options reported are direct suturing of the urethral defect via a PU with urethroscopy guidance, laser application to the edges of the defect combined with PU and buccal mucosal urethroplasty combined with PU.[4,15,16]

Diagnostic approach to horses presenting with hematuria or hemospermia is based on the identification of different degrees of blood in the ejaculate or urine, followed by visualization of a urethral rent by urethroscopy.[8,17] In horses affected with hematuria/hemospermia, clinical examination is generally unremarkable with the occasional presence of mild anemia on laboratory analysis of blood. Urine samples collected mid-stream or by bladder catheterization may appear grossly normal. Sediment examination on urinalysis or urine reagent strip may show presence of red blood cells. A thorough endoscopic evaluation of the urethra should be performed to examine the urethra, colliculus seminalis, seminal vesicles, urinary bladder, and ureteral openings to identify any evidence of trauma, presence of blood, or discontinuation of the urethral mucosa.[8,18] Almost exclusively, urethral rents appear as a 5–10 mm long, linear defect on the convex surface of the urethra at the level of the ischial arch (Figure 2).[1] The exact location can be confirmed by inserting percutaneously a hypodermic needle shaft through the perineal area at the level of the ischial arch by an assistant, while simultaneously performing the endoscopic evaluation of the urethra. The pressure applied by the needle shaft through the perineal area will deform the urethral lumen allowing to identify the exact location of the urethral rent by visualization by endoscopic camera. In some cases, urethral rents are undetected due to the collapse of the urethra in the sedated patient and small size of the tear.[4] In these cases, performing the endoscopic

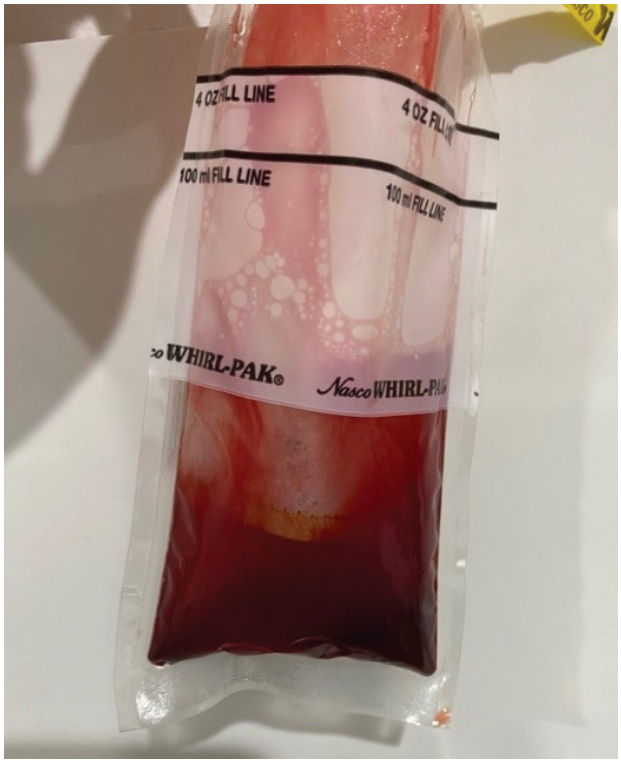

Figure 1. Presence of blood in the ejaculate (hemospermia) of a stallion with an urethral rent.

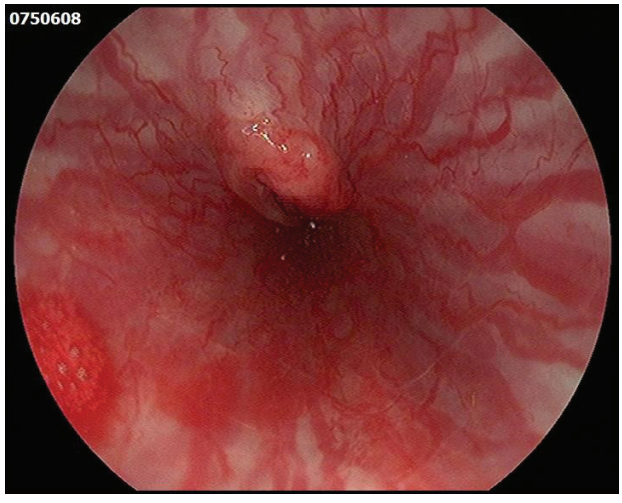

Figure 2. Urethral rent located at the level of the ischial arch in an adult stallion.

examination immediately after urination (geldings) or ejaculation (stallions) can aid to observe small traces of blood emanating from an otherwise undetected urethral rent.[19] Further diagnostic approaches involve the elimination of other causes of bleeding, such as vesicular adenitis, penile lesions (trauma, squamous cell carcinoma of urethral process or glans penis, infection, and habronemiasis), presence of calculi within any portion of the urinary tract, and midline cysts of the colliculus seminalis.[14,20,21] The ruling out process starts with a thorough physical examination of the penis and prepuce, particularly the glans of the penis and urethral opening, followed by transrectal palpation and ultrasonography of accessory sex glands (particularly seminal vesicles), bladder and kidneys.

Urolithiasis in horses accounts for approximately 8% of the diagnosis of equine urinary tract disease.[3] Clinical examination findings depend on location of the uroliths. Affected horses typically present with anuria, stranguria, pollakiuria, and/or hematuria.[3] In horses with urethral uroliths, respiratory and cardiac distress, general discomfort and straining to urinate without urine passage are commonly seen.[22] Diagnosis is based on transrectal palpation of the bladder, ultrasonography of kidneys, bladder, urethra, and urethroscopy/cystoscopy.[23,24] Cystoscopy allows direct visualization of uroliths in most cases; however, horses that have a history of urolithiasis may show urethral bruising consistent with recent calculus passage. Two types of equine cystoliths are recognized, both primarily composed of calcium carbonate.[24] Type I cystoliths account for approximately 90% of the cases, are yellow-greening appearance, have a rough surface, and variable resistance to fragmentation. Type II cystoliths contain variable amounts of phosphorus, are gray-white in appearance, have a smooth surface and are more difficult to fragment.[24] Complete calculi removal is the treatment of choice for cystolithiasis.[6,25] In male horses, described surgical approaches for cystoliths removal include PU, pararectal cystotomy (Gokel's approach), cystoscopy-guided techniques, and laparoscopy techniques (standing or under general anesthesia).[23,26,27]

Temporary PU combined with daily topical treatment with antimicrobials and anti-inflammatory drugs has been advocated as the treatment of choice in geldings where hematuria does not resolve with conservative treatment and in stallions with hemospermia caused by urethral defects.[1] Temporary PU enables access to the urinary bladder in male horses with cystoliths following minimal dissection and without accessing the abdominal cavity.[28] Moreover, PU can be performed standing thereby avoiding the risks and expenses of general anesthesia. Small cystoliths can be removed "en bloc" through a PU, although lithotripsy is required for removal of larger cystoliths.[29] Cystolith fragmentation through a PU has been performed using long-handled bone forceps, an osteotome and a mallet, laser, shockwave, and a customized scaler.[27]

Surgical technique

Preparation of the patient

PU is best approached with the horse standing in stock under sedation and analgesia.[12] Jugular vein catheter placement is recommended. Sedatives options include the combination of an α_2-agonists (detomidine hydrochloride [0.01 mg/kg IV]) or xylazine hydrochloride (0.2 to 0.5 mg/kg IV) with butorphanol tartrate (0.01 mg/kg IV) in bolus to effect. In some cases, an initial bolus can be followed by a continuous detomidine hydrochloride drip infusion at 0.01–0.04 mg/kg/h.[30] The rectum is evacuated. A sterile stallion urinary catheter is advanced using sterile technique from the urethral process into the urinary bladder to assist as a landmark for identification of the urethra during surgery. Caudal epidural anesthesia is achieved by administration of 2% lidocaine (0.22 mg/kg) either alone or in combination with 10% xylazine hydrochloride (0.15–0.2 mg/kg) diluted to a volume of 7–10mL with sterile preservative free saline (0.9% NaCl) solution is used to desensitize the perineal region. The tail is wrapped in an obstetric sleeve or bandaged, using cohesive or support bandage material, and tied laterally. The perineal region is prepared surgically. Skin and subcutaneous tissues can be infused with local anesthetic if there is presence of sensitivity in the perineal area after placing the epidural or if preferred by the surgeon. Good-quality surgical head lights are recommended to assist on visualization of the surgical field and assist on maintaining a midline orientation throughout the surgery.

Surgical approach

An approximately 7–8 cm longitudinal midline skin incision is made in the perineum extending from 4–5 cm distal to the anus ventrally to the to the level of the palpable ischial tuberosities (Figure 3).[12] The longitudinal midline incision is continued dividing the subcutaneous tissues, the paired retractor penis muscles and the BSP muscles (Figure 4). Careful dissection technique while palpating the urinary catheter is recommended to maintain the correct midline orientation[23,31] and

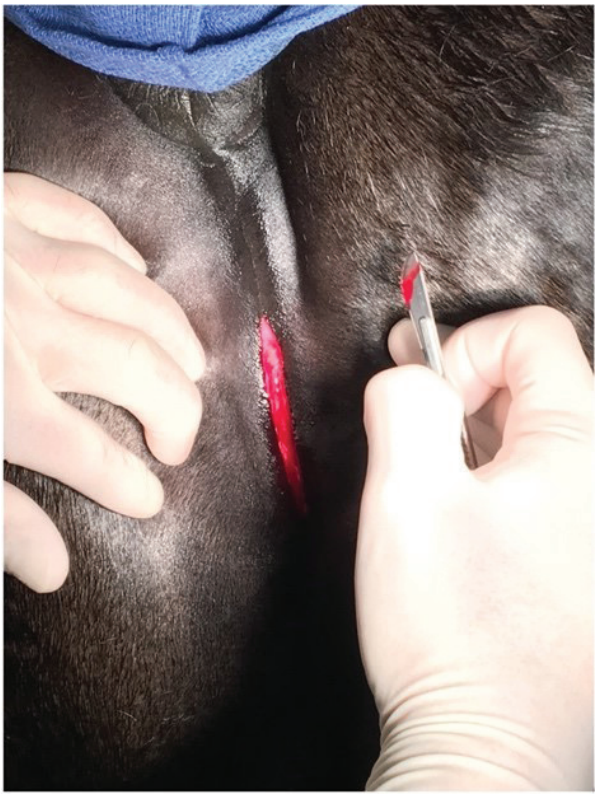

Figure 3. Midline skin incision starting approximately 4–5 cm ventral to the anal sphincter.

Citation line: Clinical Theriogenology 2023, 15, 9641, http://dx.doi.org/10.58292/CT.v15.9641

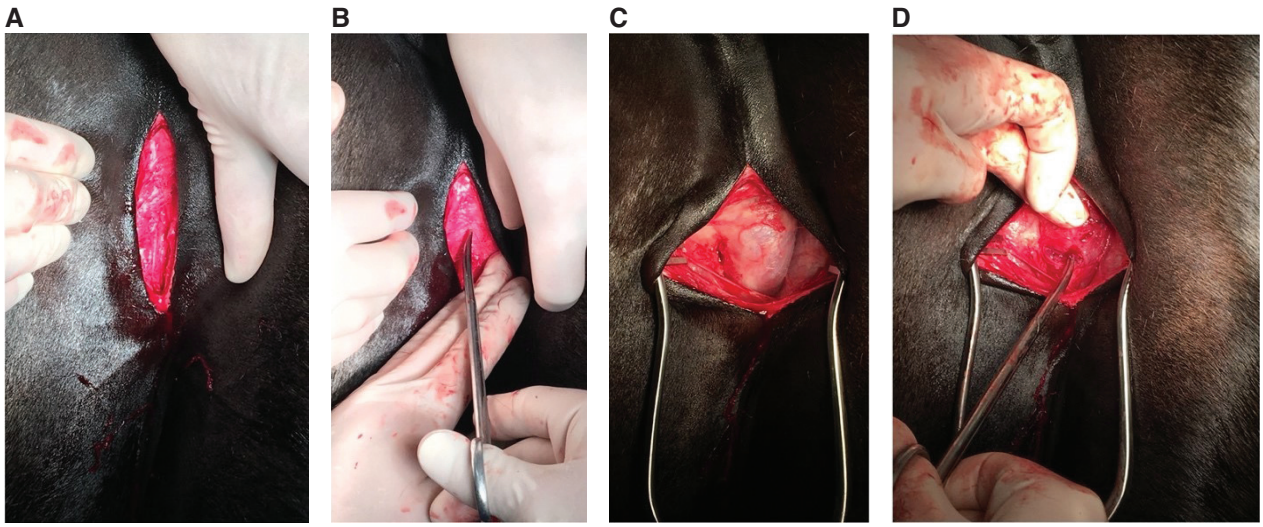

Figure 4. (A) Skin and subcutaneous tissues dissected. (B) Blunt dissection over the retractor penis muscle. (C) Exposure of the bulbospongiosum penis (BSP) muscle – The use of muscle retractors (Weitlaner) assists in improving visualization and avoid excessive tissue manipulation. (D) Blunt dissection over the bulbospongiosum penis (BSP) muscle.

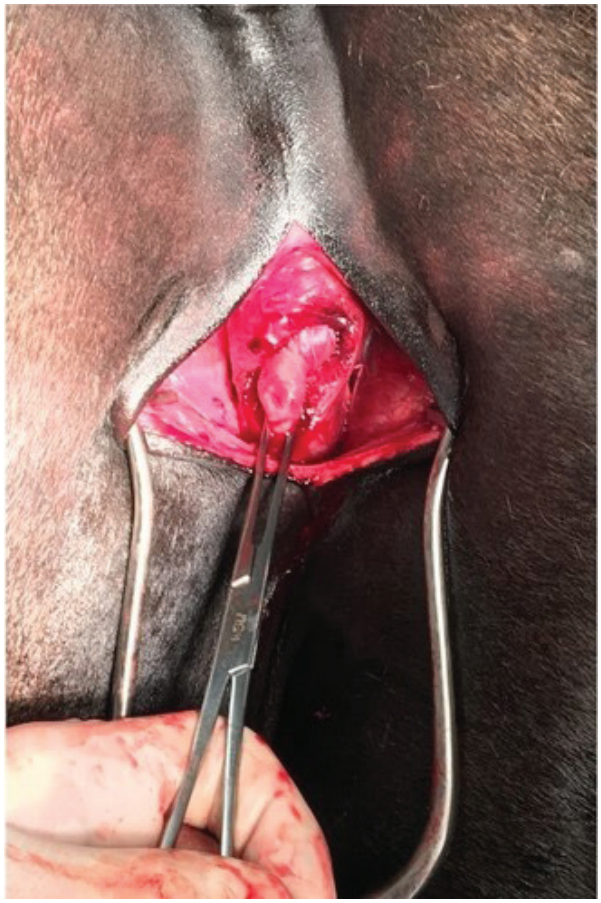

Figure 5. Corpus spongiosum penis muscle dissected with exposure of the catheterized urethra.

avoid large branches of the external pudendal artery with profuse hemorrhage and potential periurethral hematoma formation.[32] This can be assisted by a pair of muscle retractors (Weitlaner muscle retractors) to maintain dissected muscle layers out of the visual field while reducing the excessive tissue manipulation and risk of subsequent edema (Figure 4C). The dissection is continued through the CSP that envelops the urethra allowing exposure of the urethra by retraction of these muscles (Figure 5). Increased bleeding from the CSP is expected and commonly subsides spontaneously; however, it can be controlled by ligation and digital pressure if a situation warrants such measures. The length of the perineal incision should progressively decrease toward the deeper layers to avoid postoperative tissue pocketing of urine. The urethra is identified and stabilized by palpation of the urinary catheter. An approximately 3 cm longitudinal incision is made along the caudal surface of the urethra, and the mucosa is reflected abaxially (Figure 6). In horses with intraluminal obstructions such as uroliths or cystoliths, stay sutures using 0- polydioxanone (PDS) are placed on each edge to allow manipulation by either retrograde hydropulsion using urinary catheter forceps inserted through the PU incision, or urethral dilators.[29,33]

For temporary (6 to 10 weeks) diversion of urine (temporary PU), a Foley urinary catheter is placed through the temporary urethrostomy incision, and its balloon filled with sterile saline solution once enters the urinary bladder. The catheter is secured with stay sutures for 48 to 96 hours.[12]

For permanent diversion of urine (permanent PU) the CSP, BSP, and retractor penis muscles are sutured along their cut edges with a 3-0 synthetic absorbable suture in a continuous pattern. The urethral mucosa and skin are approximated (marsupialized) using a 2-0 or 3-0 synthetic monofilament absorbable or nonabsorbable suture material in an interrupted pattern.[12] Apposition of the perineal skin and urethral mucosa is important to avoid excessive tension and minimize post-operative complications.

Stallions with hemospermia and geldings with hematuria secondary to urethral rents can be initially treated alternatively with incision of the CSP without incision of the urethra, called corpus spongiotomy (CS).[1,3,31] This surgery dissipates the

pressure from the CSP into the urethra to the subischial incision allowing the urethral rent to heal.[1]

Primary closure of a urethral rent at the level of the ischial arch is performed when temporary PU or CS have not resolved the hematuria or hemospermia secondary to the urethral rent.[12]

Post-surgical care

Temporary PU and CS are allowed to heal by second intention and are commonly healed within 2–3 weeks with minimal complications.[2,33] The patient should be closely monitored to ensure that urination occurs without difficulty, particularly after PU for removal of urethral or cystic calculi. Broad spectrum antibiotics and nonsteroidal anti-inflammatory drugs are commonly administered following surgery. The surgical site should be cleaned and disinfected daily with care not to disturb the sutures (if in place). The skin of the ventral perineum, inguinal region, and adductor surfaces of the hindlimbs should be cleansed daily and protective emollients applied due to high risk of urine soilage and urine scalding. In stallions with urethral rents, strict sexual rest for 6–8 weeks is very important because erection and contractions of the bulbospongiosus muscle can prevent the rent from healing.[4,34]

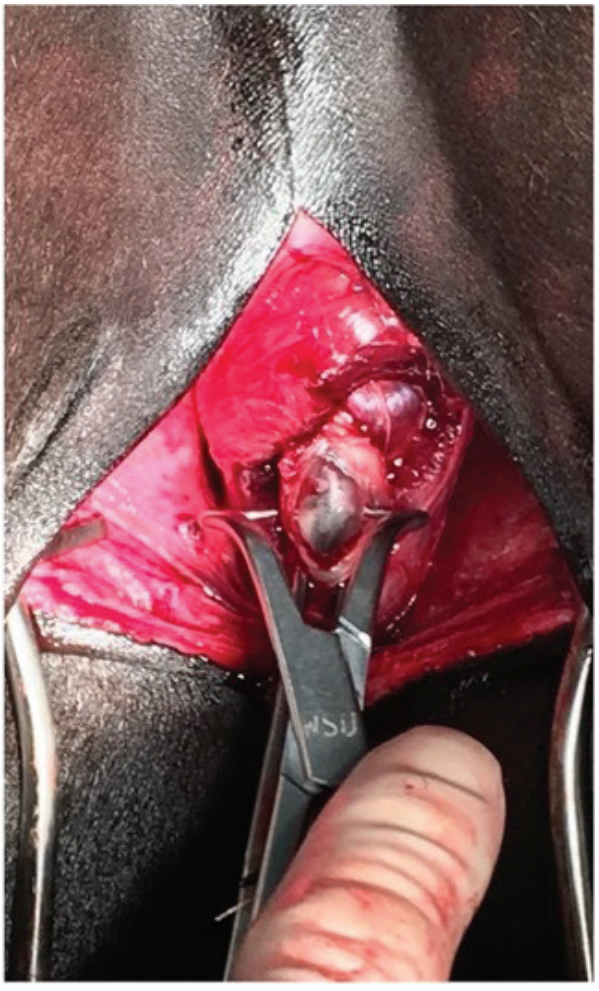

Figure 6. Exposure of urinary catheter after incision of the urethral mucosa.

Outcome

In geldings presenting with hematuria, PU was shown to effectively resolve the vast majority of the cases after 1 surgery. In one study, PU resolved hematuria in 6 geldings after 1 surgical procedure.[1] In another study, 13 out of 17 geldings underwent PU to resolve hematuria with successful results.[4] Additionally on the same study, 4 more male horses underwent CS which successfully resolved hematuria. An alternative to surgery is transendoscopic use of a neodymium:yttrium-aluminum-garnet (Nd:YAG laser) or diode laser to fuse the edges of the rent. This was successfully performed as sole treatment in one gelding and in combination with CS in another gelding.[15]

In stallions presenting with hemospermia, PU alone restored fertility in 11 out of 15 stallions after 1 surgical procedure in one study.[3] In another study, PU alone resolved hemospermia in 1 out of 2 stallions.[1] In another study, 6 stallions underwent PU with complete resolution and no complications in 4 of them. The remaining 2 stallions with recurrent hemospermia required a second PU with subsequent primary closure of the urethral rent with direct suturing guided by urethroscopic guidance.[4] A stallion with recurrent hemospermia secondary to a urethral rent was treated with a PU and application of a buccal mucosal graft to the urethral rent successfully.[16] Laser treatment alone failed to resolve hemospermia in one stallion; however, successfully resolved hemospermia recurrence in 4 stallions when combined with CS.[15] Chemical cauterization using 4% Policresulen, a polycondensation product of *meta*-cresolsulfonic acid and phenol used as a topical hemostatic and antiseptic (Albocresile 360 mg/g, Takeda Pharma

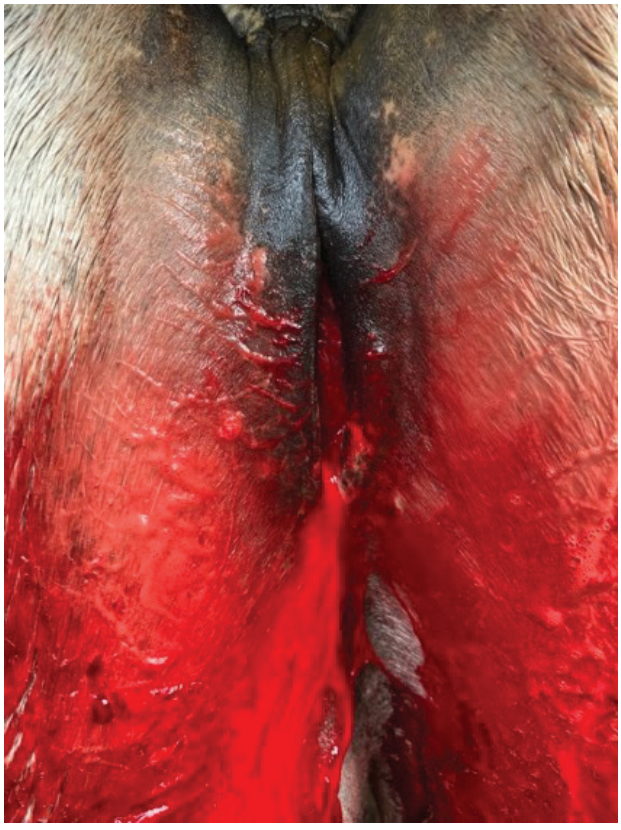

Figure 7. Mild hemorrhage presented 2hs after corpus spongiotomy surgery in a stallion.

Citation line: Clinical Theriogenology 2023, 15, 9641, http://dx.doi.org/10.58292/CT.v15.9641

Ltda, Jaguariuna, SP, Brazil) daily infused (for up to 4 days) topically in the urethra efficiently resolved hemospermia in 4 stallions.[13]

PU is an effective technique for uroliths removal in the male horse. Recent advances on the uroliths manipulation and retrieval techniques have increased the success and significantly reduced complications and recurrence.[34,35]

Complications

Previously reported complications with PU include rectal tear during cystic calculus manipulation, fistula formation, septic peritonitis, orchitis, postoperative tenesmus, excessive hemorrhage, urethral stricture, and dysuria.[17,36,37] Most of these complications appear to be closely associated with the underlying disease process (large uroliths that require manipulation) rather than with the surgical procedure.[37] The most common complications directly related to the PU are hemorrhage, urine scalding and urethral stricture at the surgical site. Mild, self-limiting hemorrhage caused by increased CSP pressure secondary to contraction of the BSP occurs at the end of urination for up to 2 weeks (Figure 7).[37] Hemorrhage from the urethral orifice and evidence of pain during urination are not commonly observed after surgery.[1] Severe hemorrhage from the PU is an uncommon complication.[37] Urine scalding has been reported as a delayed complication of permanent PU and associated with extension of the PU incision ventral to the ischium in one report[38] but not in a different study.[37] The use of appropriate regular cleaning and emollients is recommended in mild cases while surgical drains might be recommended for severe cases where there is leakage of urine from the surgical site into surrounding tissues.[12] The use of indwelling catheters left in placed postoperatively has been regularly used with the aim to ensure patency of urine voiding; however, they have been recently associated with increased risk of additional complications including severe cystitis, urine scald, urethral stricture, and ruptured bladder when meticulous care and frequent monitoring have not been performed.[37,39] For horses undergoing temporary PU, it is currently recommended to limit the duration of catheterization and remove it within 2–3 days.[39] Additionally, chances of stricture formation postoperatively may be reduced by appropriate hemostasis, tissue repair, and tissue drainage.[40]

Stricture formation has been reported in up to 30% of the horses undergoing perineal urethrostomy for calculi removal.[36,40] It has been postulated that urethral stricture formation depends on the degree of trauma induced during calculi extraction rather than the surgical approach itself.[29,41] Recent advances in cystoliths fragmentation and prevention of recurrence following cystolith removal through perineal urethrostomy in male horses has been made.[34,35] The use of urethral mechanical dilators and laparoscopic pouch retrieval has shown to reduce complications by protecting the urethral mucosa from mechanic trauma during instrument insertion/manipulation and urolith removal.[35,36,41]

For horses with urethral rents, most of the previously described complications can be avoided by changing the surgical approach from a PU to a CS, which has been successfully used for resolving hematuria in geldings with urethral rents in one surgical procedure. However, stallions presenting with hemospermia may require more than 1 PU, CS, or primary closure of the rent to resolve hemospermia.[4]

Acknowledgments

The authors are grateful to Drs. Ahmed Tibary and Allan Gunn for critical review of the manuscript.

Conflict of interest

None of the authors have any conflict of interest to declare.

References

1. Schumacher J, Varner DD, Schmitz DG, et al: Urethral defects in geldings with hematuria and stallions with hemospermia. Vet Surg 1995;24:250–254. doi: 10.1111/j.1532-950X.1995.tb01326.x
2. Taintor J, Schumacher J, Schumacher J, et al: Comparison of pressure within the corpus spongiosum penis during urination between geldings and stallions. Equine Vet J 2004;36:362–364. doi: 10.2746/0425164044890571
3. Sullins KE, Bertone JJ, Voss JL, et al: Treatment of hemospermia in stallions: a discussion of 18 cases. Compend Contin Educ Pract Vet 1988;10:1396–1403.
4. Glass KG, Arnold CE, Varner DD, et al: Signalment, clinical features, and outcome for male horses with urethral rents following perineal urethrotomy or corpus spongiotomy: 33 cases (1989–2013). J Am Vet Med Assoc 2016;249:1421–1427. doi: 10.2460/javma.249.12.1421
5. Sisson S: Equine urogenital system. In: Getty, editor: Sisson and Grossman's the Anatomy of Domestic Animals. 5th edition, Philadelphia, PA; Saunders: 1975:524.
6. Lloyd KC, Wheat JD, Ryan AM, et al: Ulceration in the proximal portion of the urethra as a cause of hematuria in horses: four cases (1978–1985). J Am Vet Med Assoc. 1989;194(9): 1324–1326.
7. Beckett SD, Purohit RC, Reynolds TM: Corpus spongiosum penis pressure and external penile muscle activity in the goat during coitus. Biol Reprod 1975;12:289–292. doi: 10.1095/biolreprod 12.2.289
8. Pearson LK, Campbell AJ, Tibary A: How to diagnose and treat hemospermia: a review and case series. Proc Am Assoc Equine Pract 2013;59:40–50.
9. Rijsselaere T, Van Soom A, Maes D, et al: Effect of centrifugation on in vitro survival of fresh diluted canine spermatozoa. Theriogenology 2002;57:1669–1681. doi: 10.1016/S0093-691X (02)00663-5
10. Turner CE, Walbornn SR, Blanchard TL, et al: The effect of two levels of hemospermia on stallion fertility. Theriogenology 2016;86:1399–1402. doi: 10.1016/j.theriogenology.2016.04.084
11. Möller G, Azevedo LR, Trein CR, et al: Effects of hemospermia on seminal quality. Anim Reprod Sci 2005;89:264–267.
12. Schott II HC, Woodie JB: Urethra. In: Auer JA, Stick JA, Kümerle JL, et al: editors. Equine Surgery. 5th edition, St Louis, MO; Saunders Elsevier: 2018:940–949. doi: 10.1016/B978-1-4377-0867-7.00066-1
13. Sancler-Silva YF, Silva-Junior ER, Fedorka CE, et al: New treatment for urethral rent in stallions. J Equine Vet Sci 2018;64:89–95. doi: 10.1016/j.jevs.2018.02.014
14. Voss JL, Pickett BW: Diagnosis and treatment of hemospermia in the stallion. J Reprod Fertil Suppl 1975;23:151.

15. Madron M, Schleining J, Caston S, et al: Laser treatment of urethral defects in geldings and stallions used as the primary treatment or in combination with a temporary subischial incision: Eight cases (2003–2011). Equine Vet Educ 2013;25:368–373. doi: 10.1111/eve.12050
16. Hackett ES, Bruemmer J, Hendrickson DA, et al: Buccal mucosal urethroplasty for treatment of recurrent hemospermia in a stallion. J Am Vet Med Assoc 2009;235:1212–1215. doi: 10.2460/javma.235.10.1212
17. Ball BA: Diagnostic methods for evaluation of stallion subfertility: a review. J Equine Vet Sci 2008;28:650–665. doi: 10.1016/j.jevs.2008.10.003
18. Tibary A. Endoscopy of the reproductive tract in the stallion. In: Samper JC, Pycock J, McKinnon AO: editors. Current Therapy in Equine Reproduction. St Louis, MO; Saunders: 2007:214–219.
19. Varner DD, Blanchard TL, Brinsko SP, et al: Techniques for evaluating selected reproductive disorders of stallions. Anim Reprod Sci 2000;60:493–509. doi: 10.1016/S0378-4320(00)00115-9
20. Pinto MR, Neild DM, Benegas D, et al: Successful treatment of seminal vesiculitis with Imipenem-Cilastatin in a Stallion. J Equine Vet Sci 2014;34:544–548. doi: 10.1016/j.jevs.2013.10.001
21. Bedford SJ, McDonnell SM, Tulleners E, et al: Squamous cell carcinoma of the urethral process in a horse with hemospermia and self-mutilation behavior. J Am Vet Med Assoc 2000;216:551–553. doi: 10.2460/javma.2000.216.551
22. Trela JM, Dechant JE, Culp WT, et al: Use of an absorbable urethral stent for the management of a urethral stricture in a stallion. Vet Surg 2016;45:41–48. doi: 10.1111/vsu.12530
23. Fubini SL, Delco M: Surgery of the equine urinary tract. Vet Clin N Am Equine Pract 2022;38:141–153. doi: 10.1016/j.cveq.2021.11.010
24. Diaz-Espiñeira M, Escolar E, Bellanato J, et al: Structure and composition of equine uroliths. J Equine Vet Sci 1995;15:27–34. doi: 10.1016/S0737-0806(07)80577-6
25. Duesterdieck-Zellmer KF: Equine urolithiasis. Vet Clin N Am Equine Pract 2007;23:613–629. doi: 10.1016/j.cveq.2007.09.003
26. Schumacher J, Vaughan JT: Surgery of the penis and prepuce. Vet Clin N Am Equine Pract 1988;4:473–491. doi: 10.1016/S0749-0739(17)30624-7
27. Hawkins JF: Surgical treatment of urolithiasis in male horses. Equine Vet Educ 2013;25:60–62. doi: 10.1111/j.2042-3292.2012.00449.x
28. Laverty S, Pascoe JR, Ling GV, et al: Urolithiasis in 68 horses. Vet Surg 1992;21:56–62. doi: 10.1111/j.1532-950X.1992.tb00011.x
29. Abutarbush SM: Diseases of the Urinary System. Ames, IA; John Wiley & Sons: 2015:559–577. doi: 10.1002/9781119265399.ch11
30. Vigani A, Garcia-Pereira F: Anesthesia and analgesia for standing equine surgery. Vet Clin N Am Equine Pract 2014;30:1–17. doi: 10.1016/j.cveq.2013.11.008
31. Schumacher J, Schumacher J, Schmitz D: Macroscopic haematuria of horses. Equine Vet Educ 2002;14:201–210. doi: 10.1111/j.2042-3292.2002.tb00173.x
32. Schumacher J, Varner DD: Abnormalities of the penis and prepuce. In: McKinnon AO, Squires EL, Vaala WE, et al: editors. Equine Reproduction. 2nd edition, Ames, IA; Wiley-Blackwell: 2011:1130–1144.
33. DeBowes RM: Surgical management of urolithiasis. Vet Clin N Am Equine Pract 1988;4:461–471. doi: 10.1016/S0749-0739(17)30623-5
34. De Bernardis NP, Seabaugh KA, Ismay J, et al: The use of pneumatic impact lithotripsy and a retrieval pouch to create a closed system for removal of cystic calculi in standing male horses. Equine Vet Educ 2019;31:659–665. doi: 10.1111/eve.12843
35. Katzman SA, Vaughan B, Nieto JE, et al: Use of a laparoscopic specimen retrieval pouch to facilitate removal of intact or fragmented cystic calculi from standing sedated horses: 8 cases (2012–2015). J Am Vet Med Assoc 2016;249:304–310. doi: 10.2460/javma.249.3.304
36. Trotter GW, Bennett DG, Behm RJ: Urethral calculi in five horses. Vet Surg 1981;10:159–162. doi: 10.1111/j.1532-950X.1981.tb00652.x
37. Kilcoyne I, Dechant JE: Complications associated with perineal urethrotomy in 27 equids. Vet Surg 2014;43:691–696. doi: 10.1111/j.1532-950X.2014.12169.x
38. Wilson DA, Kramer J, Constantinescu GM, et al: Perineal urethrotomy in males. In: Manual of Equine Field Surgery. St. Louis, MO; Saunders Elsevier: 2006:211–214.
39. Lees GE: Use and misuse of indwelling urethral catheters. Vet Clin N Am Small Anim Prac 1996;26:499–505. doi: 10.1016/S0195-5616(96)50080-X
40. Schott HC. Hematuria. In: Sprayberry KA, Robinson NE: editors. Robinson's Current Therapy in Equine Medicine. 7th edition, St Louis, MO; Saunders Elsevier: 2015:456–459.
41. Menendez MI, Fitch G: Use of a laparoscopic retrieval device for urolith removal through a perineal urethrotomy. Vet Surg 2012;41:629–633. doi: 10.1111/j.1532-950X.2012.00967.x