REVIEW ARTICLE

Complications and troubleshooting in primary penile prosthetic surgery—a review

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Penile implant surgery is the gold standard to treat erectile dysfunction with success rates of over 90%. The first penile implants were developed in the early 1900s. Since then, several types of implants have been developed including malleable implants, two-piece inflatable implants, and three-piece inflatable implants. The three-piece inflatable penile prosthesis, which was introduced in 1973, is the most widely used type of penile implant in the United States. Penile implant surgery has undergone numerous advancements over the years, improving outcomes and patient satisfaction. However, as with any surgical procedure, there are risks and complications associated with penile implant surgery. It is important for surgeons to understand these potential complications and to have strategies in place to manage and prevent them to achieve the best possible outcomes for their patients.

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INTRODUCTION

Penile prosthetic surgery is the gold standard treatment for erectile dysfunction in the setting of poor response to oral and/or injectable medications or for patients who prefer a definitive therapy [1, 2]. Various types of rigid and semi-rigid rods were originally described dating back to the early 1900s [3, 4]. The inflatable penile prosthesis was introduced into clinical practice in 1973 [5]. There have been numerous advances in device technology over the last several decades meant to enhance the ease of placement, device longevity, and "naturalness" of the erection [6]. Concurrently, there have been numerous innovations in operative technique and complications management that have been introduced by surgeons looking to optimize long-term outcomes including patient satisfaction [7, 8].

Regardless of surgeon expertise, experience, and good luck, intraoperative and post-operative complications will arise. Put another way, as a person with brilliant insight once commented, "if you don't have complications, then you aren't operating enough". This adage has been passed down in part to inject humor and humility for those of us who experience complications, but it very much rings true for penile prosthetics. By understanding the potential risks and complications associated with penile implant surgery and feeling confident and prepared to take these issues on as they arise, prosthetic surgeons can achieve the best possible outcomes for their patients. Herein, we seek to provide a review of penile prosthetic complications, discuss specific management strategies, and offer suggestions for preventing common complications that may arise. In an effort to keep this review article concise, we will focus on the three-piece device and will not specifically address adjunctive measures for Peyronie's disease, techniques and complications unique to revision surgery, and applications for gender affirmation surgery. The reader is referred to a variety of comprehensive review articles on these and other pertinent prosthetic-related topics for further information [9–13].

PREOPERATIVE CONSIDERATIONS

There are several important considerations prior to entering the operating room that allow the surgeon and patient to achieve the best outcome. First and foremost is appropriate patient selection. Patients should be well counselled and have realistic expectations for recovery and outcomes [14]. A previously published mnemonic is helpful for surgeons to identify the patient at risk for dissatisfaction postoperatively. Patients displaying any elements of the CURSED patient should give pause to the performing surgeon (compulsive/obsessive, unrealistic, revision, surgeon shopping, entitled, denial, and psychiatric) [15].

Patients should also be screened for pertinent aspects of their medical and surgical history that may impact perioperative and post-operative care. As will be discussed subsequently, certain medical conditions such as poorly controlled diabetes and spinal cord injury as well as active smoking may increase the risk for device infection [16–19]. Chronic anticoagulation is another consideration of management as the surgeon has to weigh the risks of holding anticoagulation against the risk of hematoma if anticoagulation is continued [20].

In patients who report curvature or who have not had an erection for a considerable amount of time, it is reasonable to conduct an objective curve assessment preoperatively to determine if significant curvature is present that may necessitate additional maneuvers including modeling, plication, or grafting [9, 21, 22]. Patients with prior inguinal hernia mesh or surgeries which violated the space of Retzius should be counselled on the need for possible alternative (ectopic) reservoir placement [23]. Patients with an elevated post void residual should have consideration of preoperative urethral evaluation especially with the history of prior prostate surgery [24]. Patients with urinary incontinence should be evaluated to determine if they would benefit from continence surgery or potentially a mini-jupette sling for climacturia [25]. In summary, many complications can

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Table 1. IPP Plan: a helpful acronym to systematically prevent surprises and complications during penile implant surgery.

IPP PLAN	Question(s) to ask	Complications avoided	Considerations
I - Infection	What risk factors does the patient have that will increase infection risk?	Infection	Ensure appropriate antibiotics including anti-fungals, optimize glucose control, treat any peripheral infections prior to case, ask about prior Staph infections.
P - Peyronies	Is there a curve or shortening with erection? Has the patient had a recent adequate erection to assess?	Curvature with device fully inflated	Consider artificial erection at beginning of case versus high dose penile injections pre-operatively. Moderate to severe curvature radically changes operative approach. If surprised by curve, operative time increases.
P - Place	Where will the reservoir go?	Vascular and viscous injury	For IPP revisions, always obtain pre-operative imaging assessing reservoir and adjacent structures. Discuss potential sequalae of submuscular reservoir with patient including bulge and potential auto-inflation. Avoid obliterated space of Retzius after cystectomy or other major abdominal surgery.
P - Plastics	Are there additional cosmetic procedures that need to be performed such as scrotoplasty? What are the patient's penile length expectations?	Length dissatisfaction, Untreated glans hypermobility	A technically perfect IPP can still be viewed as a failure by the patient if he is dissatisfied by length. Consider pre-operative VED use to optimize length of implant in men with known shortening/ peyronies. Severe hypermobility at time of first IPP can be addressed to potentially avoid need for subsequent surgery.
L - LUTS	Does the patient have a high post void residual (PVR) volume or untreated bladder neck contracture. Does he have bothersome incontinence or climacturia?	Prolonged post IPP catheter increasing erosion and infection risk	It is better to address necessary incontinence operations prior to IPP. Discovery of bladder neck contracture at time of implant may lead to case abortion. Climacturia can be addressed with various mini-jupette techniques.
A - Anticoagulation	Is the patient on blood thinners? Should he be?	Case cancellation due to bleeding risk, thrombotic event	Consider subQ heparin for IPPs as DVT rate is low, but real. Avoid space of Retzius if performing case with patient on active anticoagulation as this space can harbor large volume occult bleeding.
N - Narcotics	Does the patient take narcotics or any other substances routinely?	Inadequate pain control due to tolerance	Pain control is challenging in narcotic non-naïve patients after IPP. Consider incorporating pain management services and using multi-modal pain control approaches.

be avoided by asking the appropriate pre-operative questions. The authors utilize the acronym IPP PLAN to systematically prevent surprises and complications that led to the acronym's inception. Table 1 details the IPP PLAN and complications it attempts to obviate.

INFECTION

Infection was once a more common and feared complication of penile prosthesis surgery, but advances in surgical techniques and technology have greatly reduced this risk. High volume implanters now have infection rates for naïve patients nearing 1% in contemporary series [26]. This decrease in infection rates is believed to be due to several practice changes, including the use of no-touch or minimal touch techniques, antibiotic prophylaxis based on local antibiogram results, and the use of antibiotic and antiseptic irrigants during surgery [27–29]. In addition to surgical factors, patient characteristics also play a role in the risk of infection. Diabetes is a well-established risk factor for post-operative infection, although the literature is unclear on what level of HbA1c is considered the threshold for minimizing this risk [30–32]. Active smoking is also a known risk factor with a recent study showing a 4-fold increased risk compared to nonsmokers [33].

In some cases, post-operative infection is obvious on exam with purulent discharge and exposure of the device. Pump fixation to the scrotal wall is also a classic sign [34]. But in many cases, it can be more difficult to differentiate normal post-operative pain and skin changes from a smoldering infection. In these cases, an elevated erythrocyte sedimentation rate or leukocytosis may be more revealing [34]. An extended course of antibiotics may be prescribed but should the symptoms return after completion, infection must be suspected. The approach to managing device infection has evolved over time. Complete device removal used to be the mainstay but often resulted in corporal fibrosis making revision surgery more challenging [35]. In the absence of frank purulence, salvage is now preferred. The Mulcahy method of salvage was first described in 1996 and entailed a series of washout solutions followed by placement of a malleable prosthesis [36]. It was then recommended to wait 3–6 months before returning to replace the malleable with an inflatable prosthesis. Contemporary literature now suggests that immediate replacement with another inflatable penile prosthesis or washout alone also has high success rates [37, 38]. Ultimately, the method of salvage should be determined by an experienced surgeon taking into account the state of the surgical field and the patient's risk factors.

SUPERSONIC TRANSPORTER (SST) DEFORMITY

Glans hypermobility (or floppy glans) after insertion of a properly sized implant can make penetrative sexual intercourse difficult. Figure 1 depicts glans hypermobility. The hypermobility can happen in any direction and is more commonly seen in uncircumcised patients [39]. When recognized at the time of surgery, it is important to ensure the device is sized correctly and the corporal bodies have been properly dilated distally. Supersonic transporter deformity (SST; named after the appearance of the supersonic transport aircraft which genuflects the nose during takeoff) refers to ventral deflection of the glans penis, thought to be the result of undersized prosthesis cylinders [40].

A glanspexy can be performed by fixing the glans to the tunica albuginea with nonabsorbable sutures through a hemi-circumscribing incision or two small stab incisions [41]. A penoplasty has also been described, which involves excision of the excess penile shaft skin and reapproximating it [40]. SST deformity can present several months after implantation due to an unrecognized proximal perforation which will allow the cylinder to retract or may also be due to tissue expansion with aggressive cycling [39].

CROSSOVER

Crossover occurs when the implant crosses the midline tunical septum into the contralateral corporal body resulting in two cylinders occupying the same corporal body [42]. This can occur during dilatation or when passing the Furlow inserter. Distal crossover is more common with infrapubic and subcoronal approaches as the penoscrotal approach typically uses the ring retractor which helps keep the penis straight during dilation [39]. Many times, distal crossover is not readily apparent in the operating room and becomes more obvious with time. As they heal, patients will notice a bulge to one side when inflated [43]. Distal crossover is best prevented by deviating laterally whenever passing a dilator or Furlow insertion tool down the corporal bodies.

Proximal crossover is more common when utilizing the penoscrotal approach or when fibrosis is present making dilation challenging [39]. The goal post test aids in recognition of proximal crossover as the dilators will touch [39]. This can be performed in both the proximal and distal penis to confirm or refute crossover. It should be a primary consideration if it is difficult to pass the implant proximally. The dilator should be passed immediately prior to placing the cylinder proximally to give the surgeon an idea of the proper placement depth and angle.

Surrogate reservoir testing with cylinder inflation before closing the corporotomies can often identify an area of crossover where the cylinder appears indented or deviated despite multiple inflation/deflations. Once recognized, crossover is corrected by repeating dilation of the side in question while there is a large dilator such as a Uromix in the contralateral corporal body. The Furlow (if distal) or the cylinder tip (if proximal) is passed while the large dilator remains in place to preserve the integrity of the contralateral path [39, 43].

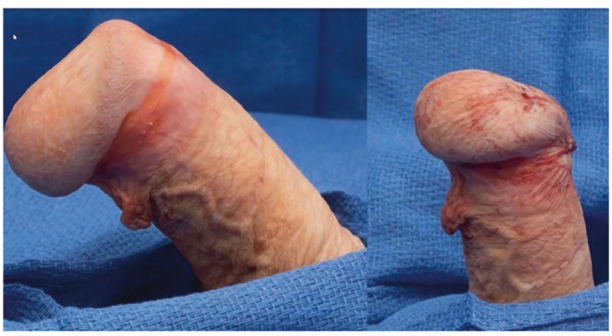

Fig. 1 Glans hypermobility, also referred to as Supersonic transporter deformity (SST). After proper tunneling for maximal corporal length, this patient has residual hypermobility, which was corrected with glanspexy through two small stab incisions just below dorsal corona. After correction, the cylinders were noted to seat in the mid-glans.

PERFORATION

Perforation typically occurs during dilation of the corporal bodies [44]. Proximally, the corporal bodies dive laterally as they split. It is important to follow this natural curve for safe dilation. Even with proper technique, patient anatomy and presence of corporal fibrosis can make perforation difficult to avoid. Using sequential dilators like cavernotomes can assist with dilating through fibrosis but also increase the risk of perforation [45].

Proximal perforation is typically realized by a sudden loss of resistance during dilation, discrepant measurements, or an uneven field goal test. Several techniques have been described for repair including the windsock technique or suture sling to prevent migration of the cylinder [44]. Historically, the windsock technique involved securing a dacron or gortex graft around the proximal end of the cylinder and securing it to the tunica albuginea. This technique is used less frequently as it adds an additional foreign body and can make replacement challenging [46]. The suture sling is more commonly used and has been well described. Briefly a nonabsorbable suture is passed through the proximal end of the cylinder or rear tip and secured to the corporotomy [47]. Figure 2 shows the normal lateral deviation of the proximal corporal body and depicts a suture sling technique.

While proximal perforation can lead to cylinder migration, distal perforation can result in imminent extrusion. Thus, it is imperative to realize and correct this intraoperatively. If sized appropriately, a distal perforation will heal over the device without long-term consequence [48]. Urethral injury must be ruled out by irrigating distally through the corporotomy. If a urethral injury is detected, management varies and this is further discussed below.

URETHRAL INJURY

Urethral injury during dissection should be a rare occurrence and is best prevented with appropriate exposure of the corporal bodies and urethra [49]. Distal urethral injury can be the result of dilation or modeling for Peyronie's Disease [47]. Irrigating the corpora with saline can identify occult urethal injury as depicted in

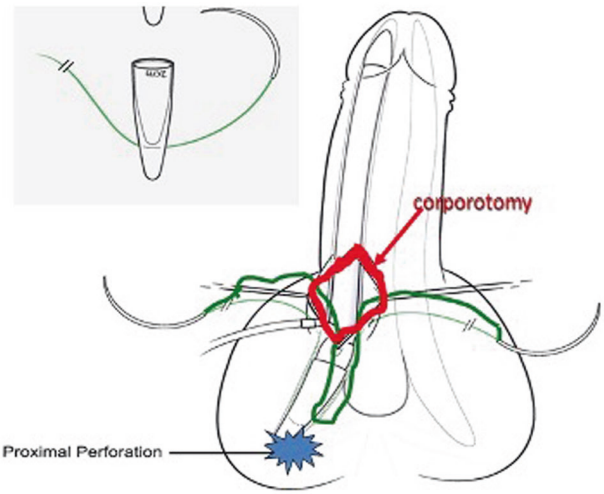

Fig. 2 Here the normal lateral deviation of the proximal corporal body is shown with a proximal perforation corrected with a suture sling. A nonabsorbable suture is passed through the proximal end of the cylinder or rear tip and secured to the corporotomy.

Fig. 3. If the urethral injury can be visualized, then it is appropriate to attempt primary repair with a two-layer closure. However, if urethral injury site is not well visualized, aborting the procedure and leaving a catheter is a reasonable option [50]. If the contralateral corporal body has already been safely dilated, some surgeons opt to place a solitary cylinder and return in 3–6 months to place a cylinder on the injured side [47]. If the injury is repaired primarily, some surgeons will proceed with implantation of the complete device [46].

CORPORAL FIBROSIS TROUBLESHOOTING

Corporal fibrosis is commonly encountered in patients with a history of intracavernosal injections, priapism, penile fracture, diabetes, and those with previously infected devices requiring removal without replacement [47]. A penoscrotal approach allows for the best exposure in fibrotic corpora. Should dilation be challenging distally, consider creating a counter incision over the area for a second corporotomy and better visualization so as to prevent urethral injury [48]. There are several options for dilating through fibrotic tissue. Some use Metzenbaum scissors to spread along the length of the corporal body taking care to follow the intended natural path. Another option is to sequentially dilate with cavernotomes [51]. Surgeons should not hesitate to extend the length of the corporotomy distally and proximally along with additional stay sutures as needed. As previously discussed, great care should be taken to avoid urethral injury or perforation.

RESERVOIR COMPLICATIONS

When determining the intended location for the reservoir, patient history plays a large role. In patients who had prior inguinal hernia repair with mesh or surgeries which violated the space of Retzius, it may not be feasible to place the reservoir next to the bladder.

When planning to place the reservoir in the space of Retzius through the external ring, the bladder should be drained to prevent injury. The iliac arteries are just lateral to the ideal site of puncture through the transversalis fascia, so care should be taken to deviate medially when possible [52]. Some argue that puncture into the space of Retzius is safely achieved with finger dissection, while others describe using scissors or a nasal speculum for assistance [53–55]. If there is concern for injury to a large vessel, it is imperative to attempt to hold pressure with a finger through the external ring and consult vascular surgery for assistance with exposure and repair [56].

In patients where a space of Retzius reservoir is not feasible, submuscular reservoir placement is preferred. In most cases, the reservoir can still be placed through the inguinal ring, however, a counter incision can be considered in cases of a hostile pelvis, inaccessible inguinal ring, or surgeon preference [57]. Originally described as high submuscular, this method was found to have a slightly higher risk of bowel injury and reservoir migration [58]. Entry into the peritoneum without bowel injury has also been reported with particular risk in thin patients. This may not require removal and replacement in the absence of associated symptoms [59, 60].

Reservoir migration is a concern regardless of where it is placed. To prevent distal/inferior migration from the space of Retzius, the fascial opening should be kept as small as possible. When a large opening is made, a fascial suture should be considered [61]. When placing submuscular, filling the reservoir to capacity is recommended and a few methods to secure placement with fascial suturing have been described [47, 62, 63].

Erosion into the bladder or bowel and bowel obstruction, while incredibly rare, have been reported [64].

GLANS COMPLICATIONS

Glans ischemia while rare is vital to identify early. Glans ischemia is very painful and reveals a uniformly dusky glans. Figure 4 shows glans ischemia. The subcoronal approach and comorbidities including smoking, radiation, vascular disease, and diabetes place patients at particular risk [65]. Loosening any penile wraps and deflating the device may aid in increasing blood flow but if the glans remains dusky, the device must be promptly removed [53]. In patients with glans ischemia who did not have the device explanted, 80% had permanent glans necrosis [65].

Sensory changes involving the glans penis is a rare complication but is a concern particularly when the implant is placed via the infrapubic approach as the sensory nerve bundle can be inadvertently damaged. With careful dissection, there has been shown little difference in sensory changes when comparing approaches [66, 67].

PENOSCROTAL WEBBING

Penoscrotal webbing refers to abnormally high insertion of scrotal skin on the ventral penile shaft, obliterating the normal penoscrotal angle. In addition to cosmetic concerns and perceived reduced penile length among patients affected, penoscrotal webbing can causes issues with proper condom fit, penetrative

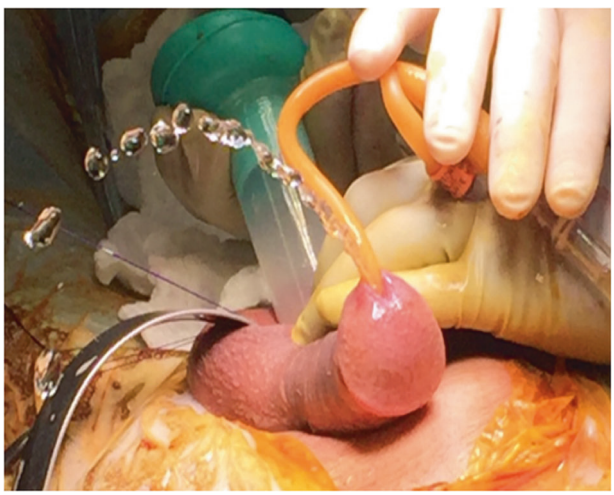

Fig. 3 Distal urethral injury identification. This patient's distal urethral injury was identified by injecting irrigation through the corporotomy resulting in fluid coming out of the meatus around the catheter.

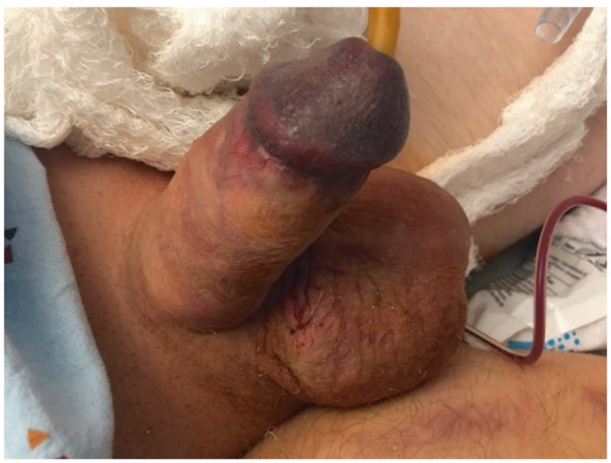

Fig. 4 Glans ischemia. Classic appearance of glans ischemia demonstrated with a uniformly dusky appearance.

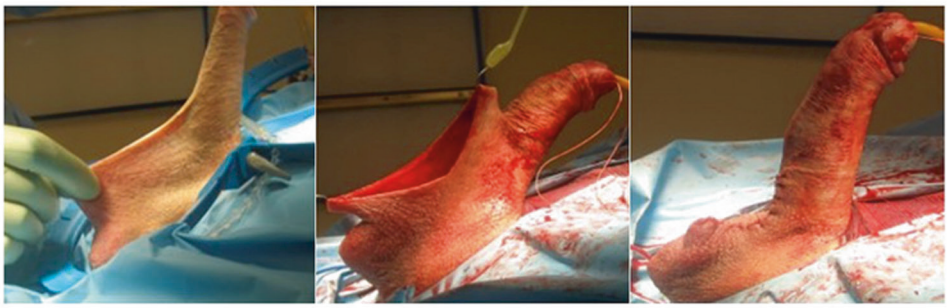

Fig. 5 Correction of penoscrotal webbing. Significant penoscrotal webbing corrected at the time of penile implant by closure of a horizontal penoscrotal incision in a vertical fashion.

intercourse, and pain with erections [68]. It results from either congenital fusion between the median raphe and ventral penile shaft skin and underlying dartos, or from removal of excessive ventral skin at the time of circumcision causing tightening of the ventral skin during erection [68]. Regardless of cause, correction of penoscrotal webbing at the time of penile prosthesis is typically straightforward, safe, and effective at improving cosmesis and related symptoms, especially when a standard horizontal penoscrotal incision is used for implant placement. In its simplest form, a scrotoplasty can be accomplished by vertically closing the horizontal incision, taking care to do so for both the dartos and skin layers. Excess skin from the superior and inferior corners can be trimmed if necessary to prevent a "dog ear" appearance at the apices of the incision. Other techniques have been described, including V-Y or Z scrotoplasty, an inverted V-shaped incision, or "check-mark" incision [69–71]. Clinical outcomes with regards to satisfaction and complication rates appear to be similar among techniques [71]. Figure 5 shows penoscrotal webbing before and after surgical correction.

PUMP AND TUBING PLACEMENT

A key component of a successful penile implant both from usability and patient satisfaction perspectives is appropriate pump placement within the scrotum and positioning the tubing such that it is deep enough to be concealed. With the penoscrotal approach, a subdartos pouch can be easily developed within the dependent portion of the scrotum. This can be done using a small nasal speculum or by bluntly using a finger in the desired location, avoiding a pocket that is too posterior (the patient may have difficulty inflating the device and may feel more discomfort when sitting due to the pump's posterior location). Once appropriately placed, dartos can then be closed in a purse-string fashion around the tubing, trapping the pump in the dependent portion of the scrotum and preventing pump migration.

For pump location to be satisfactory, tubing length and location should also be optimized. If tubing is too anterior or superficial, it will be more palpable and visible. This is often referred to as a "tail-pipe" deformity, resembling the tail pipes (exhaust pipes) of a sports car. This is not only problematic from a cosmetic standpoint, but also increases the risk of wound dehiscence and infection [72]. Making corporotomies more proximal allows the tubing to lie more posteriorly within the subdartos pouch. If corporotomies are too proximal, however, the tubing can be too short and the pump will be high riding. Alternatively, the tubing can be moved more distally by using shorter cylinder sizes with longer rear-tip extenders (RTE). The "rule of 10" applies to Coloplast devices and provides a good estimate for the cylinder size that will provide the appropriate tubing length. Using the rule of 10 to determine the proximal length, one simply subtracts 10 cm from the proximal measurement to get the length of RTE needed. The device size will be the total length minus the length of RTE [49]. In essence, this allows the proximal portion of the cylinder to be no longer than 10 cm, allowing the tubing to exit the corporotomy at the appropriate location in patients with deep proximal measurements.

Additional sutures can be used to secure the tubing within the posterior aspect of the pouch and prevent anterior migration. If several attempts to hide the tubing have been unsuccessful, a final option is to cut the tubing to a shorter length, though this is rarely necessary and does introduce the need for additional quick connects. It is important to perform device testing after the corporotomies are closed as inflation may decrease tubing length as the cylinders seat proximally. If additional length is needed, the corporotomies can be extended proximally to gain tubing length and allow the pump to rest lower in the scrotum.

DEVICE INJURY

Injury to the device should be a very rare occurrence. There are several intraoperative considerations to ensure the device integrity is not compromised. Nothing sharp should ever touch the device including instruments with teeth. Anecdotally, though not studied for publication, many surgeons avoid touching the device with any metal instrument. Closure of the corporotomy is a potentially high risk maneuver which can be mitigated with preplacement of sutures [73]. This concept can be extended to preplacement of plication sutures when straightening maneuvers are utilized. Local anesthetic can be injected prior to device placement. When necessary, cautery has been shown to be safe when used over the device in the corporal body at 35 watts on coagulation current with care to leave the inner circular fibers intact [74].

ACQUIRED BURIED PENIS

Adult acquired buried penis most often occurs when the penis becomes concealed by a suprapubic fat pad, also called an escutcheon, secondary to obesity. Not only does this pose concerns with sexual function, cosmesis, and perceived length loss, but patients also reportedly have difficulty with adequate hygiene and voiding [75]. This leads to chronic inflammation and potentially an increased risk of infection, which bears obvious concern in the setting of penile prosthesis implantation. Additionally, several psychologic sequelae exist including severe depression and suicidal ideation [76–78].

To address the above issues, patients with an excessive suprapubic fat pad can undergo escutcheonectomy in either a staged fashion or at the time of penile prosthesis implantation. It appears reasonable for surgeons to offer buried penis repair as an adjunctive procedure during penile prosthesis implantation given the high satisfaction rate with buried penis repair and significant increase in perceived penile length [76, 77]. Several authors have reported on concomitant buried penis repair and penile prosthesis. Salgado et al. described their experience with

buried penis repair at the time of penile prosthesis placement, reporting an infection in 1 out of 6 patients and average external length increase of 3.5 cm. All patients underwent inverted V-Y scrotooplasty in order to lower the penoscrotal insertion at the time of penile prosthesis followed by escutcheonectomy by plastic surgery [79]. Similarly, Baumgarten et al. reported on a series of eight patients, describing excellent penile implant functionality and one infection in the cohort [80]. Lastly, Shaeer et al. published a series of 22 patient, reporting no infections in the cohort and overall good patient satisfaction. Specifically, 86% of patients reported that post-operative penile length was longer than what they had remembered prior to ED onset [81]. Of note, these authors utilize an infrapubic approach to implantation and take advantage of the incision already made for the escutcheonectomy. Given the increasing incidence of obesity, and likely parallel increase in acquired buried penis, the need for escutcheonectomy at the time of IPP placement or in a staged fashion is likely to become more common. While the authors of this article do not currently perform buried penis repair at the time of implant placement due to potential increased infection risk, which could be catastrophic for the patient both physically and emotionally, it is worth noting that at least some authors have reported successful buried penis repair at the time of implant placement with minimal increase in infection rates. With the rising prevalence of obesity, this will need further evaluated in a larger population of properly selected patients to better elucidate the infection risk associated with buried penis repair at the time of implant placement, and this combined approach may be feasible in experienced hands.

CONCLUSIONS

Penile prosthesis placement remains a highly effective treatment of erectile dysfunction with excellent satisfaction rates, but surgeons often face anatomical challenges and intraoperative complications that must be successfully navigated to lead to successful outcomes. Good clinical judgement coupled with sound knowledge of various management strategies are critical to effectively handling the plethora of possible scenarios encountered intraoperatively. Inexperienced implanters should consider referring patients who are identified pre-operatively as having complex anatomy or other potential challenges to centers of excellence with highly experienced implant surgeons.

DATA AVAILABILITY

All discussed data can be found in the published articles or in the references where cited.

REFERENCES

1. Burnett AL, Nehra A, Breau RH, Culkin DJ, Faraday MM, Hakim LS, et al. Erectile dysfunction: AUA guideline. J Urol. 2018;200:633–41.
2. Salonia A, Bettocchi C, Capogrosso P, Carvalho J, Corona G, Hatzichristodoulou G, et al. EAU Guidelines on Sexual and Reproductive Heatlh. 2023. Available from: https://uroweb.org/guidelines/sexual-and-reproductive-health/chapter/management-of-erectile-dysfunction.
3. Gee WF. A history of surgical treatment of impotence. Urology. 1975;5:401–5.
4. Henry GD. Historical review of penile prosthesis design and surgical techniques: part 1 of a three-part review series on penile prosthetic surgery. J Sex Med. 2009;6:675–81.
5. Scott FB, Bradley WE, Timm GW. Management of erectile impotence. Use of implantable inflatable prosthesis. Urology. 1973;2:80–2.
6. Wilson SK, Delk JR. Historical advances in penile prostheses. Int J Impot Res. 2000;12:S101–7.
7. Rodriguez KM, Pastuszak AW. A history of penile implants. Transl Androl Urol. 2017;6:S851–7.
8. Barnard JT, Cakir OO, Ralph D, Yafi FA. Technological advances in penile implant surgery. J Sex Med. 2021;18:1158–66.
9. Sokolakis I, Pyrgidis N, Ziegelmann MJ, Mykoniatis I, Köhler TS, Hatzichristodoulou G. Penile prosthesis implantation combined with grafting techniques in patients with Peyronie's disease and erectile dysfunction: a systematic review. Sex Med Rev. 2022;10:451–9.
10. Ziegelmann MJ, Farrell MR, Levine LA. Modern treatment strategies for penile prosthetics in Peyronie's disease: a contemporary clinical review. Asian J Androl. 2020;22:51–9.
11. Polchert M, Dick B, Raheem O. Narrative review of penile prosthetic implant technology and surgical results, including transgender patients. Transl Androl Urol. 2021;10:2629–47.
12. Chung E. Penile prosthesis implant in the special populations: diabetics, neurogenic conditions, fibrotic cases, concurrent urinary continence surgery, and salvage implants. Asian J Androl. 2020;22:39–44.
13. Purohit RS, Kent M, Djordjevic ML. Penile prosthesis in transgender men after phalloplasty. Indian J Plast Surg. 2022;55:168–73.
14. Ziegelmann M, Köhler TS, Bailey GC, Miest T, Alom M, Trost L. Surgical patient selection and counseling. Transl Androl Urol. 2017;6:609–19.
15. Trost LW, Baum N, Hellstrom WJ. Managing the difficult penile prosthesis patient. J Sex Med. 2013;10:893–906.
16. Köhler TS, Wen L, Wilson SK. Penile implant infection prevention part 1: what is fact and what is fiction? Wilson's Workshop #9. Int J Impot Res. 2020;33:785–92.
17. Habous M, Tal R, Tealab A, Soliman T, Nassar M, Mekawi Z, et al. Defining a glycated haemoglobin (HbA1c) level that predicts increased risk of penile implant infection. BJU Int. 2018;121:293–300.
18. Hebert KJ, Kohler TS. Penile prosthesis infection: myths and realities. World J Mens Health. 2019;37:276–87.
19. Pang KH, Muneer A, Alnajjar HM. A systematic review of penile prosthesis insertion in patients with spinal cord injury. Sex Med Rev. 2022;10:468–77.
20. Masterson TA, Palmer J, Dubin J, Ramasamy R. Medical pre-operative considerations for patients undergoing penile implantation. Transl Androl Urol. 2017;6:S824–9.
21. Krakhotkin DV, Ralph DJ, Blecher GA, Chernylovskyi VA, Greco F, Bakurov EE, et al. Management of residual penile curvature after penile prosthesis placement. Asian J Androl. 2021;23:129–34.
22. Levine LA, Dimitriou RJ. A surgical algorithm for penile prosthesis placement in men with erectile failure and Peyronie's disease. Int J Impot Res. 2000;12:147–51.
23. Van Dyke M, Baumgarten AS, Ortiz N, Hudak SJ, Morey AF. State of the reservoir: current concepts of penile implant reservoir placement and potential complications. Curr Urol Rep. 2021;22:20.
24. Wen L, Köhler TS, Helo S. A narrative review of the management of benign prostatic hyperplasia in patients undergoing penile prosthesis surgery. Transl Androl Urol. 2021;10:2695–704.
25. Valenzuela RJ, Ziegelmann MJ, Hillelsohn JH, Farrell MR, Kent MA, Levine LA. Preliminary outcomes of the male urethral "mini-sling": a modified approach to the Andrianne Mini-Jupette procedure with penile prosthesis placement for climacturia and mild stress urinary incontinence. J Sex Med. 2019;16:1310–7.
26. McAbee KE, Pearlman AM, Terlecki RP. Infection following penile prosthesis placement at an academic training center remains low despite involvement of surgeons-in-training. Investig Clin Urol. 2018;59:342–7.
27. Hinds PR, Wilson SK, Sadeghi-Nejad H. Dilemmas of inflatable penile prosthesis revision surgery: what practices achieve the best outcomes and the lowest infection rates? (CME). J Sex Med. 2012;9:2483–91.
28. Eid JF. Penile implant: review of a "no-touch" technique. Sex Med Rev. 2016;4:294–300.
29. Bole Md R, Habashy Md E, Yang Md D, Ahmed MBBCh M, Trost Md L, Ziegelmann Md M, et al. Timing and causative organisms associated with modern inflatable penile prosthesis infection: an institutional retrospective. J Sex Med. 2023;20:107–12.
30. Huynh LM, Huang E, El-Khatib FM, Gross MS, Yafi FA. A systematic review of literature regarding whether immediate preoperative hemoglobin A1c or serum glucose are risk factors for infection following penile prosthesis implantation. Urology. 2021;152:15–24.
31. Talib R, Alnadhari I, Canguven O, Yassin A, Shamsodini A, Alrumaihi K, et al. HbA1c over 8.5% is not predictive of increased infection rate following penile prosthesis implant surgery in diabetic patients with erectile dysfunction. Andrologia. 2021;53:e14132.
32. Carvajal A, Benavides J, García-Perdomo HA, Henry GD. Risk factors associated with penile prosthesis infection: systematic review and meta-analysis. Int J Impot Res. 2020;32:587–97.
33. Miller JA, Bennett NE. Comparing risk factors for adverse outcomes in virgin inflatable penile prosthesis implantations and revisions: a retrospective cohort study. Sex Med. 2020;8:388–95.
34. Mulcahy JJ. Current approach to the treatment of penile implant infections. Ther Adv Urol. 2010;2:69–75.
35. Mulcahy JJ. Long-term experience with salvage of infected penile implants. J Urol. 2000;163:481–2.
36. Brant MD, Ludlow JK, Mulcahy JJ. The prosthesis salvage operation: immediate replacement of the infected penile prosthesis. J Urol. 1996;155:155–7.

37. Jiang D, Barnard J, Barham DW, Furr J, Lentz A, van Renterghem K, et al. Immediate salvage with inflatable penile prosthesis in an infected field is associated with a high success rate. Int J Impot Res. 2022. https://doi.org/10.1038/s41443-022-00576-2.
38. Swanton AR, Gross MS, Munarriz RM, Mulcahy JJ. Penile prosthesis salvage: a historical look at the Mulcahy technique and a review of the latest literature. Int J Impot Res. 2023;35:90–94.
39. Wilson SK, Parker J, Carrion R, Simhan J. Distortion of the implanted penis: SST and cylinder crossover. Int J Impot Res. 2021;33:278–85.
40. Bickell M, Manimala N, Parker J, Steixner B, Wiegand L, Carrion R. Floppy glans syndrome: pathogenesis and treatment. Sex Med Rev. 2016;4:149–56.
41. Ziegelmann MJ, Alom M, Bole R, Kohler T, Trost L. Modified glanulopexy technique for supersonic transporter deformity and glanular hypermobility in men with penile prostheses. J Sex Med. 2018;15:914–9.
42. Karpman E. Management of distal & proximal penile prosthesis crossover. J Sex Med. 2016;13:1008–12.
43. Kohler T, Gupta N, Wilson S. Wilson's pearls perils and pitfalls of penile prosthesis surgery. Fort Smith, AK: Calvert McBride Publishing; 2018.
44. Pearlman AM, Terlecki RP. Proximal corporal perforation during penile prosthesis surgery: prevention, recognition, and review of historical and novel management strategies. J Sex Med. 2018;15:1055–60.
45. Krzastek SC, Smith R. An update on the best approaches to prevent complications in penile prosthesis recipients. Ther Adv Urol. 2019;11:1756287218818076.
46. Stember DS, Kohler TS, Morey AF. Management of perforation injuries during and following penile prosthesis surgery. J Sex Med. 2015;12:456–61.
47. Mulcahy JJ. The prevention and management of noninfectious complications of penile implants. Sex Med Rev. 2015;3:203–13.
48. Sharma D, Smith RP. Troubleshooting intraoperative complications of penile prosthesis placement. Transl Androl Urol. 2017;6:S892–7.
49. Gupta NK, Ring J, Trost L, Wilson SK, Köhler TS. The penoscrotal surgical approach for inflatable penile prosthesis placement. Transl Androl Urol. 2017;6:628–38.
50. Ziegelmann MJ, Habashy E. Clinical challenges with penile prosthesis placement and Peyronie's disease. J Sex Med. 2021;18:1822–5.
51. Clavijo RI, Sávio LF, Prakash NS, Masterson T, Eid JF, Ramasamy R. Three-piece penile prosthesis implantation in refractory ischemic priapism-tips and tricks. Urology. 2017;106:233–5.
52. Henry G, Hsiao W, Karpman E, Bella AJ, Carrion R, Jones L, et al. A guide for inflatable penile prosthesis reservoir placement: pertinent anatomical measurements of the retropubic space. J Sex Med. 2014;11:273–8.
53. Yang DY, Kohler TS. Damage control considerations during IPP surgery. Curr Urol Rep. 2019;20:10.
54. Roth JD, Monn MF, Shelton TM, Mellon MJ. A novel technique for direct visualization of reservoir placement for penoscrotal inflatable penile prostheses using a single incision. Indian J Urol. 2018;34:283–6.
55. Capoccia EM, Phelps JN, Levine LA. Modified inflatable penile prosthesis reservoir placement into space of retzius: comparing outcomes in men with or without prior pelvic surgery. J Sex Med. 2017;14:968–73.
56. Scherzer ND, Dick B, Gabrielson AT, Alzweri LM, Hellstrom WJG. Penile prosthesis complications: planning, prevention, and decision making. Sex Med Rev. 2019;7:349–59.
57. Grimberg D, Wang S, Carlos E, Nosé B, Harper S, Lentz AC. Counter incision is a safe and effective method for alternative reservoir placement during inflatable penile prosthesis surgery. Transl Androl Urol. 2020;9:2688–96.
58. Morey AF, Cefalu CA, Hudak SJ. High submuscular placement of urologic prosthetic balloons and reservoirs via transscrotal approach. J Sex Med. 2013;10:603–10.
59. Gross MS, Stember DS, Garber BB, Perito PE. A retrospective analysis of risk factors for IPP reservoir entry into the peritoneum after abdominal wall placement. Int J Impot Res. 2017;29:215–8.
60. Ziegelmann MJ, Viers BR, Lomas DJ, Westerman ME, Trost LW. Ectopic penile prosthesis reservoir placement: an anatomic cadaver model of the high submuscular technique. J Sex Med. 2016;13:1425–31.
61. Mykoniatis I, Osmonov D, van Renterghem K. A modified surgical technique for reservoir placement during inflatable penile prosthesis implantation. Sex Med. 2020;8:378–82.
62. Yang D, Heslop D, Houlihan M, Helo S, Ziegelmann M, Köhler TS. The Tubing, Hitch and Lasso, Intussusception Anchor (THALIA) technique: a novel approach to fixate the penile implant reservoir. J Sex Med. 2021;18:224–9.
63. Kava BR, Lopategui DM, Levine A, Ramasamy R. Trans-fascial placement of a high, sub muscular reservoir in patients following radical cystectomy: safety, efficacy, and predictability of final reservoir location verified with abdominal imaging. J Sex Med. 2019;16:338–45.
64. Baumgarten AS, Kavoussi M, VanDyke ME, Ortiz NM, Khouri RK, Ward EE, et al. Avoiding deep pelvic complications using a 'Five-Step' technique for high submuscular placement of inflatable penile prosthesis reservoirs. BJU Int. 2020;126:457–63.
65. Wilson SK, Mora-Estaves C, Egydio P, Ralph D, Habous M, Love C, et al. Glans necrosis following penile prosthesis implantation: prevention and treatment suggestions. Urology. 2017;107:144–8.
66. Xie D, Nicholas M, Gheiler V, Perito D, Siano L, Kislinger I, et al. A prospective evaluation of penile measures and glans penis sensory changes after penile prosthetic surgery. Transl Androl Urol. 2017;6:529–33.
67. Palmisano F, Boeri L, Cristini C, Antonini G, Spinelli MG, Franco G, et al. Comparison of infrapubic vs penoscrotal approaches for 3-piece inflatable penile prosthesis placement: do we have a winner? Sex Med Rev. 2018;6:631–9.
68. Chao TC, Shei-Dei Yang S, Chang SJ, Lin CD. Webbed penis: etiology, symptoms, surgical treatments, and outcomes. Urol Sci. 2020;31:200–5.
69. Li Y, Zhu X, Feng D, Gong J, Sun G, Zhang X, et al. A modified scrotoplasty for treating severe penoscrotal webbing in children. Front Pediatr. 2020;8:551.
70. Carrion R. Ventral phalloplasty. J Sex Med. 2010;7:2914–7.
71. Bonitz RP, Hanna MK. Correction of congenital penoscrotal webbing in children: a retrospective review of three surgical techniques. J Pediatr Urol. 2016;12:161.e1–5.
72. Hellstrom WJ, Montague DK, Moncada I, Carson C, Minhas S, Faria G, et al. Implants, mechanical devices, and vascular surgery for erectile dysfunction. J Sex Med. 2010;7:501–23.
73. Montague DK. Penile prosthesis corporotomy closure: a new technique. J Urol. 1993;150:924–5.
74. Hakim LS, Kulaksizoglu H, Hamill BK, Udelson D, Goldstein I. A guide to safe corporotomy incisions in the presence of underlying inflatable penile cylinders: results of in vitro and in vivo studies. J Urol. 1996;155:918–23.
75. Pestana IA, Greenfield JM, Walsh M, Donatucci CF, Erdmann D. Management of "buried" penis in adulthood: an overview. Plast Reconstr Surg. 2009;124:1186–95.
76. Hughes DB, Perez E, Garcia RM, Aragón OR, Erdmann D. Sexual and overall quality of life improvements after surgical correction of "buried penis". Ann Plast Surg. 2016;76:532–5.
77. Voznesensky MA, Lawrence WT, Keith JN, Erickson BA. Patient-reported social, psychological, and urologic outcomes after adult buried penis repair. Urology. 2017;103:240–4.
78. Tang SH, Kamat D, Santucci RA. Modern management of adult-acquired buried penis. Urology. 2008;72:124–7.
79. Salgado CJ, Navas G, Lalama M, Tanner LM, Gheiler E. Penile prosthesis placement with immediate buried penis correction: a retrospective chart review. Surg Case Rep. 2021;1–3.
80. Baumgarten AS, Beilan JA, Shah BB, Loeb A, Bickell M, Parker J, et al. Suprapubic fat pad excision with simultaneous placement of inflatable penile prosthesis. J Sex Med. 2019;16:333–7.
81. Shaeer O, Shaeer K, AbdelRahman IF. Simultaneous suprapubic lipectomy and penile prosthesis implantation. J Sex Med. 2018;15:1818–23.

AUTHOR CONTRIBUTIONS

ERB and GNU drafted the manuscript; ERB, GNU, MJZ, and TSK were involved in revisions and final approval of the manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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