Current Sexual Health Reports (2019) 11:399–405
https://doi.org/10.1007/s11930-019-00235-6

MALE SEXUAL DYSFUNCTION AND DISORDERS (A PASTUSZAK AND N THIRUMAVALAVAN, SECTION EDITORS)

Advances in Infection Prevention Strategies for Penile Prosthesis Surgery

Michael E. Rezaee[1] · Mohit Butaney[2] · Nannan Thirumavalavan[3] · Martin S. Gross[1] · Ricardo M. Munarriz[4]

Published online: 16 November 2019
© Springer Science+Business Media, LLC, part of Springer Nature 2019

Abstract

Purpose of Review To describe recent advances in infection prevention strategies for penile prosthesis surgery.

Recent Findings Improvements in surgical technique, antibiotic prophylaxis, prosthetic device design, and patient selection have globally reduced penile prosthesis infection rates. However, current societal antibiotic prophylaxis guidelines may fail to cover all organisms implicated in penile prosthesis infections, particularly fungal and anaerobic pathogens.

Summary Although significant strides have been made in reducing penile prosthesis infections, further education and research efforts are needed to continue to prevent this infrequent, but devastating complication. This review discusses recent advances in penile infection understanding and prevention.

Keywords Erectile dysfunction · Penile prosthesis · Infection control

Introduction

Erectile dysfunction (ED) is a prevalent and potentially distressing urologic condition affecting nearly 70% of men by age 70 [1]. Inflatable penile prosthesis (IPP) surgery is widely accepted as the definitive treatment option for men with ED unresponsive to oral, intraurethral, and intracavernosal pharmacotherapy [2, 3]. Although IPP placement is an invasive surgical procedure, it is highly effective and associated with excellent long-term patient and partner satisfaction outcomes [4, 5]. However, IPP surgery is not without surgical risk. Despite improvements in device design and operative technique over the last four decades, IPP infections remain a dreaded complication for both patients and surgeons [6].

Population studies have shown that IPP infections occur in 1–3% of men receiving de novo implants and 5–18% of men undergoing revision surgery [7–9]. These infections can result in severe emotional and physical harm, loss of sexual function, increased healthcare utilization and costs, as well as considerable medicolegal consequences for providers [10–12]. In addition, device infections can result in decreased patient satisfaction and prolonged time to achieving penetrative intercourse secondary to required infection control and salvage procedures [13].

IPP infections can be grouped into two categories: immediate and indolent processes [14]. Immediate infections are less common and typically occur within 8 weeks of surgery with patients presenting with surgical site edema, erythema, purulent drainage, and possibly fever or sepsis [14, 15]. More frequently, however, patients develop an indolent infection typically occurring within a year of surgery, but sometimes longer [14]. These patients can present with persistent vague symptoms, including chronic pain, sinus tract development, and fixation of the pump to the scrotal skin, which should heighten clinical suspicion for a smoldering infection [14, 15]. As such,

This article is part of the Topical Collection on *Male Sexual Dysfunction and Disorders*

✉ Mohit Butaney
mohitbutaney@gmail.com

[1] Section of Urology, Department of Surgery, Dartmouth-Hitchcock Medical Center, One Medical Center Drive, Lebanon, NH 03756, USA

[2] Department of Urology, Mayo Clinic, Rochester, MN 55904, USA

[3] Urology Institute, University Hospitals, Case Western Reserve University School of Medicine, Cleveland, OH 44106, USA

[4] Department of Urology, Boston University Medical Center, 725 Albany St, 3rd Floor, Suite B, Boston, MA 02118, USA

infection prevention has become a key focus among urologists commonly performing this procedure.

The purpose of this review is to provide an update on recent advances in infection prevention strategies in penile prosthesis surgery. We begin with a brief review of penile prosthesis infection pathophysiology and risk factors of this complication.

Infection Pathophysiology

Immediate IPP infections classically occur when a device comes into contact with skin flora during placement, resulting in seeding of the corporal space [9]. Infections secondary to hematogenous spread from concomitant procedures may be responsible for late or indolent infections [16]. Once introduced into the corporal space, bacterial and fungal organisms adhere to the device and begin to multiply and secrete a biofilm [17]. Biofilm is a complex matrix of extracellular polymers that facilitate organismal growth, further pathogen adherence, and antibiotic resistance through gene swapping and reduction of antibiotic penetration [18, 19]. Simultaneously, the body seals the device in a dense surgical capsule which further limits the immune response and efficacy of antibiotics [20]. Consequently, capsule excision, surgical removal of the device, and antibiotic washout are necessary to clear an IPP infection [21]. Of note, biofilm-forming organisms include *Staph epidermidis*, *Staph aureus*, *Klebsiella pneumonia*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Candida albicans* [22]. Multicenter investigations have shown that 25% of IPP infections are polymicrobial, while 11.1%, 10.5%, and 9.2% are caused by Candida, anaerobes, and methicillin-resistant Staph aureus, respectively [23••].

Infection Risk Factors

Risk factors for IPP infection are well known and can be categorized into patient and procedural characteristics. Patient-specific factors include medical co-morbidities, behavioral issues, and socioeconomic status [24, 25]. In 1995, Wilson and Delk examined 1337 consecutive IPP surgeries and found no significant increased risk of device infection among diabetics [26]. However, recently in 2019, Lipsky et al. observed a 1% increased risk of device infection associated with diabetes when examining 14,969 men undergoing IPP surgery (3% vs. 2%, $p < 0.002$); their results remained statistically significant after multivariate adjustment [27]. In addition, a recent multicenter review found that 83% of fungal IPP infections occurred in patients who were diabetic or obese, ultimately further raising concern for diabetes and metabolic syndrome as a risk factor for IPP infections [28•]. However, peri-operative diabetes control appears to be a more definitive risk factor for IPP infection. Patients with a blood glucose > 200 mg/dL at the time surgery have more than a four-fold risk of IPP infection compared to those under tight glycemic control [29]. Prior research has also shown that patients with HIV, spinal cord injury, Staph aureus nasal carriage, and who are chronically immunosuppressed are at significantly increased risk for IPP infection [26, 29, 30]. In terms of behavioral risk factors, patients who smoke or misuse at least one substance (e.g., alcohol, marijuana, cocaine) at the time of surgery are at increased risk of IPP infection [29, 30]. Similarly, homelessness has been shown to increase IPP infection risk 12-fold [29].

Certain procedural characteristics may put ED patients at even higher risk for IPP infection. Most notably, infection rates are substantially higher for device revision surgeries; up to an 18% increased risk of infection compared to new implants has been reported [26, 31]. Revision surgeries may be particularly susceptible to infection due to the tissue changes that occur after initial IPP placement, including the presence of a de-vascularized surgical capsule that may reduce the effectiveness of intravenous antibiotics and the host immune response. Increased operative time and case complexity may also place patients at increased risk of IPP infection [32]. The infection rate in patients requiring extensive corporal reconstruction for Peyronie's disease, fibrosis, or a neophallus approaches 22% for these lengthy cases [33]. Further, the climate in which IPPs are placed may also be a risk factor. A recent multi-center study found that IPP infections occurred more commonly in the month of June and when average daily temperatures were greater than 55 °F [34]. Lastly, there is growing evidence that IPP infection rates may correlate with urologist experience. Onyeji et al. found that patients undergoing IPP placement by low volume urologists were approximately 2 times more likely to require reoperation for infection compared to high-volume implanters [35].

Infection Prevention Strategies

IPP infection prevention strategies are composed of a combination of evidence-based research, expert opinion, and frequent practices employed by high-volume implanters (which may or may not be supported by clinical evidence). Below, we discuss infection prevention strategies for the pre-operative, intra-operative, and post-operative settings and specifically for the placement of new devices. Table 1 summarizes infection prevention strategies that should be considered by urologists prior to performing IPP surgery.

Pre-operative Prevention

In the office, ED patients electing for IPP placement should be counseled on the risks and benefits of surgery, particularly as

Table 1 Infection prevention strategies that should be considered prior to IPP surgery

Pre-operative
1. Patient selection. Exercise caution in following high-risk patients:
   a. Diabetics
   b. Anticoagulated
   c. Polysubstance abuser
   d. Immunocompromised
   e. Spinal cord injury
   f. Complex surgery
      i. Revision/Salvage
      ii. Reconstruction/Peyronie's
      iii. Female-to-male transgender
      iv. Concomitant artificial urinary sphincter
2. Thorough physical exam negative for infection
3. Medical Optimization
   a. HbA1c
   b. Blood sugar
   c. Charlson Comorbidity Index
   d. Anticoagulation
4. Drug abuse and smoking cessation
5. Urine culture particularly for patients with neurogenic bladders
6. Pre-operative Hibiclens/Chlorhexidine scrub
7. Referral to high-volume surgeon
8. Consider pre-operative antibiotic prophylaxis
9. Patient education including risk of infection and necessary post-operative care

Intra-operative
1. Careful surgical site preparation: Chlorhexidine
2. Reduce operative time
3. Reduce operative room traffic
4. Hair removal using clippers
5. No-touch technique, i.e., minimizing skin contact
6. Perioperative or irrigative antibiotic and antifungal prophylaxis along with use of antibiotic-impregnated or implants with hydrophilic coatings

Post-operative
1. Hematoma prevention:
   a. Mummy wrap/compressive dressing
   b. Post-operative inflation
   c. Closed suction drainage
2. Antibiotic prophylaxis
3. Early discharge

Revision surgery
1. Culture device by needle aspiration or direct swabbing
2. Administer broad-spectrum antibiotics and antifungals based on local antibiogram/guidelines and clinical judgement
3. Ensure proper washout for explant/salvage

they pertain to the individual risk factors discussed above. Pre- and post-operative instructions should be reviewed with patients in detail to ensure understanding. As part of the pre-operative assessment, a thorough physical exam should be conducted to assess for open sores or signs of fungal rash involving the groin, perineum, penis, or scrotum. Candidal infections in particular may be responsible for up to 11% of IPP infections and can easily be treated with oral fluconazole prior to surgery [23••]. Evidence of cellulitis or folliculitis can also be addressed with oral antibiotics with broad skin-flora coverage. A complete blood count and urine culture should be obtained to assess for underlying or asymptomatic urinary tract infection. However, prior research has shown little correlation between pre-operative urine culture results and the bacteriology of prosthetic device infections [36].

Currently, there is no evidence to support the utility of obtaining a hemoglobin A1c prior to surgery as there is no lab value cut-off useful in predicting increased risk for IPP infection. Alternatively, hemoglobin A1c may be a useful indicator to identify patients who require more support in achieving adequate glucose control in the peri-operative setting. Further, nasal swab testing should be performed to identify patients harboring Staph aureus. A large randomized, placebo-controlled, multicenter trial performed by Bode et al. showed that pre-treating nasal Staph aureus carriers with mupirocin and washing with chlorhexidine prior to surgery resulted in significantly fewer deep surgical site infections compared to placebo (0.9% vs. 4.4%) [37]. However, the benefit of pre-operative chlorhexidine washes in preventing surgical site infections has recently been called into question [38]. Until more data are available, all IPP patients should be instructed to bathe with chlorhexidine leading up to their procedure and Staph aureus carriers should be treated with mupirocin.

In the pre-operative area, patients should again be thoroughly examined to assess for signs of infection that may require postponement of surgery. If the planned surgical site is clear, patients should receive intravenous antibiotics prior to proceeding to the operating room. Both the American Urological Association and European Association of Urology have published guidelines for broad perioperative antibiotic coverage to prevent IPP infection [39, 40]. However, a recent multi-center retrospective study of IPP infections showed that these guidelines may be insufficient and ineffective in 14–38% of cases [23••]. The authors found a high rate of infections secondary to Candida (11.1%), anaerobes (10.5%), and methicillin-resistant Staph aureus (9.2%) that were not covered by guideline-recommended antibiotic practices [23••]. As such, broader pathogen coverage that includes fungal and anaerobic organisms is likely needed to achieve adequate prophylaxis in IPP surgery.

Intra-operative Prevention

One of the most important innovations in prosthesis design has been the development of infection-resistant coatings.

Coloplast devices now have a hydrophilic coating allowing for antibiotic impregnation when bathed in antibiotic solutions prior to placement (Fig. 1). Similarly, AMS devices are now coated with a mix of rifampin and minocycline. A 2012 meta-analysis by Mandava et al. found that this device innovation alone globally reduced the incidence of IPP infections by 50% [41]. In addition to improvements in device design, greater surgeon and surgical team experience has been found to be associated with reduced infection risk. Prior research has shown that high-volume implanters have lower infection rates compared to urologists performing IPP surgery less frequently [35]. This difference may be explained by increased comfort with IPP infection prevention strategies and shorter operative times among high-volume implanters [42]. Similarly, having an operative team familiar with the goals and steps of the procedure may reduce infectious complications, particularly when utilizing an IPP-specific surgical checklist prior to incision [43].

Preparation of the operative site should be performed with chlorohexidine-alcohol solution. Surgical site preparation with povidone-iodine has repeatedly been found to be inferior to chlorhexidine-alcohol in terms of surgical site infection risk and reducing bacterial volume [44, 45]. Once prepped, the patient should be draped in a sterile fashion to facilitate a "no-touch" technique to minimize device contact with the skin [46]. Multiple glove exchanges should then be performed at each critical point in the procedure to further reduce the risk of introducing skin flora into the corporal space. Additionally, throughout the procedure, anesthesia staff should be encouraged to maintain normothermia and adequate oxygenation as both have been shown to be beneficial in reducing infection risk [47, 48]. At completion of the case, the patient's penis and scrotum should be bandaged with a Mummy wrap to prevent post-operative hematoma. This technique has been shown to simultaneously reduce hematomas and associated IPP infections by 83% [29]. Other common techniques for hematoma prevention include partial device inflation, tight corporotomy closure, and surgical drain placement. Finally, other untested techniques to decrease intra-operative infection risk may include cleansing the urethra with betadine prior to incision, washing the external Foley catheter with alcohol after seating of the catheter balloon, minimizing operating room traffic, and maintaining IPP-specific operative teams.

Post-operative Prevention

Provider survey results have shown that IPP patients are commonly discharged home with a course of oral antibiotics, commonly levofloxacin and cephalexin [40]. However, there is no evidence to support or oppose this practice at this time. In the absence of local or systematic signs of infection, antibiotic administration more than 24 h after surgery has been shown to provide no additional benefit across a variety of surgeries [49]. However, the combination of prosthetic device implantation and the location of the surgery in the groin may necessitate the need for extended post-operative antibiotic coverage in IPP patients. Future research is needed to comprehensively investigate this practice.

Prevention for Revision Surgeries

Patients with suspected IPP infections should be admitted for observation, obtainment of culture data (e.g., wound, urine, and blood), and intravenous antibiotics. Cross-sectional imaging may also be warranted to assess the extent of infection, including involvement of the reservoir. If an infection is suspected, device explantation and surgical site washout are required to obtain source control and remove residual biofilm. After explantation and washout, temporary placement of a malleable prosthesis should be considered to preserve the corporal space for future IPP re-implantation. Prior research has shown high infection-free rates among patients undergoing Mulcahy salvage procedures (see below), followed by immediate temporary malleable device placement (Fig. 2) [50•,51].

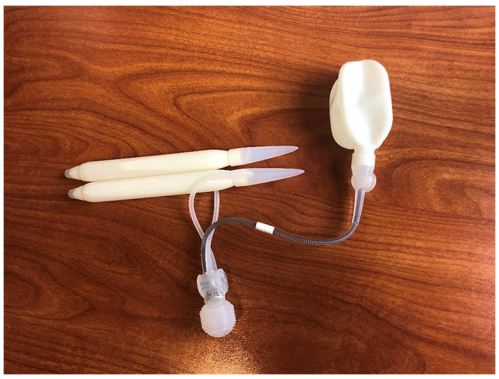

Fig. 1 Example of a three-piece inflatable prosthesis

Fig. 2 Example of one cylinder of malleable penile prosthesis

Of note, the Mulcahy protocol introduced in 1996 is often used for device salvage and consists of explantation, surgical site washout with hydrogen peroxide, and betadine solution, followed by re-implantation [52]. However, a recent critical appraisal of antiseptic irrigation has challenged the conventional use of 1.5% hydrogen peroxide and 5% betadine solution due to cytotoxicity and lack of clinical efficacy [53]. Diluted povidone-iodine solution (0.35–3.5%) may have more robust antimicrobial activity against recurrent IPP infections [53]. Similarly, data from a small single-center study suggests that surgical site washout with vancomycin and gentamicin may be superior to the traditional Mulcahy salvage procedure [54].

Future Research

It is challenging to conduct randomized clinical trials to assess the effectives of different IPP infection prevention strategies, particularly due to the resources and number of patients needed to perform such high-quality studies. However, we should continue to encourage multicenter research efforts to facilitate large, nationally-representative studies to establish best practices in IPP surgery. Despite recent advances in infection prevention strategies, IPP infection rates are still too high and significant opportunity exists to further reduce the prevalence of this devastating complication. Moving forward, we need to evaluate the role of expanded antibiotic coverage to address Candida, anaerobes, and methicillin-resistant Staph aureus. In addition, substantial research is required to understand which common, but untested, infection control practices (e.g., postoperative antibiotics, reducing operating room traffic) employed by high-volume implanters are beneficial in preventing IPP infections. Our ultimate goal should be to develop a safe and systematic methodology that can be utilized by all urologists performing IPP surgery to obtain the lowest possible infection rates.

Conclusion

IPP infections are an infrequent, but devastating complication for both surgeons and patients. Substantial advances have been made over the last 40 years to reduce infection rates, including improvements in IPP device design, surgical technique, and antibiotic prophylaxis. However, current urologic societal guidelines may fail to recommend appropriate prophylaxis for frequent causative organisms in IPP infection, including Candida and anaerobes. Significant opportunity exists to further reduce the incidence of IPP infections through continued multicenter, collaborative research endeavors and educational efforts.

Compliance with Ethical Standards

Conflict of Interest Dr. Rezaee, Dr. Butaney, and Dr. Thirumavalavan each declare they have no conflicts of interest to disclose. This research study was not supported financially.

Dr. Gross reports grants and personal fees from Coloplast, outside the submitted work.

Dr. Munarriz reports his role as a consultant and investigator for Coloplast.

Research Involving Human Participants and/or Animals This article does not contain any studies with human or animal subjects performed by the author.

References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. Feldman HA, Goldstein I, Hatzichristou DG, Krane RJ, McKinlay JB. Impotence and its medical and psychosocial correlates: results of the Massachusetts Male Aging Study. J Urol. 1994;151(1):54–61.
2. Hatzimouratidis K, Amar E, Eardley I, Giuliano F, Hatzichristou D, Montorsi F, et al. Guidelines on male sexual dysfunction: erectile dysfunction and premature ejaculation. Eur Urol. 2010;57(5):804–14.
3. Montague DK, Jarow JP, Broderick GA, Dmochowski RR, Heaton JP, Lue TF, et al. Chapter 1: The management of erectile dysfunction: an AUA update. J Urol. 2005;174(1):230–9.
4. Ji YS, Ko YH, Song PH, Moon KH. Long-term survival and patient satisfaction with inflatable penile prosthesis for the treatment of erectile dysfunction. Korean J Urol. 2015;56(6):461–5.
5. Vitarelli A, Divenuto L, Fortunato F, et al. Long term patient satisfaction and quality of life with AMS700CX inflatable penile prosthesis. Arch Ital Urol Androl. 2013;85(3):133–7.
6. Selph JP, Carson CC 3rd. Penile prosthesis infection: approaches to prevention and treatment. Urol Clin North Am. 2011;38(2):227–35.
7. O'Rourke TK Jr, Erbella A, Zhang Y, Wosnitzer MS. Prevention, identification, and management of post-operative penile implant complications of infection, hematoma, and device malfunction. Transl Androl Urol. 2017:S832–48.
8. Henry GD, Donatucci CF, Conners W, Greenfield JM, Carson CC, Wilson SK, et al. An Outcomes Analysis of over 200 Revision Surgeries for Penile Prosthesis Implantation: A Multicenter Study. J Sex Med. 2012;9(1):309–15.
9. Wilson SK, Costerton JW. Biofilm and penile prosthesis infections in the era of coated implants: a review. J Sex Med. 2012;9(1):44–53.
10. Chason J, Sausville J, Kramer AC. Penile prosthesis implantation compares favorably in malpractice outcomes to other common urological procedures: findings from a malpractice insurance database. J Sex Med. 2009;6(8):2111–4.
11. Pederzoli F, Chappidi MR, Collica S, Kates M, Joice GA, Sopko NA, et al. Analysis of Hospital Readmissions After Prosthetic Urologic Surgery in the United States: Nationally Representative Estimates of Causes, Costs, and Predictive Factors. J Sex Med. 2017;14(8):1059–65.

12. Goetz A, Yu VL, O'Donnell WF. Surgical complications related to insertion of penile prostheses with emphasis on infection and cost. Infect Control Hosp Epidemiol. 1988;9(6):250–4.
13. Habous M, Tal R, Tealab A, Aziz M, Sherif H, Mahmoud S, et al. Predictors of Satisfaction in Men After Penile Implant Surgery. J Sex Med. 2018;15(8):1180–6.
14. Swanton AR, Munarriz RM, Gross MS. Updates in penile prosthesis infections. Asian J Androl. 2019. https://doi.org/10.4103/aja.aja_84_19
15. Krzastek SC, Smith R. An update on the best approaches to prevent complications in penile prosthesis recipients. Ther Adv Urol. 2019;11:1756287218818076–6.
16. Carson CC, Robertson CN. Late hematogenous infection of penile prostheses. J Urol. 1988;139(1):50–2.
17. Welliver RC Jr, Hanerhoff BL, Henry GD, Kohler TS. Significance of biofilm for the prosthetic surgeon. Curr Urol Rep. 2014;15(6):411.
18. Donlan RM. Biofilm Formation: A Clinically Relevant Microbiological Process. Clin Infect Dis. 2001;33(8):1387–92.
19. Stewart PS, Costerton JW. Antibiotic resistance of bacteria in biofilms. Lancet. 2001;358(9276):135–8.
20. Elmussareh M, Goddard JC, Summerton DJ, Terry TR. Minimising the risk of device infection in penile prosthetic surgery: a UK perspective. J Clin Urol. 2013;6(5):280–8.
21. Henry GD, Wilson SK, Delk JR 2nd, et al. Revision washout decreases penile prosthesis infection in revision surgery: a multicenter study. J Urol. 2005;173(1):89–92.
22. Donlan RM, Costerton JW. Biofilms: survival mechanisms of clinically relevant microorganisms. Clin Microbiol Rev. 2002;15(2):167–93.
23.•• Gross MS, Phillips EA, Carrasquillo RJ, et al. Multicenter Investigation of the Micro-Organisms Involved in Penile Prosthesis Infection: An Analysis of the Efficacy of the AUA and EAU Guidelines for Penile Prosthesis Prophylaxis. J Sex Med. 2017;14(3):455–63. **Multicenter retrospective study to investigate penile prosthesis infection microbiology to consider with changes in practice could decrease infection rate, to evaluate current antibiotic prophylaxis guidelines, and to develop a proposed algorithm for penile prosthesis infections. This study showed a high incidence of anaerobic, Candida, and MRSA infections. Approximately 1/3 on infected prosthesis cases had negative cultures. Microorganisms identified in this study were not covered by the EUA and AUA antibiotic guidelines in at least 14% to 38% of cases. These findings suggest broadening antibiotic prophylaxis guidelines and creating a management now greater than for IPP infections might lower infection rate improved cell base excess**
24. Pineda M, Burnett AL. Penile Prosthesis Infections-A Review of Risk Factors, Prevention, and Treatment. Sex Med Rev. 2016;4(4):389–98.
25. Cakan M, Demirel F, Karabacak O, Yalcinkaya F, Altug U. Risk factors for penile prosthetic infection. Int Urol Nephrol. 2003;35(2):209–13.
26. Wilson SK, Delk JR 2nd. Inflatable penile implant infection: predisposing factors and treatment suggestions. J Urol. 1995;153(3 Pt 1):659–61.
27. Lipsky MJ, Onyeji I, Golan R, Munarriz R, Kashanian JA, Stember DS, et al. Diabetes Is a Risk Factor for Inflatable Penile Prosthesis Infection: Analysis of a Large Statewide Database. Sex Med. 2019;7(1):35–40.
28.• Gross MS, Reinstatler L, Henry GD, et al. Multicenter Investigation of Fungal Infections of Inflatable Penile Prostheses. J Sex Med. 2019;16(7):1100–5. **Multi-institutional database review of IPP infections to examine for common patient and surgical factors related to IPP fungal infections. Fungal infection represent 12% of all penile prosthesis infections in our series and were seen mostly in diabetic are rate patients, who may benefit from antifungal prophylaxis.**
29. Balen A, Gross MS, Phillips EA, Henry GD, Munarriz R. Active Polysubstance Abuse Concurrent With Surgery as a Possible Newly Identified Infection Risk Factor in Inflatable Penile Prosthesis Placement Based on a Retrospective Analysis of Health and Socioeconomic Factors. J Sex Med. 2016;13(4):697–701.
30. Hebert KJ, Kohler TS. Penile Prosthesis Infection: Myths and Realities. World J Mens Health. 2019;37(3):276–87.
31. Carson CC 3rd, Mulcahy JJ, Harsch MR. Long-term infection outcomes after original antibiotic impregnated inflatable penile prosthesis implants: up to 7.7 years of followup. J Urol. 2011;185(2):614–8.
32. Carrasquillo RJ, Munarriz RM, Gross MS. Infection Prevention Considerations for Complex Penile Prosthesis Recipients. Curr Urol Rep. 2019;20(3):12.
33. Jarow JP. Risk factors for penile prosthetic infection. J Urol. 1996;156(2 Pt 1):402–4.
34. Gross MS, Vollstedt AJ, Cleves MA, et al. Multicenter investigation on the influence of climate in penile prosthesis infection. Int J Impot Res. 2019.
35. Onyeji IC, Sui W, Pagano MJ, Weinberg AC, James MB, Theofanides MC, et al. Impact of Surgeon Case Volume on Reoperation Rates after Inflatable Penile Prosthesis Surgery. J Urol. 2017;197(1):223–9.
36. Kavoussi NL, Siegel JA, Viers BR, Pagliara TJ, Hofer MD, Cordon BH, et al. Preoperative Urine Culture Results Correlate Poorly With Bacteriology of Urologic Prosthetic Device Infections. J Sex Med. 2017;14(1):163–8.
37. Bode LG, Kluytmans JA, Wertheim HF, Bogaers D, Vandenbroucke-Grauls CM, Roosendaal R, et al. Preventing surgical-site infections in nasal carriers of Staphylococcus aureus. N Engl J Med. 2010;362(1):9–17.
38. Chlebicki MP, Safdar N, O'Horo JC, Maki DG. Preoperative chlorhexidine shower or bath for prevention of surgical site infection: a meta-analysis. Am J Infect Control. 2013;41(2):167–73.
39. Wolf JS, Bennett CJ, Dmochowski RR, Hollenbeck BK, Pearle MS, Schaeffer AJ. Best Practice Policy Statement on Urologic Surgery Antimicrobial Prophylaxis. J Urol. 2008;179(4):1379–90.
40. Grabe M, Bartolett R, Bjerklund Johansen TEB, et al. Guidelines of Urological Infections. https://uroweb.org/wp-content/uploads/19-Urological-infections_LR2.pdf. Published 2015. Accessed September 22, 2019.
41. Mandava SH, Serefoglu EC, Freier MT, Wilson SK, Hellstrom WJ. Infection retardant coated inflatable penile prostheses decrease the incidence of infection: a systematic review and meta-analysis. J Urol. 2012;188(5):1855–60.
42. Henry GD, Kansal NS, Callaway M, et al. Centers of excellence concept and penile prostheses: an outcome analysis. J Urol. 2009;181(3):1264–8.
43. Katz BF, Gaunay GS, Barazani Y, Nelson CJ, Moreira DM, Dinlenc CZ, et al. Use of a preoperative checklist reduces risk of penile prosthesis infection. J Urol. 2014;192(1):130–5.
44. Darouiche RO, Wall MJ Jr, Itani KM, et al. Chlorhexidine-Alcohol versus Povidone-Iodine for Surgical-Site Antisepsis. N Engl J Med. 2010;362(1):18–26.
45. Yeung LL, Grewal S, Bullock A, Lai HH, Brandes SB. A comparison of chlorhexidine-alcohol versus povidone-iodine for eliminating skin flora before genitourinary prosthetic surgery: a randomized controlled trial. J Urol. 2013;189(1):136–40.
46. Eid JF. No-touch technique. J Sex Med. 2011;8(1):5–8.
47. Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten

hospitalization. Study of Wound Infection and Temperature Group. N Engl J Med. 1996;334(19):1209–15.

48. Greif R, Akça O, Horn E-P, Kurz A, Sessler DI. Supplemental Perioperative Oxygen to Reduce the Incidence of Surgical-Wound Infection. N Engl J Med. 2000;342(3):161–7.
49. Rosenberger LH, Politano AD, Sawyer RG. The surgical care improvement project and prevention of post-operative infection, including surgical site infection. Surg Infect. 2011;12(3):163–8.
50.• Gross MS, Phillips EA, Balen A, et al. The Malleable Implant Salvage Technique: Infection Outcomes after Mulcahy Salvage Procedure and Replacement of Infected Inflatable Penile Prosthesis with Malleable Prosthesis. J Urol. 2016;195(3):694–7. **Multi-institutional retrospective review of 58 patients treated between 2002 and 2014 who underwent Mulcahy salvage with inflatable penile prosthesis removal and replacement with malleable prosthesis. This analysis shows a high infection free rate. Additionally 17 of 54 patient who remained infection free were able to successfully undergo subsequent removal of the malleable prosthesis replacement with an inflatable penile prosthesis.**
51. Lao M, Graydon RJ, Bieniek JM. Salvage penile prosthetic surgery utilizing temporary malleable implants. Transl Androl Urol. 2017;6(Suppl 5):S806–12.
52. Mulcahy JJ. Long-term experience with salvage of infected penile implants. J Urol. 2000;163(2):481–2.
53. Pan S, Rodriguez D, Thirumavalavan N, Gross MS, Eid JF, Mulcahy J, et al. The Use of Antiseptic Solutions in the Prevention and Management of Penile Prosthesis Infections: A Review of the Cytotoxic and Microbiological Effects of Common Irrigation Solutions. J Sex Med. 2019;16(6):781–90.
54. Manka M, Hebert K, Dodge N, Yang D, Kohler T, Trost L. MP27-18 INTRAOPERATIVE USE OF BETADINE IRRIGATION IS ASSOCIATED WITH A 9-FOLD INCREASE OF PENILE PROSTHESIS INFECTION. J Urol. 2019;201(Supplement 4):e370–1.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.