Review Article

# Perioperative infection prevention during inflatable penile prosthesis surgery: a narrative review

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**Background and Objective:** Penile prostheses are an option for the management of erectile dysfunction (ED). Over the years penile prosthesis surgery has become increasingly safe owing to improvements such as antibiotic usage, coated devices, and surgical techniques. However, infection remains a dreaded complication during prosthesis surgery. Efforts to minimize risk of infection in the perioperative period have been extensively studied. Herein, we performed a narrative review on preoperative, intraoperative, and postoperative strategies for infection prevention during placement of a penile prosthesis with a comparison of infection prevention strategies to other surgical fields.

**Methods:** A literature review was performed using PubMed and Google Scholar. Studies evaluating perioperative management of penile prosthesis infection were included. The following search terms were used to for our literature search: penile prosthesis, inflatable penile prosthesis, infection, prevention, perioperative management. Articles were graded based on the 2011 Oxford Centre for Evidence Based Medicine (OCEBM) guidelines and a table was generated with each intervention discussed and its level of evidence based on current literature.

**Key Content and Findings:** Optimization of patient's comorbid conditions can help reduce risk during prosthesis operations. Monitoring and optimizing a patient's glycemic control has been investigated, but the current literature does not necessarily support a strict hemoglobin A1c (HbA1c) or pre-operative blood glucose level. Surgical field preparation using chlorhexidine-based solutions has been shown to be superior to iodine-based solutions. Appropriately selected peri-operative antibiotics have also been shown to reduce infection risk. Intraoperatively, the use of coated devices in addition to a 'no touch' technique have been shown to significantly reduce the risk of inflatable penile prosthesis (IPP) infection. Post operatively, available evidence of antibiotic use has not been demonstrated to be effective in reducing infection rates.

**Conclusions:** Surgical infection following placement of an IPP is a devastating and morbid complication with infection rate up as high as 1–3% in virgin cases and 7–18% in revision cases. While perioperative techniques exist and have reduced risk of infection, more prospective data is needed to evaluate the clinical significance of these different approaches. More research in these areas, along with future options such as nanoparticles, antibiotic coated suture, and next generation sequencing (NGS) for bacterial pathogens, may shed light on further ways to optimize infection reduction strategies for prosthesis surgery.

**Keywords:** Penile implant infection; penile prosthesis; perioperative management

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## Introduction

Erectile dysfunction (ED) is a common diagnosis in men over 40 with over 30 million men in the United States suffering with the condition (1). ED is often multifactorial and can be impacted by comorbid conditions that can affect penile nerves, vasculature, smooth muscle, or sex hormone regulation. Diabetes is a major contributor to ED pathology and early ED is a predictor of cardiac risk (2). In addition, ED is a well-known complication of treatment for prostate cancer and can result from radical prostatectomy or radiation therapy. Radical prostatectomy is one of the most common treatment options in men with localized prostate cancer and can lead to ED, however this occurs less with use of nerve-sparing techniques (3,4). ED after radical prostatectomy has been to shown to be a result of direct trauma to the nerves via electrocautery, inflammation, and neurovascular separation (5,6). Some studies have reported that ED occurs at rates of 77–90% of patients after radical prostatectomy, while other sources note a return to baseline erectile function in less than 23% in men over the age of 60 years (7,8). With respect to external bean radiation therapy, ED is a common side effect that can result from vascular damage along with neurovascular bundle injury (9-11). Studies report that ED occurs in 50% of people who receive radiation therapy and this often worsens years after therapy (12,13).

Urologic andrologists are often tasked with creating treatment plans to maximize the return of erectile function in patients suffering from ED. Common modalities for treatment for ED include: phosphodiesterase-5 inhibitors, vacuum erection devices (VEDs), intracavernosal injections, intraurethral suppositories, and malleable or inflatable penile prosthesis (IPP) (14). IPP has excellent outcomes in the general population and patients undergoing prosthesis insertion after radical prostatectomy report satisfaction rates of 83–98% (5,15,16). Although IPP is a widely accepted treatment option for ED, it has risks. One of the most feared complications, albeit infrequent, is infection of the device. Recent literature has cited an infection rate of 1–3% in virgin prostheses and up to 7–18% in revision cases (17-21). Prior studies have summarized factors that influence the infection risk of IPPs, including control of comorbid conditions such as diabetes, use of pre-operative urine cultures, antibiotic coated devices, glove changes intraoperatively and post-operative antibiotics. This narrative review aims to summarize evidence-based literature to discuss methods of infection reduction in the pre-, intra-, and postoperative periods. Other novel strategies to reduce risk of infection during IPP placement are also briefly examined (*Figure 1*). We present this article in accordance with the Narrative Review reporting checklist (available at https://tau.amegroups.com/article/view/10.21037/tau-23-497/rc).

## Methods

To perform this narrative review, we conducted a comprehensive literature review using PubMed and Google Scholar. There were no restrictions on publication years. The search strategy summary is shown in *Table 1*. The search keywords included: penile prosthesis, inflatable penile prosthesis, infection, prevention, perioperative management. Literature search was conducted independently by A.N.M.O., A.N.M., E.F. and V.N. Consensus was obtained by open discussion. We reviewed references in the studies to include studies that would be relevant to this review. We included full-text English articles in peer-reviewed journals. Articles in the literature search were graded based on the 2011 Oxford Centre for Evidence Based Medicine (OCEBM) guidelines (22). We then generated a table with each intervention discussed and its level of evidence based on current literature (*Table 2*).

## Infection prevention in the perioperative period for IPP placement

### *Preprocedural*

#### Patient risk factors

Perioperative patient risk management and pre-existing infection treatment are important to reducing the risk of infection (23). It is necessary for urologic surgeons to obtain a thorough medical history so that appropriate counseling can be provided for patient populations with increased risk of infection.

Carvajal *et al.* performed a meta-analysis and systematic review of 513 studies and 175,592 patients which demonstrated that patients that were immunocompromised or had diabetes mellitus were at higher risk for penile prosthesis infection (23,24). It is well known that these states result in changes to both the adaptive and innate immune responses which fail to control the spread of invading pathogens (25,26). Moreover, Wilson *et al.* demonstrated that patients with diabetes had a 3% risk of infection compared with 1% of non-diabetic patients (27). Infection rate was as high as 18% in diabetic patients requiring revision (27). Typically, a surrogate measure for glycemic

 

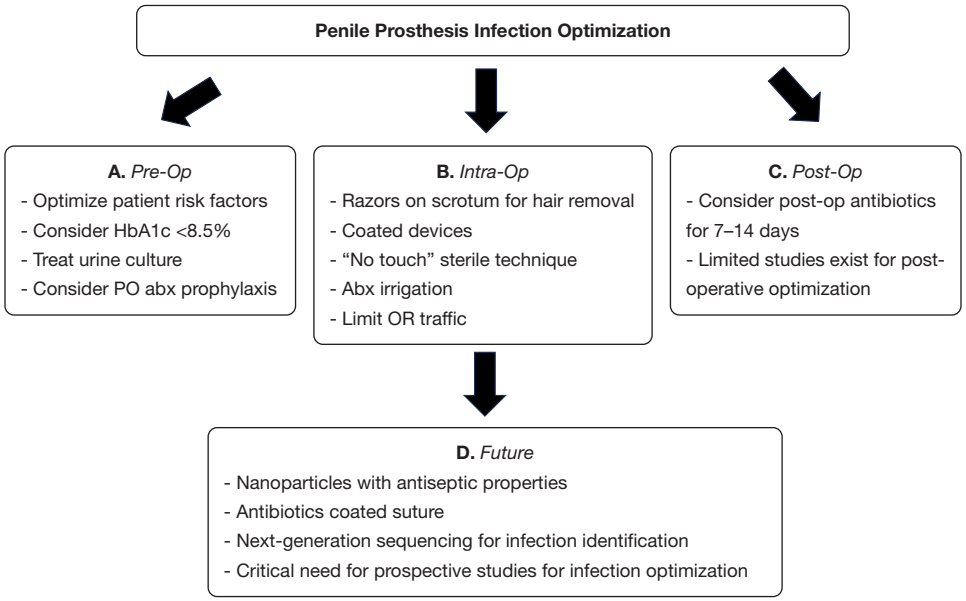


**Figure 1** Penile prothesis infection optimization showing (A) pre-operative, (B) intra-operative, (C) post-operative and future considerations for infection prevention in implant surgery. Op, operative; HgA1c, hemoglobin A1c; PO, oral; abx, antibiotics; OR, operating room.

**Table 1** The search strategy summary

| Items | Specification |
|---|---|
| Date of search | June 2023–January 2024 |
| Databases and other sources searched | PubMed and Google Scholar |
| Search terms used | Penile prosthesis, inflatable penile prosthesis, infection, prevention, perioperative management |
| Timeframe | 1987–2023 |
| Inclusion criteria | Only English language studies were included |
| Selection process | Literature search was conducted independently by A.N.M.O., A.N.M., E.F. and V.N. Consensus was obtained by open discussion |

control is the glycosylated hemoglobin A1c (HbA1c). A 2018 study by Habous *et al.* in a multicenter prospective study determined that patients with higher HbA1c, especially above 8.5%, were at higher risk for IPP infection (28). Specifically, HbA1cs of 7.6–8.5%, 8.6–9.5% and >9.5% had an infection rate of 6.5%, 14.7% and 22.4%, respectively. While other studies have showed that pre-operative HbA1c or immediate pre-op blood glucose from a finger stick has no correlation with infection risk post-operatively (28,29). Huynh *et al.* conducted a systematic review to investigate the predictive utility of HbA1c levels and preoperative glucose concentrations in assessing infection risk among patients with diabetes undergoing IPP surgery. Their analysis concluded that neither HbA1c levels nor preoperative glucose concentrations were sufficiently predictive of infection risk in this patient population (30). Despite these findings, it remains common practice for surgeons to obtain baseline HbA1c measurements close to the time of surgery, along with a perioperative of blood glucose levels.

Immunocompromised individuals, encompassing those with conditions such as chronic steroid usage, autoimmune disorders, and recipients of organ transplants, pose notable considerations in the context of IPP surgery owing to heightened susceptibility to complications such as impaired wound healing and increased infection vulnerability.

 

**Table 2** Each intervention discussed, and its level of evidence based on current literature using the 2011 OCEBM guidelines

| Perioperative factor | IPP infection risk | Level of evidence |
|---|---|---|
| HbA1c >8.5% | Increased risk of infection | Level 1 |
| Immunocompromised state | No significant increased risk of infection | Level 3 |
| Spinal cord injury patients | Increased risk of infection | Level 1 |
| Active smoker | Increased risk of infection | Level 1 |
| Preoperative urine culture | Decreased risk of infection if negative or treated | Level 5 |
| Preoperative antibiotics | Decreased risk of infection | Level 5 |
| Perioperative antibiotics | Decreased risk of infection | Level 2 |
| Hair removal method | No difference infection | Level 2 |
| Preoperative washes/scrubs | Decreased risk of infection | Level 2 |
| No touch technique | Decreased risk of infection | Level 3 |
| Antibiotic coated devices | Decreased risk of infection | Level 2 |
| Antibiotics irrigation | Decreased risk of infection | Level 4 |
| Drain placement | No effect on infection risk | Level 3 |
| Post operative antibiotics | No effect on infection risk | Level 3 |

OCEBM, Oxford Centre for Evidence Based Medicine; IPP, inflatable penile prosthesis.

However, the available data within this demographic present a spectrum of outcomes. Notably, Wilson and Delk, in a comprehensive chart review involving 1,300 patients, observed a notable 50% incidence of post-operative infections among individuals on chronic steroid therapy (27). Interestingly, their analysis revealed no infections among renal transplant recipients within the cohort. Similarly, Sidi *et al.* reported a lack of IPP infections in their cohort of diabetic patients on immunosuppressive therapy following solid organ transplantation (31). Another study identified no statistically significant variance in infection rates post IPP placement between transplant and non-transplant patients, with rates of 4.3% and 4.2%, respectively (32). This finding was further corroborated by a retrospective cohort study matching for age, demonstrating similar outcomes in infection incidence in transplant patients following IPP surgery (33). A recent longitudinal analysis that spanned a decade revealed that solid organ transplant status did not increase the risk of postoperative infections or complications in IPP surgery (34). While the available evidence is limited, these collective findings offer encouraging insights, suggesting that with appropriate optimization, IPP surgery can be undertaken safely in immunocompromised individuals especially those with history of solid organ transplantation.

Patients with spinal cord injury (SCI) and neurogenic bladder represent another patient population with high risk of prosthesis infection due to recurrent urinary tract infections (UTIs), poor circulation, and propensity for skin breakdown (35-37). Tienforti *et al.* performed a meta-analysis which demonstrated that the penile prosthesis infection rate in patients with SCI or neurogenic bladder was 6–8%, which is higher than the general population. There are limited studies assessing this patient group (35). Moreover, depending on the level of injury, patients may be insensate in the area of prosthesis placement which could potentially lead to progression of an unnoticed infection or even device erosion. A retrospective study by Collins and Hackler demonstrated that the most common complication of IPP placement in the SCI population was spontaneous erosion which occurred in the first six months (38). While there are no contraindications to IPP placement in these groups, shared decision making between patient and physicians is critical for preoperative optimization and risk stratification to promote successful outcomes of surgery.

It is well known that smokers have an increased risk of post-operative complications and infections (39). Sørensen conducted a comprehensive meta-analysis comprising 140 cohort studies which included almost 500,000 patients undergoing many types of surgeries, revealing an adjusted

 

odds ratio of 1.79 for postoperative surgical site infections (SSIs) in smokers compared to non-smokers. Smokers also had a higher risk of other complications including wound dehiscence and skin necrosis (39). While quitting smoking before surgery is preferable, it is advisable for patients to have abstained for at least four weeks preceding their operation (39). A Cochrane review by Thomsen *et al.*, showed evidence that behavioral modifications and nicotine replacement therapy increased successful short-term smoking cessation and may reduce risk of post-operative morbidity (40). While the data for smoking session is limited for IPPs, a pre-operative smoking assessment and intervention could be considered prior to IPP surgery.

Particular attention should be paid to the history of revision surgeries, as studies indicate an elevated risk of infection in patients undergoing revision IPP surgery. In 2004, Henry *et al.* aimed to elucidate the heightened infection risks associated with revision surgery by obtaining cultures from uninfected penile prostheses during revision surgeries. They discovered that 70% of patients harbored positive cultures from biofilm or pump components, despite the absence of clinical symptoms of infection (41). Subsequent studies have demonstrated an incremental rise in infection risk corresponding to the number of IPP revision surgeries a patient has undergone (42). Therefore, a patient's history should include the number of prior surgeries, as this predisposes them infectious complications.

**Pre-op urine culture**

Urine cultures are often obtained prior to urologic intervention. Per the American Urological Association (AUA) practice guidelines, surgeons should not perform penile prosthesis surgery in the presence of systemic, cutaneous or UTIs (14). Urine cultures are often obtained pre-operatively with positive cultures being treated with a course of antibiotics. However, further studies have found a poor correlation between urine cultures and risk of IPP infection (43). Expert opinion generally advocates for obtaining and treating urine cultures in symptomatic or high risk patients (44).

**Preprocedural antibiotics**

Some urologic surgeons will prescribe a 2-day course of prophylactic preoperative oral antibiotics (either sulfamethoxazole/trimethoprim or ciprofloxacin) prior to penile implant surgery, though no evidence exists on the efficacy of prophylactic antibiotics in reducing infection risk (45,46). A study by Gross *et al.* examined fungal infection after IPP placement and found that in their patient population, fungal infections affected 11–14% of penile implants of which a significant number of patients (83%) were diabetic (47,48). Thus, fluconazole can be added in patients who are diabetic. There may be a role for preoperative antibiotics, but prospective evaluation is needed to assess the true benefit of prophylactic antibiotics for penile prostheses.

**Perioperative antibiotics**

Perioperative antibiotic strategies are devised to mitigate the potential for postoperative infections. Historically, prevailing notions implicated skin flora including *Staphylococcus species* including methicillin-sensitive and methicillin-resistant *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Streptococcus species*, and fungal species, such as *Candida albicans*, as primary pathogens in implantable device infections across various surgical disciplines (49-51). Specific to penile prosthesis surgery, a retrospective analysis by Gross *et al.* revealed *Candida* species, anaerobes, and methicillin-resistant *Staphylococcus* to be implicated in 11.1%, 10.5%, and 9.2% of cases, respectively, based on intraoperative culture data obtained during IPP explantation (47). A more recent investigation utilizing next-generation sequencing, identified *Pseudomonas aeruginosa* as the predominant pathogen in prosthesis infections, while *Staphylococcus epidermidis* was the primary pathogen in erosions, and *Escherichia coli* in patients with mechanical failures (52). Discerning the microbiome of removed IPPs could inform perioperative antibiotic strategies.

The AUA's Best Practice Statement on antimicrobial use in urologic surgery advocates for preoperative administration of an aminoglycoside, with aztreonam suggested for renal insufficiency, in conjunction with vancomycin or a first or second-generation cephalosporin within 1–2 hours pre-incision for IPP procedures (53). Rezaee *et al.* demonstrated that diabetic patients exhibited a heightened infection risk with standard AUA prophylaxis compared to non-standard regimens (54). Findings were corroborated by Barham *et al.*, who noted an elevated infection risk with vancomycin and gentamicin alone compared to other antibiotic regimens for penile prosthetic surgery. Notably, antifungal usage was associated with reduced infection risk, particularly pertinent given the propensity for fungal involvement in IPP infections among diabetic patients (55). Another study showed that 83% of IPP fungal infections occurred in diabetic or obese individuals (56). Current AUA guidelines lack sufficient

 

consideration of local resistance patterns, anaerobic organism coverage, and fungal coverage. These extra factors should be considered by the surgeon when selecting appropriate antibiotics (45). Ultimately, further randomized controlled trials and prospective data are imperative to ascertain the optimal perioperative antimicrobial regimen for mitigating infection risks during IPP surgery.

**Hair clipping**

Research findings regarding the comparative risk of SSIs associated with clippers versus razors have yielded varied outcomes. A comprehensive Cochrane review spanning 11 randomized control trials conducted from 1980 to 2005 revealed mixed results. While three trials reported a statistically significant decrease in infection rates with shaving compared to clipping, seven trials found no discernible difference in infection rates when employing a depilatory cream (57). Moreover, a specific study focusing on urologic procedures found no difference in SSI rates between cohorts subjected to clippers versus razors (58). However, when viewed by a group of urologic surgeons and nurses, preoperative hair removal using a razor was associated with a more complete hair removal and less skin abrasions. The authors of this study highlighted challenges in detecting significant differences in SSI rates due to their relative rarity (less than 2% in their study), necessitating a substantial sample size for meaningful analysis. Concerns were also raised regarding the theoretical heightened infection risk associated with incomplete shaving compromising preoperative sterilization. Previous research has underscored inadequate skin preparation and improper hair removal as significant risk factors for SSI development (59). While several guidelines advocate for clipper use over razors due to insufficient evidence demonstrating a reduction in SSI risk, preoperative scrotal clipping remains a common practice in many surgical centers, particularly when combined with chlorhexidine or betadine skin prep (60,61). Among urologists, it seems as though standard practice is to use a razor for the scrotal shaving.

**Preoperative washes and scrubs**

Skin flora can be introduced into the surgical field during IPP surgery. Use of a perioperative antiseptic by patients the night before surgery has been employed by some surgeons despite limited evidence of this practice specifically in urologic prosthesis surgery (45,62,63). Traditionally a prolonged, often 10-minute scrub, with betadine was utilized to sterilize the surgical field. A landmark paper from the *NEJM* in 2010 performed a head-to-head comparison of chlorohexidine *vs.* povidone found the chlorhexidine to be significantly better at reducing SSI risk (64). This was expanded by Yeung *et al.* who found similar results when applied to skin preparation for genitourinary (GU) prostheses (61). Thus, use of chlorhexidine wash versus iodine solutions reduces the risk of infection in penile prosthesis surgery.

***Intraprocedural***

**Sterile technique**

The use of sterile gloves prevents bacteria on the skin from contaminating the sterile field. Double gloving is used to provide an additional layer between the operating surgeon and the surgical field, and there are varying beliefs on how often the operating team should exchange gloves. While no direct study has been done to demonstrate efficacy during IPP surgery, evaluation of sterile gloves or double gloves has been shown to be effective during joint placement. Some studies have shown that changing gloves based upon time can be effective while others showed that changing at specific stages, such as before handling the implant can be more beneficial (65-67).

In addition to the well-established use of sterile gloves for the reduction of infection, usage of a "no-touch" technique has been shown to further reduce the rate of infection in patients undergoing IPP surgery (68). The 'no-touch' technique was described by Dr. Eid in 2012 (68) and allows the IPP to be placed without contact with the skin, limiting contamination with skin flora. A similar 'no-touch' technique has been used during breast augmentation surgery and has been shown to significantly reduce the risk of SSI (69).

Another factor that can impact sterile technique is limiting operating room traffic. A study by Andersson *et al.* during orthopedic trauma surgery showed that decreased traffic in the OR reduced the number of bacterial colony forming units in air samples (70). While no direct correlation between reduction of SSI, anecdotally, this is a practice that urologists utilize to further reduce the risk of infection during IPP placement.

**Coated devices**

Coated devices have significantly impacted the rate of infection after IPP placement. Prior to the invention of coated devices, the risk of infection after placement was as high as ~5% in uncomplicated patients *vs.* up to ~8% in

 

patients with diabetes (71,72). In 2003, it was shown that IPPs were capable of harboring bacterial biofilms which was thought to be a mechanism by which IPPs could later become infected (73). In the early 2000's, American Medical Systems (AMS) created an implant that was impregnated with InhibiZone (Marlborough, USA), a combination of minocycline and rifampin. Additionally, in the early 2000's Mentor (now Coloplast, Humlebaek, Denmark) created an implant with hydrophilic coating that is able to absorb aqueous solutions. Therefore the device could be soaked in antibiotic solutions that would then be released into the surrounding corpora post operatively (74). These coated devices were able to reduce the infection rates to less than ~2% (75). Several studies have shown that the main pathogens for infection of implantable devices across multiple surgical fields are skin flora and fungi such as methicillin resistant *Staphylococcus aureus* and *Candida albicans* (47,49,50). Thus, antibiotic coating choices have been tested to optimize infection against these pathogens in different surgical fields using coated devices. Towe *et al.* determined that Coloplast implants dipped in antibiotic solution containing gentamicin and vancomycin were associated with lower rate of post operative infection compared to other dipping solutions such as rifampin + gentamicin, *Bacitracin* + polymyxin + gentamicin, and trimethoprim/sulfamethoxazole + gentamicin (76). Additional antimicrobial solutions are being explored as potential dips for coating of Coloplast IPPs. For example, recent studies by Karpman suggest that low concentration chlorhexidine gluconate (0.05%) antiseptic irrigation (Irrisept®, Lawrenceville, USA) can be used to dip the Coloplast Titan IPP without affecting the hydrophilic coating of the device and the Irrisept adheres to the IPP just as well as saline (77). Additionally, in 2023 Griggs *et al.* showed that dipping Titan IPP in Irrisept® can reduce microorganism colony counts against pathogens that are known to infect penile prostheses (78).

**Antibiotic irrigation**

Intraoperative wound irrigation (IOWI) is a technique utilized by surgeons to reduce debris, bodily fluids, and microorganisms in an open surgical site. Prophylactic IOWI is generally believed to help reduce the risk of SSI in the postoperative period (79). However, despite its widespread use, there remains considerable debate regarding the optimal composition of the irrigating solution. While some advocate for the use of normal saline alone, others argue for the inclusion of antiseptic or antibiotic agents. Although irrigation is commonly utilized during initial IPP placement, its significance becomes even more pronounced during salvage procedures. Brant *et al.*'s seminal work in 1996 delineated a salvage IPP procedure incorporating various irrigation solutions such as kanamycin bacitracin, hydrogen peroxide ($H_2O_2$), povidone-iodine solution, vancomycin, and gentamicin (80). The choice of irrigation solution assumes paramount importance during salvage procedures.

A review conducted by Pan *et al.* analyzed literature spanning from 2003 to 2018 to ascertain the cytotoxic and antimicrobial effects of commonly used irrigation solutions during IPP placement, aiming to establish evidence-based recommendations for commonly used irrigation solutions (81). Povidone iodine (PVI), more commonly known as betadine, emerges as a potent antimicrobial agent with a robust safety profile, exhibiting significant efficacy in both *in vitro* and *in vivo* models (81). However, its usage is contraindicated in patients with iodine allergies. A case-control study from Manka *et al.* indicated that betadine increases infection rates 9-fold when comparing to antibiotic fortified saline, therefore it is not routinely used in IPP surgery (82), $H_2O_2$, while effective as a disinfectant, demonstrates potent cytotoxic effects on tissue architecture and wound healing, precluding its use in IPP surgery irrigation due to the risk of air embolism (81). One additional irrigation solution that has been used more frequently during IPP surgery is Irrisept®. Razdan *et al.* evaluated the impact of irrigating the corporal bodies during salvage procedures with Irrisept® prior to device placement. Only four patients were included in the study but none developed perioperative infections (83). This suggests that Irrisept® could be a viable antiseptic solution that may be used during penile prosthesis placement. Much of the literature comes from retrospective reviews, and several studies state the need for procedure- and specialty-specific randomized controlled trials to determine whether antibiotic and antimicrobial agents confer any additional benefits.

**Drain placement**

During the placement of an IPP, the consideration of postoperative hematoma prompts the potential insertion of a surgical drain. Hematomas, being reservoirs of nutrient-rich substrates, may harbor bacteria, thus posing a heightened risk of infection. Despite ongoing discourse regarding the advisability of drain retention post-surgery, it is pertinent to acknowledge the potential infection risk

 

associated with drains. Nevertheless, literature on IPP procedures indicates that drain placement, including prolonged drain retention, has not demonstrated an elevation in infection rates. A multicenter study conducted in 2005 underscored this, revealing comparable infection incidence rates between patients receiving drains and those without (84). Subsequent investigations, such as the study by Osmonov *et al.* in 2023, have corroborated these findings, by showing no increased risk of infection even in patients with extended drain placement of three days (85). Overall, the literature suggests no increased risk in leaving a drain after IPP implantation.

### *Post procedural*

#### Postoperative antibiotics

Post operative antibiotics have been used after IPP surgery to reduce the risk of infection. However, literature suggested that there is no benefit in reducing infection rate with post operative antibiotics. In 2020, Dropkin *et al.* conducted a retrospective review examining the outcomes of patients with risk factors for infections who underwent implantation of IPP. Their analysis revealed no difference in the rates of explantation of IPP devices among patients who received postoperative antibiotic prophylaxis compared to those who did not. Additionally, there was no difference observed in the incidence of non-operative infectious complications between the two groups (86). A literature review by Dropkin and Kaufman in 2021 reports that the usage of postoperative antibiotics in an average-risk patient following IPP insertion may do more harm than good due to the risk of developing drug resistance (87). Patients who have a history of diabetes mellitus, SCI, or are immunosuppressed are at increased risk of developing subclinical or acute infection following surgery therefore one can consider providing post operative antibiotics to patients these risk factors (20). Wilson and Delk discussed an extended antibiotic treatment in patients with concern for subclinical infections with persistent cellulitis skin changes such that they could receive treatment with oral antibiotics for up to 12 weeks whereas acute infections require antibiotics and explantation (27,88). More data on the efficacy of post operative antibiotics is needed to evaluate the benefit of treatment and infection prevention.

### *Future considerations*

While surgeons have made significant efforts to minimize the risk of infection during IPP placement, there remain opportunities for future interventions that could further reduce the likelihood of infections. For example, the use of next generation sequencing (NGS) has the ability to increase the sensitivity of detecting infection and microorganisms involved in IPP Infection. By employing high-throughput sequencing technologies, NGS enables comprehensive analysis of the genetic material within a sample, allowing for the identification of diverse microorganisms present in implant-related infections with remarkable precision. Chung *et al.* was able to not only detect the most abundant species in IPP infection which was corroborated by the culture but also detect the lesser species and microbiomes (52). NGS holds promise for guiding personalized treatment strategies by pinpointing specific pathogens and their susceptibility patterns, thereby optimizing antibiotic selection, and enhancing therapeutic outcomes. As ongoing advancements continue to refine NGS methodologies and expand its clinical applications, its integration into the management of penile implant infections stands poised to revolutionize diagnostic and therapeutic approaches.

Another future area includes the use of nanoparticles which have antiseptic properties. Although no studies exist in IPP literature, other fields have shown nanoparticle to be efficacious in reducing infection. Nowinski *et al.* showed that the use of bone cement with a nanoparticle impregnated with antibiotics was able to reduce infection rates to 0% during total shoulder arthroplasty, as there was no detectable infection all 236 patients in the nanoparticle group (89). Tran *et al.* explored the impact of selenium nanoparticles as a coating on a titanium implant to determine if this could reduce infection in an *in vivo* model. Their work showed potent antimicrobial activity against *Staphylococcus species* both *in vivo* and *in vitro* (90).

A final intriguing avenue of exploration involves the utilization of antibiotic-laden suture. Triclosan is a phenolic antiseptic that has both bacteriostatic and bactericidal properties and has been successfully impregnated into suture material (91). Multiple studies in *in vivo* and *in vitro* models have demonstrated efficacy of triclosan coated suture in reducing bacterial load. In one study by Ming *et al.*, guinea pigs and mice were implanted with triclosan coated suture and challenged with *Escherichia coli* as well as *Staphylococcus aureus*. A decreased number in *Escherichia coli* and *Staphylococcus aureus* were detected on the implantation site in antibiotic coated suture compared to sites without coated suture (92). This promising line of investigation

 

suggests that the integration of antibiotic-laden sutures could serve as a valuable strategy in curbing infection rates associated with surgical procedures. More research in these areas may shed light on novel approaches for IPP surgery which can have important implications on reducing surgical infection risks.

## Conclusions

Surgical infection following placement of an IPP is a devastating and morbid complication. This review outlines preoperative, intraoperative and postoperative considerations for the reduction of SSI after implantation of IPP. A comprehensive approach that addresses preprocedural patient risk factors, meticulous intraoperative techniques, and vigilant postoperative management are needed to minimize the risk of infection. Preoperative risk assessment, including a thorough medical history, is crucial for identifying patients with increased susceptibility to infection, such as those with diabetes mellitus, immunocompromised states, SCIs, or a history of revision surgeries. While certain risk factors, such as diabetes mellitus, have been associated with higher infection rates, the predictive utility of specific markers like HbA1c levels remains debated.

Perioperative antibiotic strategies play a pivotal role in mitigating infection risks, with emerging evidence highlighting the importance of tailored antibiotic regimens based on patient characteristics and local resistance patterns. Coated devices and antibiotic irrigation solutions have demonstrated significant impacts on infection prevention during IPP surgery. Intraoperative practices, such as maintaining sterile technique and minimizing operating room traffic, further contribute to infection prevention efforts. While the optimal approach to drain placement remains a debated topic, current evidence suggests that drain placement does not significantly increase the risk of infection following IPP surgery.

Postoperative antibiotic prophylaxis has not been consistently shown to reduce infection rates and may pose risks of antibiotic resistance. Future directions for infection prevention in IPP surgery include the exploration of innovative interventions such as nanoparticle coatings, antibiotic-laden sutures, and next-generation sequencing for enhanced detection and management of infections. Summary of each intervention is available in *Figure 1*. Overall, ongoing research and advancements in infection prevention strategies hold promise for further optimizing the safety and efficacy of penile prosthesis surgery, ultimately improving outcomes for patients undergoing these procedures.

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*Peer Review File:* Available at https://tau.amegroups.com/article/view/10.21037/tau-23-497/prf

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