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INVITED REVIEW

Sexual Function

Current devices, outcomes, and pain management considerations in penile implant surgery: an updated review of the literature

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Penile prosthesis surgery is a definitive treatment for erectile dysfunction (ED). The two categories of penile prosthesis are endorsed by professional guidelines, inflatable penile prosthesis (IPP) and malleable penile prosthesis (MPP). Each modality of penile prosthesis offers distinct advantages and incorporates specific design features, allowing for personalized device selection that aligns with individual needs and preferences. While the overall complication rate of penile implant surgery remains low, surgeons should maintain a high index of suspicion for complications in the perioperative time period. Multimodal analgesic regimens including nerve blocks and narcotic-free pathways should be administered to manage perioperative pain. Finally, the high patient satisfaction after penile prosthesis surgery underscores the success of this ED treatment option.

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INTRODUCTION

Approximately 150 million men around the world suffer from erectile dysfunction (ED), a condition characterized by the persistent difficulty or inability to achieve and/or sustain a satisfactory penile erection for sexual activity.[1,2] The current professional guidelines recommend penile implant surgery (PIS) as the definitive treatment for patients with ED refractory to noninvasive therapies.[2] This review assesses the contemporary literature on indications, types of implants, outcomes, and pain management strategies in PIS to provide clinicians with an understanding of this surgical treatment for ED.

METHODS

A comprehensive literature search was performed through PubMed to identify peer-reviewed articles on penile implant surgery. Literature published since the first use of penile prostheses to 1 September 2023 was included to provide historical context and the evolution of the penile implants. A 10-year filter was placed for analyzing outcome data to understand the modern implications of each device currently on the market. The initial search terms included each implant's name, followed by "implant outcome" (*e.g.*, "AMS 700 implant outcome", and "ZSI 475 implant outcome"). Search results were identified, screened, and selected, as shown in **Figure 1**. Twenty-eight publications were included and examined for PIS-related data.

INDICATIONS FOR PENILE IMPLANT SURGERY

As ED is often irreversible, most patients who select penile prosthesis placement have not previously responded to conventional therapies including phosphodiesterase inhibitors, intracavernosal injections, and vacuum erection devices. The American Urological Association (AUA) guidelines indicate that treatment with penile prosthesis should be offered to all patients with ED.[2] Between 2006 and 2010, the frequency of penile implant surgeries worldwide increased annually by 8%, suggesting that this surgical option for ED is gaining popularity.[3]

Penile prosthesis effectively manages ED arising from multiple pathological processes, including Peyronie's disease, refractory ischemic priapism, and vasculogenic or neurogenic dysfunction. The most common mechanism of ED is vascular, and cardiovascular disease, diabetes, and smoking are well-recognized risk factors for ED.[4–6] Damage to the cavernous nerve or pelvic nerve plexus is commonly seen in patients with previous pelvic surgery, spinal cord injury (SCI), or diabetes and increases the risk for neurogenic ED.[7] In individuals with Peyronie's disease, the presence of fibrous plaques within the penis may damage smooth muscle tissue, resulting in insufficient blood supply needed to attain an erection. As a result, penile prosthesis placement, with or without penile plication or tunical lengthening, is a promising therapy for Peyronie's disease.[8] In addition, individuals with multiple episodes of priapism or prolonged priapism, defined as an erection lasting ≥24 h, are more likely to develop severe ED and suffer from penile fibrosis. In this population, penile prosthesis placement will recover erectile function without increasing the risk for priapism-related complications.[9] PIS is also considered a secondary option after gender-affirming phalloplasty to allow for penetrative sexual intercourse. Lastly, patient demand for penile

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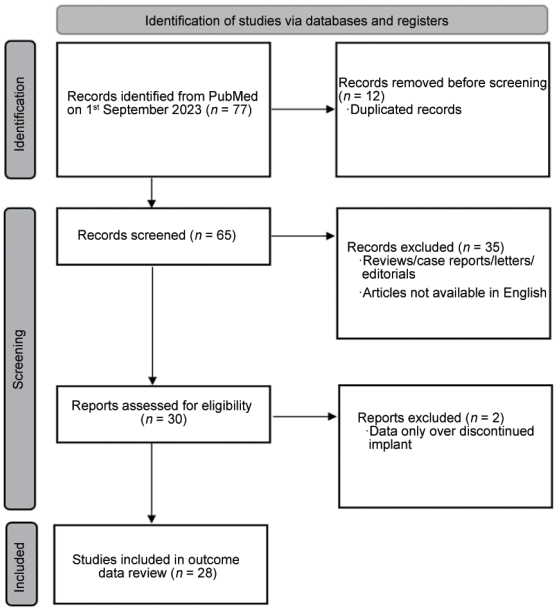

Figure 1: PRISMA 2020 flow diagram for systematic review of outcome data. PRISMA: the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

implant surgery exists due to penile dysmorphophobia. However, the European Association of Urology (EAU) guidelines advise against offering PIS to individuals who seek to increase penile length.[10] In regard to penile girth enhancement, a silicone implant called Penuma (International Medical Devices, Beverly Hills, CA, USA) has been cleared by the United States Food and Drug Administration for penile girth augmentation. However, EAU guidelines advise against the use of this subcutaneous penile implant to increase penile girth due to a paucity of data.[10]

TYPES OF PENILE IMPLANTS

Evolution of penile implants

The evolution of penile implants over the past 80 years has brought improvements in rigidity, flexibility, and postoperative pain.[11] The first penile implant was placed in 1936 using an abdominal tube pedicle graft, followed by the incorporation of rib cartilage in 1948, the introduction of acrylic stents in 1952, and the use of intracavernosal polyurethane rods in the 1960s. The National Aeronautics and Space Administration's high-grade silicone aided the development of silicone penile implants, leading to the precursor of the current inflatable penile prosthesis (IPP). Today, there are two main types of implants: IPP and malleable penile prosthesis (MPP).

IPP

IPPs are currently available as both three-piece and two-piece devices, as shown in **Table 1**. The three-piece IPP involves the implantation of two cylinders within the corpora cavernosa, a pump within the scrotum, and a reservoir under the abdominal wall or in the retropubic space. Upon manipulation of the pump, fluid from a reservoir is delivered to the intracorporeal cylinders to mimic the filling of the corpora cavernosa with blood during a physiological erection. In contrast, the two-piece IPP lacks a reservoir, and the fluid is maintained between the pump and cylinders. Both two-piece and three-piece IPPs require individuals to have adequate manual dexterity to manipulate the pump.

Dr. F Brantley Scott first commercialized an IPP through American Medical Systems (AMS, Minnetonka, MN, USA), known as the AMS 700 in 1983. Currently, AMS offers the AMS 700 CX, CXR, and LGX models. The AMS 700 CX is an upgraded version of the AMS 700 model and incorporates inner silicone tubing and a silicone-covered woven fabric layer to enhance durability, prevent cylinder aneurysms, and increase girth expansion. For individuals with narrow corpora, the AMS 700 CXR only requires dilation to 9 French. The AMS LGX is a more contemporary three-piece device designed to simulate longitudinal and radial expansion of the penis. These AMS devices are coated with InhibiZone, an antibiotic layer shown to reduce revision events due to infection.[12] In the USA, the main market competitor to AMS is Coloplast (Humlebaek, Denmark) who entered the market in 1983 and later introduced a three-piece IPP system using Bio-Flex, a durable polyurethane material. Coloplast now manufactures the Titan and Titan Touch models with pump modifications and a hydrophilic coating of polyvinylpyrrolidone (PVP) that reduces bacterial adherence and 1-year infection rates.[13]

While AMS and Coloplast dominate the USA IPP market, Zephyr Surgical Instruments (ZSI; Les Acacias, Geneve, Switzerland) and Rigicon (Ronkonkoma, NY, USA) supply three-piece devices primarily to other countries. The ZSI 475 three-piece IPP, which was first designed specifically for female-to-male phalloplasty, is used in Europe, South America, and South Asia. Lastly, Rigicon offers the Infla10 which is used primarily in Europe, South America, and Asia.

The only two-piece IPP on the market is the AMS Ambicor, which comes prefilled and preconnected to eliminate the need for a separate reservoir. As a result, this device may be preferentially selected for patients with a complex past surgical history to avoid abdominal reservoir placement. Squeezing a scrotal pump inflates the cylinder by moving fluid from the proximal to the distal section of the cylinders. While the Ambicor IPP cannot simulate girth expansion, a retrospective study on 131 men who underwent implantation of an Ambicor IPP demonstrated that 96.4% of patients were able to achieve a satisfactory erection.[14]

MPP

In contrast to the fluid-based mechanisms behind IPPs, MPPs are composed of articulating segments placed in the penile shaft that are then manipulated during sexual activity to achieve desired penile rigidity. After sexual activity, the MPP must be manually adjusted into a detumescent position. Since their development in the 1970s, MPPs have undergone advancements to strike a delicate balance between rigidity and flexibility for concealment.[15] MPPs are particularly suitable for patients with impaired dexterity such as the elderly, those with SCI, or those with Parkinson's disease.[16] In addition, MPPs have been observed to be more cost-effective when compared to IPPs, but no direct cost comparisons between MPPs and IPPs have been performed to validate this theory.

MPP devices are manufactured by AMS, Coloplast, ZSI, Rigicon, and others, as shown in **Table 2**. The three most commonly used models in the USA are the AMS 600 Spectra, AMS Tactra, and Coloplast Genesis. The AMS 600 Spectra utilizes a central spring and cable to provide rigidity and angling during sexual intercourse as well as concealment when not in use. AMS also offers the AMS Tactra, which is a newer generation MPP that incorporates dual-layer silicone and a Nitinol core to optimize natural feel, rigidity, durability, concealment, and ease of implantation. The Coloplast Genesis is another popular model due to its ability to customize the device with three diameter options, a hydrophilic coating, blunted

Table 1: Current inflatable penile prosthesis devices on the market

Device	*Number of pieces (n)*	*Antibacterial properties*	*Cylinder size (cm)*	*Cylinder diameter (mm)*	*Rear tip extender (cm)*	*Tubing length (cm)*
AMS 700 CX	3	InhibiZone antibiotic treatment	12 15 18 21 24	12–18	0.5 1.0 1.5 2.0 3.0 4.0 5.0 6.0	Penoscrotal access: 9; infrapubic access: 18; unconnected cylinders: 30
AMS 700 LGX	3	InhibiZone antibiotic treatment	12 15 18 21	12–18	0.5 1.0 1.5 2.0 3.0 4.0 5.0 6.0	Penoscrotal access: 9; infrapubic access: 18; unconnected cylinders: 30
AMS 700 CXR	3	InhibiZone antibiotic treatment	10 12 14 16 18	9.5–14.5	0.5 1.0 1.5 2.0 3.0 4.0 5.0 6.0	Penoscrotal access: 9; infrapubic access: 15; unconnected cylinders: 18
Coloplast Titan	3	Hydrophilic coating	11 14 16 18 20 22 24 26 28	NA	NA	10–28
Coloplast Titan Touch	3	Hydrophilic coating	11 14 16 18 20 22	NA	NA	11–28
ZSI 475	3	PVP coating	12 15 18 21	NA	NA	NA
Rigicon Infla10	3	Reinforced with a 4th layer over cylinders, hydrophilic coating	NA	NA	0.5 1.0 1.5 2.0 3.0 4.0 5.0 6.0	10 12 14 16
AMS Ambicor	2	NA	14 16 18 20 22	12.5 14 15.5	0.5 1 2 3	9

AMS: American Medical Systems; ZSI: Zephyr Surgical Instruments; NA: not available; PVP: polyvinylpyrrolidone

tips, rear tip extenders to adjust length, and surgeon-specified antibiotics. Furthermore, the Rigicon Rigi10 was recently approved for worldwide sales. This device is produced in six diameters which is the broadest range of diameters currently available on the MPP market. MPPs manufactured for use primarily outside of the USA include the ZSI 100, the Promedon Tube, and the Silimed penile implant. Overall, MPPs offer a viable solution for individuals who are not interested in or candidates for IPPs yet to seek a reliable and discreet penile prosthesis to enhance their sexual experience and overall quality of life.

DATA ON PATIENT SATISFACTION

The impact of PIS on patient sexual satisfaction and quality of life is quantified through outcome measurement tools, such as the International Index of Erectile Function (IIEF), the Erectile Dysfunction Inventory of Treatment Satisfaction (EDITS), the Treatment Satisfaction Scale, and the Quality of Life and Sexuality with Penile Prosthesis (QoLSPP).[17,18] Satisfaction rates identified in recent literature are summarized in **Table 3**. Patients with BMI over 30 kg m^{-2}, Peyronie's disease, and prior prostatectomy are less likely to be satisfied after PIS.[19] Reasons for dissatisfaction include perception

Table 2: Current malleable penile prosthesis devices on the market

Device	*Type*	*Cylinder diameter (mm)*	*Cylinder length (cm)*	*Device flexibility (degree)*	*Rear tip extender (cm)*
AMS 600 Spectra	Semi-rigid	9.5 12 14	12 16 20	NA	0.5 1.0 1.5 2.0 3.0 4.0 5.0 6.0
AMS Tactra	Semi-rigid	9.5 11 13	14–23 16–25 18–27	90	NA
Coloplast Genesis	Semi-rigid	9.5 11 13	14–23 16–25 18–27	90	NA
Rigicon Rigi10	Semi-rigid	9 10 11 12 13 14	23 (diameter: 9–10) 25 (diameter: 11–14)	135	0.5 1.0
ZSI 100	Semi-rigid	NA	13–25 (adjustable)	NA	NA
Promedon Tube	Semi-rigid	9 10 11 12 13	Trimmable length segment: 60, 65, 70, and 80; functional length segment: 135, 155, 170, 172, 180, and 187	130	NA
Silimed Penile Implants	Semi-rigid	9 11	NA	NA	NA

AMS: American Medical Systems; ZSI: Zephyr Surgical Instruments; NA: not available

of postoperative penile shortening, poor glandular engorgement, and partner dissatisfaction.[20] To optimize patient satisfaction, clinicians should offer thorough preoperative counseling to establish accurate postoperative expectations.

Overall, general satisfaction with PIS (mean ± standard deviation [s.d.]) is approximately 83.4% ± 9.1% based on the included studies (**Table 3**). Postoperative IIEF score (mean ± s.d.) is 30.8 ± 13.8, and postoperative EDITS score (mean ± s.d.) is 59.2 ± 26.6 (**Table 3**). IPPs have a higher mean satisfaction of 86.2% when compared to 75.1% for MPPs.[2] This is likely because IPPs can deflate, allowing for improved phallus concealment when the prosthesis is not in use. Studying partner satisfaction is also important to evaluate PIS outcomes. Partner satisfaction with IPP devices has ranged from 76.00% to 98.00% compared to 57.00%–94.30% with MPPs.[2] Overall, assessing satisfaction provides valuable insights into the effectiveness and success of PIS, ensuring that the surgical intervention aligns with the individual needs and preferences of patients.

COMPLICATIONS

In addition to satisfaction, complication rates are used to evaluate the outcomes in PIS. Postoperative complications affect 11.3%–35% of patients, the most common of which include hematoma formation, glans hypermobility, mechanical failure, erosion, and infection.[21,22]

Hematoma

The incidence of hematoma after PIS ranges from 0.2% to 3.6%.[23] The potential space of the scrotum makes it highly susceptible to hematoma formation if adequate hemostasis is not achieved. A hematoma may be managed conservatively with a combination of bed rest, scrotal elevation, and a compressive dressing. Wilson *et al*.[24] report a 2% decrease in postoperative hematoma rate when a closed suction drain was placed and the device was partially inflated compared to compressive dressing use alone. Patients should also be counseled to avoid postoperative anticoagulant therapy for at least 5 days and physical activity for 3 weeks to prevent delayed hematoma formation.[25]

Glans hypermobility

Glans hypermobility, otherwise known as "floppy glans", has been identified in up to 5% of patients after PIS.[26] This poor aesthetic outcome is thought to occur because of inadequate prosthetic cylinder sizing/positioning or anatomic variations. One such variation is a laxity of the corpora-glans ligament, which results in a loose attachment between the corpora cavernosa and the glans. The modified glanulopexy technique has been proposed to resolve glans hypermobility using sutures to anchor the glans to the corpora at an angle that helps prevent dyspareunia.[27]

Mechanical failure

Overall, mechanical failure of penile prostheses has decreased significantly due to improved prosthetic technology, but the incidence still ranges from 0 to 26.0% (**Table 3**). These failures may be attributed to tubing rupture, leading to fluid leak, cylinder migration, cylinder aneurysm, or injury to the tubing or device cylinders during implantation, among others.[23] In recent decades, manufacturers added kink-resistant tubing and altered the shape of the reservoir in three-piece devices for safer use.

Erosion

Erosion or cylinder extrusion may occur as a result of weakening of tissues at the tip of the penis. Across studies, IPPs erode less frequently (2.5%) compared to MPPs (4.1%).[2] Patients with decreased penile and bladder sensation, such as those with SCI or diabetes, are at higher risk of erosion due to the need for frequent catheter passage used for bladder management.[16] Management of erosion requires surgical intervention to reposition the prosthetic cylinder that may have

Table 3: Current penile implant outcomes and satisfaction data

Study	*Year published*	*Study design*	*Study timeline*	*Implant type*	*Manufacturer*	*Number of patients (n)*	*Mean follow-up time (month)*	*Rate of infection (%)*	*Rate of mechanical dysfunction (%)*	*Rate of explantation (%)*	*Rate of revisions required after surgery (%)*	*Patient satisfaction rate (%)*	*Preoperational vs postoperational total IIEF score (mean or mean±s.d.)*	*Preoperational vs postoperational EDITS score (mean or mean±s.d.)*
Habous *et al.*[46]	2018	Retrospective	2009–2015	IPP and MPP	Unspecified	902	28.5	NA	NA	NA	NA	78.5	NA	NA
Loh-Doyle *et al.*[47]	2018	Retrospective	2003–2016	IPP	AMS 700	78	49	2.6	11.8	NA	14.1	NA	NA	NA
Morgado *et al.*[48]	2018	Retrospective	2006–2014	IPP	AMS 700 CX, Coloplast Titan	55	NA	NA	NA	NA	NA	NA	NA	77.2±12.1 *vs* 77.5±16.6
Negro *et al.*[49]	2016	Prospective	2009–2012	IPP	AMS LGX	82	9	1.2	0	1.2	NA	80.0	10.7±2.1 (postoperational)	77.8±13.5 (postoperational)
Akdemir *et al.*[50]	2017	Retrospective	2009–2014	MPP	AMS Spectra	46	37.9	2.1	NA	NA	NA	96.2	5.9±0.9 *vs* 22.5±0.6	71.0±3.2 (postoperational)
Bennett *et al.*[51]	2017	Prospective	2011–2017	IPP and MPP	AMS 700 CX/LGX, AMS Ambicor, AMS Spectra	1135	NA	NA	NA	NA	NA	NA	NA	NA
Gentile *et al.*[52]	2016	Retrospective	2005–2013	IPP	AMS-Ambicor, Coloplast-Excell	42	27	4.8	2.4	NA	0	75.0	NA	NA
Bozkurt *et al.*[53]	2015	Retrospective	2001–2012	IPP and MPP	AMS Ambicor, AMS 700 CX, AMS Ultrex, AMS 600–650, Mentor Acu-Form	IPP: 118 MPP: 139	IPP: 34 SPP: 52	IPP: 4.2 MPP: 1.4	IPP: 4.2 MPP: 0.7	IPP: 1.7 MPP: 2.2	IPP: 7.6 MPP: 0.7	NA	IPP: 10.1±4.5 *vs* 23.4±1.5 MPP: 8.2±5.5 *vs* 22.8±1.8	IPP: 78.0±11.0; MPP: 57.0±8.0 (postoperational)
Carvalheira *et al.*[54]	2015	Retrospective	2003–2012	IPP and MPP	AMS 700 CX, AMS Tactile Pump, Coloplast Titan, AMS Spectra, Dura II	47	38.3	10.6	2.1	2.1	NA	78.7	NA	NA
Falcone *et al.*[55]	2013	Retrospective	2010–2012	MPP	AMS Spectra	NA	NA	NA	NA	NA	NA	86.4	28.5 *vs* 53.9	45.2 (postoperational)
Lindeborg *et al.*[56]	2014	Retrospective	2008–2011	IPP	Coloplast Titan	33	16	3.0	9.1	3.0	9.1	85.0	NA	NA
Chung *et al.*[57]	2013	Retrospective	2006–2010	IPP	AMS 700 CX, Coloplast Titan	138	AMS 700 CX: 40.6 Coloplast Titan: 35.4	2.0	5.0	2.0	6.0	AMS 700 CX: 86.0 Coloplast Titan: 90.0	NA	NA
Kim *et al.*[58]	2019	Retrospective	2014–2016	IPP	AMS 700 LGX	342	NA	0.3	2.9	NA	NA	NA	23.2±2.9 *vs* 41.8±4.5	NA
van Renterghem *et al.*[59]	2022	Retrospective	2018–2019	IPP	AMS 700, Coloplast Titan	809	3	3.7	NA	NA	4.6	NA	NA	NA
Mykoniatis *et al.*[60]	2020	Retrospective	2016–2019	IPP	AMS 700, Coloplast Titan	253	9.1	0.8	NA	NA	NA	NA	NA	NA
Dardenne *et al.*[61]	2019	Retrospective	2004–2014	IPP	AMS 700 CX, Coloplast Titan	67	43	NA	NA	11.2	NA	71.1	NA	NA
Palmisano *et al.*[62]	2022	Retrospective	2008–2018	IPP and MPP	Coloplast Titan, other unspecified models	576	NA	6.1	4.0	NA	NA	82.0	NA	NA
Blewniewski *et al.*[63]	2017	Retrospective	2012–2016	IPP	ZSI 475	28	35.1	0	7.1	NA	7.1	NA	6.0 *vs* 23.0	NA

Contd...

Table 3: Contd...

Study	*Year published*	*Study design*	*Study timeline*	*Implant type*	*Manufacturer*	*Number of patients (n)*	*Mean follow-up time (month)*	*Rate of infection (%)*	*Rate of mechanical dysfunction (%)*	*Rate of explantation (%)*	*Rate of revisions required after surgery (%)*	*Patient satisfaction rate (%)*	*Preoperational vs postoperational total IIEF score (mean±s.d.)*	*Preoperational vs postoperational EDITS score (mean±s.d.)*
Verla *et al.*[64]	2021	Retrospective	2017–2021	IPP	ZSI 475	57	16	14.0	7.0	22.8	NA	NA	NA	NA
Colombo *et al.*[65]	2021	Retrospective	2014–2018	IPP	ZSI 476	15	22	6.7	26.0	6.7	26.0	NA	NA	NA
Neuville *et al.*[66]	2019	Retrospective	2016–2017	IPP	ZSI 477	20	8.9	14.2	9.5	4.7	19.0	NA	20.2 (postoperational)	82.0 (postoperational)
Wilson *et al.*[67]	2023	Retrospective	2019–2021	IPP	Rigicon Infla10	319	21.2	0	2.5	4.4 (explantation or revision)	4.4 (explantation or revision)	NA	NA	NA
Wilson *et al.*[68]	2023	Retrospective	2019–2022	MPP	Rigi10	605	21.6	0.03	0	NA	1.0	99.5	NA	NA
Neuville *et al.*[69]	2016	Retrospective	2007–2015	IPP and MPP	AMS Ambicor, AMS 700 CXR, AMS 700 CX, AMS 600–650	69	48	4.2	10.5	NA	NA	NA	NA	NA
van der Sluis *et al.*[70]	2019	Retrospective	1989–2018	IPP and MPP	AMS Dynaflex, AMS Ambicor, Coloplast Genesis, AMS Spectra	32	NA	16.0	6.0	NA	44.0	NA	NA	NA
Mohamed *et al.*[71]	2016	Retrospective	2008–2015	MPP	Promedon Tube	128	42–43	5.5	2.3	9.4	NA	78.5	NA	NA
Pigot *et al.*[72]	2020	Retrospective	NA	MPP	ZSI 100	25	6.3	12.0	NA	44.0	NA	NA	NA	NA
Kılıçarslan *et al.*[73]	2014	Retrospective	2008–2013	IPP and MPP	AMS Ambicor, AMS 600–650	72	NA	NA	NA	NA	NA	Ambicor: 73.9; AMS 600–650: 34.8	NA	NA

IPP: inflatable penile prosthesis; MPP: malleable penile prosthesis; AMS: American Medical Systems; ZSI: Zephyr Surgical Instruments; NA: not available; IIEF: International Index of Erectile Function; EDITS: Erectile Dysfunction Inventory of Treatment Satisfaction; s.d.: standard deviation

moved into the head of the penis. Explantation is often required due to concomitant infection.

Scrotal skin violation

Scrotal skin violation is another rare complication that may occur if the pump is placed too superficially in the scrotum, resulting in inadequate pump concealment, pump extrusion through the skin, infection, hematoma formation, delayed wound healing, and scarring. Close monitoring of the scrotal skin integrity during and after surgery is imperative, ensuring timely identification and prompt management of any violations. Removal of the device may be necessary to prevent further complications.

Infection

Infection after PIS occurs in 0–16.0% of patients, most frequently within the first 3 months after surgery, due to bacterial colonization of the implant (**Table 3**).[2] Proposed risk factors include diabetes, immunosuppressed state, SCI, and IPP revision. A 2019 study analyzing 14 969 patients with IPPs reported infectious complications in 3% of diabetic patients versus 2% of nondiabetic patients, demonstrating that diabetes is an independent risk factor for IPP infection.[28] When evaluating diabetic patients, a hemoglobin A1c >8.5% has been shown to increase the risk of infection, but studies remain inconclusive on the utility of this clinical marker to predict infection.[29,30] In patients using immunosuppressive medications, the increased use of steroids has been hypothesized to increase infection risk, but this theory has yet to be supported by current literature.[31] Furthermore, patients with SCI are more likely to develop infectious complications due to catheter-associated urinary tract infections and decreased skin sensation.[31,32] This risk may be mitigated with preoperative negative urine cultures, consistent follow-up examinations, and the avoidance of indwelling catheters. Furthermore, patients with polysubstance use disorder and lack of housing at the time of operation are 892% and 1170% more likely to develop an infectious complication, respectively.[33] Lastly, patients undergoing revision surgery are at an increased risk for infection because penile prosthetic devices are prone to developing a bacterial biofilm after initial implantation.[34]

Infection after PIS may present with a variety of symptoms ranging from minimal penoscrotal pain to visible implant exposure. If infection is suspected, broad-spectrum antibiotics must be initiated and the device must be explanted.[34] The traditional management is a two-staged approach where removal and replacement of a prosthesis are separated in time to reduce further risk of infection. However, a prolonged waiting period also leads to increased rates of corporal fibrosis, which can result in a more challenging reimplantation.[23] To solve this dilemma, Mulcahy[34] proposed a salvage technique for reimplantation at the time of device removal. This technique involves the immediate removal of all foreign components, thorough antiseptic irrigation, and subsequent device replacement. This resulted in an 82% long-term infection-free rate, making it a currently practiced technique today.[35,36] Since its inception, the Mulcahy approach has been modified with various antiseptic irrigant formulations and reimplantation techniques to yield similar infection-free rates.[35] Infectious complications may be minimized with the use of preoperative and postoperative antibiotics, prostheses preinfused with antibiotics, skin preparation, and surgical site hair removal.[37,38] Antibiotic coatings on IPP cylinders significantly reduced the rate of prosthesis removal or replacement due to infection by 3%.[39]

Although serious complications after PIS remain uncommon, clinicians should thoroughly counsel patients about potential adverse outcomes before PIS and remain vigilant for complications in the extended postoperative period. Further research is warranted to investigate interventions that continue to improve the safety and efficacy of PIS.

PAIN MANAGEMENT

Another important consideration of PIS is pain management, which presents challenges due to the sensitivity of external genitalia to surgical manipulation. With regard to preoperative pain management, research has indicated that providing a multimodal analgesic regimen including acetaminophen, nonsteroidal anti-inflammatory drugs (NSAIDs), and gabapentin/pregabalin preoperatively can reduce the need for narcotics following IPP placement.[40] Evidence also supports the use of cyclooxygenase-2 (COX-2) inhibitors. An example regimen was evaluated by Parsa *et al*.,[41] who demonstrated that combining 1200 mg of gabapentin with 400 mg celecoxib 30–60 min before surgery resulted in reduced narcotic use within the first 5 days after plastic surgery.

Intraoperative analgesia during PIS involves the administration of a dorsal penile nerve block and a pudendal nerve block, although the type of analgesic and concentration used is surgeon-dependent. Raynor *et al*.[42] conducted a randomized controlled trial comparing a dorsal penile nerve block before IPP placement with equal parts 1% lidocaine and 0.5% bupivacaine to saline control and demonstrated reduced pain in the nerve block group immediately and 4 h after surgery. Another study by Xie *et al*.[43] investigated the combination of penile dorsal nerve and ring block with bupivacaine or ropivacaine versus no injection, and both treatment groups reported significantly less postoperative pain when compared to the control.

For postoperative pain management, multimodal analgesia (MMA) has gained attention in recent years. MMA regimens are an effective alternative to narcotic-based protocols in other urological procedures.[44,45] In the same study described above, Tong *et al*.[40] compared an MMA regimen of acetaminophen, gabapentin, and meloxicam to a narcotic-based control in patients undergoing 3-piece IPP placement. The MMA group reported significantly lower postoperative pain and used fewer narcotics in the postanesthesia care unit and upon discharge.[40] Overall, comprehensive pain management strategies are critical to optimizing short-term outcomes and patient satisfaction with this elective procedure.

CONCLUSION

Penile implant surgery has emerged as a cornerstone in the surgical management of erectile dysfunction. The evolution of penile prostheses has contributed to enhancing the durability of the devices, refining surgical techniques, limiting complications, and improving patient satisfaction. Understanding the progression and current landscape of penile implants is important to facilitate future innovation and advancements in the surgical management of erectile dysfunction.

AUTHOR CONTRIBUTIONS

NA, ME, TW, SG, KH, IB, and ECO all contributed to the literature review and writing of the manuscript. All authors read and approved the final manuscript.

COMPETING INTERESTS

All authors declare no competing interests.

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