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INVITED REVIEW

# Fundamentals of prosthetic urology

Operational Andrology

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The field of prosthetic urology demonstrates the striking impact that simple devices can have on quality of life. Penile prosthesis and artificial urinary sphincter implantation are the cornerstone procedures on which this specialty focuses. Modern research largely concentrates on decreasing the rates of complication and infection, as the current devices offer superior rates of satisfaction when revision is not necessary. These techniques are also able to salvage sexual function and continence in more difficult patient populations including female-to-male transgender individuals, those with ischemic priapism, and those with erectile dysfunction and incontinence secondary to prostatectomy. This review summarizes modern techniques, outcomes, and complications in the field of prosthetic urology.

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## INTRODUCTION

Prosthetic urology is a field that exhibits the true wonder of modern medicine. From those struggling with urinary incontinence being able to regain social function to the transgender person feeling more whole in their physical body, this branch of urology is ripe with achievement and room for development. This publication provides a survey of the two cornerstone procedures in the field: penile prosthesis (PP) implantation and artificial urinary sphincter (AUS) placement. Devices such as these elevate quality of life to match the increased lifespan that modern medicine affords us. For instance, the 15-year survival rate for prostate cancer across all stages is 96%; however, some estimates of erectile dysfunction (ED) after radical prostatectomy surpass 70% and rates of stress urinary incontinence (SUI) over 50%.<sup>1</sup> Similarly, mortality for diabetes and atherosclerotic disease have been decreased by contemporary therapy, but these illnesses predispose patients to ED that may become refractory to nonsurgical treatment as vascular injury inevitably mounts. PP implantation offers both a definitive solution for recalcitrant ED and an earlier treatment option that trumps noninvasive therapy in terms of satisfaction.<sup>2</sup>

## METHODS

A detailed, comprehensive literature review was performed to identify all published peer-reviewed articles which include PP and AUS in the urological literature over a 19-year period, *i.e.*, between 2000 and 2019. The search was conducted through MEDLINE® database, the Cochrane Library®, Central Search, Web of Science, and Google Scholar. The initial search terms were PP and AUS. Search results were screened for appropriate studies with particular emphasis placed on clinical and experimental studies as well as review articles. Articles referenced were screened to maximize review and inclusion of pertinent data. While English-language text was not a specific search parameter, only English-language publications were considered. All relevant studies collected were carefully examined to extract relevant data pertaining to PP and AUS.

## Past, present, and future development of penile prosthesis implantation

Penile implants have evolved from the earliest days of using prosthetic material to salvage quality of life, into the most effective treatment of ED. Although Ambroise Paré fashioned a wooden phallus for soldiers affected by penile trauma in the 1500s, his device was only designed to aid in urination in a standing position.<sup>3</sup> The first prosthetic created for urinary and sexual function was made of rib cartilage and designed by Nikolaj A Bogoraz in 1936.<sup>3</sup> Years of experimentation with other materials lead to F Brantley Scott's development of the ancestor to modern inflatable penile prostheses in 1973.<sup>3</sup> Once the pattern of inserting prosthetic material into the corpora cavernosa was established as an effective technique, the modern era of PP implantation emerged.<sup>3</sup>

Today's penile prostheses can largely be grouped into inflatable penile implants and semirigid devices. The most commonly implanted device in the United States is currently the three-piece inflatable penile prosthesis (IPP).<sup>4</sup> It consists of two inflatable cylinders, a pump which is often implanted into the scrotum and a reservoir. These devices are the most commonly used because they offer optimum rigidity to perform sexual function and can deflate to a comfortable level. Drawbacks are that using the pump requires a certain amount of manual dexterity that may be difficult in those with poor sensation or motor control such as diabetics.<sup>5,6</sup> The two-piece model is an IPP, which comprised only of cylinders and a pump. Two-piece IPPs make up <5% of implanted PPs, but offer simpler inflation and deflation which is beneficial to an elderly population with poor sensation.<sup>6</sup> In addition, its lack of a reservoir makes it ideal in those with extensive abdominopelvic surgical scarring.<sup>5,6</sup> Although this implant's rigidity is not as robust as that of the three-piece IPP, patients largely report that they are able to have coitus and satisfaction rates rival the three-piece IPP.<sup>5</sup> The malleable penile prosthesis (MPP) is made up of a semirigid rod placed in the corpora cavernosa. By nature, the device is constantly rigid and can be manipulated by patients, but will never achieve a state of detumescence

similar to the inflatable devices. Satisfaction rates for these devices are high (**Table 1**), and they are useful in salvage procedures after explanation of previously infected or damaged penile implants, which will be discussed later.<sup>7,8</sup>

The remarkable success of modern devices has directed research to modifying current models instead of trying to revolutionize the system.<sup>3</sup> The current literature centers on reducing infection and complication rates which are the bane of PP implantation. There is also promising investigation in consolidating multiple operations into one procedure such as simultaneous AUS and IPP placement or radical prostatectomy and IPP implantation.<sup>9</sup> Being able to perform both operations in one setting may decrease the rate of IPP underutilization by motivating patients who are hesitant to take multiple trips to the operating theater. There is some early development of a nickel-titanium memory alloy prosthetic by Dr. Brian Le, which changes shape based on heat; however, this project is in its infancy.<sup>10</sup> Finally, there are reports of prosthetic urological procedures such as malleable PP implantation being performed in the office under local anesthesia as a cost-saving measure.<sup>11</sup> This may encourage more patients to undergo PP implantation who are fearful of general anesthesia.

ED is estimated to affect 52% of men over the age of 40 years.<sup>12</sup> It can be secondary to or exacerbated by general comorbidities such as hypertension, hyperlipidemia, and diabetes mellitus as well as other urological-related conditions such as penile trauma, Peyronie's disease, and testosterone deficiency.<sup>3</sup> Although less invasive medical therapies dominate the market, PP implantation is the definitive treatment for erectile dysfunction.<sup>13</sup> PP placement has not only demonstrated a higher rate of satisfaction than oral phosphodiesterase-5 inhibitors and intracorporeal injection therapy in retrospective trials, but also it is the only therapy able to treat refractory disease.<sup>14</sup>

Satisfaction rates in recent literature are summarized in **Table 1**. Notably, there have been multiple studies validating that penile implants are also successful in special populations such as those who have a history of radical prostatectomy, pelvic radiation and priapism as well as female-to-male transgender patients and those with a neophallus generated after trauma.<sup>15</sup>

Patients who are dissatisfied with their prostheses are made up mostly of two subpopulations. The first are those who have had complications and undergone revisions.<sup>16</sup> Complications are examined in their own section, but infection is the most drastic and is estimated to affect 1%–4% of primary penile implantations.<sup>16,17</sup> Each complication that requires revision leads to an increased chance of additional complications as well as the risk of cavernosal fibrosis which makes future procedures more challenging and often requires smaller cylinders.<sup>7</sup> The second group of patients more likely to be dissatisfied are summarized by the characteristics described in the mnemonic "CURSED" by Trost *et al.*<sup>18</sup> in 2013. Patients who are identified as being "Compulsive/obsessive, Unrealistic, Revision, Surgeon Shopping, Entitled, Denial, or Psychiatric" are more inclined to have lower satisfaction rates.<sup>18</sup> These patients should be managed by discussing clear expectations of outcomes and complication rates.<sup>2,18</sup>

Even including these subpopulations, PP implantation is a successful procedure that is underutilized. Less than 5% of those eligible for PP implantation receive the surgery.<sup>10</sup> In addition, the rates of PP insertion in the United States fell from 4.6% to 2.3% of eligible patients from 2002 to 2010.<sup>19</sup> Theories explaining low implantation rates include lack of advertising and patient education as well as increased use of medical therapy. Cost effectiveness is a factor that varies considerably

based on the health system. In any case, work should be done to expand the reach of penile implantation, which is the gold standard of ED treatment.<sup>19</sup>

#### ***Modern techniques in penile prosthesis implantation***

IPPs are by far the most used penile prostheses. The two main surgical approaches are via penoscrotal or infrapubic incisions.<sup>20</sup> Both techniques have been examined by multiple recent studies that have demonstrated that neither is clearly superior, but each method has distinct advantages.<sup>20–22</sup> The penoscrotal approach provides better corporal exposure, less risk of damage to dorsal nerves especially during revisions, and the ability to place the pump directly into the scrotum and is easier accomplished in obese patients.<sup>20,21</sup> Drawbacks include blind placement of the reservoir and risk of urethral damage.<sup>21</sup> The infrapubic approach can be accomplished faster, provides visualization of the reservoir during placement, and is simpler to perform in those with previous pelvic surgery.<sup>20,22</sup> Cons include theoretical risk of dorsal nerve damage as well as more difficult scrotal pump placement.<sup>22</sup>

Reservoir placement can also be accomplished via varying methods. Conventionally, it was placed in the space of Retzius; however, this can be problematic in patients with previous pelvic surgery, so ectopic placement has been more commonly accepted.<sup>23,24</sup> The submuscular placement of the reservoir places it between the transversalis fascia posteriorly and the abdominal musculature anteriorly.<sup>24</sup> The traditional placement has a risk of damage to the bladder and other pelvic vasculature; however, this is rarely reported in the literature.<sup>23</sup> The submuscular approach is easier to accomplish in patients with previous pelvic surgery, but has a higher rate of herniation than placement into the space of Retzius.<sup>24</sup>

#### ***Penile prosthesis implantation complications***

##### ***Penile shortening***

Although there is measurable evidence that penile shortening does not occur postuncomplicated PP implantation, over 70% of men report this phenomenon, making it the most commonly cited cause of dissatisfaction.<sup>16</sup> The least invasive way to address this is to set reasonable expectations including preoperative measurement of stretched flaccid penile length which best approximates postoperative results.<sup>25</sup> More intensive ways of length preservation have been offered to men who have risk factors for penile shortening such as those undergoing revision surgery or patients who have undergone prostatectomy. These methods include preoperative use of vacuum or penile traction devices which can allow larger cylinders to be implanted.<sup>26</sup> Surgical techniques to reduce the appearance of penile shortening include the modified sliding technique which involves making a dorsal and ventral incision on the tunica albuginea and using a larger cylinder, thereby extending the penis and leaving a defect in the tunica.<sup>27</sup> This procedure carries the risk of glans necrosis, which is catastrophic, so it should be used in select cases by experienced surgeons. However, the technique was successfully performed by Egydio *et al.*<sup>27</sup> and resulted in an average of 3.1 cm in penile length without a significant increase in infection. Another approach includes simultaneous suprapubic lipectomy which results in a gain of 3.72 cm on average from preoperative stretched length without an increase in the rate of infection or complication.<sup>28</sup> A major caveat is that this study was carried out by high-volume urologists, and the theoretical risk of infection in less experienced hands may necessitate a staged approach.

##### ***Infection***

Infection is the most feared complication of PP implantation because it often leads to explantation, which can result in penile shortening

**Table 1: Summary of modern penile prosthesis implantation outcomes**

Author	Year	Study	Device type	Device brand	Patients (n)	Mean follow-up (month)	Infection (%)	Postoperative IIEF Score	Postoperative EDITS Score	Satisfaction (%)	Penile length change (cm)
Loh-Doyle <i>et al.</i> <sup>15</sup>	2018	Retrospective	IPP	AMS 700	78	49	2.6	-	-	-	-
Habous <i>et al.</i> <sup>60</sup>	2018	Prospective	IPP + MPP	Various (IPP; MPP)	45; 88	27.2	-	-	-	-	(+) 0.62 cm; (+) 0.22 cm
Habous <i>et al.</i> <sup>61</sup>	2018	Retrospective	IPP + MPP	Various	204 versus 588	-	-	-	-	76 versus 86.8	-
Morgado <i>et al.</i> <sup>62</sup>	2018	Retrospective	IPP	AMS 700C and Coloplast Titan	55	-	-	-	77.2±12.1 versus 77.5±16.6	-	-
Akdemir <i>et al.</i> <sup>8</sup>	2017	Retrospective	MPP	AMS Spectra	46	38.28	2.17	63	71.06	96.2	-
Bennett <i>et al.</i> <sup>63</sup>	2017	Retrospective	IPP + MPP	Various Ambicor devices	1255	>24	-	99	-	-	-
Gentile <i>et al.</i> <sup>64</sup>	2016	Retrospective	IPP	Two-piece Ambicor and Coloplast Excel	42	26.7	4.8	-	75 modified EDITS	-	-
Bozkurt <i>et al.</i> <sup>55</sup>	2015	Retrospective	IPP + MPP	Various (IPP; MPP)	118; 139	34; 52	-	78; 57	78; 57	-	-
Carvalho <i>et al.</i> <sup>66</sup>	2015	Retrospective	IPP	Various	47	38.27	-	-	-	79	-
Falcone <i>et al.</i> <sup>67</sup>	2013	Prospective	MPP	AMS Spectra	22	24.3	-	53.9/75	45.2	86.4	-
Menard <i>et al.</i> <sup>68</sup>	2011	Retrospective	IPP	Various Two-Piece Devices	210	37.6	1.1	>85	-	-	-
Bettocchi <i>et al.</i> <sup>69</sup>	2010	Retrospective	IPP	AMS CX 700	80	-	-	-	-	90	-
Wang <i>et al.</i> <sup>70</sup>	2009	Prospective	IPP	AMS 700 CX and Coloplast Titan	11	12	-	-	-	-	(-) 0.74 cm
Natali <i>et al.</i> <sup>71</sup>	2008	Retrospective	IPP	Various	200	60	3.1	-	81/91	-	-
Lux <i>et al.</i> <sup>72</sup>	2007	Retrospective	IPP	Two-piece	146	38	0.7	-	88/76	-	-
Deveci <i>et al.</i> <sup>73</sup>	2007	Retrospective	IPP	Various	56	-	-	(+) 15.6 change	62.4	-	-
Minervini <i>et al.</i> <sup>74</sup>	2006	Retrospective	IPP + MPP	Various	447	50	8	-	-	81	-
Borges <i>et al.</i> <sup>75</sup>	2006	Retrospective	IPP	Coloplast Alpha 1	303	-	-	-	-	93	-
Mulhall <i>et al.</i> <sup>76</sup>	2003	Retrospective	IPP	Various	96	12	-	59/75	81/100	-	-
Rajpurkar and Dhabuwala <sup>77</sup>	2003	Prospective	IPP	Various	32	18.91	-	-	36.09	93.8	-
Levine <i>et al.</i> <sup>78</sup>	2001	Retrospective	IPP	Two-piece Ambicor	131	43.4	4.6	-	90.6/82.6	95.5	-
Montorsi <i>et al.</i> <sup>79</sup>	2000	Retrospective	IPP	AMS Three-piece	200	59	6	-	-	92	-
Carson <i>et al.</i> <sup>80</sup>	2000	Retrospective	IPP	AMS 700CX	372	-	3.2	-	-	86.5	-
Holloway and Farah <sup>81</sup>	1997	Retrospective	IPP	AMS 700 Ultrex	145	42	8	-	-	85	-

This table summarizes published literature on outcomes of penile implantation from 1997 to publication date. AMS: American Medical Systems; EDITS: Erectile Dysfunction Inventory of Treatment Satisfaction; IIEF: International Index of Erectile Function; IPP: inflatable penile prosthesis; MPP: malleable penile prosthesis. -: no value reported; (+): positive change in value; (-): negative change in value



and cavernosal fibrosis.<sup>16,29</sup> Furthermore, each revision increases the risk of additional infection and complication due to a more hostile surgical environment and potentially from remnants of a previous bacterial biofilm.<sup>2,16</sup> As stated earlier, the risk of infection in PP implantation is estimated at 1%–4% in virgin cases.<sup>16</sup> Factors that have been demonstrated to increase the risk of infection are smoking, revision surgery, poorly controlled diabetes mellitus (hemoglobin A1c >11.5%), and spinal cord injury.<sup>16,30–32</sup> Modifiable risk factors should be controlled preoperatively. Methods demonstrated to reduce the risk of infection include the “no skin touch” technique which involves changing surgical gloves and considering all surgical equipment contaminated after the initial incision is made and then using a barrier to prevent contact between anything with the skin until surgical closure.<sup>33</sup> This method was shown to decrease infection rates of a particular surgeon from 1.99% to 0.44% with only 15 min of additional operative time.<sup>33</sup> Perioperative antibiotics are recommended to further reduce infection risk.<sup>34</sup>

Mulcahy described a salvage technique for infected PP in 1996.<sup>16</sup> It involves removing the device completely performing multiple different antiseptic lavages, followed by resterilization by changing gowns, drapes, and instruments and reimplantation of another device.<sup>17</sup> This procedure has a reported success rate of 84%.<sup>16</sup> However, those with an infection that compromises scrotal tissue are not candidates for immediate placement of IPP, so the malleable implant salvage technique was introduced in 2009.<sup>7</sup> This procedure is similar to the one mentioned above, but instead implants an MPP which serves as either a permanent replacement or a bridge to future IPP implantation. Immediate MPP placement is done to prevent extensive corporal fibrosis. This procedure has a success rate of over 90%.<sup>7</sup> Reimplantation of an IPP in a severely fibrotic corpus is a technical challenge that may require special instrumentation such as Carrion–Rosello device or Mooreville dilator which facilitate space for the placement of the new prosthetic device.<sup>17,35</sup> Preoperative vacuum rehabilitation regimens are another strategy for reimplantation in hostile corpora.<sup>17</sup>

### **Erosion and extrusion**

Erosion is another devastating complication of penile prosthesis and occurs in an estimated 1%–6% of cases.<sup>17</sup> It is more likely to occur if the urethra is damaged intraoperatively and in spinal cord injury patients who require intermittent catheterization.<sup>16</sup> Although erosion into the urethra is a feared complication, it can also affect the lateral aspect of the corpora, the glans, and other surrounding structures. If there is suspicion that cylinders in the process of eroding are infected, they should be explanted.<sup>16</sup> Ventrolateral and ventromedial erosion can be salvaged by Mulcahy’s (natural tissue repair) corporoplasty which creates a space to position a new device more medially than the previously eroded one.<sup>16</sup> Erosion of the device into the urethra is covered below in the urethral injury section.

### **Corporal crossover and perforation**

Corporal perforation and crossover are occurrences that are more common in fibrotic corpora. In fact, a 31% proximal perforation rate and 25% distal perforation rate was reported in a series of IPP implantations placed in fibrotic corpora.<sup>16</sup> These complications are often detected when loss of resistance is felt during dilation of the proximal corpora and can be confirmed by comparing the measurements of dilators inserted in both corpora.<sup>16,17</sup> A difference >1 cm indicates probable proximal perforation.<sup>16</sup> Proximal corporal perforation can be surgically corrected by placing corporotomy sutures around the outlet tubing and using a rear tip extender sling or windsock

patch to prevent migration.<sup>16</sup> The unaffected corpora should be used to size the implant. Distal perforations are more grievous because they risk urethral injury. Irrigating the affected corpora while watching for leakage around the urinary meatus should be performed.<sup>16</sup> If a distal perforation occurs during the first cylinder’s insertion, the operation is aborted and attempted later; however, if it occurs during the placement of the second cylinder, the first can be left in place and the removed cylinder side tubing capped to provide the patient with some rigidity.<sup>16,17</sup> The explanted side can be reinserted 3–6 months later if the patient desires. If a cylinder perforates in a manner that exposes it to the outside environment, it should be considered contaminated and managed accordingly.<sup>16</sup>

### **Urethral injury**

Urethral injury occurs in 1%–3% of PP of virgin implantations and can occur intraoperatively or secondary to erosion, which presents in a delayed fashion.<sup>36</sup> Dense corporal scarring and penile modeling in Peyronie’s disease patients are risk factors for intraoperative urethral injury.<sup>36</sup> 71.1% of reported intraoperative urethral injuries are due to distal corporal perforations during dilation.<sup>37,38</sup> Urethral injury can be avoided during dilation by always proceeding cautiously in a lateral direction.<sup>36</sup> As mentioned earlier, corporal irrigation revealing leakage at the urinary meatus confirms urethral perforation.<sup>16</sup> Expert opinion advises aborting the operation if this complication occurs while inserting the first cylinder and leaving the first cylinder in if it occurs during the second cylinder’s implantation.<sup>16,36</sup> There are case reports of implanting both cylinders successfully after primary urethral repair, but this is at the hands of a high-volume surgeon.<sup>38</sup> Very minor distal injuries can be managed by leaving a Foley catheter in place and monitoring for a few days.<sup>36</sup> Other more severe injuries necessitate urethroplasty that could require multiple revisions to complete the urethral repair and PP implantation.<sup>38</sup> Urethral erosion from PP presents in a delayed fashion and extravasation of urine into the corpora can cause pain and risk of infection.<sup>16,38</sup> This type of perforation requires washout and often delayed prosthetic replacement to allow for urethral repair and recovery.<sup>36</sup>

### **Reservoir, pump, and tubing issues**

Penile prostheses are very reliable with mechanical survival rates of 78%–100% at 5 years across devices.<sup>2</sup> Although autoinflation of three-piece penile implants occurred in the past, the introduction of lockout valves has mitigated this problem.<sup>39</sup> Reservoir migration is possible and there are a few documented cases of submuscularly placed reservoirs entering the peritoneum, but all were repaired without complication.<sup>40</sup> A case series reported difficulty in cycling the three-piece IPPs after weeks of disuse. This problem was previously managed by replacing the device; however, recent literature has demonstrated that the issue can be resolved by forced deflation and cycling in the office.<sup>39</sup> There is theoretical risk of bladder, bowel, and vascular damage during placement or removal of the reservoir from the space of Retzius.<sup>23</sup> A retrospective review of 400 cases only identified six reservoir-related complications, making this an uncommon problem, but damage to branches of the external iliac artery, bladder, or bowel can be disastrous, so care should be taken especially during revision surgery when approaching the reservoir.<sup>41</sup>

### **Glanular hypermobility**

Hypermobility of the glans penis is a rare complication that is also known as the supersonic transporter (SST) deformity due to the ventrally drooping glans appearing similar to the dipping nose of a

Supersonic Concorde jet. It can lead to difficulty or discomfort during intercourse, increasing the rates of dissatisfaction.<sup>42</sup> Previously thought to be due to undersized cylinders, it is now believed that a number of other comorbidities can cause this issue due to inadequate glanular support despite proper sizing.<sup>43</sup> Risk factors include fibrotic corpora, uncontrolled diabetes, previous penile surgery, androgen deprivation therapy, and priapism.<sup>43</sup> Repair of this deformity can be performed postoperatively or intraoperatively if hypermobility is noticed after cylinder inflation.<sup>43</sup> Ziegelmann *et al.*<sup>43</sup> characterized the Modified Glanulopexy Technique in 2018, which uses sutures to anchor the glans to the corpora and provides a more ergonomic angle between the glans and the penile shaft which prevents dyspareunia.

#### ***Penile wobble effect***

Recent literature has identified proximal corporal deformities which may lead to devices that can be cycled but are wobbly and unstable leading to difficulty with use.<sup>44</sup> These patients were treated with proximal corporoplasty and reimplantation with a prosthetic device. Subsequently, all recorded cases reported greater penile stability and satisfactory sexual intercourse.<sup>44</sup>

#### ***Past, present, and future development of artificial urinary sphincter implantation***

Urinary incontinence is a condition that dramatically decreases the quality of life. As mentioned previously, the oldest documented penile prosthetic, Ambroise Paré's 16<sup>th</sup> century wooden phallus, was used for micturition.<sup>3</sup> Wilhelm Fabricius Hildanus followed in the 1600s by creating a penile clamp to manage stress urinary incontinence which inspired the creation of a bulbar urethral compression belt in 1747 by Lorenz Heister.<sup>45</sup> These devices provided the foundation for the modern AUS. Frederic Foley is credited for the first device that surrounds and compresses the corpus spongiosum in 1948 and the same Brantley Scott who developed the modern PP in 1973 also described the first multicomponent AUS in the same year.<sup>45</sup> Today's AUSs are similar to what Scott introduced with minor cuff variations and antimicrobial covering.<sup>46</sup>

Present-day AUSs consist of a pressure-regulating balloon (PRB), pump, and a cuff. The cuff fits around the urethra and the PRB ensures that the urethra is compressed sufficiently to prevent gross urinary leakage. When the pump is triggered, liquid will flow from the cuff to the PRB allowing micturition. Finding the adequate pressure for the cuff is a balance which involves several factors. The cuff must provide enough pressure to prevent urinary leakage taking into account increases in intra-abdominal pressure during everyday activities such as lifting or straining.<sup>45</sup> In addition, the cuff should not be inflated to the point of causing urethral erosion or be so tight that urine cannot leak out in the setting of pressures sufficient to cause ureteral or renal dilation.<sup>45</sup> The most used devices of this era employ a PRB with a standard pressure between 61 cm and 70 cm of H<sub>2</sub>O with the activating pump device placed in the scrotum and the cuff surrounding the proximal bulbar urethra.<sup>45</sup>

Future development for AUSs includes a multitude of concepts which are being tested *ex vivo*. They include using shape metal alloys as a cuff, magnetic devices to deflate the cuff, and wireless communication devices for cuff deflation as well as piezoelectric and electroactive polymer components.<sup>45</sup> These devices underscore the urge to develop a product that is more convenient to use and less likely to erode the urethra, but they are all in early stages of development or limited by factors such as high voltage or temperature inside the body.<sup>45</sup>

Successful AUS outcomes are not judged based on complete dryness, but a significant reduction in urinary leakage often measured as 0–1 pad per day. Using that scale, modern success of these devices ranges between 46% and 88.5%.<sup>47–50</sup> When compared to other treatments for stress urinary incontinence in men, the AUS implantation is still the gold standard.<sup>48</sup> Although slings have become more popular in the last few years, they have a lower success rate. While there are no current randomized control trials that measure AUS versus sling, 13% of men with a sling will eventually require an AUS.<sup>47,48</sup> In addition, when a sling fails which can be up to 60% of the time based on clinical literature, patients are six times more likely to be incontinent when a sling revision is performed instead of an AUS implantation.<sup>47,51</sup> Because there is no evidence that implanting an AUS in a patient status postsling procedure poses a significantly higher risk of complication or residual incontinence, the 6th International Consultation on Incontinence considers AUS implantation the definitive treatment of stress urinary incontinence in men; using a sling is an option in men with mild stress incontinence who prefer it.<sup>48</sup>

Modern outcomes for AUS are summarized in **Table 2**. The rates of revision oscillate widely between studies due mainly to infection or erosion. Like PP implantation, AUS placement is a definitive and effective treatment whose main drawback is the rate of revision and complication.<sup>45,47</sup>

#### ***Modern techniques in artificial urinary sphincter implantation***

AUSs can be implanted via a perineal or penoscrotal approach. The perineal technique was traditionally used until the penoscrotal method was introduced in 2003. The penoscrotal approach is a faster technique that only requires a single incision.<sup>52,53</sup> Since then, the rate of penoscrotal AUS placement has been increasing despite evidence that the perineal approach has superior outcomes.<sup>52</sup> Two multicenter evaluations of these techniques revealed that the perineal approach had double the rate of effectiveness in the virgin procedure as well as lower rates of revision.<sup>52</sup> It is hypothesized that the lower success rates in the penoscrotal approach are due to more distal cuff placement on the bulbar urethra.<sup>53</sup> The bulbar urethra's tissue is thinner distally that may contribute to a higher rate of erosion.

#### ***Artificial urinary sphincter implantation complications***

##### ***Urinary retention***

Urinary retention was found in 31% of procedures, making it the most prevalent complication identified in a 2015 retrospective review.<sup>54</sup> Those who experience postoperative urinary retention have a higher revision rate than the average patient (76% vs 89%,  $P = 0.04$ ) and a higher infection rate.<sup>54</sup> Retention may be due to temporary bladder dysfunction from anesthesia and narcotics, so using a small caliber catheter for 24–72 h and re-evaluating is an appropriate management strategy.<sup>49,54</sup> Retention persisting longer than this may be due to transient edema or a cuff that is too tight, so revision or placement of a suprapubic catheter and revisiting in 1 month are potential strategies for evaluation.<sup>49</sup> A recently published article claims that most patients managed with suprapubic catheter and long-term follow-up demonstrate resolution of urinary retention without AUS revision.<sup>49</sup>

##### ***Loss of efficacy***

Some patients may notice a slight decrease in continence over time even after successful surgery which may lead to a request for re-evaluation.<sup>54</sup> If infection, erosion, urge incontinence, and overflow incontinence are ruled out as potential etiologies, then mechanical failure should

**Table 2: Summary of modern artificial urinary sphincter implantation outcomes**

Author	Year	Study type	Device	Patients (n)	Mean follow-up (month)	Infection (%)	Continence (%)	Satisfaction (%)
Sacomani <i>et al.</i> <sup>82</sup>	2018	Retrospective	AMS 800	121	62.4	–	87.6	–
Serag <i>et al.</i> <sup>83</sup>	2018	Retrospective	AMS 800	84	39	2.4	80.7	–
Ostrowski <i>et al.</i> <sup>84</sup>	2018	Prospective	ZSI 375	50	21	0	58	–
Ostrowski <i>et al.</i> <sup>85</sup>	2017	Retrospective	ZSI 375	147	–	6.12	83.5	–
Linder <i>et al.</i> <sup>86</sup>	2015	Retrospective	AMS 800	1802	62.4	0.082	59	94
Leon <i>et al.</i> <sup>87</sup>	2015	Retrospective	AMS 800	57	180	3.51	77.19	89.5
Gulpinar <i>et al.</i> <sup>57</sup>	2013	Retrospective	AMS 800	56	96	7.1	46	–
Bordenave <i>et al.</i> <sup>88</sup>	2011	Retrospective	AMS 800	159	5.75	4.4	74.2	–
Kim <i>et al.</i> <sup>89</sup>	2008	Retrospective	AMS 800	124	81.6	5.64	82	–
Lai <i>et al.</i> <sup>90</sup>	2007	Retrospective	AMS 800	270	36	5.5	69	–
Petero and Diokno <sup>91</sup>	2006	Retrospective	AMS 800	108	97.2	1.14	62	–
Raj <i>et al.</i> <sup>92</sup>	2005	Retrospective	AMS 800	554	50.4	0.5	88.5	–
Venn <i>et al.</i> <sup>93</sup>	2000	Retrospective	AMS 800	100	132	37	84	–
Gousse <i>et al.</i> <sup>94</sup>	2001	Retrospective	AMS 800	131	92.4	1.4	59	77
Montague <i>et al.</i> <sup>95</sup>	2001	Retrospective	AMS 800	209	61.2	–	64	–
Elliott <i>et al.</i> <sup>96</sup>	1998	Retrospective	AMS 800	323	68.4	1.75	–	–
Klijin <i>et al.</i> <sup>97</sup>	1998	Retrospective	AMS 800	27	35	–	81	–
Haab <i>et al.</i> <sup>98</sup>	1997	Retrospective	AMS 800	68	86.4	–	80	3.9/5 scale
Fulford <i>et al.</i> <sup>99</sup>	1997	Retrospective	AMS 800	68	120	–	61	–

This table summarizes artificial urinary sphincter outcomes from 1997 to publication date. AMS: American Medical Systems; ZSI: Zephyr Surgical Implants. –: no value reported

be investigated.<sup>49</sup> Device failure often presents as increased stress incontinence without hematuria and its onset is more rapid than urethral erosion.<sup>49</sup> Mechanical failure can be identified by a lack of typical fullness during cycling or the sound of air in the system.<sup>49</sup> If device failure is suspected but not apparent, then sonography or other imaging modalities can be used to visualize the devices ability to cycle. Of device malfunctions, 46% are cuff related, while 23% are due to the PRB.<sup>50</sup> Studies have been undertaken to determine if replacing individual parts could be as effective as total device replacement, and while findings did not rise to the level of significance, replacing the entire device had a slightly higher rate of 3-year functionality (76% vs 60%,  $P = 0.11$ ).<sup>55</sup>

Nonmechanical causes of loss of efficacy were previously attributed to urethral atrophy due to the appearance of device uncoupling on imaging.<sup>56</sup> More recent literature suggests that it is more likely due to fibrotic encapsulation of the device, which can be surgically managed with capsulotomy. There is some debate as to whether entire device replacement would be more prudent in these cases due to the PRB's loss of pressure profile over time.<sup>49,56</sup>

### Infection

Infection is an equally grave complication as in PP implantation, but there has not been an extensive investigation of the risk factors and etiologies in this case. Infection rate has been reported as high as 7% in modern trials.<sup>57</sup> Although negative preoperative urinary cultures are routinely advised, there is literature debating this practice.<sup>58</sup> There is no salvage procedure described for AUS implantation, so an infected device should be removed in its entirety. Despite this, there are few published case reports of replacing single components with limited success.<sup>49</sup>

### Erosion

Erosion is a relatively common complication estimated to occur around 18% of procedures.<sup>59</sup> Patients at higher risk of erosion include those with prior pelvic radiation, myocardial infarction, hypogonadism, urethroplasty, treatment for bladder neck contracture or urethral stricture, history of urethral stent, as well as prior infected

or eroded AUS.<sup>59</sup> Erosion is managed by device removal and delayed reimplantation.<sup>49</sup>

### CONCLUSIONS

Prosthetic urology is a surgical field that provides life-altering therapies for its patients. Devices such as IPPs and AUSs are the cornerstone of the discipline which are effective and only limited by rates of revision. Future research will be directed at lowering complication rates and optimizing their management, so that these remarkable procedures can continue to have their uses expanded.

### AUTHOR CONTRIBUTIONS

KPA was responsible for data acquisition and drafting the manuscript. KPA and OAR contributed to reviewing the manuscript. Both authors read and approved the final manuscript.

### COMPETING INTERESTS

Both authors declared no competing interests.

### REFERENCES

- Haglund E, Carlsson S, Stranne J, Wallerstedt A, Wilderang U, *et al.* Urinary incontinence and erectile dysfunction after robotic versus open radical prostatectomy: a prospective, controlled, nonrandomised trial. *Eur Urol* 2015; 68: 216–25.
- Levine LA, Becher EF, Bella AJ, Brant WO, Kohler TS, *et al.* Penile prosthesis surgery: current recommendations from the International Consultation on Sexual Medicine. *J Sex Med* 2016; 13: 489–518.
- Rodriguez KM, Pastuszak AW. A history of penile implants. *Transl Androl Urol* 2017; 6: S851–7.
- Wallen JJ, Barrera EV, Ge L, Pastuszak AW, Carrion RE, *et al.* Biomechanical comparison of inflatable penile implants: a cadaveric pilot study. *J Sex Med* 2018; 15: 1034–40.
- Ko OS, Bennett NE Jr. Ambicor two-piece inflatable penile prosthesis: background and contemporary outcomes. *Sex Med Rev* 2018; 6: 319–27.
- Abdelsayed GA, Levine LA. Ambicor 2-piece inflatable penile prosthesis: who and how? *J Sex Med* 2018; 15: 410–5.
- Tatem A, Kovac JR. The importance of the malleable implant salvage technique (MIST) in modern prosthetic urology. *Transl Androl Urol* 2017; 6: S813–4.
- Akdemir F, Okulu E, Kayigil O. Long-term outcomes of AMS Spectra® penile prosthesis implantation and satisfaction rates. *Int J Impot Res* 2017; 29: 184–8.
- Patel N, Golan R, Halpern JA, Sun T, Asafu-Adjei AD, *et al.* A contemporary analysis of dual inflatable penile prosthesis and artificial urinary sphincter outcomes. *J Urol* 2019; 201: 141–6.



- 10 Rodriguez KM, Kohn TP, Davis AB, Hakky TS. Penile implants: a look into the future. *Transl Androl Urol* 2017; 6: S860–6.
- 11 Alom M, Ziegelmann M, Savage J, Miest T, Kohler TS, et al. Office-based andrology and male infertility procedures—a cost-effective alternative. *Transl Androl Urol* 2017; 6: 761–72.
- 12 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: 54–61.
- 13 Darouiche RO, Bella AJ, Boone TB, Brock G, Broderick GA, et al. North American consensus document on infection of penile prostheses. *Urology* 2013; 82: 937–42.
- 14 Kucuk EV, Tahra A, Bindayi A, Onol FF. Erectile dysfunction patients are more satisfied with penile prosthesis implantation compared with tadalafil and intracavernosal injection treatments. *Andrology* 2016; 4: 952–6.
- 15 Loh-Doyle J, Patil MB, Nakhoda Z, Nassiri N, Yip W, et al. Three-piece inflatable penile prosthesis placement following pelvic radiation: technical considerations and contemporary outcomes. *J Sex Med* 2018; 15: 1049–54.
- 16 Scherzer ND, Dick B, Gabrielson AT, Alzweri LM, Hellstrom WJ. Penile prosthesis complications: planning, prevention, and decision making. *Sex Med Rev* 2019; 7: 349–59.
- 17 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; 6: S832–48.
- 18 Trost LW, Baum N, Hellstrom WJ. Managing the difficult penile prosthesis patient. *J Sex Med* 2013; 10: 893–906.
- 19 Lee DJ, Najari BB, Davison WL, Al Hussein Al Awamlh B, Zhao F, et al. Trends in the utilization of penile prostheses in the treatment of erectile dysfunction in the United States. *J Sex Med* 2015; 12: 1638–45.
- 20 Palmisano F, Boeri L, Cristini C, Antonini G, Spinelli MG, et al. Comparison of infrapubic vs. penoscrotal approaches for 3-piece inflatable penile prosthesis placement: do we have a winner? *Sex Med Rev* 2018; 6: 631–9.
- 21 Gupta NK, Ring J, Trost L, Wilson SK, Kohler TS. The penoscrotal surgical approach for inflatable penile prosthesis placement. *Transl Androl Urol* 2017; 6: 628–38.
- 22 Vollstedt A, Gross MS, Antonini G, Perito PE. The infrapubic surgical approach for inflatable penile prosthesis placement. *Transl Androl Urol* 2017; 6: 620–7.
- 23 Capoccia EM, Phelps JN, Levine LA. Modified inflatable penile prosthesis reservoir placement into space of retzius: comparing outcomes in men with or without prior pelvic surgery. *J Sex Med* 2017; 14: 968–73.
- 24 Thirumavalavan N, Gross MS, Munarriz R. Techniques of ectopic reservoir placement and their pitfalls. *J Sex Med* 2017; 14: 1451–4.
- 25 Narang GL, Figler BD, Coward RM. Preoperative counseling and expectation management for inflatable penile prosthesis implantation. *Transl Androl Urol* 2017; 6: S869–80.
- 26 Moskovic DJ, Pastuszak AW, Lipshultz LI, Khera M. Revision of penile prosthesis surgery after use of penile traction therapy to increase erect penile length: case report and review of the literature. *J Sex Med* 2011; 8: 607–11.
- 27 Egydio PH, Kuehhas FE, Valenzuela RJ. Modified Sliding Technique (MoST) for penile lengthening with insertion of inflatable penile prosthesis. *J Sex Med* 2015; 12: 1100–4.
- 28 Shaer O, Shaer K, AbdelRahman IF. Simultaneous suprapubic lipectomy and penile prosthesis implantation. *J Sex Med* 2018; 15: 1818–23.
- 29 Trost L, Hellstrom WJ. History, contemporary outcomes, and future of penile prostheses: a review of the literature. *Sex Med Rev* 2013; 1: 150–63.
- 30 Sorensen LT. Wound healing and infection in surgery. The clinical impact of smoking and smoking cessation: a systematic review and meta-analysis. *Arch Surg* 2012; 147: 373–83.
- 31 Wilson SK, Zumbo J, Henry GD, Salem EA, Delk JR, et al. Infection reduction using antibiotic-coated inflatable penile prosthesis. *Urology* 2007; 70: 337–40.
- 32 Wilson SK, Carson CC, Cleves MA, Delk JR 2<sup>nd</sup>. Quantifying risk of penile prosthesis infection with elevated glycosylated hemoglobin. *J Urol* 1998; 159: 1537–9.
- 33 Eid JF. Penile implant: review of a “no-touch” technique. *Sex Med Rev* 2016; 4: 294–300.
- 34 Wolf JS Jr, Bennett CJ, Dmochowski RR, Hollenbeck BK, Pearle MS, et al. Urologic Surgery Antimicrobial Prophylaxis. American Urological Association 2008.
- 35 Mooreville M, Adrian S, Delk JR 2<sup>nd</sup>, Wilson SK. Implantation of inflatable penile prosthesis in patients with severe corporal fibrosis: introduction of a new penile cavernotome. *J Urol* 1999; 162: 2054–7.
- 36 Carlos EC, Sexton SJ, Lentz AC. Urethral injury and the penile prosthesis. *Sex Med Rev* 2019; 7: 360–8.
- 37 Morey AF. Re: survey on the contemporary management of intraoperative urethral injuries during penile prosthesis implantation. *J Urol* 2018; 200: 491.
- 38 Sexton SJ, Granieri MA, Lentz AC. Survey on the contemporary management of intraoperative urethral injuries during penile prosthesis implantation. *J Sex Med* 2018; 15: 576–81.
- 39 Kavoussi NL, Viers BR, VanDyke ME, Pagliara TJ, Morey AF. “Stiction syndrome”: non-operative management of patients with difficult AMS 700 series inflation. *J Sex Med* 2017; 14: 1079–83.
- 40 Gross MS, Stember DS, Garber BB, Perito PE. A retrospective analysis of risk factors for IPP reservoir entry into the peritoneum after abdominal wall placement. *Int J Impot Res* 2017; 29: 215–8.
- 41 Levine LA, Hoeh MP. Review of penile prosthetic reservoir: complications and presentation of a modified reservoir placement technique. *J Sex Med* 2012; 9: 2759–69.
- 42 Morey AF. Reconstructing penile supersonic transporter (SST) deformity using glanulopexy (glans fixation). *J Urol* 2005; 174: 969.
- 43 Ziegelmann MJ, Alom M, Bole R, Kohler T, Trost L. Modified glanulopexy technique for supersonic transporter deformity and glanular hypermobility in men with penile prostheses. *J Sex Med* 2018; 15: 914–9.
- 44 Rajih E, Burnett AL. Penile wobble effect: proximal corporal deformities as a cause of penile prosthesis failure. *Sex Med* 2018; 6: 267–71.
- 45 Chong JT, Simma-Chiang V. A historical perspective and evolution of the treatment of male urinary incontinence. *Neurourol Urodyn* 2018; 37: 1169–75.
- 46 Light JK, Reynolds JC. Impact of the new cuff design on reliability of the AS800 artificial urinary sphincter. *J Urol* 1992; 147: 609–11.
- 47 Ajay D, Zhang H, Gupta S, Selph JP, Belsante MJ, et al. The artificial urinary sphincter is superior to a secondary transobturator male sling in cases of a primary sling failure. *J Urol* 2015; 194: 1038–42.
- 48 Averbeck MA, Woodhouse C, Comiter C, Bruschini H, Hanus T, et al. Surgical treatment of post-prostatectomy stress urinary incontinence in adult men: report from the 6<sup>th</sup> International Consultation on Incontinence. *Neurourol Urodyn* 2019; 38: 398–406.
- 49 Chouhan JD, Terlecki RP. A user's guide for surgery involving the artificial urinary sphincter. *Sex Med Rev* 2019; 7: 167–77.
- 50 Cohen AJ, Kuchta K, Park S, Milose J. Patterns and timing of artificial urinary sphincter failure. *World J Urol* 2018; 36: 939–45.
- 51 Van Bruwaene S, De Ridder D, Van der Aa F. The use of sling vs. sphincter in post-prostatectomy urinary incontinence. *BJU Int* 2015; 116: 330–42.
- 52 Henry GD, Graham SM, Cleves MA, Simmons CJ, Flynn B. Perineal approach for artificial urinary sphincter implantation appears to control male stress incontinence better than the transscrotal approach. *J Urol* 2008; 179: 1475–9.
- 53 Henry GD, Graham SM, Cornell RJ, Cleves MA, Simmons CJ, et al. A multicenter study on the perineal versus penoscrotal approach for implantation of an artificial urinary sphincter: cuff size and control of male stress urinary incontinence. *J Urol* 2009; 182: 2404–9.
- 54 Linder BJ, Piotrowski JT, Ziegelmann MJ, Rivera ME, Rangel LJ, et al. Perioperative complications following artificial urinary sphincter placement. *J Urol* 2015; 194: 716–20.
- 55 Moses RA, Keihani S, Craig JR, Basilius J, Hotaling JM, et al. Efficacy of pressure regulating balloon exchange in men with post artificial urinary sphincter persistent or recurrent stress urinary incontinence. *Urology* 2019; 123: 252–7.
- 56 Pearlman AM, Rasper AM, Terlecki RP. Proof of concept: exposing the myth of urethral atrophy after artificial urinary sphincter via assessment of circumferential recovery after capsulotomy and intraoperative pressure profiling of the pressure regulating balloon. *Investig Clin Urol* 2018; 59: 275–9.
- 57 Gulpinar O, Suer E, Gokce MI, Haliloglu AH, Ozturk E, et al. Functional outcomes and long-term durability of artificial urinary sphincter application: review of 56 patients with long-term follow-up. *Korean J Urol* 2013; 54: 373–6.
- 58 Kavoussi NL, Viers BR, Pagliara TJ, Siegel JA, Hofer MD, et al. Are urine cultures necessary prior to urologic prosthetic surgery? *Sex Med Rev* 2018; 6: 157–61.
- 59 Brant WO, Erickson BA, Elliott SP, Powell C, Alsikafi N, et al. Risk factors for erosion of artificial urinary sphincters: a multicenter prospective study. *Urology* 2014; 84: 934–8.
- 60 Habous M, Giona S, Tealab A, Aziz M, Sherif H, et al. Penile length is preserved after implant surgery. *BJU Int* 2019; 123: 885–90.
- 61 Habous M, Tal R, Tealab A, Aziz M, Sherif H, et al. Predictors of satisfaction in men after penile implant surgery. *J Sex Med* 2018; 15: 1180–6.
- 62 Morgado A, Cavadas AS, Pacheco Figueiredo L, Tomada N. Long-term patient-reported satisfaction with different inflatable penile prosthesis: Comparison between AMS 700CX and Coloplast Titan. *Rev Int Androl* 2018; 16: 112–8.
- 63 Bennett N, Henry GD, Karman E, Brant W, Jones L, et al. Ambicor penile prosthesis: uses and outcomes. *J Sex Med* 2017; 14 Suppl: e13.
- 64 Gentile G, Franceschelli A, Massenio P, Tuccio A, Cocci A, et al. Patient's satisfaction after 2-piece inflatable penile prosthesis implantation: an Italian multicenter study. *Arch Ital Urol Androl* 2016; 88: 1–3.
- 65 Bozkurt IH, Arslan B, Yonguc T, Kozacioglu Z, Degirmenci T, et al. Patient and partner outcome of inflatable and semi-rigid penile prosthesis in a single institution. *Int Braz J Urol* 2015; 41: 535–41.
- 66 Carvalho A, Santana R, Pereira NM. Why are men satisfied or dissatisfied with penile implants? A mixed method study on satisfaction with penile prosthesis implantation. *J Sex Med* 2015; 12: 2474–80.
- 67 Falcone M, Rolle L, Ceruti C, Timpano M, Sedigh O, et al. Prospective analysis of the surgical outcomes and patients' satisfaction rate after the AMS Spectra penile prosthesis implantation. *Urology* 2013; 82: 373–6.
- 68 Menard J, Tremieux JC, Faix A, Pierrelcin J, Staerman F. Erectile function and sexual satisfaction before and after penile prosthesis implantation in radical prostatectomy patients: a comparison with patients with vasculogenic erectile

- dysfunction. *J Sex Med* 2011; 8: 3479–86.
- 69 Bettocchi C, Palumbo F, Spilotros M, Lucarelli G, Palazzo S, *et al.* Patient and partner satisfaction after AMS inflatable penile prosthesis implant. *J Sex Med* 2010; 7: 304–9.
- 70 Wang R, Howard GE, Hoang A, Yuan JH, Lin HC, *et al.* Prospective and long-term evaluation of erect penile length obtained with inflatable penile prosthesis to that induced by intracavernosal injection. *Asian J Androl* 2009; 11: 411–5.
- 71 Natali A, Olianias R, Fisch M. Penile implantation in Europe: successes and complications with 253 implants in Italy and Germany. *J Sex Med* 2008; 5: 1503–12.
- 72 Lux M, Reyes-Vallejo L, Morgentaler A, Levine LA. Outcomes and satisfaction rates for the redesigned 2-piece penile prosthesis. *J Urol* 2007; 177: 262–6.
- 73 Deveci S, Martin D, Parker M, Mulhall JP. Penile length alterations following penile prosthesis surgery. *Eur Urol* 2007; 51: 1128–31.
- 74 Minervini A, Ralph DJ, Pryor JP. Outcome of penile prosthesis implantation for treating erectile dysfunction: experience with 504 procedures. *BJU Int* 2006; 97: 129–33.
- 75 Borges F, Hakim I, Kline C. Surgical technique to maintain penile length after insertion of an inflatable penile prosthesis via infrapubic approach. *J Sex Med* 2006; 3: 550–3.
- 76 Mulhall JP, Ahmed A, Branch J, Parker M. Serial assessment of efficacy and satisfaction profiles following penile prosthesis surgery. *J Urol* 2003; 169: 1429–33.
- 77 Rajpurkar A, Dhabuwala CB. Comparison of satisfaction rates and erectile function in patients treated with sildenafil, intracavernous prostaglandin E1 and penile implant surgery for erectile dysfunction in urology practice. *J Urol* 2003; 170: 159–63.
- 78 Levine LA, Estrada CR, Morgentaler A. Mechanical reliability and safety of, and patient satisfaction with the Ambicor inflatable penile prosthesis: results of a 2 center study. *J Urol* 2001; 166: 932–7.
- 79 Montorsi F, Rigatti P, Carmignani G, Corbu C, Campo B, *et al.* AMS three-piece inflatable implants for erectile dysfunction: a long-term multi-institutional study in 200 consecutive patients. *Eur Urol* 2000; 37: 50–5.
- 80 Carson CC, Mulcahy JJ, Govier FE. Efficacy, safety and patient satisfaction outcomes of the AMS 700CX inflatable penile prosthesis: results of a long-term multicenter study. AMS 700CX study group. *J Urol* 2000; 164: 376–80.
- 81 Holloway FB, Farah RN. Intermediate term assessment of the reliability, function and patient satisfaction with the AMS700 ultrax penile prosthesis. *J Urol* 1997; 157: 1687–91.
- 82 Sacomani CA, Zequi SC, Costa WH, Benigno BS, Campos RS, *et al.* Long-term results of the implantation of the AMS 800 artificial sphincter for post-prostatectomy incontinence: a single-center experience. *Int Braz J Urol* 2018; 44: 114–20.
- 83 Serag H, Bang S, Almallah YZ. Artificial urinary sphincters for treating postprostatectomy incontinence: a contemporary experience from the UK. *Res Rep Urol* 2018; 10: 63–8.
- 84 Ostrowski I, Ciechan J, Sledz E, Dys W, Golabek T, *et al.* Four-year follow-up on a zephyr surgical implants 375 artificial urinary sphincter for male urinary incontinence from one urological centre in Poland. *Cent European J Urol* 2018; 71: 320–5.
- 85 Ostrowski I, Blewniewski M, Neugart F, von Heyden B, Selvaggio O, *et al.* Multicentre experience with ZSI 375 artificial urinary sphincter for the treatment of stress urinary incontinence in men. *Urologia* 2017; 84: 148–52.
- 86 Linder BJ, Rivera ME, Ziegelmann MJ, Elliott DS. Long-term outcomes following artificial urinary sphincter placement: an analysis of 1082 cases at Mayo Clinic. *Urology* 2015; 86: 602–7.
- 87 Leon P, Chartier-Kastler E, Roupret M, Ambrogi V, Mozer P, *et al.* Long-term functional outcomes after artificial urinary sphincter implantation in men with stress urinary incontinence. *BJU Int* 2015; 115: 951–7.
- 88 Bordenave M, Roupret M, Taksin L, Parra J, Cour F, *et al.* Long-term results of the treatment of urinary incontinence with bulbar implantation of artificial urinary sphincter in men: a single-center experience. *Prog Urol* 2011; 21: 277–82. [Article in French].
- 89 Kim SP, Sarmast Z, Daignault S, Faerber GJ, McGuire EJ, *et al.* Long-term durability and functional outcomes among patients with artificial urinary sphincters: a 10-year retrospective review from the University of Michigan. *J Urol* 2008; 179: 1912–6.
- 90 Lai HH, Hsu EI, Teh BS, Butler EB, Boone TB. 13 years of experience with artificial urinary sphincter implantation at Baylor college of medicine. *J Urol* 2007; 177: 1021–5.
- 91 Petero VG Jr, Diokno AC. Comparison of the long-term outcomes between incontinent men and women treated with artificial urinary sphincter. *J Urol* 2006; 175: 605–9.
- 92 Raj GV, Peterson AC, Toh KL, Webster GD. Outcomes following revisions and secondary implantation of the artificial urinary sphincter. *J Urol* 2005; 173: 1242–5.
- 93 Venn SN, Greenwell TJ, Mundy AR. The long-term outcome of artificial urinary sphincters. *J Urol* 2000; 164: 702–6.
- 94 Gousse AE, Madjar S, Lambert MM, Fishman IJ. Artificial urinary sphincter for post-radical prostatectomy urinary incontinence: long-term subjective results. *J Urol* 2001; 166: 1755–8.
- 95 Montague DK, Angermeier KW, Paolone DR. Long-term continence and patient satisfaction after artificial sphincter implantation for urinary incontinence after prostatectomy. *J Urol* 2001; 166: 547–9.
- 96 Elliott DS, Barrett DM. Mayo Clinic long-term analysis of the functional durability of the AMS 800 artificial urinary sphincter: a review of 323 cases. *J Urol* 1998; 159: 1206–8.
- 97 Klijn AJ, Hop WC, Mickisch G, Schroder FH, Bosch JL. The artificial urinary sphincter in men incontinent after radical prostatectomy: 5 year actuarial adequate function rates. *Br J Urol* 1998; 82: 530–3.
- 98 Haab F, Trockman BA, Zimmern PE, Leach GE. Quality of life and continence assessment of the artificial urinary sphincter in men with minimum 3.5 years of followup. *J Urol* 1997; 158: 435–9.
- 99 Fulford SC, Sutton C, Bales G, Hickling M, Stephenson TP. The fate of the 'modern' artificial urinary sphincter with a follow-up of more than 10 years. *Br J Urol* 1997; 79: 713–6.

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