



# Penile fibrosis—still scarring urologists today: a narrative review

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**Background and Objective:** Implantation of penile prosthesis (PP) into scarred and fibrotic corpora can be a difficult challenge. In this review article, we provide a review of penile fibrosis, discuss current medical and surgical management and summarize preventative strategies.

**Methods:** In this study, we searched PubMed between the years 2000–2023 for publications with search strategy: “penile fibrosis” OR “scarred corpora” OR “fibrosed corpora”.

**Key Content and Findings:** This search returned a total of 137 articles. We examine the evidence for preoperative patient evaluation and penile ultrasound (US), oral phosphodiesterase-5 inhibitors, pentoxifylline, and L-arginine, vacuum device therapy and the use of surgical approaches and tools in the context of complex penile fibrosis cases. Severe penile fibrosis is most associated with priapism and infection. Estimating the degree of fibrosis via preoperative US may help set realistic patient expectations. Phosphodiesterase inhibitors and L-arginine reduce fibrosis in animal models however their impact in humans remains unclear despite theoretical advantage for their use. Vacuum device therapy may preserve penile length following priapism and infected PP cases. The use of Coloplast Narrow-Based or AMS-700 CXR implants are used primarily for severe fibrosis. Various surgical excisional/incisional techniques, the Carrion-Rossello, Mooreville Uramix cavernotomes and reverse cutting scissors are all options, and their use varies from case to case. Finally, prevention of penile fibrosis in patients with history of penile implant infection and the safety of early implantation of a penile implant in patients with refractory priapism is encouraged.

**Conclusions:** The management of penile fibrosis remains a challenge but there are multiple options to assist clinicians. Complex cases should be managed and studied at high volume centers.

**Keywords:** Penile fibrosis; corporal fibrosis; penile prosthesis (PP)

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## Introduction

Penile prosthesis (PP) placement is an accepted treatment option for patients with erectile dysfunction. Implantation of a PP into fibrotic corpora can be a difficult challenge even for the most experienced and skilled prosthetic surgeon. Corporal fibrosis denotes the replacement of

smooth muscle cells with fibrotic tissue inside of the corpora cavernosa after an incitive event (1). After the insult has occurred to the tissue, profibrotic factors and reactive oxygen species (ROS) are released, causing an excessive deposition of collagen fibers and extracellular matrix components (2). In addition, there is a reduction in functional smooth muscle cell numbers and an accumulation

**Table 1** The search strategy summary

Items	Specification
Date of search	21/03/2023
Databases and other sources searched	PubMed
Search terms used	“penile fibrosis” OR “scarred corpora” OR “fibrosed corpora”
Timeframe	01/01/2000 – 21/09/2023
Inclusion criteria	English
Selection process	Authors conducted independently

of myofibroblasts. This leads to loss of corpora cavernosa sinusoid architecture, disorganized extracellular matrix, excessive collagen deposition, and scar contraction. Overall, this pathophysiology results in dense fibrosis, penile length loss and/or curvature (2).

Penile fibrosis has been described secondary to multiple etiologies including diabetes, Peyronie’s disease (PD), intracavernosal injection, and trauma (3-5). A more severe and robust fibrosis can be seen in patients with a history of ischemic priapism and in those that had an infected PP removed without immediate replacement (1,6-8). Interestingly, the corporal fibrosis occurring secondary to ischemic priapism is typically more severe and dense distally; while after removal of an infected PP, the more severe and dense fibrosis is noted proximally (1,9).

Throughout the years multiple procedures have been described in the literature to help prosthetic surgeons efficiently and safely place a PP in this complex group of patients. In addition to a wide selection of surgical options, specialized instruments, such as cavernotomes, have been developed to help with the dilation of these scarred corporal bodies.

Additionally, specific models of inflatable penile prosthesis (IPP) have emerged, with narrower and tapered cylinders as excellent options for these scenarios; Titan® Narrow Base (Coloplast®, Minneapolis, MN, USA) and AMS 700™ CXR (Boston Scientific, Marlborough, MA, USA).

In addition to the discussion of different surgical techniques, cavernotomes and penile implant models suited for patients with corporal fibrosis, we will also review some of the preoperative considerations that could help aid the surgeon in the preoperative planning and intraoperative options. Discussing these preoperative considerations and options with the patient are important since these can help set realistic expectations during this process, as well as improve their satisfaction. The latter is extremely important

and directly affected by the patient’s expectations. We present this article in accordance with the Narrative Review reporting checklist (available at <https://tau.amegroups.com/article/view/10.21037/tau-23-206/rc>).

## Methods

We conducted a narrative review searching PubMed for English publications with search strategy: “penile fibrosis” OR “scarred corpora” OR “fibrosed corpora” (Table 1). This search returned a total of 137 articles. Of the total articles returned, 34 were review articles, 2 systematic reviews, 3 randomized controlled trials (involving alprostadil for ED), 10 non-randomized clinical trials, and the remaining 88 articles were retrospective case reports/case series discussing prevention and/or management techniques. This review was intended to provide expert commentary on the topic and not intended to be a systematic review. We prioritized articles in which the surgical techniques for placement of a PP in a fibrosed corpora were described, especially those that also presented their outcomes and results.

## Preoperative evaluation and considerations

A shortened phallus with little or no stretch is a typical presentation of penile fibrosis. Placement of a PP in a patient with mild fibrosis can often be addressed successfully by all levels of prosthetic surgeons with careful technique. However, in our experience, cases of severe fibrosis are frequently referred to high-volume practices that specialize in prosthetic surgery to address this difficult scenario (1).

## Patient satisfaction

Placement of an implant in a fibrotic corpora typically is a complex surgical procedure which may require longer operative times (10). This, along with the presence of

fibrosis/scar could potentially lead to a decreased perfusion in the surgical site, therefore placing the patient at a higher risk of infection (10,11). Montgomery *et al.* have reported that risk of PP infection increases with each subsequent infection: 1st revision case (6.8%; 3/44), 2nd (18.2%; 4/22), 3rd (33.3%; 4/12), 4th (50%; 4/8), and 5th (100%; 2/2) (12). Depending on the degree of fibrosis and surgical difficulty encountered, possible outcomes in cases of severe fibrosis may include a standard sized IPP, narrow based IPP, malleable prosthesis, a solitary malleable or inflatable cylinder, or failure to place an implant entirely. If a standard-dimension 3-piece inflatable prosthesis is desired, more than one surgical procedure may be required to reach a satisfactory outcome, using the smaller devices as a temporary spacer. For all the above-mentioned reasons, it is extremely important for patients and their partners to be appropriately counseled about postoperative outcomes, again so that realistic expectations are set which could then translate to patient and partner satisfaction.

Fibrosis and loss of penile length after removal of an infected PP can be a significant detriment to patient satisfaction. Even after a successful placement of a PP into the scarred corporal bodies, the length of the new cylinders can be up to 7cm less than the length of the original prosthesis cylinders (6,13,14). This expected, and almost inevitable loss of length can negatively impact the satisfaction of not only the patient but also their partner. Kava *et al.* (15) demonstrated this objectively, since patients that had an implant placed into a fibrotic corpora had lower overall score in the Index of Erectile Function (IIEF), as well as lower scores in the erectile function and satisfaction domain when compared with those that underwent revision surgery due to extrusion or malfunction.

### ***Penile ultrasonography***

As part of the preoperative evaluation, a penile US can be performed to further assess the degree and the extent of the fibrosis, as this may help with preoperative planning. Diffuse corporal fibrosis will typically demonstrate an increased echogenicity and thickness throughout the length and circumference of the corpora, or as hyperechogenic areas within them (16,17). Two-dimensional shear wave elastography (2D-SWE) is a newer technique whereby soundwaves on US exam can cause shear waves that transversely propagate through tissue that can be measured to estimate tissue stiffness. Stiffer tissue on elastography is strongly correlated to fibroblast activity and collagen

deposition (18). Richards *et al.* have shown in humans that 2D-SWE imaging finds tissue involved in penile curvature that has firmer by elastography measurement than normal tissue despite no findings on standard ultrasound (US) or palpation (19). Other authors have shown an increase in elastography to be correlated with ED, PD, age (20,21).

Finally, penile SWE may be used in future studies examining protocols to reduce fibrosis preoperatively by estimating the relative amount of smooth muscle cells and elastic fibers in the penis before and after interventions (21). In our experience, this allows us to evaluate the range of the fibrosis for surgical planning as stated above; but more importantly the patient can appreciate the fibrosis in real time, allowing him to better understand the clinical scenario. This in turn can help the patient and their partner to set realistic expectations in the postoperative period, thus potentially improving satisfaction.

### ***Vacuum erection devices (VEDs)***

VEDs have been shown to increase blood flow to the penis, improve the oxygenation of the penile tissues, preserve or recover tissue pertinent to penile functioning, and suppress apoptosis and fibrosis (22). Sellers *et al.* (23) demonstrated that the use of a VED once a day or twice a day, the latter used in patients with fibrosis, for two months before IPP implantation increased the ease of corpus cavernosum dilation and allowed to accommodate larger cylinders. In the setting of an infected IPP, which was removed, and no salvage procedure was performed at the time, the use of the VED without the constriction ring could help decrease the shortening of the penis as well as an associated ventral curve that could typically will develop (11).

Tsambarlis *et al.* (24) further demonstrated the utility of the use of a VED in the preoperative period on patients with severe corporal fibrosis secondary to a prior PP infection or ischemic priapism. Their protocol consisted of using the VED for 10–15 min, at least two times a day, for a minimum of three months, before attempting to insert the implant. Measurement of the stretched flaccid penile length was the same or increased in all the patients (n=13) after VED use and prosthesis implantation. The authors refer that due to the use of the VED, they had no difficulty in dilating the corpora up to 12mm using Brooks and were able to place standard-sized cylinders.

### ***Oral medication therapies***

Transforming growth factor beta 1 (TGF- $\beta$ 1) and

plasminogen activator inhibitor 1 (PAI-1), along with other cytokines and profibrotic factors, and ROS are important precursors of the fibrotic response (2). Therefore, any treatment targeted to the cellular response, may then directly or indirectly modify the fibrotic response. We will briefly discuss some of these medications, their mechanisms and rationale for use. Most of the studies that have focused on these are *in vitro*, with only very few clinical studies and small cohorts; and the data is conflicting.

L-Arginine is the metabolic precursor of nitric oxide (NO); NO reduces the number of profibrotic ROS and can cause myofibroblast apoptosis (25). Also, it increases cyclic guanosine monophosphate (cGMP), which in turn appears to have antifibrotic properties by inhibiting collagen synthesis (26). Inducible nitric oxide synthetase (iNOS) expression also counteracts fibrosis by producing NO (26). However *in vitro* studies have suggested that exogenous use of L-Arginine does not stimulate the production of NO or cGMP (27).

Pentoxifylline (PTX) is a cyclic adenosine monophosphate (cAMP)-dependent non-selective phosphodiesterase inhibitor. It has been shown to reduce the production of tumour necrosis factor (TNF), downregulate TGF- $\beta$ , suppress the production of platelet-activating factors, and inhibit the action of platelet-activating factor on neutrophils (28). Eslahi *et al.* (29) demonstrated how PTX diminished the formation of collagen bundles and the number of fibroblasts. PTX has also been demonstrated to reduce blood viscosity thus improving circulation; this increase in microcirculation may also play a role in the prevention or management of fibrosis (30).

Phosphodiesterase 5 inhibitors can increase cGMP, thus having antifibrotic properties as previously stated. Upregulation of iNOS by PDE5i has also been suggested as an anti-fibrotic strategy (31). Ferrini *et al.* (31) studied the effects that administration of Sildenafil had on aging rats; and an increase in the ration of smooth muscle cells to collagen along with an improvement in corporal fibrosis was noted in those treated with Sildenafil. In other animal studies, Vardenafil has been demonstrated to reduce the smooth muscle:collagen ratio, decrease the numbers of myofibroblasts, increase iNOS expression, and increase the replication of smooth muscle cells (32,33).

Animal studies by Valente *et al.* (34) investigated the effects of combination therapy consisting of PDE5i, PTX, and L-Arginine on penile fibrosis. Collagen deposition was reduced with a possible increase in apoptosis of fibroblasts and myofibroblasts. It was also noted that these medications

downregulated the synthesis of collagen I but not collagen III and interfered with the differentiation of fibroblasts to myofibroblasts. A combination of these three medications has been suggested to ameliorate the fibrosis that is seen after ischemic priapism (25).

At the cellular level, any treatment targeted to upregulate the NO-cGMP pathway, theoretically could prevent or reverse fibrosis. In our practice, patients that have undergone any of the insults known to cause severe penile fibrosis are placed on this regimen of three medications, along with the use of the VED before placement of a new PP is attempted. We also use the penile Doppler to further assess the extent of the fibrosis and aid in the surgical planning. More importantly the patients are able to visualize the fibrosis that we discuss with them, and this visual aid can also help set realistic expectations.

### Intraoperative tools

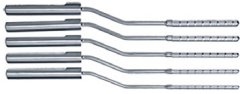


Multiple tools have been invented to assist the surgeon in dilating or creating a space in a fibrotic corpora cavernosa, including specialized cutting dilators, and scissors. Also, narrower and tapered models have been developed by prosthetic companies in order to assist in accommodating an implant in a smaller caliber corpus. In cases in which the corpora cannot be closed, grafting material has been used to aid in its closure.

### Cavernotomes

Given the difficulty and sometimes inability to dilate using blunt tipped dilations, cavernotomes were then introduced (Table 2). With the emergence of these cutting dilators, more options were now available for the surgeon to manage corporal fibrosis. Their use will be limited to cases where an initial tract or channel is established (35). If a dedicated cavernotome is unavailable, the Otis Urethrotome has also been described however we would advocate that complex cases be done at high volume centers who have dedicated intraoperative equipment suitable for the task (36).

The Rossello-Carrion cavernotome (Coloplast, Minneapolis, MN, USA) (37) features a backward cutting rasp allowing resection of the fibrotic tissue when they are withdrawn. Like standard dilators, they are sized sequentially from 8–12 mm. Space within the corpora is created by repeatedly passing it in and out of the corpora, to file down the fibrotic tissue. The smooth surface of these cavernotomes is kept angled towards the septum and

**Table 2** Available cavernotomes for management of dense penile fibrosis

Cavernotome names	Sizes	Mechanism	Image
Rossello-Carrion Dilator	8–12 mm	Backward cutting rasp	
Uramix Mooreville Dilator	6–13 mm	Forward rotational cutting	
Wilson Reverse Cut	N/A	Insert and spread to cut	

urethra to avoid inadvertent urethral damage.

Another cutting dilator model is the Mooreville cavernotome (Uramix, Lansdowne, PA, USA), invented by Dr. Michael Mooreville (38). These are also sequentially sized from 6–13 mm in diameters, but rather than a backward cut, it has a 1mm cutting blade that does not extend beyond the diameter of the dilator. The instrument is used in a rotating fashion, propelling it forward in small increments.

The Wilson backward cutting scissors (Uramix, Lansdowne, PA, USA), also called Freeman Kaye or Gourney scissors, can help in making the initial space within the corpora, in order to fit the cavernotomes (8). These will cut in the traditional manner and will also allow cutting when the scissors blades are spread in the scarred tissue since the outside of the scissor blade is sharp as well.

### Types of PP

Oftentimes, despite using different tools and surgical approaches, severely scarred corpora may not be able to accommodate a standard diameter IPP cylinder. The diameter required to pass the Furlough instrument is 9 mm. When using standard sized cylinders, proximal dilation should be at least 10mm if using an AMS 700™ CX or LGX cylinder and 12 mm if using the Coloplast® Titan®.

If the corporal space is not able to be dilated enough for proper placement of standard sized cylinders, narrower cylinders are available from both companies. The AMS 700™ CXR requires dilation of only 9 mm, while Coloplast® Titan® Narrow Base (NB) requires dilation of 10 mm (8). Adding rear tip extenders (RTEs) to any of the cylinders

will not increase the diameter. The base of both the AMS 700™ CXR and the Titan® NB have an additional 3 cm of non-inflatable area in the proximal aspect of the cylinders to facilitate in its insertion when compared to the non-inflatable area of the standard sized cylinder (8).

In these cases, Wilson (6,8) recommends the “liberal or generous use” of RTEs to avoid running the input tubing inside the corpora alongside with the cylinder. Despite a “kink-proof” construction, the tubing can be compressed by the stenotic corpora thus allowing inflation but not deflation. For AMS 700™ CXR up to 7.5cm of RTEs can be added, while only 6 cm can be added to Coloplast® Titan® NB. Despite the narrower profile, these implants can still provide adequate and satisfactory penile rigidity. Placing a narrower or tapered cylinder should never be considered as a failure.

### Grafting

It is not uncommon during implant placement in a complex, fibrotic penis to encounter defects in the tunica albuginea which are tight and unable to be closed to properly accommodate the cylinders. Leaving these open will allow an implant to extrude and this is a significant risk for distal erosion (39). This has prompted the use of a variety of patch materials if the corporotomy cannot be closed primarily. Available graft material includes both synthetic and biologic materials, as well as autologous harvests.

Unfortunately for the most part, even with experienced surgeons, these procedures are time consuming with high morbidity, high rates of complications and low implant survival (7,40,41). Some series have presented infection

rates up to 30% of patients requiring device explant (42). Therefore, the use of synthetic grafts is no longer recommended as a first option given the high inflammatory response and subsequent elevated complication rate (43).

Regarding biologics, both bovine and cadaveric pericardial graft have been commonly used. These non-autologous “off the shelf” xenografts and allografts can add a greater expense, but shorter operative times are noted when compared with the use of autologous grafts with none of the complications seen related to the harvesting (43). Multiple reports have demonstrated the feasibility and safety of pericardial grafts with low complication rates (44–48). In our institution, we use Tutoplast (Coloplast, Minneapolis, MN), a lab processed human pericardium, due to its ease of use and thicker profile which can be readily sewn into a defect of the tunica albuginea with adequate coverage of the implant.

The use of an acellular porcine dermal matrix such as small intestinal submucosa (SIS) has been extensively used with satisfactory results (49,50). Hatzichristodoulou *et al.* have presented the use of TachoSil (Corza Medical, Del Mar, CA, USA) with excellent outcomes (46,51). This collagen fleece is composed of human fibrinogen and human thrombin coated in an equine collagen sponge (51). Both SIS and TachoSil were compared by Falcone *et al.* in men with PD who underwent plaque incision with concomitant placement of an IPP (52). The TachoSil group was favored in shorter operative times and lower costs when compared to SIS.

Finally, autologous grafts are readily available and theoretically do not pose any risk for rejection of the graft (43). These include dermis, saphenous vein, tunica albuginea, tunica vaginalis, oral mucosa, fascia lata, rectus fascia, among others (43,45,53,54). However, graft contraction, complications related to the harvesting, and of course increased operative times decrease the overall utility of these grafts except in select cases.

### **Surgical techniques**

In response to the surgical challenge that the surgeon will most likely encounter in patients with corporal fibrosis, multiple surgical techniques have been described for implantation of a PP into scarred and fibrotic corpora. In addition to these techniques, the timing of the implantation itself is important since the fibrosis-inducing event could play a role in the complications seen, as well as with patient satisfaction.

Hebert *et al.* compared the rate of intraoperative and

postoperative complications in patients that underwent IPP placement early (<4 months; n=30) and late (>4 months; n=42) since the fibrotic-induced event. In their series there were no statistically significant differences in the intraoperative complications for both groups. However, among those that underwent delayed implantation the postoperative complication rate was 33.3%; whereas only 13.3% of those that underwent early implantation presented with postoperative complications (7).

### **Techniques with scar excision**

Extensive excision of scar typically involves the use of a midline longitudinal penoscrotal incision and larger than standard corporotomies. The fibrosed corporal tissue is then dissected away from the tunica albuginea, creating a space where the implant can be placed. In many instances these large corporotomies required the use of a grafting material. Wilson *et al.* (41) reported in their series the use of Gore-Tex (W.L. Gore & Associates, Flagstaff, AZ, USA) with only 50% of prosthesis survival. Other complications reported were urethral laceration, prosthetic infection and inadequate proximal dilation.

The use of a transverse penoscrotal incision, with another incision extending from that penoscrotal area all the way up to the frenulum, in an inverted T fashion has also been described (55). This incision allows for long corporotomies, and a plane between the tunica albuginea and the fibrotic core can be developed with the use of Metzenbaum scissors. Once the fibrotic core is completely mobilized a Penrose drain is passed and used as a retractor to aid with the dissection and mobilization of this scarred core, which is then transected as proximally and distally as possible.

Using this technique, no patients require the use of a graft to close the corpora once the IPP was placed. Both small-diameter cylinders (AMS 700<sup>TM</sup> CXM) were used (n=7) as well as standard-diameter cylinders (AMS 700<sup>TM</sup> CX) (n=2).

The use of two incisions to aid in this difficult dilation has been presented by multiple authors. Herschorn *et al.* presented the use of a combined penoscrotal and subcoronal technique for patients with severe distal corporal fibrosis (56). Brusky *et al.* also described a technique which combined a penoscrotal and a perineal approach with the patient in the low lithotomy position (57).

Ghanem *et al.* described a technique which involved a midline infrapubic incision for the proximal crural dilation using a combination of Metzenbaum scissors, Hegar dilators, and Dilamezinsert instrument (58). Once this is

completed a subcoronal incision is performed and the corpora is dilated in the same manner creating subtunical tunnels; with the most distal corpora dilated with a hemostat under direct vision. They reported being able to place two rods in all the cases they presented in their series (n=16). Only one intraoperative complication occurred, which was a proximal perforation, that the authors repaired through a perineal incision.

Minimal scar excision has also been reported, in which only the fibrotic tissue at the corporotomy site is excised. George *et al.* described the use of a midline perineal incision in addition to a circumferential subcoronal or midline incision if the distal corpora was not easily dilated (59). The tract was then created using a combination of Mayo scissors, Hegar dilators and Dilamezinsert instruments.

In their series, 7 patients had semi-rigid penile prosthesis (SRPP) successfully placed and 5 patients received an IPP. A larger series (n=34) using this approach was presented by Rajpurkar *et al.* further demonstrating the safety and the success of it (60).

Bozkurt *et al.* presented a minimally invasive technique for excavation of scarred tissue with the use of a microdebrider and subsequent prosthesis placement (61). They published two cases, where this technique was used; being able to place in one patient a SRPP (through an infrapubic incision) and one IPP (through a penoscrotal incision). No intraoperative or postoperative complications were seen; and the mean time of the surgery was less than 60 minutes. With this technique an increase of almost 2 cm was seen in both patients.

### *Techniques under direct visualization*

Blind forceful dilation of the fibrosed corpora can result in crossover, and corporal perforation both proximally and distally, with the latter causing injury to the distal urethra.

Shaeer's technique involves the use of a penoscopy, and under direct visualization allows for the resection of the fibrotic tissue creating a tunnel-like space where the implant is to be placed, rather than placing the implant alongside the fibrosed tissue (62). First the visual urethrotomy blade (or alternatively transurethral resection loop) is used to incise the fibrotic tissue sharply in a stellate configuration, under direct visualization away from the urethra. Afterwards blunt dilators are used to dilate the incision previously performed. Each of these stellate incisions is approximately 1 cm long; and this process is repeated throughout the whole pendulous penis. A diathermy loop can be used after this, to smooth the inner aspect of the tunnel created after the dilations. The risk of perforation is still present, but since

this is done under direct visualization, it should occur less frequently.

Shaeer's group published their series (n=6) of PP implantation in severely fibrotic penises (63). The etiology of severe penile fibrosis was attributed to a prolonged/neglected ischemic priapism (n=1), removal of an infected PP without salvage procedure (n=3), and PD (n=2). All patients were evaluated with a penile duplex preoperatively. In their series, the use of the optical corporotomy was not required in the PD patients. In two of the cases the fibrotic tissue encountered was very dense, and the cold blade was not able to open the space and required the use of a cutting diathermy current. In all patients they were able to place a PP, either a semirigid implant (n=4) or an inflatable model (n=2). No intraoperative complications occurred. Penile length was measured at the beginning of the procedure and after implantation, and an average increase in 2 cm was noted; as well as increase in penile girth of approximately 40%, most evident in those patients that underwent implantation of an inflatable device.

Injury to the urethra or perforation of the tunica albuginea can occur with both the blunt dilation against resistance as well as the use of sharp dissection blindly. Therefore, the use of a US has been described in these cases for further prevention of this. Shaeer reported a technique in which a 5 mm laparoscopic sheath is advanced into the fibrosed corpora under US guidance until where the fibrosis allows (64). Then a laparoscopy trocar with blades at the distal end is passed and with a slow side-to-side rotation the fibrotic tissue is shaved while drilling into the corpora. This in turn creates a space that can be dilated easily up to 13 mm using Hegar dilators. In their series (n=5) all implants survived, and no complications were noted. The patient and partner were satisfied as noted with the pre and post operative IIEF score, and the EDITS questionnaire.

A combination of these modalities was also described by Shaeer (65). He described the use of US to insert a guidewire into the corpora with the aid of a 14G central venous pressure catheter. This guidewire is left in place as a safety wire, so the penoscopic resection can be performed without the need for constant monitoring with the US. Using this technique, he was able to place two-piece inflatable prosthesis (n=4) and 13 mm semirigid rods (n=8).

### *Downsizing and upsizing cylinders*

In some instances, only a narrow-based implant can be placed within the corpora given the extensive fibrosis.

Wilson *et al.* suggested that in these cases, when a downsized cylinder is placed, it may serve as a tissue expander, thus eventually allowing for a larger sized implant to be placed during a revision surgery (13). Their series (n=37) included patients with corporal fibrosis secondary to removal of an infected PP (n=29) and post-priapism (n=8). All patients in their series initially had narrower cylinders placed; Mentor Narrow Base (n=18), AMS 700™ CXM (n=9), and AMS 700™ CXR (n=10). The patients were then encouraged to maximally inflate their device and keep it inflated up to 3 h daily, for 8–12 months. All patients underwent revision surgery, and standard size implants were able to be placed in them; AMS 700™ CX (n=23), Mentor Alpha 1 (n=10) and Mentor Titan® (n=2). Among the patients that had a previous infection the corporal length measurements were on average 2.2cm longer; this final cylinder length represented a 12.4% decrease in the length of the first cylinder that was placed before the infection happened, and a 15.4% increase from the downsized cylinder. Post-priapism patients did not demonstrate a statistically significant increase in length but did demonstrate an improved girth and appearance once regular sized cylinders were used.

Chung *et al.* also demonstrated the use of IPP as a tissue expander; in their series (n=717) AMS 700™ LGX, AMS 700™ CX, and Titan® implant models were reported. At  $\geq 2$  years the mean cylinder length and the percent change of cylinder length increased equally for all devices; 60% of patients increased  $>0.5$  cm and 40% increased  $\geq 1$  cm. When the devices were replaced  $<2$  years the mean cylinder length did not decrease (66).

### Other techniques

Despite all the techniques previously described, in some instances it is not possible to create a space within the corpora in order to place the prosthesis due to the severity of fibrotic tissue. In these instances, Shaeer and Shaeer described an extracorporeal transeptal implantation of a single malleable rod as a last resort typically after failing prior alternative techniques (67). In their series (n=10), no intraoperative complications occurred; only one patient developed a postoperative infection, requiring explant. On this patient and using this technique a new prosthesis was placed 6 months later, without any subsequent infection. All patients referred to an acceptable coital relationship and concealment.

Finally, Dr. Rassoul described an “unfolding” technique

in 15 cases post-priapism by a single surgeon at a single center. In this technique, the urethra is dissected away from the corpora, fibrosed corpora are divided medially and, the septum filleted open and unfolded along the length of the shaft. The corpora are then dilated proximally and distally using cavernotomes. A malleable penile prosthesis (MPP) placed within the larger combined space and corpora are sutured together in midline. They describe successful surgery in 13 of 15 patients with 2 reports of infection but no crossover or urethral injury (68). However, this technique requires both a circumcising incision, degloving and delivery of the penis through a midline longitudinal perineal incision. It also requires extensive dissection/mobilization of the penile urethra. Therefore, we advise caution in adopting this technique, as retrograde and antegrade flow to the glans may be disrupted causing glans necrosis (69).

## Special considerations—preventing fibrosis

### Penile implant infections

Throughout the years there has been a significant improvement in preventing prosthesis infection, with different implants, antibiotics, irrigations, techniques, pre and post operative care, among many other variables being studied and developed. Despite all these efforts, penile implants continue to become infected.

When an infection occurs, the presence of biofilm dictates that the most conservative management in this scenario is complete removal of the infected implant, obtain intraoperative cultures, and irrigation of all the spaces that have come into contact with the prosthesis. If a salvage implantation is not able to be performed at the time of removal of the implant, the space within the corpora will inevitably fibrose. Brant *et al.* in 1996 described a salvage technique involving removal and immediate replacement with a MPP at time of removal and infection wash-out (70). Jiang *et al.* conducted a multi-institutional retrospective cohort study on immediate IPP after infection and describe a high success rate after a full Mucachy washout with recurrent infection occurring in 3 of 19 (15%) cases and 1 reservoir hernia. They did not find any prognostic factors in predicting postop recurrent infection but do demonstrate similar infection rates as replacement with MPP (71).

For those patients in which salvage implantation was not a possibility, several options have been described to prevent the imminent fibrosis thus allowing placement of a new implant with less complication. At the University of South



Florida, Dr. Carrion and his team (72) presented the use of an antibiotic impregnated, high purity calcium sulfate component as a temporary spacer at the time of removal of an infected PP. The “Carrion cast” typically takes 4–6 weeks to dissolve. As it dissolves, it provides constant delivery of antibiotics to the local tissue. In their preliminary series (n=2), they noted that when the implant is placed within 6 weeks, dilation and implantation was uneventful and no special techniques were required. Due to social reasons the one patient underwent re-implantation at 16 weeks and significant fibrosis was encountered (73). This technique continues to be refined and is not widely used.

Taking advantage of the antibiotic activity of Mitomycin C, and its anti-proliferative effects on fibroblasts, Shaeer’s anti-scarring technique was developed (74). Their technique consisted of removing the infected penile implant, and at that time performing a washout with Mitomycin C.

Reimplantation was then attempted after 10–12 weeks with successful placement of IPP (n=1) and SRPP (n=4). No intraoperative or postoperative complications were noted. When comparing the length of the implant removed and implant placed, four patients had the same size, and one had smaller implant placed than the one explanted by 1 cm.

### Ischemic priapism

Ischemic priapism is initially managed with drainage, irrigation and the use of intracavernosal injection of sympathomimetic agents such as phenylephrine. If these initial methods fail, surgical shunting may be performed. Most patients with refractory priapism, in which surgical shunting has failed, will experience corporal fibrosis and erectile dysfunction for which a PP can be considered (75). Even in those patients who had a successful detumescence after shunting, significant corporal fibrosis with compromise of erectile function may still develop depending on the severity and length of the ischemic priapism event. However, there is little consensus as to the timing of the implantation.

In their series, Ralph *et al.* (76) presented the insertion of IPP (n=7) and SRPP (n=43) in patients with a mean duration of 209 h of the priapism episode. Only 3 patients developed a postoperative infection requiring removal of the implant and subsequent placement. Concluding that the placement of a PP in the acute episode can be safely performed.

Zacharakis *et al.* (77) compared early and delayed placement of a PP in patients with refractory priapism. Early insertion was within a median of 7 days, both SRPP

(n=64) and IPP (n=4) models were implanted.

While in the delayed insertion the median time for insertion was 5 months; and again, both SRPP (n=12), and IPP (n=15) models were used; however, the latter were narrow base models. Despite both groups presenting with infections (7% for the early, and 19% for the delayed), statistical significance was noted in favor of early implantation regarding revision rate, penile shortening and satisfaction rate. Also in the early implantation group, corporal dilation was not a significant issue.

### Conclusions

Placement of a PP into a fibrosed corpora continues to remain a challenge. The development of multiple surgical tools to aid in dilation, along with the extensive description of surgical approaches has allowed successful placement of PP in these patients. Further understanding the pathophysiology of penile fibrosis will allow to expand the treatment options, from a pharmacological and mechanical standpoint.

It is extremely important that realistic expectations are set in the preoperative setting for both the patient and their partner(s), as this will play a pivotal role in the postoperative satisfaction. Despite all surgical techniques that has been described, the limited published series, the small cohorts of patients, and the lack of long-term data, still makes placement of a PP in a severely fibrotic corpora a surgical challenge (35).

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