Review Article

Surgical Management for Peyronie's Disease

Robert L. Segal, Arthur L. Burnett

Department of Urology, The James Buchanan Brady Urological Institute, Johns Hopkins Medical Institutions, Baltimore, MD, USA

Peyronie's disease is a common debilitating condition for both men and their partners that results in penile deformity and compromises sexual functioning. While there are a myriad of medical therapeutic options, these have not been demonstrated to correct the deformity and restore sexual function definitively. As such, surgery is the mainstay of treatment for this disease, and multiple surgical approaches may be considered depending on disease characteristics, patient co-morbidity, and findings on preoperative diagnostic testing. The purpose of this review is to highlight the different surgical approaches and different procedures within each approach, and to examine important issues for surgeons to consider for administering the best treatment that restores function while reconciling patient expectations.

Key Words: Erectile dysfunction; Penile prosthesis; Penile induration

INTRODUCTION

Peyronie's disease, recognized as early as the 16th century and eponymously described in 1743 by François Gigot de la Peyronie, the personal surgeon to King Louis XV of France,[1] is characterized as a fibrotic wound-healing disorder of the tunica albuginea.[2] Although it may be precipitated by either blunt penile trauma or trauma incurred during sexual intercourse, as much as 70% of Peyronie's disease is idiopathic, without an inciting event.[3] Most commonly, the associated penile deformity is characterized by penile curvature, although other features may include palpable penile plaques, hourglass defects, penile hinging/instability, and penile shortening. Additionally, there may be associated psychological distress for the patient and the partner, as well as relationship strife.[4] Associated co-morbidities include diabetes mellitus, hypertension, dyslipidemia, ischemic cardiomyopathy, smoking, excessive alcohol consumption,[5] and radical prostatectomy for the treatment of prostate cancer.[6] Conditions thought to be related include Dupuytren's contracture, Ledderhose disease, and tympanosclerosis.[7] Erectile dysfunction (ED), a critical finding in these patients, especially as it relates to prospective treatment, may be caused by or occur independent of the presence of Peyronie's disease.

A multitude of medical and non-surgical treatments have been attempted for this potentially debilitating disease, without much evidence-based data supporting their use. Multiple guidelines endorse the use of surgery in the treatment of penile deformity as a result of Peyronie's dis-

ease, and surgery is considered the gold-standard treatment by some.[3,8] A variety of strategies can be used for the surgical management of Peyronie's disease, each of which has its own specifications, risks, and consequences for the patient. The purpose of this review is to examine the different surgical strategies for the treatment of Peyronie's disease.

SURGICAL PLANNING

Surgical planning commences with the initial patient encounter, as history and physical examination are critical in order to establish who is a potential surgical candidate. Important issues for the clinician to discern include the presence of penile pain and the evolution of penile deformity. Peyronie's disease is characterized by an early inflammatory phase, which can be notable for penile pain upon erection and intercourse, as well as progressive penile curvature.[3,8] The second phase of the disease is a stable phase, wherein any pain experienced resolves, and the curvature stabilizes. This stable phase typically sets in 12 ~18 months after the onset of symptoms. This natural history must be carefully determined, as surgical intervention is not recommended within the first 12 months after disease onset orbefore penile deformity has been stable for at least 6 months.

Objective determination of stretched penile length (SPL), as well as the degree of curvature, if any, is important, as patients are notorious for overestimating the degree of their deformity.[9] Determination of SPL at the initial visit is important as both the disease itself, as well as any potential surgical interventions, may result in penile shortening.

Because this is a disorder characterized by impaired sexual functioning, true sexual dysfunction as a result of the penile deformity must be assessed. Inability of the patient to engage in penetrative sexual intercourse may primarily relate to three issues: 1) penile deformity, which physically limits penile penetration; 2) dyspareunia experienced by either the patient or partner as a result of the penile deformity; or 3) ED, by which the penis cannot achieve or maintain the rigidity necessary for the completion of coitus. Surgery is indicated if any of these issues are present, whether or not medical management has been attempted.

Documenting the erectile functional capacity of the patient is very important, as this will certainly influence the decision of how to manage the patient surgically, and will influence how the patient is counseled about post-operative expectations. In Peyronie's disease, ED may result from either veno-occlusive dysfunction (in reference to the impaired ability of the tunica to expand and accommodate increased blood inflow as a result of the scarring, resulting in failure of occlusion of the subtunical venules) or impaired cavernosal arterial inflow.[10] The former may present clinically as the ability to achieve, but not maintain, a rigid erection, while the latter may present as the inability to achieve a rigid erection altogether. At the very least, a patient-reported subjective erectile assessment utilizing validated questionnaires, such as the Sexual Health Inventory for Men or the International Index of Erectile Function (IIEF) should be routinely employed. Although not essential, many surgeons will routinely employ dynamic duplex penile ultrasound with provocative injection of vasoactive medication for any patient with Peyronie's disease prior to surgical intervention.[8] This is a good way for the surgeon to evaluate the degree of patient deformity objectively, and may be more reliable than the patient providing serial penile images by way of at-home photography or erections induced with a vacuum erection device.[11] Additionally, penile ultrasound provides objective, validated hemodynamic parameters to gauge the adequacy of erectile function, which facilitates surgical planning, enables proper patient counseling, and establishes baseline erectile function important for medico-legal documentation. Most commonly, the assessed parameters include peak-systolic velocity (PSV), end-diastolic velocity (EDV), and resistive index (RI). Compromised arterial inflow is represented by $PSV < 25$ cm/s, veno-occlusive dysfunction by $EDV > 5$ cm/s, and overall ED by $RI < 0.8$.[12]

Establishing a diagnosis of ED prior to surgery for the treatment of Peyronie's disease is crucial because a documented risk of developing ED after penile straightening is known, for both tunical plication and excision/incision-grafting approaches. This outcome may relate to risk factors associated with different surgical approaches, which are documented in the subsequent sections, or may

relate to the *de novo* onset of ED related to other medical co-morbidities. In a study attempting to establish risk factors for ED development after penile straightening surgeries, no pre-operative risk factors or duplex ultrasound findings were definitively predictive of ED development.[13] This was a single center, retrospective study with a small patient population, so further study in this regard is needed.

Evidence does not support the use of other diagnostic tests in planning for surgery, such as penile magnetic resonance imaging or biothesiometry for the assessment of penile sensation.

The importance of informed consent prior to any surgical intervention for Peyronie's disease cannot be overstated. The risks of surgery (highlighted in the subsequent sections), as well as the aforementioned risk of post-operative development of ED, must be explained clearly. It is incumbent on the surgeon to be honest about his own personal experience and outcomes, so that the patient is not given unrealistic expectations. Above all, the patient must understand that surgery for this problem is meant to restore sexual functionality and not necessarily acquire the peak level of function that he may have experienced when he was younger. Certain outcomes, such as perfect straightness, recovery of substantial penile length or normalized penile sensation, and spontaneously normalized erectile function, may not always be possible. Clear documentation of the discussion of the risks and expectations of surgery is essential.

SURGICAL STRATEGIES

The purpose of surgery for the treatment of Peyronie's disease is to enable the patient to resume his normal sexual relationship. This objective translates into reconstructing a functionally straight and sufficiently rigid penis that is usable for penetrative intercourse.

Several strategies exist for attaining this goal, with each strategy having multiple approaches. The first essentially encompasses tunical ('shortening') plication corporoplasty procedures, whereby attention is focused on the non-affected convex (or longer) side of the penis, with the ultimate purpose of restricting that side to match the length of the oppositely affected (scarred) shorter side. In

these procedures, it is penile deformity, and not erection quality, that is addressed, and the plaque/scar that is present within the penis accounting for the deformity is not treated. The second strategy consists of procedures (tunical 'lengthening') whereupon the affected concave (shorter) side of the penis is addressed, and a restriction is released to match the length of the unaffected convex (longer) side. In these procedures as well, penile deformity alone, and not rigidity, is addressed. Typically, these approaches consist of some variation of plaque incision or excision, most commonly followed by grafting of either autologous or non-autologous material to cover the generated tunical defect associated with plaque treatment. Finally, specifically when penile deformity is a concern and the patient's best erectile function is either compromised or refractory to non-surgical therapy, insertion of a penile prosthesis may be considered. This surgery can correct both issues simultaneously with one procedure, namely restoring a functionally straight penis whereby good rigidity is assured. If this approach is chosen, some straightening maneuver may be required, and the plaque may or may not be incised or excised.

Multiple algorithms have been proposed for the surgical treatment of Peyronie's disease. Levine and Lenting[14] proposed that the patient who either subjectively (by self-report) or objectively (after intracavernous injection of a vasoactive substance) demonstrates good quality erections and possesses a unidimensional penile curvature ＜60 degrees with no hourglass defect or hinge effect should proceed with plication surgery; the patient with good quality erections with either complex multidimensional curvatures, an hourglass defect, or hinging with erection should undergo a procedure consisting of plaque incision or partial excision; and the patient with poor spontaneous erections or who did not adequately respond to intracavernous pharmacotherapy should receive penile prosthesis surgery. Among 103 prospectively enrolled patients managed according to this algorithm, 94.2% retained full erectile capacity, and 92.2% achieved complete straightening.

In a slightly modified algorithm targeted towards patients with concomitant Peyronie's disease and ED, Mulhall et al[15] assessed all patients initially with dynamic infusion cavernosometry and cavernosography (DICC),

wherein the penile deformity was objectively assessed. Patients were then challenged with sildenafil, and if no penetrative erection was generated, challenged with tri-mix (papaverine, phentolamine and prostaglandin E1) intracavernous injection therapy. If a sufficient erection was still not generated, then patients were counseled to proceed to penile prosthesis insertion as definitive surgical correction. If quality erections were obtained with pharmacotherapy, then patients either received modified corporoplasty (plication) surgery (if there was a uniplanar deformity ≤60 degrees and predicted loss of erect penile length of ≤20% [based on the difference in lengths between the dorsal and ventral surfaces of the penis as measured during DICC]) or plaque incision and grafting surgery, if any of the above features were present. With this method, the authors reported successful surgical outcomes based on IIEF scores, with corporoplasty and penile prosthesis patients having significantly better outcomes than the plaque incision and grafting patients. They concluded that based on these results, not all patients necessarily require penile prosthesis insertion if Peyronie's disease and ED are concomitant, but that in these circumstances, plaque incision and grafting are a poor treatment option.

In the following sections, we delve into the technical details regarding each of the surgical approaches and review evidence supporting each approach.

PLICATION APPROACHES

Nesbit[1] was the first to employ such an approach for the treatment of penile deformity in 1965. The procedure was intended for the treatment of congenital penile curvature, and was applied for the treatment of Peyronie's disease by Pryor and Fitzpatrick[16] in 1979. The surgical approach consists of a 'plication' on the unaffected longer side of the penis to make it comparable in length to the affected concave side of the penis. Most commonly, a circumcising incision is made, with skin degloving to the penile base. Alternatively, for a dorsal curvature, a midline ventral incision may be performed. An artificial erection is induced either by saline injection into the corporal bodies using a small-caliber butterfly needle, or pharmacologically. Once the point of maximal curvature is defined, Buck's

fascia on the contralateral convex side of the penis is incised and raised on either side, exposing the underlying tunica albuginea. Care is taken to preserve the neurovascular bundle dorsally and the corpus spongiosum/urethra ventrally. Allis clamps on the convex side are employed to grasp the tunica albuginea, so as to straighten the penis. Multiple clamps can be applied and adjusted, to achieve as straight an erection as possible. When satisfied with the appearance, the clamps are released and full thickness elliptical corporotomy defects are created sharply, and re-approximated with either non-absorbable or slowly-absorbable sutures, which effectively counteracts the curvature.[17] In order to avoid indentations on the ipsilateral side of the repair or a hinging effect, it is advisable to avoid excising wedges that are too large; rather, it is preferable to remove multiple smaller wedges, if necessary, to achieve functional straightness.

Outcomes of this surgery are generally quite favorable, with penile straightness achieved in 80~90% of cases.[18,19] In the study with the longest post-operative follow-up to date (median 7 years), 90.5% of patients had functionally straight penises, and 76.2% of patients were fairly satisfied with the surgical outcome.[20]

Variations of the original Nesbit plication have been described. Rolle et al[21] described using U-shaped knots where the clamps are applied, and the excess overlying tunica between the knots is excised. The purported benefit of this adjustment is that the tunica is excised only after the straightening has been achieved (thereby mitigating the risk of over- or under-correction of the curvature). An overall patient satisfaction rate of 94% was reported. Schwarzer and Steinfatt[22] described a novel plicative procedure: the tunica albuginea underlap. This involves sharply incising a U-shaped flap of tunical albuginea on the convex side of the curvature, and advancing and underlapping it under the remaining tunical tissue, and securing it in a watertight fashion. The authors reported a definitive curvature correction of 94% and 87% patient satisfaction at a mean interval of 23 months in 50 patients. Seventy-eight percent of patients who followed up reported some penile shortening, and there was a 13% risk of a decline in erectile function, even though there was no difference in pre- and post-operative Erection Hardness Scores. Although the authors allege that this double-layer, watertight closure of the tunica

preserves high tensile strength within the corporal bodies during erection (and hence precludes ED secondary to veno-occlusive dysfunction), the reported decline in erectile function argues against this claim. Additionally, because no tunical tissue is removed, risk for curvature over-correction is absent, and the curvature correction may be adjusted before definitive suturing occurs.

The Duckett-Baskin tunical plication, originally described to correct pediatric chordee associated with hypospadias,[23,24] has been used as a plication corporoplasty approach for correcting Peyronie's penile deformity. In a subtle variation of the classic Nesbit, only the outer longitudinal layer of the tunica albuginea is excised after estimating the curvature correction with the application of clamp instruments. This can be done with transverse parallel or elliptical incisions. The edges are then re-approximated. This may be advantageous because it avoids a full thickness defect through the tunica, which conceivably reduces the risk of post-operative veno-occlusive dysfunction and resultant ED.

Yachia's corporoplasty technique[25] is another modification which involves closing a vertical tunical incision horizontally, in the Heineke-Mikulicz fashion.

Techniques for penile plication that do not involve tunical dissection have been described. The 16-Dot technique, originally described by Gholami and Lue,[26] involves marking the center of the curvature and the entry and exit points for sutures on the convex side of the penis. The sutures are then placed full thickness through the tunica where specified and clamped with a rubber shod, so that the erect penis may be examined. Once satisfied with the straightness of the penis, the sutures are tied. With this technique, all patients surveyed had acceptably straight erections at 6 months post-operatively. This approach has been modified to enable plication without penile degloving through a penoscrotal incision on the convex surface of the curvature, which enabled correction of complex multiplanar deformities.[27,28] The particular benefit of avoiding a circumcising incision and degloving is the avoidance of risk for penile lymphedema and/or phimosis in patients who are uncircumcised.

Possible adverse effects of these plication procedures include residual penile curvature, penile shortening, altered penile sensation and penile indentations or palpable

bumpy areas, palpable knots, chronic pain, and ED. The exact frequencies of these effects are difficult to define precisely, as they depend upon the location and severity of the curvature, type of repair utilized, type of suture employed, and surgeon's experience. Overall, surgical straightening success has been reported to be 85~100% with these techniques.[8] While penile shortening has been noted with these procedures and is an important issue for many patients, it is felt that the bulk of penile shortening that these patients experience is a result of the scarring from the disease itself and not the surgical correction. The aforementioned studies reveal that most patients do not experience a change in SPL,[26,28] and may even experience an improvement in SPL.[28] Furthermore, for those patients who do experience shortening, the loss is typically 1 cm or less.[26,29] If viewed from the perspective of the percentage of pre-operative length that is lost after plication surgery, it tends to be around 2%.[29] Length loss has been correlated with the direction of curvature (ventral or ventrolateral), pre-operative penile length (the longer the pre-operative length, the longer the length lost), and pre-operative degree of penile curvature (the greater the curvature, the greater the length lost).[29] Finally, changes in penile sensation, particularly anesthesia/numbness, are typically transient and improve post-operatively over time, unless there is obvious neurovascular bundle injury.

Overall, tunical plication procedures are considered safe, with effective and durable functional outcomes with an acceptable risk of complications. They may be successfully applied to most patients with Peyronie's disease who require surgical correction, although adherence to the aforementioned surgical planning algorithms and guidelines that specify surgical indications and criteria for such procedures is recommended so as to limit the occurrence of unsatisfactory surgical outcomes. Evidence to suggest that one plication technique is better than any other is currently lacking,[8] and the choice of which technique to employ should be based upon the surgeon's experience, comfort, and technical ability.

INCISION/EXCISION WITH GRAFTING APPROACHES

As discussed previously, these procedures are in-

dicated for severe and/or complex penile deformities in patients with erectile function persisting post-operatively. This last point is critical, as procedures which involve tunical incision or partial excision with grafting are known to be associated with a greater risk of post-operative ED than plication procedures.[3,8] Indeed, historically, total plaque excision was performed, which resulted in unacceptably high rates of ED.[9] This outcome is thought to be related to veno-occlusive dysfunction as a result of structural changes involving the corporal bodies during erection.[30] This practice has subsequently been abandoned and is not recommended.

Another disadvantage of these procedures is that the operations are potentially more complicated and may take longer to perform than plication procedures. This relates to the more challenging deformities typically encountered, as well as the time required to identify, dissect, and incise/excise the plaque. Finally, time is required for (autologous) graft harvest and the preparation (including sizing and rehydration) of both autografts and non-autologous 'off-the-shelf' allografts.

The main purported advantage of these procedures is that they are not associated with penile 'shortening,' as is the perception with plication procedures. This is because the shorter (concave) side of the penis is being released, and no tissue is being excised from the opposite (convex) side.

Table 1. Graft options

Graft types
Autologous
Dermis
Vein (saphenous, dorsal penile)
Temporal fascia
Fascia lata
Tunica vaginalis
Prepuce
Buccal mucosa
Non-autologous: allografts
Processed human cadaveric
Pericardium
Dermis
Fascia lata
Dura mater
Processed animal grafts: xenografts
Bovine pericardium
Porcine small intestinal submucosa
Porcine dermis

Another debate surrounds which graft is best employed in these procedures. The ideal graft material should be inexpensive, readily available, durable, non-reactive/inflammatory, harmless to erectile function, and devoid of penile shortening risk. A variety of options are available (Table 1). Definitive evidence does not exist to support the use of one option over another with regard to surgical outcomes. The only recommendation is that synthetic grafts should not be employed because they are associated with risks of infection, fibrosis, and possibly compromised functional outcomes.[3,8,31,32] Further research investigating novel techniques for grafting to treat Peyronie's disease is underway. A Canadian group is currently exploring the feasibility of an autologous tissue-engineered endothelialized graft derived from skin biopsy in animal models.[33] Early histological results have demonstrated evidence of collagen I and elastin in the extracellular matrix on immunofluorescence. Mechanical testing on tabularized tissue grafts showed robust tensile force, which would seem to be adequate for preservation of the veno-occlusive mechanism required during erection. Although encouraging, further study of this possibility is needed, and the authors acknowledge limitations including the expense and duration of time required for fabrication of the graft material.

The surgical approach is initially similar to plication procedures in terms of tunical exposure and creation of an artificial erection. Once the plaque has been identified, it is either partially excised or incised, most commonly with a modified H- or double Y-incision to create a square or rectangular tunical defect. Care should be taken to carefully dissect the tunica from the underlying corpus cavernosal tissue, to avoid injuring it and inducing scarring, which may predispose the patient to post-operative ED. The defect should be precisely measured while on stretch for accurate graft sizing. The graft is then procured (by either harvesting it from a donor site or preparing it via rehydration in the case of the 'off-the-shelf' allografts) and prepared by sizing it to the tunical defect. Certain grafts may need to be oversized as they are associated with slight contracture over time. The graft is secured to the tunica surrounding the defect with continuous suturing, and verification of watertight closure is performed by inducing another artificial erection. The choice of exactly how the in-

cision/partial excision is to be performed, as well as type of graft material to be employed, is based on the surgeon's preference and experience.

Attempts to be even more precise in terms of graft measurement have led to utilizing mathematical principles for graft sizing. Egydio et al[34] have championed taking advantage of geometric principles to determine the exact location and shape of the tunical incision that should be employed. Hsu et al[35] have employed exact formulae derived from calculus and goniometry to define meticulously the dimensions of the graft required for tunical application. The supposed benefit of these approaches is that the dimensions of the graft may be determined prior to tunical incision, which may save surgical time if a separate team prepares the graft. The obvious drawback is the complex measurements and calculation that are required for this approach, and it is difficult to imagine that these approaches will be widely adopted by urologists.

Strategies have been proposed to enhance post-operative recovery and allow for maximal recovery of erectile function and maintenance of penile straightness. Penile massage and stretching exercises may be initiated,[3,8] and a protocol of nightly phosphodiesterase inhibitors has been suggested to enhance nocturnal erections, stretch the tissue, and encourage blood flow to the graft.[36] Penile traction therapy has been studied in this context and found to be of some benefit. The purported advantage of this is to prevent penile length loss, possibly to encourage length gain, and to allow healing in the straightened condition, much like a splint.[37] In this single-center study of 111 patients, traction therapy was recommended for 2~6 hours per day for 3 months starting 3~4 weeks post-operatively. With this strategy, significantly increased post-operative objective measurements were determined compared to pre-operative status, on the order of 0.8~1.5 cm, without subjectively perceived loss of penile length. It remains to be seen whether these options represent clinically meaningful and functional improvements, and if they are practical for routine use. Prospective clinical studies of these proposed interventions are required to verify their value in this context.

Possible adverse effects associated with the various grafting options for the treatment of Peyronie's disease include risk for recurrent deformity (0~26%), ED (0~53%),

and diminished penile sensation (0~31%).[9] The reason for such wide incidence ranges is that the majority of studies pertaining to these grafting options are single-center case series with small patient populations. Recurrent deformity, whether this relates to re-curvature, additional scar formation, or penile shortening, likely relates to derangements of the graft, including contracture, ballooning, or inclusion cyst formation.[38] These complications may or may not require re-operation depending upon whether functionally straight erections are achievable. Post-operative ED likely relates to compromised veno-occlusive function.[30] In an effort to determine the risk factors for the development of ED after a grafting procedure, the only reliable predictor was the presence of pre-operative ED.[36] Other risks, specifically in the context of autologous tissue grafts, relate to donor site complications, such as pain, bleeding, and infection. Overall, patients who either ask for or necessitate such procedures should be clearly counseled as to the associated risks and be provided with realistic expectations regarding surgical outcomes. In particular, they must clearly understand that compromised erectile function may result, and while their penis should not be shorter, it may not be appreciably longer than that observed pre-operatively, and may not approximate the penile length prior to the onset of Peyronie's disease.

TREATMENT UTILIZING PENILE PROSTHESES

Penile prostheses for the treatment of Peyronie's disease are indicated when the patient has concomitant clinical ED that is either refractory to medical ED management (phosphodiesterase inhibitors, intraurethral prostaglandin E1 suppositories, vacuum erection devices), or when diagnostic workup with erection challenge utilizing a provocative intracavernous penile injection with vasoactive medication demonstrates lack of an erectile response. Of note is the absence of guidelines condemning the use of such injections for the treatment of ED in the presence of Peyronie's disease, even though a theoretical risk of inducing further scarring as a result of both the needle trauma within the corpora cavernosa, as well as from the injected medication, particularly papaverine,[39] exists.

The approach to penile prosthesis insertion in men with known Peyronie's disease resembles routine placement of

a penile prosthesis, with the exception that some straightening maneuver (most commonly penile manual modeling and tunical incision/excision with or without grafting) may be required. Studies have shown that in a large percentage of cases, the penis becomes functionally straight alone with the inflation of the cylinders of an inflatable three-piece prosthesis (IPP) (61~90%).[40-42] Defining the need for intra-operative straightening maneuvers has been studied. Mulhall et al[40] retrospectively assessed 36 patients who had undergone penile prosthesis insertions, and noted that if the pre-operative penile curvature was ≤30 degrees, no straightening maneuvers were required; whereas with curvatures of 31~45 degrees, 12.5% required straightening; with 46~60 degrees, 75% required straightening; and with >60 degrees, 100% needed some sort of straightening. Given that a straightening maneuver may be required, use of a penoscrotal, rather than an infrapubic approach, to easily access the corpora cavernosa, should be considered.

The type of prosthesis to use in a patient with Peyronie's disease is also important to consider. Semi-rigid cylinders have been utilized in the context of Peyronie's disease, although persistent or recurrent deformity resulted in patient dissatisfaction in 35% of cases.[43] Additionally, straightening maneuvers with semi-rigid cylinders are less successful in terms of achieving adequate straightening than IPPs.[41] As such, use of semi-rigid prostheses has fallen out of favor when treating men with Peyronie's disease. Furthermore, it has been noted that use of the American Medical Systems, Inc. (AMS; Minnetonka, MN, USA) lengthening three-piece device (AMS 700 Ultrex) did not achieve straightness with cylinder implantation alone and required more corporoplasty maneuvers when compared to the controlled expansion cylinders of the AMS 700 CX series.[44] Although the Ultrex is no longer in use, it is the predecessor to the contemporary AMS 700 LGX (length and girth expansion). As such, it is preferred to employ the CX series if an AMS IPP will be used. Finally, no difference in outcomes or patient satisfaction has been noted when comparing manual modeling with the AMS 700 CX (AMS) and the Coloplast Titan IPP (Coloplast, Minneapolis, MN, USA) models.[42]

If the penis is not adequately straightened as a result of cylinder implantation and inflation, manual penile modeling is typically the next step in the straightening algorithm.[45] After the device is maximally inflated, the tubing to the pump is shodded to protect it from back pressure, and the corporotomies are supported by the surgeon's thumb and fingers to prevent blowout. The cylinders are then forcibly counter-flexed in the direction opposite that of the curvature, with the possibility of hearing or feeling cracking, indicating plaque rupture. The original description of the technique specified holding this position for a total of 90 seconds, although this is up to the surgeon's discretion. The penis should then be re-assessed for straightness, and if it is not functionally straight, the process may be repeated once more. If straightness is not achieved after 2 modeling sessions, then other straightening maneuvers will likely be required. The drawbacks of manual modeling include the fact that penile shortening is not addressed as well as the risk of urethral injury, which is reported to occur in 3% of cases.[45] Another adverse outcome is a greater risk of device malfunction overall,[46] specifically with respect to the AMS 700 CX compared to the Mentor Alpha I IPP (predecessor to the contemporary Coloplast Titan IPP), requiring surgical revision,[45] owing possibly to abrasion of the outer cylinder coating. This finding has not been corroborated in other series.[42]

For surgeons who elect not to pursue penile modeling because of concerns about the risk of complications[40] or for those patients in whom modeling does not result in functional straightening, the last resort is corporoplasty involving tunical incision or excision with or without grafting. Although no definite guidelines specifically refer to this issue, grafting is advisable if there is a tunical defect with underlying cylinder exposure of >2 cm. While incisions of either the outer or inner tunical layer may be sufficient to achieve straightness, more complicated techniques of reconstruction may be indicated, specifically if penile length recovery is of major concern to the patient. These include circumferential[47] or double dorsal-ventral grafting techniques.[48] In the context of IPP, avoiding the use of autologous dermal grafts is recommended, as there is a theoretical risk of seeding the IPP with bacteria and increasing the risk of post-operative infection.[8]

An innovative technique which combines relaxing tunical incisions and saphenous vein grafting in the presence of a soft axially-rigid prosthesis cylinder scaffold has been described.[49] The uniqueness of this technique is that an oversized cylinder is placed after minimal corporal dilation that accentuates the curvature and allows for precise

planning of the tunical incision location. The tunical defect is closed, and the cylinders are subsequently left in place. They allow for rigidity in the event of concomitant ED, but if intracorporal blood flow is retained, they allow for spontaneous tumescence with engorgement around the cylinders. Another recently described technique may allow for the avoidance of any adjuvant straightening maneuver prior to IPP insertion. Trans-corporal incision of Peyronie's plaques using endoscopic instruments, either with a cold-knife or cautery, has been attempted.[50] The potential benefits of this technique include obviated neurovascular bundle dissection, obviated sizing of the cylinders after straightening is achieved (which may allow for a longer device to be implanted and hence mitigate penile shortening), and avoidance of the risks of manual modeling or incision and grafting. As there are only individual reports of these techniques, further studies are required.

Overall, the use of IPP for the surgical treatment of Peyronie's disease is safe and effective, without definitive evidence that outcomes are compromised compared to those when IPP is performed without Peyronie's disease.[3,8]

CONCLUSION

Surgical correction of deformity associated with Peyronie's disease is the definitive management for this debilitating condition. Surgery is also indicated when the patient reports concomitantly compromised erectile function, with the choice of procedure dictated by both the degree of penile deformity, as well as the level of ED. In men who are preoperatively potent, either tunical plication or incision/excision with grafting procedures may be employed, and in men with concomitant ED, the treatment of choice is insertion of an IPP, enabling the best possible correction of both the deformity as well as ED simultaneously. All approaches and particular procedures feature possible adverse effects, which must be clearly detailed for the patient in order to mitigate false and unreasonable postoperative expectations.

REFERENCES

1. Nesbit RM. Congenital curvature of the phallus: report of three cases with description of corrective operation. J Urol 1965;93:230-2

2. Larsen SM, Levine LA. Review of non-surgical treatment options for Peyronie's disease. Int J Impot Res 2012;24:1-10

3. Levine LA, Burnett AL. Standard operating procedures for Peyronie's disease. J Sex Med 2013;10:230-44

4. Nelson CJ, Mulhall JP. Psychological impact of Peyronie's disease: a review. J Sex Med 2013;10:653-60

5. Rhoden EL, Riedner CE, Fuchs SC, Ribeiro EP, Halmenschlager G. A cross-sectional study for the analysis of clinical, sexual and laboratory conditions associated to Peyronie's disease. J Sex Med 2010;7:1529-37

6. Tal R, Heck M, Teloken P, Siegrist T, Nelson CJ, Mulhall JP. Peyronie's disease following radical prostatectomy: incidence and predictors. J Sex Med 2010;7:1254-61

7. Jordan GH, McCammon KA. Peyronie's disease. In: Wein AJ, Kavoussi LR, Novick, AC, Partin AW, Peters CA, editors. Campbell-Walsh urology. 10th ed. Philadelphia: Saunders; 2007;792-809

8. Ralph D, Gonzalez-Cadavid N, Mirone V, Perovic S, Sohn M, Usta M, et al. The management of Peyronie's disease: evidence-based 2010 guidelines. J Sex Med 2010;7:2359-74

9. Bacal V, Rumohr J, Sturm R, Lipshultz LI, Schumacher M, Grober ED. Correlation of degree of penile curvature between patient estimates and objective measures among men with Peyronie's disease. J Sex Med 2009;6:862-5

10. Chung E, De Young L, Brock GB. Penile duplex ultrasonography in men with Peyronie's disease: is it veno-occlusive dysfunction or poor cavernosal arterial inflow that contributes to erectile dysfunction? J Sex Med 2011;8:3446-51

11. Ohebshalom M, Mulhall J, Guhring P, Parker M. Measurement of penile curvature in Peyronie's disease patients: comparison of three methods. J Sex Med 2007;4:199-203

12. Sikka SC, Hellstrom WJ, Brock G, Morales AM. Standardization of vascular assessment of erectile dysfunction: standard operating procedures for duplex ultrasound. J Sex Med 2013;10:120-9

13. Taylor FL, Abern MR, Levine LA. Predicting erectile dysfunction following surgical correction of Peyronie's disease without inflatable penile prosthesis placement: vascular assessment and preoperative risk factors. J Sex Med 2012;9: 296-301

14. Levine LA, Lenting EL. A surgical algorithm for the treatment of Peyronie's disease. J Urol 1997;158:2149-52

15. Mulhall J, Anderson M, Parker M. A surgical algorithm for men with combined Peyronie's disease and erectile dysfunction: functional and satisfaction outcomes. J Sex Med 2005;2:132-8

16. Pryor JP, Fitzpatrick JM. A new approach to the correction of the penile deformity in Peyronie's disease. J Urol 1979; 122:622-3

17. Gur U, Jordan GH. Surgical treatment of Peyronie's disease. In: Graham Jr SD, Keane TE, editors. Glenn's urologic surgery. 7th ed. Philadelphia: Lippincott, Williams & Wilkins; 2010;481-6

18. Ralph DJ, al-Akraa M, Pryor JP. The Nesbit operation for

Peyronie's disease: 16-year experience. J Urol 1995;154: 1362-3

19. Savoca G, Trombetta C, Ciampalini S, De Stefani S, Buttazzi L, Belgrano E. Long-term results with Nesbit's procedure as treatment of Peyronie's disease. Int J Impot Res 2000;12:289-93

20. Syed AH, Abbasi Z, Hargreave TB. Nesbit procedure for disabling Peyronie's curvature: a median follow-up of 84 months. Urology 2003;61:999-1003

21. Rolle L, Tamagnone A, Timpano M, Destefanis P, Fiori C, Ceruti C, et al. The Nesbit operation for penile curvature: an easy and effective technical modification. J Urol 2005;173:171-3

22. Schwarzer JU, Steinfatt H. Tunica albuginea underlap--a new modification of the Nesbit procedure: description of the technique and preliminary results. J Sex Med 2012;9: 2970-4

23. Baskin LS, Duckett JW. Dorsal tunica albuginea plication for hypospadias curvature. J Urol 1994;151:1668-71

24. Levine LA. Penile straightening with tunica albuginea plication procedure: TAP procedure. In: Levine LA, editor. Peyronie's disease: a guide to clinical management. Totowa, NJ: Humana; 2006;151-9

25. Yachia D. Modified corporoplasty for the treatment of penile curvature. J Urol 1990;143:80-2

26. Gholami SS, Lue TF. Correction of penile curvature using the 16-dot plication technique: a review of 132 patients. J Urol 2002;167:2066-9

27. Dugi DD 3rd, Morey AF. Penoscrotal plication as a uniform approach to reconstruction of penile curvature. BJU Int 2010;105:1440-4

28. Adibi M, Hudak SJ, Morey AF. Penile plication without degloving enables effective correction of complex Peyronie's deformities. Urology 2012;79:831-5

29. Greenfield JM, Lucas S, Levine LA. Factors affecting the loss of length associated with tunica albuginea plication for correction of penile curvature. J Urol 2006;175:238-41

30. Dalkin BL, Carter MF. Venogenic impotence following dermal graft repair for Peyronie's disease. J Urol 1991;146: 849-51

31. Kadioglu A, Sanli O, Akman T, Ersay A, Guven S, Mammadov F. Graft materials in Peyronie's disease surgery: a comprehensive review. J Sex Med 2007;4:581-95

32. Brannigan RE, Kim ED, Oyasu R, McVary KT. Comparison of tunica albuginea substitutes for the treatment of Peyronie's disease. J Urol 1998;159:1064-8

33. Imbeault A, Bernard G, Ouellet G, Bouhout S, Carrier S, Bolduc S. Surgical option for the correction of Peyronie's disease: an autologous tissue-engineered endothelialized graft. J Sex Med 2011;8:3227-35

34. Egydio PH, Lucon AM, Arap S. A single relaxing incision to correct different types of penile curvature: surgical technique based on geometrical principles. BJU Int 2004;94:1147-57

35. Hsu GL, Hsieh CH, Wen HS, Ling PY, Chen SY, Huang HM, et al. Formulas for determining the dimensions of ve-

nous graft required for penile curvature correction. Int J Androl 2006;29:515-20

36. Levine LA, Greenfield JM, Estrada CR. Erectile dysfunction following surgical correction of Peyronie's disease and a pilot study of the use of sildenafil citrate rehabilitation for postoperative erectile dysfunction. J Sex Med 2005;2:241-7

37. Rybak J, Papagiannopoulos D, Levine L. A retrospective comparative study of traction therapy vs. no traction following tunica albuginea plication or partial excision and grafting for Peyronie's disease: measured lengths and patient perceptions. J Sex Med 2012;9:2396-403

38. Thiel DD, Broderick GA, Wu KJ. Inclusion cyst and graft contraction in Tutoplast human cadaveric pericardium following Peyronie's grafting: a previously unreported complication. Int J Impot Res 2005;17:550-2

39. Hwang TI, Yang CR, Ho WL, Chu HW. Histopathological change of corpora cavernosa after long-term intracavernous injection. Eur Urol 1991;20:301-6

40. Mulhall J, Ahmed A, Anderson M. Penile prosthetic surgery for Peyronie's disease: defining the need for intraoperative adjuvant maneuvers. J Sex Med 2004;1:318-21

41. Garaffa G, Minervini A, Christopher NA, Minhas S, Ralph DJ. The management of residual curvature after penile prosthesis implantation in men with Peyronie's disease. BJU Int 2011;108:1152-6

42. Chung E, Solomon M, Deyoung L, Brock GB. Comparison between AMS 700™ CX and Coloplast™ Titan Inflatable Penile Prosthesis for Peyronie's Disease Treatment and Remodeling: Clinical Outcomes and Patient Satisfaction. J Sex Med 2012 [Epub ahead of print]

43. Ghanem HM, Fahmy I, el-Meliegy A. Malleable penile implants without plaque surgery in the treatment of Peyronie's disease. Int J Impot Res 1998;10:171-3

44. Montague DK, Angermeier KW, Lakin MM, Ingleright BJ. AMS 3-piece inflatable penile prosthesis implantation in men with Peyronie's disease: comparison of CX and Ultrex cylinders. J Urol 1996;156:1633-5

45. Wilson SK, Cleves MA, Delk JR 2nd. Long-term followup of treatment for Peyronie's disease: modeling the penis over an inflatable penile prosthesis. J Urol 2001;165:825-9

46. DiBlasio CJ, Kurta JM, Botta S, Malcolm JB, Wan JY, Derweesh IH, et al. Peyronie's disease compromises the durability and component-malfunction rates in patients implanted with an inflatable penile prosthesis. BJU Int 2010; 106:691-4

47. Sansalone S, Garaffa G, Djinovic R, Egydio P, Vespasiani G, Miano R, et al. Simultaneous penile lengthening and penile prosthesis implantation in patients with Peyronie's disease, refractory erectile dysfunction, and severe penile shortening. J Sex Med 2012;9:316-21

48. Rolle L, Ceruti C, Timpano M, Sedigh O, Destefanis P, Galletto E, et al. A new, innovative, lengthening surgical procedure for Peyronie's disease by penile prosthesis implantation with double dorsal-ventral patch graft: the "sliding technique". J Sex Med 2012;9:2389-95

49. Austoni E, Colombo F, Romanò AL, Guarneri A, Kartalas Goumas I, Cazzaniga A. Soft prosthesis implant and relaxing albugineal incision with saphenous grafting for surgical therapy of Peyronie's disease: a 5-year experience and long-term follow-up on 145 operated patients. Eur Urol 2005;47:223-9

50. Shaeer O. Trans-corporal incision of Peyronie's plaques. J Sex Med 2011;8:589-93