Review Article

Urethroplasty for Stricture Disease: Contemporary Techniques and Outcomes

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Urethral reconstruction is now considered optimal therapy for most men presenting with symptomatic urethral strictures. The rapid development of innovative tissue transfer techniques over the past decade provides today's reconstructive urologist with a high probability of achieving excellent long-term outcomes after urethroplasty, even in the reoperative setting. Fundamental principles such as accurate initial stricture staging by urethrography, along with critical assessment of both stricture severity and tissue quality during urethroplasty are critical for success. This review illustrates the way in which stricture length, location, severity, and etiology influences the application of reconstructive techniques during contemporary urethroplasty. UROLOGY 89: 12–18, 2016. © 2016 Published by Elsevier Inc.

Urethral strictures have been recognized since antiquity. The oldest known documentation of treatment for urethral stricture comes from India in the 6th century BCE,[1] where it was palliated with dilation. Various forms of internal urethrotomy and attempts at urethrostomy were subsequently developed over the past few centuries. Staged urethroplasty and excision with direct anastomotic urethroplasty only came into prominence in the second half of the 20th century, offering the possibility of a cure for what had always previously been considered to be an incurable, chronic disease.[1]

This is an exciting time for urethral stricture treatment, perhaps even a "golden age" of urethroplasty. It is now widely recognized that internal urethrotomy is a poor treatment option with 5-year success rates of less than 10%.[2] Rather than a salvage procedure when all else has failed, urethroplasty has become the first-line treatment of stricture disease due to its reliable long-term results and low morbidity. Creative surgeons from multiple high-volume centers of excellence continue to refine and popularize advanced reconstructive techniques. This article reviews current urethroplasty techniques and outcomes, organized by anatomic area of the urethra (penile, bulbar, and posterior), with the proviso that stricture disease may affect more than one segment.

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ANATOMICAL CONSIDERATIONS

The extensive vascular supply to the bulbar urethra affords a variety of definitive treatment options based on stricture length and etiology. The bulbar arteries directly supply the proximal corpus spongiosum, while retrograde flow is also contributed from the dorsal penile arteries via the glans to the spongiosum. Additionally, there are circumflex branches of the dorsal arteries that run from dorsal to ventral within Buck's fascia,[3] and perforating vessels traversing the corpora cavernosa.

The anatomy of the penile urethra makes treatment of stricture disease much more challenging than in the bulbar urethra. Unlike the bulbar urethra, where excision with primary anastomosis urethroplasty (EPA) is highly successful, EPA is rarely an option in the penile urethra because shortening the urethra here is likely to cause penile curvature. Thus, substitution urethroplasty (bringing in new tissue from outside the urethra) is the general rule. Unlike in the bulbar urethra, the spongiosum surrounding the penile urethral lumen is less hearty, and thus less optimal for support of grafts. To increase stability, grafts in the penile urethra are often placed directly against the surface of the corporal bodies. A pedicled penile skin flap brings with it its own blood supply and may alternatively be placed on the ventral surface of the urethra.

Prior to a discussion of techniques, it should be noted that retrograde (and if possible, voiding) urethrography should be considered mandatory to provide a "roadmap" prior to urethral reconstruction. The finding of a tight stricture endoscopically rarely provides enough information to guide effective therapy. Urethrography, although imperfect, remains the most effective diagnostic technique in planning treatment for stricture disease.

The concept of urethral rest is important to accurately diagnose stricture severity. If a man has had recent urethral catheterization or instrumentation, urethrography may

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not manifest the full extent of the stenosis for several weeks afterward. A 4-8 weeks period of tissue recovery after catheter removal (with concomitant placement of a suprapubic catheter if warranted) will facilitate stricture remodeling, thus facilitating the performance of a successful urethroplasty.[4]

PENILE URETHRAL STRICTURES

Stricture etiology is particularly important in the penile urethra, where strictures tend to be diffuse in nature—especially those associated with lichen sclerosus (LS), alternatively known as balanitis xerotica obliterans. LS is thought to be an autoimmune disease associated with extensive scarring and functional loss of the penile skin, urethral meatus, and/or anterior urethra. Urethroplasty techniques using penile skin as grafts and/or flaps have up to 100% stricture recurrence rate and should not be used when a patient is suspected of having LS.[5] Men with a history of prior hypospadias repair represent another group where penile skin flaps are discouraged because the vascular pedicle (tunica dartos) that supports the skin island has been disrupted by prior surgery.

Isolated strictures of the meatus or fossa navicularis may be treated through simple or complex techniques. Perhaps the simplest form of urethroplasty is an extended meatotomy, cutting through the stenotic distal urethra ventrally, with excision of periurethral fibrosis and suturing the edge of urethral mucosa to the edge of penile skin until a wide, healthy urethral lumen is found. When this continues onto the penile shaft, this is often referred to as a first-stage Johanson urethroplasty, as it was described as the first stage in a two-stage procedure. If the patient is accepting of a ventral urethral opening and the associated urinary spraying, a surgeon may perform this simple maneuver as a definitive procedure with success rates exceeding 90%.[6] As in all men who are offered treatment for stricture disease, urethrography and intraoperative calibration are critical to confirm that the intended technique is appropriate. If a man has panurethral stricture disease, meatotomy alone may not be an effective treatment; on the other hand, many diffuse penile strictures have a "decrescendo" pattern, normalizing soon after distal stricturotomy to an acceptable luminal diameter.

Tissue Transfer (Substitution) Urethroplasty

An alternative to deliberately creating a hypospadiac meatus is use of a ventral penile fasciocutaneous skin flap to augment the fossa navicularis, either with division and closure of the glans[7] or via flap tunneling under the glans.[8] Published success rates are in excess of 80%, although the authors no longer advocate this method in patients with LS.[7,9]

For nonobliterative strictures of the penile urethra, grafts or flaps may be used to augment the size of the existing lumen. A minimum lumen size of 5Fr or a urethral plate of 5 mm or greater is recommended for straightforward onlay procedures.[10] Pedicled penile skin flaps consist of a skin island mobilized on its tunica dartos pedicle. Ventral flap onlay is generally preferred due to its simplicity, as dorsal tissue transfer requires mobilization of the densely adherent penile urethra from the corporal bodies. The ventral longitudinally oriented flap popularized by Orandi[11] requires relatively little dissection but has limited mobility and may involve hair-bearing skin on the proximal shaft. The circular fasciocutaneous flap according to Buckley and McAninch[12] is more versatile but requires extensive dissection of the penile skin, with reported 10-year stricture-free success of 79%.[9] Penile skin flaps require extensive penile skin dissection that may lead to tethering, torsion, or ischemic complications of the remaining foreskin, which is especially bothersome to sexually active men. Penile skin flaps are discouraged proximal to the penoscrotal junction, where they tend to be under excessive tension during erections.

Tissue transfer by grafting into the urethra has been well accepted since the 1960s, beginning with penile skin grafts.[13] Over the past 20 years, oral mucosal grafts have demonstrated better handling characteristics and long-term stricture-free outcomes, and have thus replaced both penile skin grafts and flaps.[14] Barbagli et al described dorsal placement of grafts in the penile as well as bulbar urethra.[15] Kulkarni et al popularized treatment of panurethral stricture disease with a dorsally placed oral mucosal graft with one-sided urethral dissection via penile invagination through a perineal incision.[16]

Obliterative penile urethral strictures cannot be treated by simple stricture incision and tissue augmentation alone (Fig. 1). Obliterative strictures require full or segmental urethral replacement, and the urologist must consider whether urethroplasty can be effectively performed in one operation or in a staged fashion. Complete urethral substitution

Figure 1. Retrograde urethrogram demonstrating stricture of the penile and distal bulbar urethra after neodymium: yttrium-aluminum-garnet/potassium titanyl phosphate laser prostatectomy.

with a single, tubularized graft or flap in one stage is generally discouraged, although the combination of a flap or graft on top of a grafted plate has shown promise in focally severe strictures.[17] This involves resection of the obliterated segment, recreating the dorsal urethral surface by grafting, and with the ventral surface replaced by a penile skin flap[18] or another graft supported by dartos or tunica vaginalis.[10] Staged urethroplasty gained greater use in the 1990s after Bracka reported this in the setting of prior failed hypospadias repair.[19] Here, the entire circumference of the urethra is excised and a new urethral plate created by a wide graft placed on the ventral surface of the penis. The urethral plate is tubularized several months later after neovascularization is complete and lymphedema has resolved. During the intervening time, the patient must void through a hypospadiac meatus, often at the base of the penis or even more proximally. This approach places a substantial burden on the patient, both a psychological burden in the visible disfigurement of the penis as well as the difficulty of maintaining hygiene and cleanliness when voiding through such a proximal urethral opening. Occasionally, a 2-stage plan may at times require an intervening surgery before final tubularization.[20] Staged urethroplasty is often the most appropriate choice in patients with prior hypospadias surgery (86% success[21]) or extensive stricture disease caused by lichen sclerosus (73% success[22]).

BULBAR URETHRAL STRICTURES

Anastomotic Techniques

Excision with Primary Anastomosis (EPA) Urethroplasty. For patients presenting with short bulbar strictures, EPA remains the standard and definitive option for urethral reconstruction with a greater than 90% success rate.[23-25] As the name implies, EPA involves transection of the corpus spongiosum and excision of the urethral stricture with distal and proximal mobilization of the urethra prior to creation of a tension-free anastomosis. EPA for strictures in the proximal bulbar urethra enables greatest use of the elastic lengthening gained from full bulbar mobilization to the fixed membranous urethra. In one series, EPA was feasible in patients with proximal bulbar strictures as long as 5 cm,[25] although EPA is more commonly limited to strictures of 3 cm or less. Because it is more difficult to gain the elastic lengthening of full bulbar urethral mobilization in treating distal bulbar urethral strictures (upper perineum and scrotal portion of urethra), EPA remains a technically challenging option in such patients.

EPA urethroplasty is a highly reproducible option for patients with short bulbar strictures and avoids the technical complexity and morbidity of grafts and/or flaps.[26-29] A meta-analysis of a total of 17 series with 1234 patients similarly confirmed greater than 93% success of EPA in the management of bulbar urethral stricture disease.[28] Complications following EPA performance are usually minimal and transient.[28] Several recent rigorous peri-procedural complication assessments have demonstrated that EPA for bulbar strictures might be associated with temporary sexual dysfunction.[30,31] Ventral curvature and penile shortening following EPA can be prevented by fully mobilizing the distal bulbar urethra to the level of the penoscrotal junction and by avoiding EPA for distal bulbar strictures greater than 2 cm, particularly for sexually active men with shorter-than-average stretched penile length.[24,25]

Concern regarding the potential for troublesome sexual side effects after urethral transection remains a controversial topic within reconstructive urology,[3,32,33] including theoretical risks of anastomotic ischemia, stricture recurrence, sexual dysfunction, penile shortening/chordee.[34] However, despite these concerns, contemporary urethroplasty series report a remarkably low incidence of sexual side effects after EPA.[9]

Although EPA is widely accepted in patients presenting for primary urethral reconstruction, its role in reoperative urethroplasty has become increasingly clear. In a recent large tertiary referral series of 37 patients undergoing reoperative urethroplasty, 95% experienced treatment success with performance of repeat EPA following failed primary EPA, and EPA following failed substitution urethroplasty was also similarly successful in 94% of cases.[24] These data suggest that EPA is reliable as a potential salvage treatment option for problematic short bulbar stricture recurrences in experienced hands (Fig. 2).

Vessel/Spongiosum-sparing EPA Urethroplasty. Jordan and colleagues[33] described dissection and sparing of the bulbar arteries from the posterior aspect of the corpus spongiosum prior to stricture excision and subsequent anastomosis. Maintenance of antegrade blood flow to the bulbar urethra could benefit patients who may need future artificial urinary sphincter placement and prevent subsequent device erosion.[33] Another group at risk of spongiosal arterial insufficiency includes those with a history of hypospadias, as retrograde blood flow through the glans to the corpus spongiosum is often quite limited in these patients.[3,33] The most appropriate candidates for vessel-sparing EPA appear to be those with short, proximal bulbar

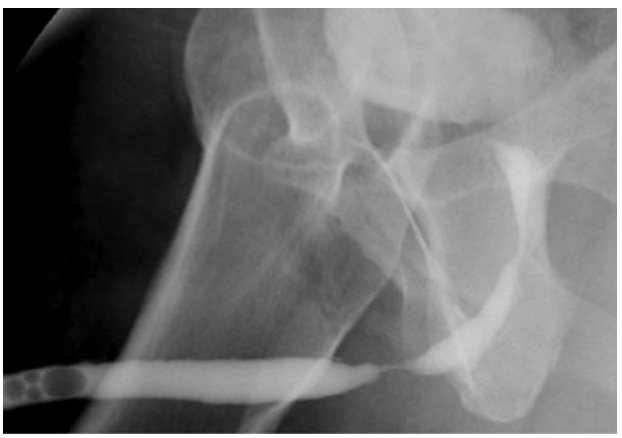

Figure 2. Dense stricture of bulbar urethra apparent on retrograde urethrogram after prior EPA urethroplasty, treated successfully with revision EPA. EPA, excision with primary anastomosis.

strictures.[29] Performance of vessel-sparing EPA is technically challenging and a significant learning curve is likely required.

A non-transecting approach to anastomotic urethroplasty has been advocated by Andrich and Mundy and associates for those presenting with nontraumatic short bulbar strictures.[3] This technique involves maintenance of the intact corpus spongiosum during dorsal urethral incision and stricture excision with subsequent urethral anastomosis. In select short cases where only a "thin, membrane-like" stricture exists, a longitudinal dorsal stricturotomy with transverse closure has been proposed in a Heinecke-Mickulicz fashion. The initial report regarding this procedure with a description of outcomes revealed a 100% success rate in 16 patients undergoing repair with greater than 1-year follow-up.[3] Although excellent long-term results with conventional EPA have repeatedly been demonstrated with formal excision of the diseased urethral segment,[25,26,28] urethral transection does present the theoretical risk of alteration of spongiosal blood flow, which may be of concern when tissue quality is already thought to be poor, such as in patients with a history of hypospadias, radiation, peripheral vascular disease, or prior urethral surgery. For most cases, it is important to recognize that these vessel- and spongiosum-preserving techniques are not a substitute for complete resection of fibrotic tissue during anastomotic urethroplasty; we have found these techniques most applicable in cases having synchronous strictures because retrograde blood supply is preserved.

Tissue Transfer (Substitution) Urethroplasty

Dorsal or Ventral Onlay Buccal Grafting. Patients with longer bulbar urethral strictures (Fig. 3) or those with vascular compromise who are unable to undergo EPA urethroplasty are usually appropriate candidates for substitution urethroplasty with buccal mucosa grafting. Originally described several decades ago, ventral onlay buccal grafting involves a ventral bulbar incision through a thick corpus spongiosum with onlay of the buccal graft and subsequent spongiosal closure.[35] The most appropriate patients for this technique have nontraumatic strictures with a healthy dorsal urethral plate (>5 mm) that does not require formal excision. The main advantage of ventral onlay buccal grafting is the technical ease of direct ventral graft placement (compared to dorsal or lateral grafting techniques that require further circumferential urethral dissection). Disadvantages include management of patients with obliterated urethral plates as well as potential technical difficulties that may be encountered with suture placement in patients with proximal bulbar strictures near the verumontanum.[35] Barbagli et al later popularized the dorsal graft onlay approach that has also been widely adopted with similar excellent results.[15] The dorsal technique is more technically challenging because it requires a circumferential mobilization of the urethra with opening of the stricture along the dorsal surface of the urethra. The graft is then fixed securely to the underlying tunica albuginea while its margins are then sewn to the cut edges of the urethra. In a large, 10-year experience with over 200 patients, Barbagli et al demonstrated an 85.5% success with ventral onlay buccal grafting of bulbar strictures as small as 1.3 cm (range 1.3-6.8 cm).[35] They advised direct suturing of the onlay graft to the spongiosum instead of the urethral mucosa in a narrow caliber urethral plate, thereby further increasing urethral diameter.

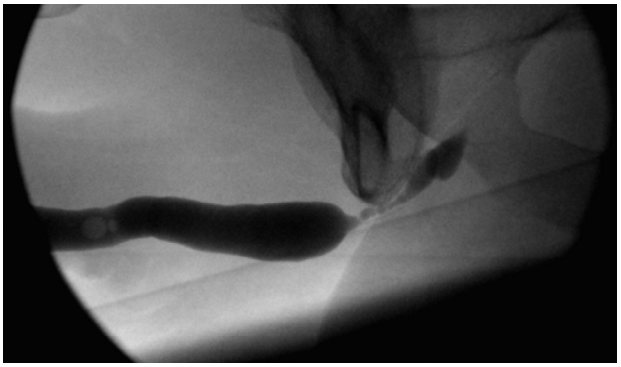

Figure 3. Retrograde urethrogram demonstrating ~4 cm stricture in proximal bulbar urethra, requiring substitution urethroplasty. This patient was successfully treated with augmented anastomotic urethroplasty.

Both dorsal and ventral approaches to bulbar urethral reconstruction appear to provide an equivalently high rate of success.[36] The ventral approach requires less dissection and may be technically easier where the spongiosum in the mid- and proximal bulb is thick, whereas the dorsal approach may be a good choice in the distal bulb where the ventral spongiosum may be insufficient for graft support. Another recent technique supports a ventral graft in the distal bulb with "pseudospongioplasty," covering the graft with tunica dartos or tunica vaginalis where the ventral spongiosum is inadequate.[10]

Augmented Anastomotic Urethroplasty (AAU). AAU combines urethral scar resection with an onlay graft. Performed through either a dorsal or ventral onlay approach, this technique allows for stricture wide areas of fibrosis excision with dorsal or plate reanastomosis, using substitution grafts on the opposing surface to avoid a direct anastomosis that may be under tension (Fig. 3). As a result, stricture excision for longer segments (eg, >2-3 cm) is facilitated with limited risk of penile shortening or chordee. With a mean onlay length of 4.5 cm and a mean stricture excision of 1.2 cm, the initial report of the AAU in 29 patients by Guralnick and Webster revealed a success rate of 93%.[34] A subsequent larger series by Abouassaly and Angermeier revealed 62 successful AAU repairs in 69 patients (90%) with a median follow-up of 34 months.[37]

Overlapping Dorsal and Ventral Buccal Grafting. Whereas most bulbar strictures are amenable to repair with excision or augmentation with buccal grafting, some strictures are simply too long for excision and/or have a nearly obliterative urethral plate unfit for simple augmentation,

thus requiring reconstruction of the full circumference of the urethra. Single-stage reconstruction with overlapping ventral and dorsal buccal mucosal graft urethroplasty (OBMGU) offers an alternative to multistaged approaches. Patients who may benefit include those with long bulbar strictures, or those with altered blood supply to the bulb, such as men with a history of hypospadias and/or prior distal urethroplasty.

OBMGU has been described through either a ventral or dorsal approach. In the ventral approach, a standard long ventral stricturotomy is made, then a short dorsal graft is placed within the incised urethral plate as originally described by Asopa et al.[38] A ventral graft is then placed and the spongiosum closed. The OBMGU concept allows use of more narrow ventral grafts, and thus less likelihood of sacculation.[10,39] Importantly, this technique avoids tubularized grafts and urethral transection. Palminteri et al reported an 88% success rate in 73 patients with bulbar strictures undergoing OBMGU.[39] In an expanded assessment of OBMGU, a recent multi-institutional analysis of 36 patients validated these promising results for strictures along the entire anterior urethra with an 89% success rate following a mean of 16 months after urethroplasty.[10]

Gelman and Siegel described a similar version of OBMGU through a dorsal approach, thus preserving the ventral corpus spongiosum.[17] This technique utilizes circumferential urethral mobilization and a dorsally placed buccal mucosal graft, as Barbagli described.[15] But in areas of obliterated urethral lumen, the ventral surface of the urethra is reconstructed by grafting directly onto the remaining nontransected corpus spongiosum, after resecting stenotic urethral mucosa. In the initial report describing preliminary outcomes, Gelman and Siegel reported a 94% success rate in 18 patients undergoing repair, with a mean follow-up of 50 months.

PERINEAL URETHROSTOMY

Many men with severe or panurethral stricture disease, primarily those with LS or recurrent diffuse stricture after hypospadias repairs, may be best served by perineal urethrostomy instead of complex reconstruction or staged urethroplasty.[40] Rather than seeing this as "defeat," urologists should see this as a simple and practical option to offer in patients presenting with highly refractory or complex strictures. Elderly patients and those with multiple comorbidities along with extensive/severe distal strictures should be strongly counseled about the simplicity and reliability of this approach, although cultural tendencies may prevent serious consideration of this approach in certain areas.

The technique of creating a perineal urethrostomy after penile cancer surgery involves bringing an end-urethrostomy to the skin. In urethral stricture disease, however, the urethra is often left in situ and perineal skin is mobilized down to the urethra to better preserve urethral blood supply. Popularized by Blandy, this advances a wide, inverted-U posterior perineal/scrotal skin flap into the proximal bulbar urethra, even up to the membranous urethra.[41] This technique requires surgical planning to create the posterior perineal flap from the beginning, and it can be difficult to get a posterior flap to reach the membranous urethra in obese patients. Revision rates for recurrent stenosis may be as high as 30%.[42] A novel "7-flap" technique uses a smaller laterally based perineal skin flap brought down to the transected, spatulated urethra to reduce tension on the skin-to-urethra anastomosis.[43] Benefits of this newer technique include flap creation after performance of the customary midline perineal incision and dissection, thus allowing the surgeon greater intraoperative flexibility in urethrostomy creation, especially in obese patients. However, the lateral perineal skin flap should be considered a random pattern flap and not extend beyond three times the width of its base.

Patients undergoing creation of a definitive perineal urethrostomy are among those with the most severe stricture disease. Success appears to be greatest when stricture disease is limited to the penile and distal bulbar urethra. Fortunately, even men with severe urethral and penile skin fibrosis tend to have normal perineal and scrotal skin, and thus tend to often be readily amenable to successful perineal urethrostomy.

POSTERIOR URETHRAL STENOSES

Radiation-associated Bulbomembranous Urethral Stricture

Pelvic radiation for prostate or rectal cancer has increasingly been associated with subsequent bulbomembranous urethral stricture. EPA has been reported with success rates of 70% at a median follow-up of 3.1 years with de novo incontinence observed in 18.5%.[44] In contrast to anterior urethral strictures, radiation-induced strictures do not have healthy tissue on the proximal side of the stenosis, which is one possible explanation for the higher failure rate. Another technique to address this difficult cohort of patients is to place a buccal mucosal graft ventrally and provide a healthy graft bed via a gracilis muscle rotational flap.[45]

Pelvic Fracture Urethral Injury (PFUI)

Urethral injury secondary to pelvic fracture is a challenging traumatic condition that often results in posterior urethral stenosis. These are not referred to as strictures, a term that refers to a narrowing of an intact lumen. In PFUI, the urethra is usually transected and the gap between the urethral edges fills completely with fibrotic scar. Whereas optimal initial management of acute PFUI is often debated, repeated endoscopic interventions are discouraged because the vast majority of men with complete urethral disruption will ultimately require bulbomembranous anastomotic urethroplasty (BMAU) to regain long-term urethral patency.[46] BMAU in PFUI patients is often technically challenging and involves aggressive bulbar urethral mobilization, complete resection of urethral fibrosis, and precise epithelial apposition. Ancillary maneuvers including corporal splitting and supracrural rerouting[47] are usually

unnecessary, whereas inferior pubectomy is reserved for the most complex of cases with bone displacement.[46] Contemporary success rates following BMAU following PFUI are well above 90% in experienced hands.[48]

Men who suffer from PFUI often have erectile dysfunction secondary to cavernosal nerve and/or pudendal artery injury relating to the pelvic fracture. Some authors have suggested that lack of blood flow through the internal pudendal supply to the urethra and penis after PFUI may lead to ischemic injury after urethroplasty[49] and have advocated penile Doppler ultrasounds to determine feasibility of penile revascularization prior to urethral reconstruction.[49] Recent data, however, have demonstrated that poor cavernosal flow is not predictive of urethroplasty failure.[50]

Intraprostatic Strictures and Resistant Postprostatectomy Anastomotic Strictures. With the widespread adoption of new lasers and endoscopic treatments for benign prostatic hyperplasia, intraprostatic strictures have become increasingly common. These strictures may occur anywhere within the prostatic fossa and may also occur after simple prostatectomy. Those that have failed initial dilations often require temporary suprapubic tube placement, followed by antegrade and retrograde imaging to delineate the precise anatomic location of stenosis. Fortunately, most intraprostatic strictures are quite amenable to deep lateral transurethral incisions.

Anastomotic strictures after radical prostatectomy are less common nowadays because robotic prostatectomy affords a more precise mucosal anastomosis. Anastomotic disruption may occur, however, in the setting of severe pelvic bleeding. Some have advocated mitomycin C injection in conjunction with endoscopic incisions.[51] In refractory cases, excision and primary anastomosis has often provided durable relief, via either a perineal or abdominoperineal approach. Postprostatectomy patients who have strictured after adjuvant radiation comprise a uniquely challenging subset.

CONCLUSION

Tissue transfer techniques for urethral reconstruction continue to expand, and a wide variety of good options now exist for stricture patients, regardless of stricture location, severity, and etiology. In many men with recurrent severe strictures, consideration should be given to preliminary suprapubic tube diversion, which enables precise imaging and a controlled preparation for elective reconstruction. Whereas buccal mucosal graft urethroplasty is a highly versatile technique for longer strictures, excisional techniques are often best for patients with short, dense bulbar urethral strictures. The variety of surgical treatment options summarized in this review demonstrates the potential for excellent results in such patients presenting with urethral stricture disease.

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