Review Article

Artificial urinary sphincter and stricture disease: surgical principles in management

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Abstract: Iatrogenic stress urinary incontinence (SUI) is the most common complication of surgical treatment of prostate cancer, regardless of operative approach, and has a major impact on patients' quality of life. Although SUI can occur after surgical treatment of benign prostatic hyperplasia, specifically transurethral prostate resection, laser enucleation of the prostate, and simple open prostatectomy, these therapeutic modalities play a much less significant role in the etiology of SUI. Artificial urethral sphincter (AUS) implantation is considered the standard treatment modality providing high success rates, including durable efficacy, and optimal patient satisfaction for moderate to severe urinary incontinence resulting mainly from radical prostatectomy. However, although complication rates are generally acceptably low, revision and/or explantation may be required due to mechanical failure and non-mechanical problems, specifically urethral atrophy/cuff deficient occlusion, infection, and cuff erosion. Several risk factors for AUS failure associated with a fragile, compromised urethra have been identified and these play a critical role in device cuff erosion and subsequent removal of the device. Among others, apparently the most impacting factors are irradiation, urethral stent placement, a previous AUS placement, and importantly presence of urethral stricture or prior urethroplasty. Generally, any clinical situation leading to a diseased urethra or lack of urethral integrity is associated with impaired local blood perfusion, and consequently lower success rates. The present review aims to evaluate the impact of the presence of prior urethral strictures and urethroplasty on the outcomes of AUS implantation on one hand, and vice-versa, the influence of AUS placement on later urethral stricture surgery, particularly following cuff erosion.

Keywords: Artificial urinary sphincter (AUS); male urinary incontinence; urethral stricture; urethroplasty; urethral cuff erosion

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Introduction

The artificial urinary sphincter (AUS) is an implantable device designed to replace the function of the natural urinary sphincter mechanism and, thus treat moderate to severe urinary incontinence due to urinary sphincter weakness or dysfunction, mostly in men. The AUS was pioneered by F. Brantley Scott (urologist) from Baylor College, Houston, Texas, in collaboration with William Bradley (neurologist) and Gerald Timm (biomedical engineer), both from University of Minnesota. The research led to the development and implantation of the first AUS in 1972. Although several AUS models have been developed and are currently available, the most utilized undoubtedly is the AMS800™ (Boston Scientific, Malborough, MA, USA). The current model was produced in 1987 after introduction of a narrow-backed urethral cuff, which provides better and safer pressure distribution to the urethra. Further recent modifications have included a tubing quick-connector system, smaller cuff sizes, and device antibiotic coating. The key design of the current AMS800 model has remained essentially unchanged over the last 30 years.

The AUS is unquestionably the standard treatment of moderate to severe urinary incontinence following radical prostatectomy. It is estimated that more than 150,000 patients worldwide have received an AUS (1). In a systematic review published in 2013, urinary continence rates (defined by the authors as the use of ≤1 pad daily) ranged from 61% to 100% following AUS placement with high patient satisfaction, the evaluation of which included validated questionnaires (1). However, this improved quality of life (QoL) was associated with a high revision rate resulting from urethral atrophy/lack of efficient urethral coaptation, infection, erosion, and mechanical malfunction. This high revision rate may reach 53% in the first 5 years after AUS placement, even in high-volume, tertiary referral institutions (2,3). Noteworthy, in approximately 8.5% (1/10) patients AUS cuff erosion with subsequent device explantation was a major complication in a systematic review involving 623 patients (1) (*Figure 1*). Relevant risk factors for cuff erosion such as hypertension, cardiovascular diseases, previous AUS erosion or infection, prior pelvic irradiation, and prior urethral stricture disease or surgery have been identified and reported (4-8) (*Table 1*). Cuff erosion is known to increase the likelihood of urethral stricture formation compromising subsequent AUS reimplantation (9-11).

Low testosterone levels have been implicated as a significant independent adverse factor for AUS cuff erosion (12). About 60% of the hypogonadal men experienced AUS erosion versus 8.7% of eugonadal men (13). However, significant selection bias was apparent in this study. In a later study, the same authors suggested that urethral vascularity was compromised by an androgen receptor process thereby increasing the risk of AUS cuff erosion in hypogonadal men (14). However, more robust randomized control studies are currently needed to support the preliminary evidence that hypothesized a significant role in urethral angiogenesis. Until then, routine testosterone replacement therapy recommendation remains optional and carefully discussed with patients.

Traditionally, the primary approach to deal with cuff erosion requires AUS removal and transurethral catheter placement for urinary diversion and urethral rest (15,16). However, reports suggest the viability of synchronous *in situ* urethral repair at the time of AUS removal in an attempt of reducing the stricture formation rate (11). These same reports suggest that patients undergoing an in situ urethroplasty (ISU) received significantly fewer interim procedures before device replacement and had a higher chance of eventually receiving a subsequent AUS reimplantation surgery. ISU also decreased delay in AUS replacement, with an average interval of 9 months compared to 17 months. No patient who underwent secondary AUS implantation surgery experienced subsequent erosion over a mean follow-up interval of 24 months. Outcomes of AUS implantation in the setting of complex urethral and perineal anatomy should be carefully evaluated and considered in patient counselling regarding risks, as well as whether further reimplantation may be in their best interests or just another futile attempt to treat urinary incontinence. This review evaluates the evidence regarding urethral strictures and vesicourethral anastomotic stenosis (VUAS) and how these clinical entities affect AUS implantation and vice versa.

This article is structured in two main sections: (I) AUS implantation after urethroplasty (impact of urethral stricture and urethroplasty on AUS outcomes); and (II) urethroplasty after AUS cuff erosion (impact of AUS cuff erosion on urethroplasty outcomes).

Artificial urinary sphincter implantation after urethroplasty

AUS implantation after urethroplasty is a challenging endeavor. Regardless of the primary initial surgical success, these complex cases are potentially associated with long-

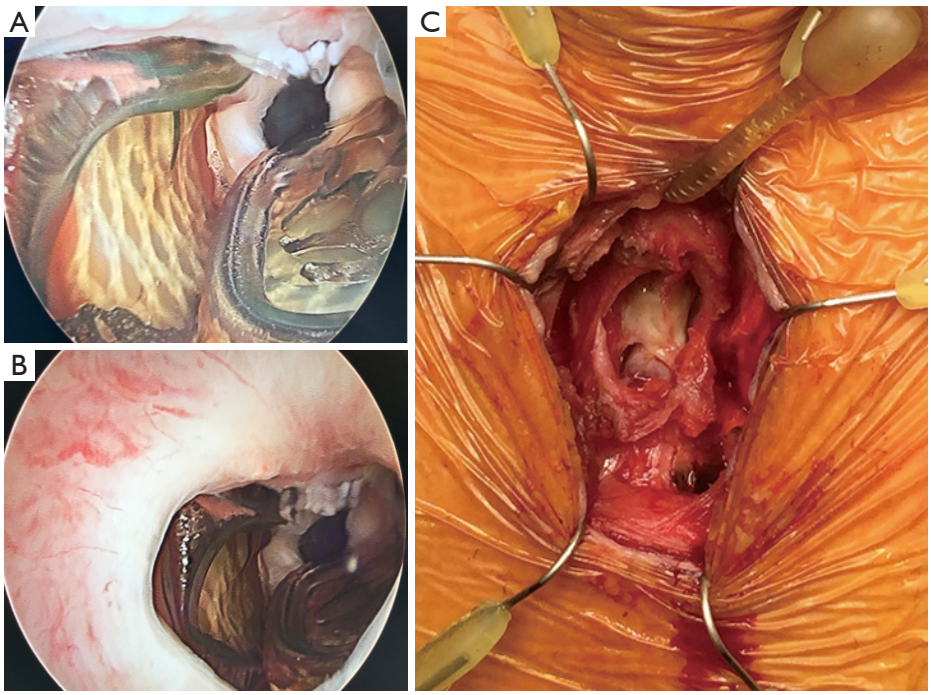

Figure 1 Patient with fragile urethra and multiple AUS erosions. (A,B) Endoscopic views; (C) surgical perineal view. AUS, artificial urinary sphincter.

Table 1 Risk factors for AUS cuff erosion (5)

Small cuff (3.5 cm)
Urethral catheterisation without deactivation
Endo-urological procedures
CISC
Radiotherapy
Hypertension
Coronary artery disease
Previous AUS
Previous urolume

AUS, artificial urinary sphincter; CISC, clean intermittent self-catheterization.

term complications commonly leading to the necessity of AUS device explantation. Previous literature strongly suggest that previous irradiation, urethral surgery, and urethral stent placement have a significant impact on the loss of urethral integrity and health, and this may be a key factor for AUS failure (15-17). In this section of this article, we will review the outcomes of AUS implantation after previous urethroplasty.

Complex urethral reconstruction may be required for severe obstruction of vesicourethral anastomosis and membranous urethra following prostate cancer treatments as well as treatments of strictures of the anterior urethra. Several reconstructive strategies have been developed recently (18-20). VUAS can be managed through a retropubic, perineal or combined abdominoperineal approach. The indications for each one of these surgical approaches depend on the patient's local anatomy, degree of tissue damage primarily associated with single, or multimodality treatment employed, and pre-operative continence status. Adjunct maneuvers, such as pubectomy, may be required due to an inferiorly recessed VUAS making visualization from an abdominal approach extremely difficult. Additionally, some of these patients have already been rendered incontinent from prior conservative, endoluminal management. Abdominal approaches can potentially spare the membranous sphincter and therefore preserve urinary continence. The perineal approach is better suited for lower VUAS and membranous urethral stenosis

induced by surgery, preferentially without radiotherapy. In this situation, the membranous urethral sphincter is most likely injured if it was not already following repetitive endoluminal procedures. In the perineal approach, similar steps as used for post-traumatic posterior urethral repair, such as bulbar urethral mobilization and crural separation, can be necessary, to bridge gaps created by resection of fibrous tissue and unhealthy, irradiated urethra, to produce a healthy anastomosis to the bladder neck. In this scenario, the bulbar arterial supply may already be severely compromised by scarred tissue, leaving the urethra dependent upon retrograde flow and from perforators originating in the penile arteries.

In theory, the placement of an AUS may cause obstruction of the retrograde blood flow of the urethra and lead to ischemia of the interval segment between the AUS and the vesicourethral anastomosis. The urethra *per se* is already atrophic and densely fixed in the perineum from prior operative procedures. In summary, these anatomical and operative factors, after urethral reconstruction, potentially make this subset of patients the most problematic for successful AUS implantation.

The literature is relatively scarce on the influence of previous urethroplasty on urinary continence outcomes and complication rates after AUS placement in men with severe non-neurogenic urinary incontinence. In a small series of 6 patients, anastomotic urethroplasty was performed for strictures resulting from surgical treatment for benign prostatic hyperplasia (BPH) and VUAS due to radical prostatectomy without radiotherapy. Anastomotic urethroplasty was successful in all 6 patients (21). All patients underwent perineal AUS placement (4.0-cm cuff), without using a transcorporal approach, at 7 months after urethroplasty. One patient (17%) had erosion in the first 6 months of implantation. No anastomotic recurrence was reported. However, it was expected the urethral blood flow to be compromised after urethral transection in anastomotic repairs (21). In another study by Keihani *et al.* including 27 men (87%), the AUS was replaced at median of 6.0 months [interquartile range (IQR), 4–7 months] after urethroplasty. In 25 patients with >3 months of follow-up after AUS replacement, urethral complications requiring AUS revision or removal occurred in 9 patients (36%) and included subcuff atrophy and erosion (8).

In a multi-institutional series, Brant *et al.* analyzed risk factors associated with AUS explantation, such as infection, erosion, and urethral atrophy, and found the explantation rate to be only 3.6% (1 out of 28 patients after urethroplasty) at a mean 2.3-year follow-up (15). This outcomes study confirms that urethral risk factors, including radiation history, prior AUS erosion, and a history of urethral stent placement, increase the risk of AUS explantation (up to 8.03%) in short-term follow-up. However, the study does not mention the time window between urethroplasty and the subsequent AUS implantation However, the authors did not provide details of the urethroplasties, but the majority were performed for bulbomembranous stenosis, or earlier AUS erosions. However, McGeady *et al.* published a series of 23 mostly high-risk patients with compromised urethras due to radiation, previous AUS, and urethroplasty (16). They all underwent bulbomembranous anastomotic urethroplasty. Explantation for erosion, infection, and atrophy occurred in 9 out of 23 patients (39%). Because several of these patients had more than one risk factor (e.g., radiotherapy and urethroplasty), the authors performed a subanalysis of these men with only one risk factor comparing risk of erosion between radiotherapy, urethroplasty, and previous AUS and concluded that urethroplasty was the worst risk factor. Forty-four percent of patients with a history of urethroplasty experienced erosion, compared with 29% of those with radiotherapy and 20% with previous AUS (16).

More recently, Sayedahmed *et al.* evaluated the impact of previous urethroplasty on complication rates and postoperative urinary continence after primary AUS implantation in men with severe incontinence (22). Overall sphincter erosion rate was 12.3%, but significantly higher in patients after urethroplasty (23.3% *vs.* 8.0%, P=0.038). AUS explantation rate was threefold higher (P=0.016) in the urethroplasty group. On logistic regression analysis, previous urethroplasty was the only significant predictor for AUS explantation (P=0.016) (22). Furthermore, this study concludes that previous urethroplasties (anastomotic or grafting), long strictures and previous visual internal urethrotomy increased risk of erosion (22). However, this may not be the case for augmented urethroplasties. However, another study showed no significant difference in complications and explantation-free survival (log rank, P=0.191) between patients who had undergone buccal mucosal graft urethroplasty (BMGU) before AUS compared to those who did not. These authors concluded that AUS implantation was a feasible, safe, and effective treatment for urinary incontinence despite previous BMGU (23).

Several surgical strategies have been devised for AUS placement in revisional surgery (*Table 2*). A transcorporal

placement of AUS is advocated by many urologists after urethroplasty to avoid dorsal erosion, and simultaneously improve outcomes of AUS placement around a densely scarred urethra following previous surgery (*Figures 2,3*). Guralnick *et al.* at Duke University popularized this approach in the early 2000s, but no robust literature regarding its benefits or perils exists (24). A lateral flap of the tunica albuginea is developed on both sides of the urethra to avoid dissection of the dorsal urethra off the corporal bodies. This technique will apparently generate sufficient bulk to the dorsal aspect of the bulbar urethra. In a small retrospective series, Aaronson *et al.* compared 8 men after transcorporal AUS implantation with 18 men who received standard AUS technique (25). Approximately half of the patients in each group had received radiation therapy, 89% of the transcorporal arm patients had received ≥2 previous urethral procedures, including urethroplasties, compared to only 22% in the standard technique arm. AUS explantation occurred twice as often (28%) in the standard technique compared to the transcorporal implantation (13%). Despite the small patient number, the results of the study supported the transcorporal placement technique. Several centers have shown the merits and successful results of the transcorporal placement of the AUS cuff in high-risk non-neurogenic urinary incontinence patients resulting in high social continence rates approaching 80% (17,26,27). Mock *et al.* reported 80% social continence rate in a cohort of 15 patients at a median follow-up of 45 months (17). The authors observed a 10.8% erosion rate at a median 8.5-month follow-up. They also noted an increased risk in patients with previous penile prosthesis implantation. These studies also demonstrated the significantly negative impact of multiple urethral risk factors, specifically in addition to pelvic irradiation, on revision-free rates (17,28). However, it is important to remember that the transcorporal approach only protects the dorsal aspect of the urethra. Ortiz *et al.* retrospectively reviewed 723 AUS cases in 611 patients with 54 (7.5%) cuff erosions and found that cuff erosions predominantly occur ventrally. They found a higher rate of erosions in the transcorporal

Table 2 Surgical strategies in AUS revisional surgery (21)

Transcorporal cuff placement
Tandem/double cuff placement
Cuff over bulbospongiosus muscle
Rectus fascia wrap of corpus spongiosum
SIS wrap of corpus spongiosum
ATOMS sling, ProACT

AUS, artificial urinary sphincter; SIS, small intestinal submucosal; ATOMS, adjustable transobturator male system.

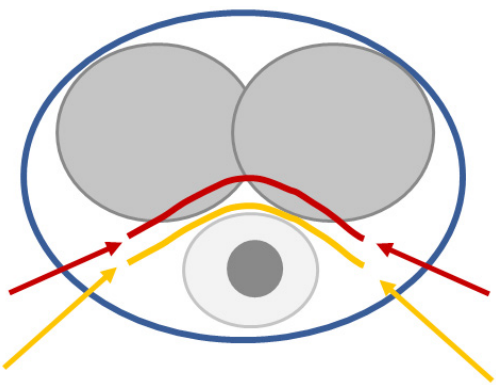

Figure 3 Standard cuff placement (in yellow); transcorporal cuff placement (in red).

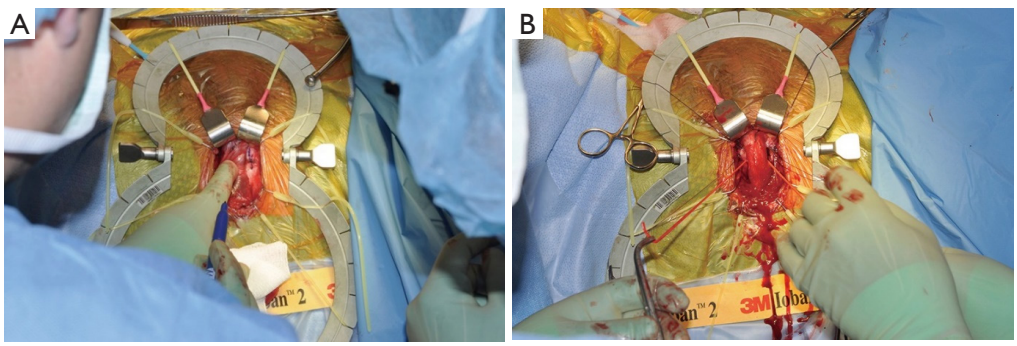

Figure 2 Transcorporal technique. (A) Marking the tunica albuginea; (B) a vessel loop has been passed through the transcorporal tunel.

Table 3 AUS in fragile urethra (13,17,32,33)

Etiology of fragile urethra
XRT
Previous urethroplasty
Previous AUS erosion(s)
Testosterone deficiency
Preventive therapeutic strategies
Delay radiotherapy until after implantation
11% erosion pre-AUS placement
0% erosion post-AUS placement
Delay implantation >15 months after prostatectomy
Lower pressure PRB (51–60 cmH_2O)
Leave deactivated for longer (12 weeks)
Proximal cuff site placement

AUS, artificial urinary sphincter; XRT, radiotherapy; PRB, pressure regulating balloon.

cuff group (18.3%) than in the standard group (6.1%), even though the groups were similar in regard to history of radiotherapy, prior urethroplasty, hypogonadism, and cuff size. Hence, they concluded that the protective effect of the transcorporal approach could not be demonstrated (29).

A 17% erosion rate was reported when double cuffs were placed for previous urethral atrophy (30,31). However, these studies did not find a significant difference in overall survival between single cuff downsizing and double/tandem cuff placement during AUS revision for urethral atrophy (*Table 3*). Nonetheless, caution should be used regarding standard double cuff placement in a fragile urethra, or even avoided if possible. Furthermore, the use of transcorporal double cuff reduced urethral survival compared to single cuff, respectively 44% *vs.* 80% at 3-year follow-up (30,31).

Ahyai *et al.* compared single cuff proximal placement to double cuff placement in patients with severe urinary incontinence (31). Although similar objective continence rate was observed, the explantation rate was higher in the double cuff cohort compared to the single proximal cuff implantation. This said, we believe that tandem/double cuffs should be avoided as they seem to compromise urethral vascularity even further of an already compromised urethra leading to higher complication (especially erosion of the distal cuff) and revision rates without any benefit on continence rates. Additionally, the two cuffs remove some location flexibility for placement of future cuffs. For these reasons, we recommend single cuff placement if at all possible (15). Roth *et al.* reported on the safe AUS placement in 21 patients at high-risk for erosion with preservation of the bulbospongiosus muscle complex (34). The authors reported long-term favorable results in this high-risk population with 66.7% of the patients considering themselves "cured" or "significantly improved". No erosion was reported at a median follow-up of 35.8 months. Three revisions were needed to downsize the cuff. Collado Serra *et al.* reported 76.8% continence and satisfaction at a median follow-up of 46 months, with 1.2% erosion rate (35). Cheung *et al.* reported on their modified technique in AUS implantation, consisting of preserving the dorsolateral fibromuscular tissue surrounding the bulbar urethra. They reported a 2.9% erosion rate in a total cohort of 208 patients (32). They concluded that the technique was feasible, efficacious, safe, and with low infection and erosion rates, whilst providing good social continence rates of 74%. Gani *et al.* proposed the use of rectus fascial wrap in irradiated patients with severe SUI. The technique involves harvesting of a 1.5 cm wide strip of rectus fascia, which is then placed around the bulbar urethra before cuff implantation. They reported one erosion among 23 patients (4.3%) after a median follow-up of 32 months (33). In 2012, Trost *et al.* described the use of small intestinal submucosal (SIS) to wrap around the urethra at the time of AUS placement as a salvage option for risk patients following multiple prior sphincter failures and erosions (36). At a median follow-up of 12.4 months, 38% (3/8) of patients were dry, requiring no pads. AUS explantation was required in 3 (25%) patients for erosion and/or infection. Patients with prior irradiation accounted for 80% (4/5) of procedure failures. This procedure should be used as a last option only in well selected patients after full counseling about the expected risks and potential outcomes of surgery.

Low serum testosterone is reported to be an independent risk factor for AUS cuff erosion. Wolfe *et al.* recently performed a retrospective analysis of 161 AUS implantations. Cuff erosion was identified in 42 men (26.1%), most of whom (30/42, 71.4%) were testosterone deficient (<280 mg/dL) (37). Several studies have reported similar results. However, to our knowledge, there have been no trials studying the effect of presurgical testosterone supplementation before AUS surgery to reduce the risk of erosion. Preoperative testosterone replacement therapy has

been described to be beneficial in the outcome of urethral reconstruction (38).

Urethroplasty after artificial urinary sphincter implantation/erosion

AUS erosion is a relatively infrequent but serious adverse and morbid event for the patient. This usually leads to infection and complex management of the eroded urethra, often causing stricture and fistulation to the perineum. This sequence of events often dictates a prolonged recovery interval until reimplantation of a subsequent AUS device, if at all possible. The incidence of urethral stricture caused by AUS cuff erosion ranges from 8.3% to 32% (8,9). The literature is sparse regarding urethroplasty outcomes after AUS cuff erosion. The AUS erosion rates vary remarkably, and result from several factors. Linder *et al.* reported erosion in 6% of a large series of 497 men receiving an AUS for the first time at a median follow-up of 2 years (39). Other authors reported erosion rates from 2% to 13% (2,5,12,28,38). Both patient and surgical adverse features have been implicated in an increased risk of AUS cuff erosion: hypertension, coronary artery disease, prior pelvic irradiation, previous AUS cuff erosion, prior AUS revision surgery, previous urethroplasty, double cuff placement, urethral stenting, use of a 3.5-cm cuff, and placement of a urethral catheter by untrained personnel (2,5,12,29,40-42). The risk of cuff erosion increases even further from 25% to 75% if multiple adverse features are simultaneously present (17,18).

Segmental urethral loss is a severe, often challenging complication that can develop after AUS cuff erosion. This loss of urethral tissue will result in dense fibrosis and stricture formation in most cases (*Figure 1*). The incidence of urethral stricture will depend on the strategies used for management of AUS cuff erosion. There are several management options for cuff erosion such as urinary drainage alone (usually with a suprapubic catheter), or immediate repair of the injured urethra to prevent urethral stricture formation or fistulation to the perineum (11). In this study, the authors evaluated retrospectively their experience with this immediate salvage approach versus catheter placement alone. The *in-situ* repair involved closure of the ventral portion of the urethra, the most severely affected portion of the urethra, avoiding mobilization of the dorsal urethra. The authors found a significant decrease in the stricture formation rate from 85% in the urethral catheter group to 38% in the immediate repair group. The major weakness of this study was selection bias due to non-randomization. However, another study from the Cleveland Clinic comparing three patient arms (urethral catheter alone, *in-situ* abbreviated urethroplasty, and full anastomotic urethroplasty) reached a contradictory conclusion, that is, the stricture formation was higher in the urethroplasty groups (17% in the catheter alone group, and 33% and 25% in the abbreviated and anastomotic urethroplasty groups, respectively) (42). Again, this study was also compromised by asymmetry among patient cohorts, especially 70% of patients had catheter drainage compared to the two different urethroplasty cohorts. The analysis at 3 months' follow-up included only 3 and 8 men who underwent abbreviated and full anastomotic urethroplasties, respectively. Nonetheless, the authors suggested that stratifying the degree of urethral damage is essential to identify those patients who will reliably heal with a urethral catheter alone compared to those who need urethral reconstruction.

Gross *et al.* evaluated the influence of both repair type and degree of cuff erosion on post-operative urethral stricture rate (9). This retrospective multi-institutional study included 80 patients treated for AUS cuff erosions. Erosion patients were categorized into one of three repair types at the time of explantation: catheter alone, single-layer capsule to capsule repair (urethrorraphy), and formal urethroplasty. Stricture formation was more common in the urethrorraphy group (40%), followed by catheter alone group (29%), and formal urethroplasty group (14%). In this study, the stricture rates did not vary significantly by type of urethral repair (P=0.2). Strictures were significantly more frequent after complete cuff erosions (58%) versus partial erosions (25%; P=0.037). Patients with partial erosion had a trend to undergo urethrorraphy (60%; P=0.002) (9). The authors concluded that the repair type, whether catheter only, urethrorraphy, or formal urethroplasty, did not seem to have a significant influence on the post-operative stricture formation rate.

In a study by the TURNS group (Trauma and Urologic Reconstruction Network of Surgeons), the success of urethroplasty for urethral strictures caused by AUS erosion and rates of subsequent AUS replacement were investigated (8). Thirty-one patients met the study inclusion criteria. They concluded that urethroplasty was feasible and successful. However, AUS cuff erosion and sub-cuff urethral atrophy had a higher incidence (36%) in patients who underwent AUS replacement after urethroplasty even in the short-term. The urethral stricture length was also more significant in this cohort (2.2 *vs.* 1.5 cm; P=0.04) (8).

Kuhlencord *et al.* described and analyzed outcomes of a standardized less invasive approach to manage patients with urethral stricture following AUS explantation due to cuff erosion (43). Contrary to most studies, these authors observed a considerably low rate of urethral stricture formation and, therefore, could neither recommend primary urethroplasty nor delay in salvage treatment of urinary incontinence.

Globally, management of urethral cuff erosion includes removal of the entire AUS device, eventually leaving the pressure balloon reservoir *in situ*, and either place an indwelling urethral or suprapubic catheter for at least 6 months (42,44). Chertak *et al.* reported 38% stricture rate with indwelling urethral catheterization in patients with severe erosions compared to 5% stricture rate in mild erosions (42). Tandem cuff placement was also associated with a significantly higher stricture rate compared with single cuff, respectively 33% and 4% (9,11,43). Primary urethroplasty was associated with a 38% urethral stricture rate compared to 85% in the indwelling catheter patient cohort (8,11). Primary urethroplasty was associated with a 54% success rate of a second reimplantation compared to 15% in the group with indwelling catheter. Repeat AUS implantation after urethroplasty was associated with a 24% erosion rate within the first 6 months (9,11,42).

Currently, the literature on urethral stricture management after AUS erosion is limited regarding well conducted studies and management algorithms supported by robust evidence. Similarly, the data is scarce in terms of subsequent successful rate of AUS reimplantation. It is critical to understand the potential long-term outcomes in this specific patient population. If these outcomes prove to be inferior, eventually unacceptable, for AUS reimplantation compared with other reported adverse factors associated with cuff erosion, then surgeons should follow a different approach, such as definitive urethral closure and some type of urinary diversion, including suprapubic cystostomy, or other formal types of urinary diversion. This approach would avoid the unfortunate and frustrating cycle of urethral reconstruction, AUS reimplantation, and subsequent cuff erosion and device removal.

An individualized patient-oriented approach, including specific individual clinical data and adverse features, should be the main determinant in the decision-making process. As these decisions are sometimes taken intraoperatively, it is important that the reconstructive surgeon should have a flexible mind to adapt to or adopt a new, different, and better strategy to what he had initially planned for the patient.

Recent innovations and considerations

Recently, the robot has been increasingly used by some surgeons to treat posterior urethral (bulbomembranous and vesicourethral) stenoses (19,45). However, the literature is still sparse on this topic. Nonetheless, robotic posterior urethral reconstruction appears to be a safe and effective surgical option for males with posterior urethral stenoses without pelvic radiation. The robotic approach may be associated with several potential advantages including smaller incisions, magnified field of vision, magnified field of vision, near-infrared fluorescence (NIRF) imaging to characterize tissue integrity, enhanced dexterity within the deep and narrow confines of the male pelvis, sparing of the perineal planes, and shorter convalescence. These authors predict a redefinition of the paradigm of posterior urethroplasty through the robotic approach in the near future.

The concept/idea of leaving the cuff sizer as a spacer around the urethra during urethroplasty to enable easier placement of a future AUS cuff and thus avoid the need for a more invasive transcorporal approach has not been published in peer review international literature to our knowledge. Although anecdotally, it may seem to be a procedure worthwhile trying and that definitely should be kept in mind for complex cases in the near future.

Endoluminal (endoscopic incision and urethral dilatation) minimally invasive approaches can (and eventually should as much as possible) be attempted as 1st-line treatment for a non-obliterative VUAS or radiation-induced bulbomembranous stenoses (BMS). Recently, transurethral incision with transverse mucosal realignment for VUAS and BNC has been reported with a high success rate of 89% after one procedure and 100% after a second procedure without *de novo* urinary incontinence or major complications (46). This approach may avoid perineal surgery or other more invasive approaches. However, more studies and longer follow-up are still needed to establish its reproducibility.

Recently, other rescue options have been suggested. In a retrospective multicenter study, Angulo *et al.* evaluated treatment options after surgical revision of adjustable transobturator male system (ATOMS) and the results of further implantation for incontinence (47). There was no difference between a 2nd ATOMS or an AUS in terms of postoperative complications. The predominant cuff size for AUS was 4.5 cm (59.3%). Mean follow-up after the second implant was 29.1±25.8 months. Postoperative efficacy of

secondary treatment results favored ATOMS based on pad-test and patient satisfaction.

The literature on the specific use of ProACT periurethral balloons after AUS failure is very scanty. Some authors reported on the use and outcomes of ProACT as second line therapy after male sling failure for persistent or recurrent mild post-prostatectomy urinary incontinence. ProACT was shown to be a safe and efficient treatment that can be used as second line therapy after failure of other slings without significant complications (48,49). Nonetheless, because there is still no strong evidence supporting either procedure (ATOMS or ProACT), more studies are needed for more conclusive reproducibility of these procedures as salvage therapeutic options.

The safety of clean intermittent catheterization (CIC) in men with an AUS at the bulbar urethra remains unclear. The functional and surgical impact of CIC protocols have been evaluated in men with a bulbar AUS in place. In a study by Krughoff *et al.* involving 57 patients with a history of CIC and AUS placement, the authors found no difference in AUS cuff erosion rate amongst patients who continued or discontinued CIC after AUS placement (17.9% *vs.* 22.2%, P=0.79) as well as no difference in future AUS removal or replacement (56.4% *vs.* 44.4%, P=0.41) (50). Both groups experienced improvement in urinary incontinence after AUS implantation. Therefore, AUS implantation in the setting of continuous CIC can be considered in patients who are not surgical candidates for definitive treatment of their outlet obstruction.

Conclusions

Urethral stricture and VUAS are two important and common issues that should be included in the discussion prior to AUS implantation for severe urinary incontinence. Conservative, intraluminal therapeutic options have been used successfully depending on patient's healing characteristics and presence of urethral risk factors. If more invasive options are needed for completely obliterative or more challenging circumstances such as pelvic irradiation, traditional open (abdominal or perineal) or robotic approach may be necessary and successful. However, after surgical urethral reconstruction, regardless of its type, patients become at risk for urethral complications after AUS placement. Many of these complications can be managed successfully and, even despite concerns about disruption of blood supply to the urethra, the risk of proximal urethral necrosis has not been reported in the available literature. Urethral erosions caused by AUS can be a therapeutic challenge. Milder cases involving less than 50% of the urethral circumference can be managed with closing the ventral defect and/or suprapubic catheter drainage with minimal risk of stricture formation. Conversely, more severe erosions usually require anastomotic urethroplasty whenever possible. Data on AUS reimplantation after urethroplasty for post-erosion strictures are still limited. Transcorporal AUS reimplantation following urethroplasty or in compromised, fragile urethras, can help minimize urethral injury and reduce erosion rates, apparently making this approach an essential surgical choice.

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Footnote

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