



Female urethroplasty: contemporary thinking

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Abstract

Purpose Female urethral stricture disease is a rare entity. To date, its diagnosis and treatment have been poorly studied, with small numbers, and variable definitions of success. With growing interest in this area of reconstructive urology, there is an increased number of surgical techniques. In this article, we review current trends, definitions, etiologies and surgical techniques available for management of FUSD.

Method We completed a review of publications in: English; Pubmed, and Google scholar. Key words identified for review were, female urethra stricture, female urethroplasty and female urethral dilation, female pelvic fracture, and female urethral reconstruction. Papers were reviewed, and references of relevant papers reviewed.

Results Iatrogenic injury is the most common cause of female urethral stricture disease. Assessment requires a thorough patient history, examination and either flexible cystoscopy and/or fluoroscopic urodynamics to determine the most appropriate surgical approach for stricture repair. Multiple open urethroplasty techniques are described with various grafts and flaps, with good medium-term success. Minimally invasive techniques remain well-employed but have poor long-term success, with increased failure with multiple attempts at treatment.

Conclusion Female urethral stricture disease is a complex clinical entity that requires a measured and thorough evaluation. Individualized approach should be undertaken reviewing the patient's symptoms, the stricture's etiology, surrounding vaginal tissue health and stricture location. Promising medium-term success rates with vaginal flaps and buccal mucosal graft urethroplasty have been reported, with disappointing long-term results from repeated urethral dilation. Further research comparing techniques and defining successful long-term outcomes is required.

Keywords Female urethroplasty · Female urethral stricture · Female urethral dilation · Urethral stricture · Vaginal flaps · Buccal mucosal graft

Introduction

Female urethral stricture disease (FUSD) is a rare entity, with reported rates between < 1 and 4.9% of women presenting with lower urinary tract symptoms (LUTS) [1]. Its diagnosis and treatment has been poorly studied to date, with small numbers, variable definitions of success and a paucity of data regarding long-term surgical outcomes. Of that data that is available, high-quality evidence and long-term follow-up are often lacking, especially in light of the absence of any randomized controlled trials.

Much of the surgical treatment has been extrapolated from reconstructive techniques for male urethral stricture disease, with published case series suggesting that definitive surgical interventions have a better outcome than minimally invasive techniques. Despite the small numbers, there is a growing interest in this area of reconstructive urology, prompting an increased number of descriptions of surgical techniques, aiming for longevity of surgical success in FUSD without further surgical interventions. In this article, we review current trends, definitions, aetiologies and surgical techniques available for management of FUSD.

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Method

Published research was identified via completion of a PubMed and Google Scholar search, utilizing the search terms female urethral stricture, female urethroplasty and female urethral dilation, female pelvic fracture, and female urethral reconstruction. Studies were limited to human and female studies. Studies in which urethral reconstruction was not completed as the primary procedure were not included. The studies were independently reviewed by the two authors, and references of papers were reviewed for potential missed studies.

Definition

Much of the difficulty in data provision arises from the fact that even the definition of FUSD has proven elusive, and currently there is no standardized definition of what constitutes a female urethral stricture.

Many studies define a stricture as failure to calibrate or catheterize the female urethra, while others delineate it as the finding of stricture during attempted cystourethroscopy. One suggested definition is “a fixed anatomical narrowing of the urethra such that the lumen will not accommodate instrumentation without disruption of the urethral mucosal lining. It should be differentiated from functional or physiological narrowing of the urethra as seen on radiographic imaging—e.g. that is associated with striated sphincter dyssynergia or dysfunctional voiding” [2]. A more concise definition by Osman et al. states that it is a “symptomatic, anatomical narrowing of the urethra based upon a failure of catheterization, urethral calibration, visual inspection, or endoscopy or radiography” [3]. Whilst these suggested definitions help clarify the broad functional sequelae of strictures, they do not go further in offering quantitative values and measurements, or agreement as to what size French is considered pathological. Such quantitative measurements will allow for patient stratification for surgical modalities, and meaningful comparison of both surgical and functional outcomes.

Evaluation

There is no standard assessment protocol for FUSD, so most investigators rely upon a mixture of patient history and examination, in addition to a variety of clinical investigations. Presenting symptoms can be vague and non-specific, such as incomplete emptying, poor flow and

recurrent UTIs, so a high index of suspicion is required to ensure FUSD is not missed.

Faiena et al. [4] suggest that a thorough physical examination should include bimanual pelvic, vaginal and speculum examinations. This allows the assessment of the health of the vaginal and vulval tissue for consideration for utilization as graft material, as well assessing for potential pelvic malignancies. Most studies employ either or both flexible cystoscopy and voiding cystourethrography to define location and presence of stricture. Radiographic findings reveal an open bladder neck with narrowing more distally within the urethra, and relaxation of the sphincter if fluoroscopic urodynamics (UDS) are utilized [5] (Fig. 1).

The diagnosis of obstruction via UDS has been suggested in patients showing a detrusor contraction at a maximum flow of > 25 cm H₂O, with a flow < 12 cm³/s [5], though many would argue that a Q_{max} of < 20 ml/s on a plain voiding flow rate (VFR) in a female is abnormal. VFR and post-void residual (PVR) are also useful, both in pre-operative assessment and later to document objective post-intervention outcomes.

Utilization of magnetic resonance imaging (MRI) with endovaginal coil may be considered if concurrent urethral diverticulum is suspected, or in cases of possible malignant pathology. The published use of MRI in FUSD is small, however, it has been utilized in the diagnosis of peri-urethral



Fig. 1 Voiding cystourethrography show ballooning of bladder neck and distal narrowing of urethra

fibrosis, though this has not been associated with any prognostic significance with regard to surgical outcome [3].

Urethral calibration is often discussed when evaluating the urethra, and different papers proffer different ideas regarding diagnostic catheterization calibers, from the inability to catheterize with anything < 12 Fr [5] up to as capacious as 20 Fr [3, 6–9]. However, in the absence of defined calibration criteria for FUSD, or studies that we are aware of that directly link urethral diameter with degree of symptomatology or surgical outcomes, it appears that urethral calibration may be more helpful in assessment of the return of FUSD in the post-operative setting.

Anatomy

The female urethra is 4 cm long with two circumferential coats of smooth muscle, an inner longitudinal layer and outer circumferential layer. These muscular layers thin towards the distal urethra, particularly the outer layer, and in the last quarter of the urethra terminate in a thick collagenous ring, with minimal compliance [1, 2]. The striated urethral sphincter lies external to the smooth muscle layer, and extends the entire length of the urethra, though it is thickest in the mid third, and mainly located dorsally. This lends an effective horseshoe configuration to the sphincter at this point, with a less developed ventral part of the striated sphincter. The sphincter is anchored anteriorly to the vaginal wall. Further muscle fibers from the compressor urethrae run inferior to the sphincter, and anterior to the urethra, originating from the ischiopubic rami [3]. The urethral urothelial lining changes from transitional epithelium proximally to non-keratinised stratified squamous cells with glands more distally.

Other anatomical relations of the urethra include the clitoral tissue, lying along the dorsal aspect of the urethra, and the neurovascular bundles, which traverse along the ischiopubic ramus [1]. There are several ligaments which also give support to the urethra, namely the pubourethral and urethropelvic ligaments. The former arise from peri-urethral connective tissue, and attach to the pubic end of the parietal pelvic fascia; the two leaves of the urethropelvic ligament act to maintain the urethral resting angle at 45°, providing support laterally to suspend the urethra via attachments to both the endopelvic and peri-urethral fascias [3].

Etiology/pathology

Iatrogenic injury is the most frequent cause of FUSD in the Western world. Anterior vaginal wall surgery, urethral surgery (including diverticulectomy), and traumatic urethral or

long-term catheterization are noted in up to 88% of patients presenting with FUSD [10].

Radiation therapy is a well-documented causative agent of stricture disease in male patients. It is acknowledged as a risk factor in FUSD, however, due to the small cohorts of research in FUSD, the risk of radiation and its long-term sequelae of stricture are not well-understood.

Traumatic urethral injury in females is most commonly the result of obstetric complications, such as obstructed labor; or pelvic fracture (more frequently in girls than adult women) [2]. Traumatic urethral injuries are associated with 5% of pelvic fractures; these can be severe in nature, and include avulsion, vesico-vaginal fistula, or distraction injuries.

Idiopathic causes of FUSD range from 42 to 49% in modern reviews [1, 2, 7]. Other rarer causes include malignancy (such as advanced cervical or local urethral carcinoma), and infection.

Management options

Many surgical options are available for the management of FUSD, which can be divided into minimally invasive surgeries and open urethroplasties. All techniques aim to allow the patient to void without pain, and result in the resolution of LUTS. However, success is not uniformly defined, nor equivalent across all techniques.

As with male urethral stricture disease, consideration of the length and location of the stricture, health of surrounding tissues, and availability of flap or graft tissue need to be considered prior to undertaking a repair.

Minimally invasive techniques

Urethral dilatation

Urethral dilatation is the most frequently employed surgical intervention for presumed FUSD but is often used indiscriminately to treat a variety of non-specific LUTS in women, including frequency/urgency, bladder pain syndrome, and recurrent UTIs, despite a lack of evidence or support by controlled clinical studies [2].

Contemporary studies that have reported on urethral dilatation for FUSD have all used different definitions for FUSD and treatment success [2, 8, 11]. In the post-operative period, varying intermittent self-dilatation (ISD) programs were employed, and defined this as successful, an outcome which is not considered as successful in men. They also excluded many patients with increased risk factors for recurrence of FUSD, such as previous pelvic radiation, history of gynecological/urological

malignancy (bladder or urethral cancer), as well as meatal stenosis, and/or prior incontinence procedures.

Smith retrospectively reviewed seven women with urethral stricture over a 5-year period, utilizing urethral dilatation to ≥ 30 Fr, with subsequent daily ISD. All women required long-term ISD to maintain the improvement in their LUTS; those that did not undertake the ISD program experienced recurrences of their stricture disease (three of seven patients), requiring further dilation within 1–39 months [2]. Similar results were described by Popat and Zimmern [12], who had a success rate of 43% in 30 women who underwent urethral dilatation. Of 17 patients who failed, many underwent a period of continued ISD (non-standardized program of ISD between patients), whilst 15 of these patients underwent at least one further dilatation, and 6 underwent a third. The mean time between initial and subsequent dilatation was 15 months.

Romman et al. reported on patients who underwent GA urethral dilatation for distal intramural urethral pathology. They found 101 cases over a 12 year period, who were dilated to 41 Fr, with concurrent haemostatic suture placement if urethral meatal tearing was noted. Success was defined as one dilatation resulting in complete or major resolution of LUTS at a minimum of 6 months of follow-up, and no need for a further procedure. Their success rate was 51%, with mean time to failure of 12 ± 15 months [11].

Romman et al. [11] and Osman et al. [3] noted a higher failure rate with an increasing number of urethral dilations, with a shorter time to failure. These findings are keeping in with male urethral stricture disease studies that demonstrate that urethral dilatation alone is insufficient to cure urethral stricture disease. Patients with FUSD should be considered for urethroplasty if they fail dilation, as recidivist dilation does not confer long-term relief of symptoms and may worsen the stricture, thereby increasing the difficulty of urethroplasty at a later stage.

Optical urethrotomy

Female optical urethrotomy is described by Rosenblum and Nitti [13], with cold knife or Holmium laser endoscopic incision at 3 and 9 o'clock, with a third incision at 12 o'clock if required. A "cut to the light approach" has also been advocated for complete urethral obliteration [13]. There are minimal studies assessing these techniques for long-term efficacy and complications, including stress urinary incontinence, and all procedures advocate a long period of post-operative catheterization.

Open urethroplasty

Vaginal flap urethroplasty (VFU)

The vaginal flap was initially described for replacing vaginal tissue loss and utilizes an advancement flap of vaginal

mucosa. The technique was modified allowing the flap to be inlaid and sutured into the urethra as the VFU. Typically, the flap is raised from an inverted U-shaped vaginal incision, with alternative flaps including a C-shaped flap repair and vestibular vaginal flap utilization via a dorsal approach [14, 15]. The benefit of VFU is the tissue is locally available and well-vascularized and allows either a dorsal or ventral orientation for the urethroplasty. However, if the vaginal tissue is unhealthy or lacking pliability due to atrophy, previous radiation, or scarring then this tissue may not be appropriate, and another flap or graft should be considered.

VFU have been reported in 5 studies with a total of 55 patients [3, 5, 8, 14–16] (Table 1). The U-shaped inlay was completed in 32 women, followed by 17 vestibular and 6 C-shaped flaps. These were placed in both a dorsal (17/55) and ventral (38/55) orientation, with 12 other concurrent procedures. Success was 91% at a mean follow-up of 32 months, but 19 patients had been instructed to perform ISD during this time [3]. Only one incidence of urge urinary incontinence was documented [4]. Importantly, despite the majority of these patients ($n = 33$) having had a minimum of one previous surgical intervention for their FUSD, the success was still 91%, which is an improvement on urethral dilation outcomes in the same setting.

Labial flap urethroplasty

Labial pedicled flaps have been described by Tanello et al. [17] and Falandry et al. [18]. Both groups demonstrate the versatility of this flap, using it for complete urethral reconstruction, tubularised flaps, augmented patch and inlay in a stricturotomy. Success for this adaptable flap ranges from 82 to 100% at greater than 24 months follow-up.

Xu et al. [19] reported on repair of pelvic fracture-induced urethral strictures, using a tubularised labial flap. They utilized a trans-pubic approach in eight patients, and the neourethra was constructed from either single or bilateral labial flaps and joined to the bladder, and then wrapped in a pedicled rectus muscle flap. After a mean of 48 months, one patient required urethral dilatation, but all others were voiding well.

Vaginal and labial graft urethroplasty

Like the vaginal and labial flap urethroplasties, both dorsal and ventral onlay techniques have been described (Table 2), with many advocating for the dorsal approach to minimize damage to the urinary sphincter and guard against de novo stress urinary incontinence (SUI). It has also been advocated in cases where a concurrent SUI procedure is planned, in that the urethra remains fully intact ventrally, minimizing the risk of sling erosion or fistula formation.

Table 1 Outcomes of vaginal and labial flap urethroplasty

References	No. of pts	Age	Type of reconstruction	Median FU (range)	Concurrent procedure	Flaps used	Success (%)	Complications
Flisser and Blaivas [35] (urethral reconstruction, not only for stricture—includes fistula)	74	22–80	72 vaginal flap 1 Tanagho bladder flap 1 primary repair with urethrolysis	1.5 years (1–15)	56 pubovaginal sling 5 modified Pereyra procedure 1 Kelly plication	58 Martius flaps 3 omental flaps 1 gracilis myocutaneous flap	93	12 de novo urge/UII 1 sling revision for obstruction 2 persistent vaginal pain 2 recurrent fistulas
Blaivas et al. [8]	17	32–91	9 VFU 1 BMG (+2 delayed BMG for VFU failure)	4 years (1–12)	5 pubovaginal sling 1 apical fistula repair 1 diverticulectomy	4 Martius flap	100% at 1 year 78% at 5 years	2 recurrent strictures in VFU
Kowalik et al. [28]	10	32–74	5 VFU 1 vaginal island flap 4 BMG	34 months (10–74)	1 PVS 1 lap nephrectomy		80	2 VFU strictures—dilated
Gormley [5]	12	NS	VFU	3 years (3 months–9 years)	2 PVS		83	1 dilatation 1 EUA + GA IDC insertion
Onol et al. [16]	17	23–67	10 VFU (anterior) 1 urethral mucosa graft 4 BMG (ventral × 2, dorsal × 2) 2 circular BMG	24 months (6–78)		2 Martius flap	100 (objective) 88 (subjective)	2 inward-directed urinary stream (VFU) 2 persistent urge symptoms 1 persistent SUI (had refused concurrent PVS)
Simonato et al. [15]	6	57–72	VFU (C-shaped)	70.8 months (25–110)			83	1 × elevated PVR due to cystocele (ISC initiated)
Tanello et al. [17]	2	23, 70	Labia minora flap	24 months			100	Nil documented
Montorsi et al. [14]	17	41.2 (mean)	Vaginal flap	12 months			88	Nil documented
Radwan et al. [44] Series of complete urethral loss	16	15–54	Anterior bladder flap × 6 Labial flap × 10	42 months (15–100)	TOT sling × 9		100 successful reconstruction 66.6% total continence Partial continence 13.3. %	1 lost to FU Failure × 3 (second procedure): 1 × meatal stenosis 2 transient retention (ISC)
Xu et al. [19]	8	17–46	Pedicled labial flap (minora or majora): single flap × 5 bilateral flap × 3	48.2 months (10–118)	All cases associated with urethrovaginal fistula Trans-pubic approach		87.5	1 × SUI (spontaneous resolution) 1 × recurrent stricture (dilated)

Table 2 Outcomes of vaginal and labial graft urethroplasty

References	No. of pts	Age (years)	Type of reconstruction	Graft orientation	Median FU—months (range)	Success (%)	Complications
Petrou et al. [9]	11	39–75	Free vaginal graft	Dorsal	22.7 (6–46)	82	2 recurrent stricture (dilatation) 1 persistent ISD (pt choice) 1 persistent SUI 1 de novo urgency 8 persistent recurrent UTI
Rehder et al. [21]	8	28–67	Free labia minora graft	Ventral (6 o'clock)— reported in paper as dorsal	24	78.5 (1 year) 75 (2 years)	1 meatal stenosis (meatoplasty performed)
Onol et al. [20]	7	39–56	Labia minora	Ventral	18.2 (3–30)	86	1 × urethrotomy required 8 months post-op 1 × post-op UTI
Gozzi et al. [22]	4	53–63	Labia minora	Ventral	15 (11–19)	100	Dysuria
Tsivian and Sidi [23]	3	60	Vaginal graft × 2 BMG × 1	Dorsal	1–27	100	Nil reported

Onol et al. [20] published a series of 7 ventral inlay labia minora graft urethroplasties in mid-distal strictures, in whom five patients had undergone previous dilatation/urethrotomy. They reported an 86% success rate with a mean follow-up of 18.2 months, with statistically significant improvement in mean peak flow and mean AUA symptoms scores, with no report of fistula or de novo SUI. Rehder et al. [21] performed labia minora graft urethroplasty in eight patients with mid-proximal urethral stricture. They incised the urethra in the 6 o'clock position from the meatus, through stricture to healthy tissue, also incising part of the anterior vaginal wall. They reported 7/8 patients successful at 12 months follow-up with improvement in voiding symptoms and no new SUI.

Petrou, Gozzi and Tsivian analyzed vaginal grafts in ventral and dorsal onlay techniques, respectively [9, 22, 23]. Gozzi et al. [22] performed five volar labia minora graft urethroplasties; all patients had undergone previous dilatation/urethrotomy. All patients had a patent urethra at 11–19 months of follow-up, with no new SUI and no recurrent UTI.

Dorsal onlay female urethroplasty was described by Tsivian [23] in 3 women (2 vaginal graft, 1 BMG) via a suprimeatal incision and dissection of the urethra, with urethral incision in the 12 o'clock position, with 100% success, and this was re-evaluated by Petrou et al. [9] who performed dorsal onlay vaginal mucosal graft in 11 women. Petrou recorded statistically significant mean improvement in Qmax and PVR, with eight patients not requiring further intervention post-operatively. Three of seven patients had their pre-operative urinary urgency improve post-procedure.

Oral mucosal graft urethroplasty

Replicating the techniques of oral mucosal graft use in male stricture disease, many groups have demonstrated similar success in FUSD. Using both ventral and dorsal approaches, different groups have demonstrated both sustained outcomes and importantly significant improvement in AUA scores (Table 3).

Osman et al. [3] and Faiena et al. [4] reveal a mean success rate of 94% in the 7 mucosal graft urethroplasty studies they reviewed, with an average follow-up of 15 months in 32 patients [8, 20, 23–27]. The majority of patients in these groups underwent dorsal placement of their graft, with only four ventrally placed, and two circumferential reconstructions. Two patients had concomitant Martius flap placement, and no de novo SUI was documented.

Kowalik et al. [28] assess their VFU and dorsal buccal mucosal graft (BMG) urethroplasty success, reporting 100% success in the BMG group at a mean follow-up of 34 months. Both Goel et al. [29] and Powell and Daniels [30] reported significant improvement in AUA symptom score, Qmax and PVR, with overall success rates of 62.5–67%.

Hoag et al. suggested a modified approach for ventral onlay BMG urethroplasty for pan-urethral stricture in a single patient, avoiding vaginal incision, instead dilating the urethra to allow instrumentation and use of nasal speculum, before incising the entire ventral urethra in the 6 o'clock position for placement of the BMG. They reported success at 10 months of follow-up, with no need for further intervention [31].

Table 3 Outcomes of oral mucosal graft urethroplasty

References	No. pts	Age	Type of reconstruction	Graft orientation	Median FU (range)	Concurrent procedure	Success (%)	Complications
Onol et al. [20]	17	23–67	10 vaginal flap 1 urethral mucosa graft 4 BMG 2 circular BMG	Anterior Ventral × 2 Dorsal × 2 Circumferential	24 months (6–78)	2 Martius flap	100 (objective) 88 (subjective)	2 inward-directed urinary stream (VFU) 2 persistent urge symptoms 1 persistent SUI (had refused concurrent PVS)
Goel et al. [29]	8	34–60	BMG	Dorsal	14.8 months (3–24)		62.5	3 recurrent strictures (dilated + ISD)
Powell and Daniels [30]	6	52.7 (mean)	BMG	Dorsal	18.6 months (1–43.4)		67	2 stricture recurrences Oral donor site numbness
Spilotros et al. [1]	26	30–71	VFU × 2 BMG × 14 Dilatation × 8 Urethrotomy × 1 Meatoplasty × 1	Not specified	35.6 months (15–96)		100 93 0 0 NS	1 recurrent stricture (dilatation) 23% de novo mild SUI in BMG (improved with physio)
Tsivian and Sidi [23]	3	60	Vaginal graft × 2 BMG × 1	Dorsal	(1–27) months		100	Nil reported
Hoag et al. [31]	1	51	Vaginal-sparing BMG	Ventral	10 months		100	Nil reported
Sharma et al. [26]	15	25–65	Lingual mucosa graft	Dorsal	12 months			1 × submeatal stenosis (dilated) in pt who had post-op infection
Migliari et al. [24]	3	46–65	BMG	Dorsal	6 months		100	2 × mild irritative voiding symptoms (spontaneous resolution)
Berglund et al. [25]	2	46–50	BMG	Ventral	12–30 months		50%	1 × meatal stenosis (dilatation)
Castillo et al. [27]	2		BMG	Dorsal	18 months		100	1 × graft donor site haematoma

Distal urethrectomy and advancement meatoplasty or reconstruction

Rosenblum and Nitti [13] have described treating very distal urethral strictures (within 0.5–1 cm of meatus) with primary excision and advancement meatoplasty. Interrupted sutures are placed in healthy urethral tissue proximal to the proximal extent of the stricture to prevent mucosal retraction. The meatus is then circumferentially incised, and the

distal urethra excised. The healthy urethral mucosa is then advanced and sutured to the vaginal mucosa.

Onol et al. [16] also described tubularised BMG urethroplasty for reconstruction of severe distal stricture resulting in almost complete meatal obliteration. The distal urethra was mobilized through a circum-meatal incision. The healthy proximal mucosa was then incised at 6 o'clock, and the BMG sutured into the apex of the V. The graft was then tubularised around a catheter with the long edge sutured

circumferentially to the proximal urethra. The graft mucosa was then folded back on itself and sutured to the initial circum-meatal incision. These patients were followed up for 6–12 months, with no recurrence of stricture, and improved AUA symptom scores, and resolution of their pre-existing UUI.

Primary closure/anastomotic urethroplasty

Due to the short length of the female urethra, primary closure can be challenging. Nevertheless, it may be employed in certain circumstances where the primary urethral deficit is small, such as in urethral erosion from synthetic slings. Primary closure has been described by Ackerman et al. [32] with employment of a Heineke–Mickulicz type approach for short mid-urethral strictures, using ventral incision through the stricture with horizontal primary closure, though there is little published evidence utilizing this technique in FUSD.

Likewise, excision and re-anastomosis has been discussed in the literature, but carries a risk of both stress incontinence, and devascularisation of the distal urethra. Ackerman advocated this approach in a circumferential incision associated with significant spongiositis, in situations where graft onlay may not provide sufficient urethral caliber. There is little published evidence for this technique, though it has been used in reconstruction following diverticulectomy [32].

Bladder flap urethroplasty

Tanagho [33] described bladder flaps for the reconstruction of congenital absence of the urethra in 1975. Since then there have been variations in the technique, but it remains well-utilized in the presence of significant urethral loss and/or obliteration, particularly in the setting of pelvic trauma. The benefits of a bladder flap include the reliable vascularity, as well as presence of smooth muscle fibers and α -adrenergic receptors that may aid continence in the repaired urethra [4, 34].

Hemal et al. [34] published a series of five girls with urethral obliteration following pelvic fracture, of whom three were treated with bladder flaps combined with bladder neck suspension. Two patients were able to void immediately following catheter removal; one required ISC for 6 months but was then voiding independently. The remaining two patients are reported as having limited dry periods immediately after removal of catheter, but improvement after 6 months to periods of 2–4 h at a time.

Female urethral reconstruction in combination with anti-incontinence surgery

Within the cohorts of VFU assessed in the aforementioned reviews, only seven patients (of 57) underwent a concurrent

anti-incontinence procedure in the form of a pubovaginal sling (PVS). Another case series review of urethral reconstruction published by Flisser and Blaivas [35] assessed vaginal flap reconstruction of female urethral pathology (not only FUSD) in 74 patients, of whom 56 had a concomitant PVS placed. Many of these patients (62/74) had pre-operative incontinence; however, PVS was also preemptively employed in those that underwent extensive bladder neck dissection and those with an urethrovaginal fistula as they were deemed at high risk of post-operative SUI. Overall, 87% considered themselves improved with respect to their incontinence post-operatively, and there were only 4 failures with recalcitrant SUI, in whom 3 had undergone a Pereyra repair rather than PVS. There were no reported cases of sling erosion during the follow-up period.

The placement of a synchronous pubovaginal sling is advocated by some authors in the present of stress incontinence, and dependent on the dissection undertaken [8, 35]. Their arguments for this are that a delayed 2-stage approach may result in significant scar tissue, making subsequent sling placement more difficult, with a potentially higher change of urethral damage or sling erosion. Some urethral surgeons have proposed a diminished risk of post-operative SUI when a dorsal surgical approach is used, as the urinary sphincter is less likely to be damaged than when a ventral approach is used [3], but there is some disagreement even about this [8, 35]. Certainly the use of mesh slings would usually be considered a contra-indication in the setting of urethroplasty [4]. Given the paucity of research negating or supporting a synchronous approach, each case should be considered individually until further quality research can be completed.

Tissue engineering

Tissue engineering (TE) is a new and swiftly changing discipline, offering alternative graft material in complex stricture disease where there is poor or minimal native tissue available. Tissue-engineered templates can include de-cellularised tissue, or de novo materials prepared from natural or synthetic origins [36], including porcine tissues. They are prepared by mechanical, enzymatic or chemical treatment to yield tissue that is minimally immunogenic, yet retains collagen, glycosaminoglycans, fibronectin, laminins and other growth factors to allow native tissue cellular attachment and integration [37]. Currently, there are approximately 23 clinical studies describing TE, with only 2 including FUSD [36]. Potential advantages of engineered tissue include diminished donor site morbidity, decreased operative time, and less limitation of surgical technique due to tissue availability.

Mantovani et al. [38] describe the first use of TE matrix in FUS, utilized to repair a 3 cm stricture in a single female. At 6 months, they described radiological and urodynamic

success. Ansari and Karram [39] reported bladder matrix reconstruction outcomes in two women with complete loss of their posterior urethra with urethrovaginal fistula. Only short-term outcomes were reported; one patient had recurrent SUI at 7 months, the other patient had vaginal wall breakdown but the urethra remained intact. To date, most research has focused on male urethral reconstruction [36, 37], and whilst results appear promising, further studies are needed to assess utility in FUS.

Discussion

Female urethral stricture disease is a rare but morbid condition that significantly decreases quality of life. Due to its rare nature, the lack of consensus as to what defines a FUS, and no standardized gradation of surgical success, there remain many questions about the optimal surgical management and graft material.

Despite the small numbers, there is growing interest in this area, and there have been several recent reviews addressing the varying surgical techniques [3, 4, 6–8]. There appears to be a greater appreciation of FUSD as a potential cause of female LUTS, and a concomitant desire to provide a definitive and effective treatment for those women affected, rather than proceeding with the historically utilized recurrent dilatations \pm ongoing ISD.

Many women are still treated with serial urethral dilation, which is costly and painful, and seldom leads to a lasting cure as a standalone procedure. There is questionable evidence for urethral dilation outside of stricture disease [40], and this injudicious use of urethral dilatation may in fact be a causative factor in many women presenting with stricture disease, due to bleeding, extravasation, and resultant peri-urethral fibrosis. Santucci et al. [41] looked at patterns of urethral dilatation and costs to the health care system. They found that despite a relatively low reported incidence of true female urethral strictures in published literature, female urethral dilatation accounted for a reasonably high percentage of office urology visits (929 per 100,000 patients), and an increasing cost to the US health system of \$61 million per year, and that this has increased incrementally by 10–17% annually since 1994.

Urethroplasty is clearly superior to repeat urethral dilation in the male, in whom dilatation success rates vary from as low as 8% to as high as 20% [42, 43]. It stands to reason that the same should be true in females, but unfortunately dilation remained the most common treatment method as reported by Osman et al. [3] in a recent meta-analysis. They found a 47% female dilation success rate but a large majority still requiring ongoing regular intermittent self-catheterization, a result that would be unacceptable and considered a failure in male urethral stricture disease.

The research has some limitations in that it is composed of essentially retrospective reviews with small cohorts of patients, with often limited follow-up. There are no randomized control trials, nor are there every likely to be due to small numbers, and there are very few direct comparative studies between different methodologies. Nevertheless, the evidence presented has revealed good success in female urethral stricture reconstruction with short to medium-term follow-up, particularly with respect to both flap and free graft reconstruction.

The lack of standard definitions and parameters for diagnosing and grading female strictures also limits the quality of the data available, and meaningful direct comparison between studies. Additionally, the intentional exclusion of populations at high risk of stricture or recurrent stricture disease in many studies further limits the numbers available for evaluation, and also the assessment of treatment efficacy in these high-risk groups. In addition, better delineation of site, length and caliber of stricture with respect to type of reconstruction would also be useful for future comparison of which techniques are best suited to certain types of stricture.

Whilst most studies report on voiding function and further interventions, many offer limited commentary regarding stress urinary incontinence post-procedure, despite this being listed as a significant risk factor for consideration when deciding upon different surgical options. Furthermore, many studies fail to report on other symptoms such as sexual dysfunction, which is also purported to be a potential risk factor in urethroplasty, and a significant quality of life issue. Those complications that are reported have not been standardized or reported in a manner that allows meaningful comparison between studies. Perhaps moving forward, further research would be aided by the adoption of a standardized definition and diagnostic parameters, as well as better patient inclusion, standardized reporting of complications (such as with the Clavien-Dindo classification system), and inclusion of sexual side effects of surgery, as well as formal, reproducible assessment of patient satisfaction/improvement.

Conclusion

Despite the small numbers and series published, there is increasing appreciation that female strictures are a distinct clinical and pathological entity in themselves, which can cause significant voiding dysfunction and diminished quality of life for those affected. It needs to be emphasized still that not all female LUTS are due to strictures, and likewise not all female LUTS respond to “therapeutic urethral dilatation,” which in fact, could be causing strictures.

Female urethral strictures should be carefully evaluated and afforded the same respect in terms of decision making and outcome measures that male urethral strictures

are. Women with problematic strictures should be offered appropriate counseling, investigation, and explanation of all treatment options available. Given the very good results published to date with female urethral reconstruction, women who fail one attempt at dilatation should be offered definitive reconstruction, unless they are unsuitable or do not wish to consider this as a treatment option. The most important factor in selecting surgical technique is location and length of stricture, followed by availability and health of local and/or graft tissues. Surgeon preference and familiarity with approach also play a significant role in technique selection. Hopefully with clarification of definition and diagnostic criteria, as well as further research and comparison of techniques with longer periods of follow-up, remaining questions regarding technique and patient selection will be able to be better answered.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interest.

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