Reconstruction. Literature Review

JCU

Journal of Clinical Urology
2019, Vol. 12(1) 20–31

DOI: 10.1177/2051415818772218
journals.sagepub.com/home/uro
SAGE

Contemporary management of ureteral strictures

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Abstract

Ureteral stricture disease is a luminal narrowing of the ureter leading to functional obstruction of the kidney. Treatment of strictures is mandatory to preserve and protect renal function. In recent times, the surgical management of ureteral strictures has evolved from open repair to include laparoscopic, robotic and interventional techniques. Prompt diagnosis and early first line intervention to limit obstructive complications remains the cornerstone of successful treatment. In this article, we discuss minimally invasive, endo-urological and open approaches to the repair of ureteral strictures. Open surgical repair and endoscopic techniques have traditionally been employed with varying degrees of success. The advent of laparoscopic and robotic approaches has reduced morbidity, improved cosmesis and shortened recovery time, with results that are beginning to mirror and in some cases surpass more traditional approaches.

Level of evidence: Not applicable for this multicentre audit.

Keywords

Endoscopic, laparoscopy, open surgical repair, robotic, ureteral stents, ureteral stricture

Date received: 17 December 2017; accepted: 17 January 2018

Introduction

Ureteral stricture disease is a luminal narrowing of the ureter leading to functional obstruction of the kidney. Treatment of strictures is mandatory to preserve and protect renal function. Often, the degree of obstruction is dependent on the location, severity and primary cause of the ureteral stricture.

In recent times, management of ureteral strictures has evolved from open repair to include laparoscopic, robotic and interventional techniques. In this article, we will discuss minimally invasive, endo-urological and open approaches to the repair of ureteral strictures.

Aetiology

An understanding of the aetiology of a ureteral stricture is crucial to determining the appropriate course of management. Many times, the aetiology of a ureteral stricture can fall under the umbrella of benign or malignant disease, as well as the secondary effect of intrinsic or extrinsic ureteral obstruction.

Whether benign or malignant, most ureteral strictures form after a period of prolonged ischaemia leading to inflammation, fibrosis and stricture formation. Often a histological examination of tissue from a ureteral stricture will reveal inflammation, collagen deposition and fibrosis.

Among the most common causes of malignant ureteral stricture are urothelial carcinoma, or metastatic cervical, prostatic, ovarian, breast and colon cancer.[1] Lower ureteral

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strictures are often the result of the treatment for certain pelvic malignancies; a review of a large prostatectomy cohort also revealed an intraoperative incidence of ureteral injury of approximately 1–2%. Panurethral stricture after endoscopic treatment of low grade urothelial carcinoma is estimated at approximately 8.6%.[2] In contrast, upper ureteral strictures are uncommon, and typically represent approximately 2% of iatrogenic ureteral strictures related to cancer treatment, usually related to partial nephrectomy or radiofrequency ablation.[3]

Benign causes of ureteral strictures include radiation, infection, trauma, aortic aneurysms and most importantly, nephrolithiasis and ureteral instrumentation.

A recent series examining over 270,000 patients undergoing ureteroscopy and extracorporeal shock-wave lithotripsy (ESWL) for nephrolithiasis revealed that patients undergoing ureteroscopy carried a significantly higher risk of stricture (3.0%) over ESWL (2.0%).[4] Stricture was also more commonly seen in female patients, patients presenting with preoperative hydronephrosis and patients with known renal calculi. The degree and type of force required for manipulation and fragmentation may play a role in stricture formation. Stone passage is also affiliated with ureteral stricture, particularly in patients with an impacted calculus for at least 2 months' duration.

Infections including tuberculosis and schistosomiasis have also been implicated in the formation of ureteral strictures.

Radiation therapy and retroperitoneal fibrosis have been shown to induce slowly progressing microvascular injury and stromal fibrosis. Stricture formation in these patients is often secondary to hypoperfusion. The effects of radiation for cervical cancer has been well documented and has been shown to have an increased risk of ureteral stricture, as the radiation dose to the ureters is often higher in this cohort than those for bladder or rectal cancer. In one Canadian series that retrospectively examined the aetiology of ureteral strictures diagnosed in the office setting, 28% of patients were found to have a history of pelvic radiation.[5] The time to the development of stricture after radiation therapy is variable; a recent prospective study found that the mean time to diagnosis of stricture after radiation therapy was approximately 2.75 years.[6] Many patients who undergo pelvic radiation and ureteral manipulation are likely to be at increased risk of ureteral stricture development.

Iatrogenic injury during gynaecological and urological surgery continues to contribute to the development of ureteral strictures, typically at the level of the distal ureter.[7] After ureteroscopic procedures, the rates of injury are approximately 11%.

Diagnosis

Diagnosis of ureteral strictures remains a challenge for most practitioners. History and physical examination may reveal intermittent flank pain and fullness, especially at the time of diuresis; however, many diagnoses are made incidentally under direct visualisation at the time of the ureteroscopic procedure. Patients with a solitary kidney may also present with worsening renal function.

Imaging

An ultrasound may be used as a screening examination for hydronephrosis; however, this is not an ideal imaging modality for ureteral stricture. However, cross-sectional imaging is needed to delineate clearly the extent and location of a given stricture. Previously, intravenous pyelogram was commonly used as a diagnostic tool in this patient population; however, this has been superseded by advanced computed tomography (CT) and magnetic resonance imaging techniques.

CT urography

CT urography remains the gold standard for the diagnosis of ureteral stricture disease. This imaging modality is effective for delineating a patient's anatomy as well as the location of a ureteral stricture. Non-contrast CT urography has also been used to identify perinephric fat stranding, calculi and urine extravasation. At this time, the radiation dose for a CT urogram has been found to be comparable to intravenous urography and therefore poses no increased risk.

However, the use of intravenous contrast is limited in patients with contrast allergies and poor renal function.

Magnetic resonance urography

Dynamic or gadolinium-enhanced magnetic resonance urography, especially in the paediatric population, has the advantage of providing functional and anatomical information on the genitourinary tract, without the risk of radiation exposure. Function can be accessed by renal transit time for gadolinium through the renal unit. A $t_{1/2}$ of less than 10 minutes is considered normal, 10–20 minutes intermediate and over 20 minutes is considered obstructed. Magnetic resonance urography has also been found to be capable of delineating an acute narrowing of the ureter in the absence of obstruction.[8–10]

Invasive imaging

Invasive techniques such as retrograde pyelography are highly sensitive at diagnosing small intraluminal soft tissue defects and are also useful in relaying this information in real time intra-operatively to guide endoscopic or surgical repair of strictured areas. It also avoids the use of intravenous contrast.

Endoscopic intraluminal ultrasound of the ureter has been shown to be useful in assessing the mucosa, submucosa and periureteral anatomy including the presence of crossing vessels and therefore in characterising the nature and density of strictures and the likelihood of their response to endoscopic treatment.[11] Its disadvantages are that it is invasive, subjective, requires specialist training and is unsuitable for those with near to complete ureteral obstruction. Although it may play a role in diagnosis and directing treatment, its use is not currently well established.

Virtual endoscopy has long been established in the investigation of hollow organs and is widely used in colorectal surgery. Several small studies into the use of CT and magnetic resonance virtual upper urinary tract endoscopy have shown promising results, especially in providing virtual endoluminal navigation both cephalic and caudal to a stenosed segment; however, larger comparative trials are required.[12]

Nuclear medicine

In order to establish the degree of function of the affected kidney, nuclear medicine diuretic imaging is used. While of limited value in defining the anatomy, the measurement of isotope tracer clearance over time provides an accurate estimate of renal blood flow and therefore renal function. At least 20% function is required in the ipsilateral kidney to achieve a reasonable outcome from endoluminal repair, and less than 15% is associated with a poor outcome.[13]

Open surgical repair

Depending on the location and length of the strictured segment, uretero-ureterostomy (UU) or uretero-neocystostomy with or without a psoas hitch/Boari flap is often the procedure of choice.

In certain selected situations a transuretero-ureterostomy, intestinal (ileal) interposition, or renal mobilisation and autotransplantation may be more appropriate alternatives.

Various techniques are employed in open surgical repair of a ureteral stricture. A detailed evaluation to determine the origin, severity and location of the stricture as well as the anatomy of surrounding structures is useful in deciding which technique to employ.

The choice of surgical incision depends on the level of the ureteral stricture. A flank incision is appropriate for the upper ureter. A lower midline incision is suitable for the middle and lower ureter. The approach is usually extraperitoneal except in cases of transperitoneal surgical ureteral injury. Options for repair are:

1. Uretero-ureterostomy;
2. Uretero-neocystostomy;
3. Psoas hitch;
4. Boari flap;
5. Transuretero-ureterostomy;
6. Intestinal substitution;
7. Renal autotransplantation.

Uretero-ureterostomy

This approach is suitable only for short, 2–3 cm or less, mid or proximal ureteral strictures.[14] A water-tight anastomosis is performed over a JJ ureteral stent using absorbable sutures. This method of repair may be combined with a psoas hitch or occasionally a Boari flap. It is contraindicated in strictures greater than 3 cm. Guiter et al.[14] reported success rates of over 90% with this procedure in renal transplantation. Fistulae have been reported in up to 4% of repairs. Other complications include anastomotic urine leakage and stenosis.

Uretero-neocystostomy

This approach is appropriate for managing distal ureteral strictures of 4–5 cm or less with or without a Psoas hitch or Boari flap. Lucas et al. were among the first to report excellent results.[15] In a retrospective review of uretero-neocytostomies in adults, Stefanovic et al. compared rates of stenosis and renal impairment in anti-reflux and non-antireflux procedures and found no significant difference in outcome.[16] Urinoma from chronic anastomotic urine leakage, peritonitis and retained ureteral stents are some of the other possible complications.

Psoas hitch

This technically simple but effective procedure is often used as an adjunct to UU or uretero-neocystostomy to minimise tension following ureteral anastomotic repair for strictures involving the distal ureter. A psoas hitch may be useful in bridging distal ureteral defects up to 8 cm from the ureteral orifice. Warwick and Worth described the ‘psoas bladder-hitch procedure’[17] in 1969, a development of earlier techniques by Dolff[18] and Paquin.[19] Excellent success rates have been reported with this procedure.[20–22] Staehler et al., however, reported a failure rate of 16% in 111 patients, 46% was for distal ureteral strictures.[21] A psoas hitch should be avoided in any poorly compliant bladder with limited capacity and restricted mobility. Bladder outlet obstruction and neurogenic bladders are other contraindications. Common complications include urinary fistulae, ureteral obstruction, urosepsis, injury to genitofemoral/femoral nerve and/or adjacent vessels/viscera.

Boari flap

This technique involves the construction of a bladder flap, which is used as a substitute for lost lower ureteral tissue. Previously, this technique was to be employed solely as an adjunct to uretero-neocystostomy in situations in which extensive ureteral structuring has resulted in the loss of up to 10–15 cm of viable mid-distal ureteral tissue. However, more recent reports reveal that a downward nephropexy in addition to a Boari flap can be used. Boari first described this technique in 1899.[23] Published long-term reports are limited and involve only a small number of patients. Results are nevertheless encouraging with successful outcomes in over 90% of patients reported in some cases.[24–26] A modified spiralled bladder flap has been explored in patients with longer stricture lengths with no evidence of ureteral stricture recurrence at 4 years' follow-up.[27] This procedure should ideally be avoided in untreated bladder outlet obstruction or in neurogenic bladders. Flap ischaemia, stricture recurrence and urosepsis are the most frequently cited complications.

Transuretero-ureterostomy

This technique is useful in cases in which the length of healthy ureter is insufficient to create a tension-free anastomosis and psoas hitch or Boari bladder flap are impractical. It is also useful in situations involving chronic/recurrent pelvic pathology, or in the context of a previously radiated pelvis. Contraindications to a transuretero-ureterostomy include insufficient donor ureteral length, contralateral ureteral stricture disease, nephrolithiasis, urothelial malignancy, prior genitourinary tuberculosis, chronic pyelonephritis, abdominal/pelvic radiation and retroperitoneal fibrosis. The earliest reports of successful procedures were in the paediatric population,[28–30] but more recent series in adults have shown similar results.[31, 32] Complications include urine leakage at the anastomotic site, stenosis at the site of anastomosis, reflux, ureteral stenosis, requiring re-operation and, rarely, nephrectomy.

Transuretero-pyelostomy is an even rarer alternative with a lower risk of stricture in the recipient ureteral segment; however, this is known to have an increased risk of donor ureteral obstruction secondary to ureteral kinking as it is stretched across the retroperitoneum.[33]

Uretero-calicostomy

This is another rare technique used to approach proximal ureteral strictures involving the ureteropelvic junction. This approach is typically used in children and patients with horseshoe kidneys. This is also a viable option for salvage of a failed robotic pyeloplasty. In a series of 22 patients, Osman et al. reported no recurrence of obstruction by intravenous pyelogram or nuclear renography.[34] Patients who failed typically underwent definitive treatment with nephrectomy or chronic double J ureteral stents.

Intestinal substitution

This procedure is rarely performed but may be the only practical option when complex and multiple strictures involve the entire ureter and a Boari flap is contraindicated. Ileal ureteral substitution was attempted on human patients in 1906, studied in canine models in 1958, and later popularised by Goodwin and colleagues by the middle of the 20th century.[35–37] Waldner et al. noted that using ileal segments greater than 15 cm in length appeared to discourage reflux reaching the renal pelvis.[38] The major benefit of this intervention is that patients avoid the problems associated with long-term percutaneous kidney drainage, ureteral stents and nephrectomy. Furthermore, the ileal ureter requires no external devices and preserves renal function.[39] Careful preoperative patient selection is essential for good outcomes. Initial comparisons with laparoscopic outcomes have shown a decreased length of stay and improved recovery time.[40] Patients with serum creatinine over 2 mg/dl should ideally be avoided. Other contraindications included bladder dysfunction, outlet obstruction, inflammatory bowel disease and radiation cystitis. Armatys et al. reported improved or stable renal function in almost 75% of patients.[39] Hyperchloremic metabolic acidosis may be present in up to 14% of patients with 10–14% developing other major complications requiring intervention.[39, 41, 42] Four cases of malignant transformation from the ileal ureter have been reported worldwide, hence endoscopic surveillance of the interposed segment is recommended.[43]

Renal autotransplantation

This option is considered in cases of complex multiple or extensive ureteral strictures for which the contralateral kidney is either non-functioning or absent and other methods of ureteral repair/substitution is contraindicated. Rajfer et al. reported excellent long-term results in eight patients following successful pyelovesicostomy.[44]

In general, open surgical repair still has a place in the management of ureteral stricture disease. In broad terms, the prognosis is excellent if diagnosis is made promptly and a timely appropriate corrective procedure is instituted.

Laparoscopic/robotic approaches to ureteral reconstruction

Surgery for ureteral reconstruction revolves around the core principles of ensuring adequate vascular supply, tension-free anastomosis with direct mucosal apposition, as well as ensuring the complete excision of pathological segments. In theory, the options for laparoscopic or robotic-assisted approaches to ureteral reconstruction are viable across the entire length of the ureter, mirroring open surgical techniques.[45]

A rising trend for robotic-assisted approaches over laparoscopic techniques, in order to facilitate minimal access surgery, has been observed.[46] The main advantages of minimal access surgery for ureteral reconstruction are reduced physiological insult of surgery, reduced blood loss intraoperatively, reduced postoperative pain and a more rapid recovery with a more acceptable cosmetic outcome for the patient.

Traditionally, the laparoscopic and robotic options for repair include:

1. Ureteral re-implantation with a Boari flap;
2. Uretero-ureterostomy;
3. Ureterolysis.

Ureteral re-implantation with Boari flap

Studies comparing open and robotic approaches to uretero-neocystostomy with the creation of a Boari flap have suggested that robotic intervention provides excellent outcomes in addition to significantly decreased operative time and decreased estimated blood loss.[45, 47] Recurrence-free survival at 12 months has also been shown to be excellent.[48]

Laparoscopic and robotic comparisons for this technique have shown that patients had similar outcomes, operative times, estimated blood loss and lengths of stay.[49]

Uretero-ureterostomy

Similar to the open approach, the UU is suitable only for short 2–3 cm or less mid or proximal ureteral strictures.[50] The patient is traditionally positioned in dorsal lithotomy and Trendelenburg positions. The ureter is mobilised, the pathological segment is excised, the ureteral end is spatulated for 5 mm on the distal and proximal segments, and an end-to-end anastomosis is created. A water-tight anastomosis is performed over a JJ ureteral stent using absorbable sutures. Occasionally, a peritoneal/omental overlay flap may be used to increase the blood supply to the anastomosis. A psoas hitch with Boari flap or nephropexy may be used to ensure a tension-free anastomosis. The first laparoscopic UU was reported in 1992 by Nezhat and Nezhat;[51] this was followed by several retrospective reviews comparing open and laparoscopic outcomes after UU.[52–54] More recently, a review of seven patients who had undergone laparoscopic UU were re-evaluated at 1 and 5 years postoperatively.[55] Five out of seven patients (70%) experienced a complete recovery, defined as no clinical, biochemical or radiological recurrence at 5-year follow-up. The procedure's limitations are predominantly related to the absence of tactile feedback, limiting complete resection of the stricture. Several authors have recommended the use of a rigid ureteroscope to confirm the length of the stricture.[56, 57] Recently, a single surgeon operative experience with robotic UU for upper, mid and distal ureteral strictures found that patients had 100% recurrence-free survival at 3 years follow-up; however, this procedure is technically limited by complex port placement.[58]

Ureterolysis

Laparoscopic ureterolysis has been reported in cases of failed endoscopic intervention for patients with complex or long ureteral strictures.[59] This is typically performed in the Valdivia–Galdakao decubitus position, a modified lithotomy position that allows for concomitant ureteroscopic intervention for patients with impacted ureteral calculi.

Overall, robotic-assisted surgery offers a greater ergonomic advantage for the surgeon and a shorter learning curve than laparoscopic surgery, but with similar overall clinical outcomes. It is probable that the use of robotic-assisted surgery in reconstruction will be initially in centres where the expertise is already present, followed by more widespread adoption with the increased uptake of the technology.

Ureteral replacement

Previously, for multifocal and complex ureteral strictures, the creation of an ileal ureter or renal autotransplantation remained the mainstays of the urologists' armamentarium for treatment. Initial attempts to perform robotic or laparoscopic ureteral replacement have shown promising results in terms of time to recovery.[40, 60] However, the reconstruction itself is associated with high morbidity and a high complication rate. Many studies have sought to address this issue by finding an alternative acceptable ureteral replacement.

Buccal mucosal grafts

Theoretically, buccal mucosal grafts present an attractive option for ureteral substitution in otherwise challenging proximal ureteral strictures due to their thick, non-keratininised epithelial layer and vascular lamina propria, as well as their histological similarity to urethral mucosa. Somerville and Naude first described a technique for ureteral reconstruction using buccal mucosa in 1984, and the concept has continued to gain traction ever since.[61] This technique has taken many forms, including an omental onlay and augmented anastomotic techniques.[62–65] Initial series reveal promising results, with no evidence of recurrence at 24 months' follow-up,[64] but longer follow-up is undoubtedly needed.

Biological grafts

Both acellular and cellular biological grafts are also being explored for the treatment of ureteral strictures, with current *in vivo* studies demonstrating the development of tissue histologically analogous to the native ureter.[66]

Human dura mater and amniotic membrane allografts have been explored with promising results at long-term follow-up.

Other studies have demonstrated the feasibility of generating cartilaginous stents *in vitro* and *in vivo* using chondrocytes which may be used in the treatment of ureteral strictures.[67] Glybochko et al. in a review, have reported tissue engineering in ureteral reconstructive surgery.[68] It involves the usage of matrices and cells. Tissue engineering for different ureteral impairments has been reported in preclinical studies. Currently, there are no data on the use of tissue engineering for ureteral reconstruction in humans.[68] Another study demonstrated the differentiation potential of adipose-derived stem cells into smooth muscle cells required for ureteral tissue engineering.[69]

Endoscopic management

Ureteral stent

Ureteral stent insertion is performed in the acute phase to decompress the upper renal tract, for infected systems, or to preserve renal function. This can be carried out in a retrograde or percutaneous antegrade fashion. The purpose of ureteral stent is temporarily to maintain the patency of the upper renal tract until the cause of the stricture, either extrinsic or intrinsic, is addressed. The most common polymeric compounds used to form ureteral stents include polyurethane, Silitek, C-flex, Percuflex or Tecoflex.

In patients with terminal malignancy causing extrinsic compression, a ureteral stent may be used as 'long-term' solution but is not without its problems. Initial retrograde stenting in these patients is often challenging, with some series quoting insertion failure rates up to 52%,[70–72] especially in patients in whom significant extrinsic radial compression is the primary aetiology of stricture. Those with ureteral stent *in situ* may experience early failure, with stent obstruction necessitating further stent change or percutaneous nephrostomy. In one series involving 157 patients, Ganatra and Laughlin[72] reported a 36% stent failure rate in patients with malignant extrinsic ureteral compression. Twenty per cent of the patients required percutaneous nephrostomy, on average 6 months after the initial stent. Chung et al.[73] showed a similar stent failure rate of 41% within a year and 30% of patients required percutaneous nephrostomy at a mean of 40 days. Tandem ureteral stent has been suggested to be more effective but there are very limited data on this.[74, 75] A few studies have also compared the impact on quality of life (QoL) in patients with either ureteral stent or percutaneous nephrostomy to relieve ureteral obstruction using validated surveys. Joshi et al.[76] showed that patients with ureteral stents have more irritative urinary symptoms but there is no difference in the overall gross impact on health-related QoL. More recently, Monsky et al.[77] also concluded that there was no significant difference in QoL between the two groups, although patients with ureteral stent have a higher incidence of pain and required more frequent changes of tube.

The coating of stents with antifouling agents, heparin, polymers, silver, diamond-like hydrocarbons and hydrogel has been used to decrease the adhesion of bacteria and thereby prevent stent encrustation, with variable results. Heparin-coated stents *in vivo* have been shown to have no encrustation at one year from the time of placement, as compared to 76% of polymeric stents with encrustation within the same time frame.[78]

Drug-eluting stents using fluoroquinolones, nitrofurantoin, Triclosan, ketorolac and taxols have been studied *in vitro* and in animal studies, with some evidence of decreased adhesion in common species such as *Eschericia coli, Klebsiella pneumonia* and *Staphylococcus aureus*.[79–83] However, larger scale human studies are needed and US Food and Drug Administration approval has been limited by concerns about the development of bacterial resistance.

In patients requiring stenting of a transplant ureteral stricture, tandem stents have been explored as temporary management of patients with these strictures, and may occasionally be used after balloon dilation of the strictured segment.

Extra-anatomical stents have also been investigated as a possibility for long-term management in these patients with the advantages of an improved QoL, minimal encrustation, and no requirement for an external drainage device. In one series of nine patients, all patients reported a significantly improved QoL. However, this technique may not be used in patients with extensive pelvic tumours due to the risk of fistulisation and tumour seeding of the surgical tract.

Balloon dilatation

Balloon dilatation is commonly used in the initial management of ureteral stricture but is mainly reserved for benign aetiology, as studies have shown poor results with malignant extrinsic obstruction.[84, 85] Similar to ureteral stent insertion, the procedure can be performed in either retrograde or antegrade fashion. The key steps involve getting guidewire access in the upper urinary tract past the stricture, placing and inflating the balloon catheter under fluoroscopic guidance and insertion of a ureteral stent.

The reported success rates vary between 48% and 88%, with a mean success rate of 55%, with most studies having follow-up of less than 2 years.[86] There is, however, no consensus in practice in terms of the balloon size used, number of inflation cycles, or the duration for which the ureteral stent must be left *in situ*. In another review, Goldfischer and Gerber reported a success rate of 50–76%, with short and non-anastomotic strictures having more favourable outcomes.[87] Richter et al. showed that balloon dilatation was not only more successful in benign short strictures but also those with intact vascular supply, with an 89% success rate compared to a 40% success rate in the control group.[85] In a prospective study, Byun et al. concluded that a benign ureteral stricture length of less than 2 cm was a significant prognostic factor for better outcome.[84] Antegrade balloon dilatation of ureteropelvic junction and ureterovesical junction ureteral strictures was explored in a series of 12 paediatric patients with good outcomes, and is now considered an additional option for the management of postoperative strictures. While this procedure allows for lower perioperative morbidity and shorter hospitalisation, some complications include renal haemorrhage, urinary tract infections and urinoma.[88]

Overall, balloon dilatation is a minimally invasive procedure with acceptable results for benign short strictures and should be considered as first line management in such strictures.

Endoureterotomy

Endoureterotomy is another useful part of the armamentarium to urologists and is often performed in combination with balloon dilatation. The procedure can be performed with cutting devices under direct ureteroscopic vision or by fluoroscopic guidance using a cutting balloon catheter. Whenever possible, a retrograde approach should be used as it is less invasive and the miniaturisation of endoscopes has enabled better and safer access of the upper renal tract. The general principle with endoureterotomy is to make an incision from the ureteral lumen out to the periureteral fat in full thickness and should include 2–3 mm of normal tissue proximally and distally. As a precaution to avoid nearby vessel injury, distal ureteral strictures are incised along the anteromedial wall, whereas upper ureteral strictures are incised posterolaterally. Various cutting devices are available including cold knife, electrocautery and holmium laser. Cold knife requires a rigid ureteroscope, whereas electrocautery and laser fibre can be passed through a flexible ureteroscope.

The cutting balloon catheter can be passed retrogradely or antegradely in a similar way to balloon dilatation under fluoroscopic guidance. In a multicentre study, Preminger et al. reported a success rate 55% in 49 patients with an average follow-up of 9 months.[89]. Two other smaller series with a longer follow-up of 22 months demonstrated success rates of 61% and 73%.[90, 91] Seseke et al. found that patients with strictures of less than 1.5 cm, renal function greater than 25% of total function and time from iatrogenic injury to appearance of stricture more than 6 months have favourable outcomes.[91]

Yamada et al. treated 19 patients with cold-knife endoureterotomy combined with balloon dilatation and reported a success rate of 85% with an average follow-up of 18 months.[92] Schneider et al. also showed a similar success of 83% with cold-knife endoureterotomy in 12 patients with distal ureteral strictures.[93]

The success rates of endoureterotomy with holmium laser varies from 53% to 88%.[94–99] In a series of 35 patients with benign ureteral stricture who underwent laser endoureterotomy, Gnessin et al. reported that 82% of patients were symptom free and 79% had no radiological evidence of obstruction.[96] Overall, the success rate was higher for non-ischaemic strictures and stricture lengths less than 1 cm. Razdan et al. also identified stricture length over 2 cm as a significant predictor of treatment failure.[100]

Although most series report favourable outcomes with various modalities for endoureterotomy, there has been no study to compare the effectiveness between the different cutting devices. At present, holmium laser is the preferred choice due to its haemostatic effect, compatibility with the flexible endoscope and it is now widely available in most urology units.[99]

Combined antegrade and retrograde approach

For complex or obliterated ureter, a combined antegrade and retrograde approach may be utilised to re-establish patency. This is achieved by passing a guidewire from one of the lumens, through and through to the other lumen, under direct vision and fluoroscopic guidance. A ‘cut to the light’ technique can also be useful when cutting is made at one end and guided towards the light source from the ureteroscope on the opposite end of the stricture. Knowles et al. reported a 90% patency rate in 10 patients with obliterated distal ureteral stenosis at 36 months’ follow-up.[101] Conlin et al. also showed successful outcomes in seven out of eight patients with complete ureteral obstruction and recommended a combined approach for strictures less than 2 cm long.[102] Lingeman et al. performed the ‘cut to the light’ technique in six patients and were successful in all of them.[103] Macri et al. also managed to perform ureteral stenting successfully in 16 cases using the combined approach without any morbidity.[104] Overall, endoscopic UU should be considered for initial management in patients with short, complex stricture or obliterated ureter, especially in those in whom open surgery is expected to be technically difficult.

Metallic stents

Over the last two decades, various metal ureteral stents have been developed in an attempt to provide more efficient drainage and patency with minimal symptoms. These are primarily targeted for patients with extrinsic malignant ureteral obstruction but are also used in selected patients with benign aetiology. The three main types of metal stents are described below.

Wallstent (Schneider, Switzerland) is a self-expandable, segmental stent made from stainless steel wire mesh. It was first used in the 1990s.[105, 106] Following the insertion of a Wallstent, the stent causes urothelial hyperplasia and oedema. For this reason, a JJ stent is usually placed *in situ* for up to 4 weeks to avoid obstruction.[105, 107] Lugmayr and Pauer first reported a high primary patency rate of 83% at 30 weeks.[105] However, their mid-term results showed a primary patency rate of 31% after 12 months, with 49% of cases requiring re-intervention to establish the patency of the stent.[108] Richter et al. demonstrated a higher patency rate of 58% in 31 patients with at least 2 years follow-up.[85]

In one of the largest series of 90 patients with malignant ureteral obstruction, Liatsikos et al. reported a primary patency rate of 51% within 15 months' average follow-up.[109] Almost half of the patients required secondary intervention to improve patency. Hekimoglu et al. also raised similar issues, involving urothelial hyperplasia and encrustations, which limit the longevity of the stent.[110]

The Memokath 051 stent (Engineers & Doctors A/S, Denmark) is a segmental, thermo-expandable memory stent made of nitinol. It softens and uncoils at temperatures of less than 10°C and expands into position at 60°C. Kulkarni and Bellamy showed promising results in 37 stent insertions, including 18 malignant and 10 benign ureteral strictures.[111] In total, 15 stents were functional at 19 months, while eight patients died with 13 functioning stents. In addition, none of their patients had sepsis, pain or haematuria.[111] In a larger series involving malignant and benign ureteral strictures, Papatsoris and Buchholz reported a 79% overall stent patency at 17 months.[112] Klarskov et al., however, had less favourable results in a series of 33 patients with an overall failure rate of 59%.[113] Other reported complications associated with Memokath stents are stent migration and encrustation.[112–114] Memokath stents have, however, been shown to provide better QoL and less stent-related symptoms when compared to conventional JJ stents.[115]

The Resonance stent (Cook Ireland, Limerick, Ireland) is a continuous metal coil without a lumen, in the shape of a JJ stent, consisting of MP35N alloy (nickel–cobalt–chromium–molybdenum alloy). MP35N is a corrosion-resistant stent with high tensile strength and magnetic resonance imaging compatibility. As it is unfenestrated, urine drains around the outer aspect of the spiral coil. To maintain patency, the manufacturer recommends that the stent is changed every 12 months. The success rates with Resonance stents range from 65% to 77%.[116–118] Kadlec et al.[117] reviewed a total of 139 Resonance stents placed in 47 patients for both malignant and benign aetiology. They reported a success rate of 72% with an average follow-up of 20 months. They concluded that the failure rates were similar for both benign and malignant aetiology.[117] Liatsikos et al., however, demonstrated a 100% stricture patency rate in patients with malignant aetiology but only 44% in patients with benign aetiology at an average follow-up of 8.5 months.[119] Various studies also looked at the cost-effectiveness of using Resonance stents compared to conventional JJ stents.[119–121] The studies concluded that metallic stents are well tolerated and have a significant cost benefit.

Future approaches

Various techniques have been reported in the literature that may be used in future for the management of ureteral strictures.

For the identification of strictures, one retrospective series demonstrated the role of Indocyanine green dye that can be visualised under near-infrared fluorescence during robotic-assisted ureteral reconstructions. This technique was reported to be accurate for the identification of the ureter and the precise localisation of ureteral strictures.[122]

Anti-reflux procedures also remain an important focus of stricture management. Several authors have investigated anti-reflux procedures, including submucosal tunnelling and ureteral plication. A review of 34 patients with bilharzial strictures recently underwent re-implantation with placement of an intravesical nipple with minimal to no reflux at 6 months' follow-up.[123, 124]

Continuing advances in radiation-induced ureteral strictures include the use of adjunct hyperbaric oxygen therapy and the use of omental flaps to promote the development of healthy ureteral tissue.[6]

Further studies will be needed in human models to ascertain the efficacy and long-term viability of these surgical techniques.

Conclusion

The surgical management of ureteral stricture disease has rapidly evolved over the past 20 years. Prompt diagnosis and early first line intervention to limit obstructive complications remains the cornerstone of successful treatment. The advent of laparoscopic and robotic approaches has reduced morbidity, improved cosmesis and shortened recovery time, with results that are beginning to mirror and surpass traditional open surgical repair.

Conflicting interests

The authors declare that there is no conflict of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethical approval

Not applicable.

Informed consent

Not applicable.

Guarantor

JM.

Contributorship

VV researched literature and contributed in writing Introductory section of manuscript. EJ researched the literature, wrote the section on open surgical repair of ureteral stricture and the conclusion, arranged individual sections / subheadings and references and edited the final version of the manuscript. KW researched the literature and wrote the section on endoscopic management. MI researched the literature and wrote the section on laparoscopic / robotic approach to ureteral

reconstruction. SJ researched the literature and wrote the section on future approaches. NG edited the manuscript. JM conceived the article, reviewed and edited the final draft of the manuscript. LK conceived the article.

Acknowledgements

None.

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