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INVITED REVIEW

Prostate Disease

Transurethral resection of the prostate stricture management

Jian-Wei Wang, Li-Bo Man

For more than nine decades, transurethral resection of the prostate remains the gold standard for the surgical treatment of lower urinary tract symptoms due to benign prostatic obstruction. The occurrence of urethral strictures after transurethral resection of the prostate is one of the major late complications and has been reported as the leading cause of iatrogenic urethral strictures in patients older than 45 years who underwent urethroplasty. Although several postulations have been proposed to explain the urethral stricture after transurethral resection of the prostate, the exact etiology of urethral stricture after TURP is still controversial. Suggested etiological factors of urethral stricture formation after transurethral resection of the prostate include infection, mechanical trauma, prolonged indwelling catheter time, use of local anesthesia, and electrical injury by a stray current. One single treatment option is not appropriate for all stricture types. The management of urethral stricture following transurethral resection of the prostate includes minimally invasive endoscopic methods, including urethral dilation and direct visual incision, or open surgical procedures with varying urethroplasty techniques. Although scientific studies focusing on urethral strictures after transurethral resection of the prostate are relatively limited and sparse, we can apply the principles of urethral stricture management before making decisions on individual stricture treatment.

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INTRODUCTION

For more than nine decades, transurethral resection of the prostate (TURP), generally carried out as monopolar transurethral resection of the prostate (M-TURP), has been the gold standard for the surgical treatment of lower urinary tract symptoms due to benign prostatic obstruction (BPO) and is regarded as both clinically effective and cost-effective.[1–5] The advent of bipolar TURP (B-TURP) offered an attractive alternative to M-TURP with similar efficacy but lower perioperative morbidity using normal saline irrigation.[1–3,5] Irrespective of the energy source, the occurrence of urethral strictures after TURP is one of the major late complications and has been reported as the leading cause of iatrogenic urethral strictures in patients older than 45 years who underwent urethroplasty.[6] The purpose of this mini-review is to summarize the epidemiology, etiology, and management of TURP stricture.

EPIDEMIOLOGY

Despite decades of use, M-TURP still has a considerable intraoperative and postoperative complication rate.[7] The early complications include hemorrhage, transurethral resection syndrome, and urinary infection/sepsis. Late complications include urethral stricture (US), bladder neck contracture, urinary incontinence, and retrograde ejaculation. The incidence of reported urethral stricture after M-TURP varies widely. Rassweiler *et al.*[4] found that in a series of larger studies and randomized clinical trials, 2.2%–9.8% urethral stricture cases and 0.3%–9.2% bladder neck contracture cases were reported. Although B-TURP addresses a fundamental flaw of M-TURP, it uses normal saline for intraoperative irrigation and thereby eliminates the dilutional hyponatremia risk;[8,9] each system of bipolar resection differs slightly in technologic design as to the electric current delivery (**Table 1**).[8,10–13]

Michielsen and Coomans[12] reported an incidence of 3.3% US associated with bipolar techniques, which is not significantly different from the incidence using conventional M-TURP (2.9%, $P = 0.739$). An international multicenter randomized control trial (RCT) compared the incidence of urethral stricture in B-TURP versus M-TURP and showed that the cumulative short-term urethral rates did not differ significantly (M-TURP *vs* B-TURP: 6.6% *vs* 6.7%; $P = 1.000$) between the two groups, with a mean follow-up of 28.8 months. Furthermore, the midterm results showed that 10 urethral stricture cases were observed in each arm (M-TURP *vs* B-TURP: 9.3% *vs* 8.2%; $P = 0.959$). Tang and colleagues[14] performed a systematic review and meta-analysis of bipolar transurethral resection versus monopolar transurethral resection for benign prostatic hypertrophy, in which 36 and 38 cases of urethral strictures were found in the M-TURP (909 patients) and B-TURP group (948 patients), respectively, in eleven RCT studies or subgroups. In fact, pooled analysis revealed no significant difference in the incidence of urethral stricture and bladder neck contracture between M-TURP and B-TURP.

Common sites of TURP-related urethral strictures are the meatus and fossa navicularis, the penoscrotal junction, the mid-bulbar region, and just below the urethral sphincter.[15] Interestingly, urethral stricture related to transurethral resection by the TURis system

Department of Urology, Beijing Jishuitan Hospital, The Fourth Medical College of Peking University, Beijing 100096, China.
Correspondence: Dr. LB Man (manlibo@yeah.net)
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Table 1: Five different types of bipolar resection devices have been described in medical literature: Gyrus (Gyrus Medical Limited Co., Cardiff, United Kingdom), VIST-CTR (ACMI, Southborough, MA, USA), TURis (Olympus, Tokyo, Japan), S(a)line Resectoscope (Richard Wolf GmbH, Knittlingen, German), and AUTOCON II 400 ESU (Kark Storz Endoskope, Tuttlingen, Germany)[8,10,11]

Bipolar resection devices	*Characteristics of electric current delivery*
Gyrus (PlasmaKinetic System)	"PlasmaKinetic" resection uses a single platinum-iridium loop as an active electrode. The distal end of the loop serves as a neutral electrode
VISTA-CTR (ACMI Elite System)	The first bipolar resectoscope uses two parallel loops, the proximal of which is the active electrode
Autocon II 400 ESU	The resectoscope consists of two opposite loops with the passive electrode as a counterpart
TURis	The resectoscope uses the resectoscope sheath as a neutral electrode
S(a)line Resectoscope	The same principle as TURis

In the TURis system, the return electrode is incorporated in the sheath, and the active electrode is a single cutting loop. Thus, there is a potential chance to expose the entire urethra and penis of the patient to the return energy, although the sheath is double protected to prevent electric current leakage. Some authors have commented that the special electron collection electrode may enable the TURis system to address the potential causes of postoperative urethral stricture, which seems to be related to the pattern of electric current flow during the transurethral resection maneuver[12,13]

(Olympus, Tokyo, Japan) appeared to be more commonly located in the membranous urethra.[13]

ETIOLOGY

The exact etiology of urethral stricture after TURP is still controversial.[16] Suggested etiological factors of urethral stricture formation after TURP include infection, mechanical trauma, prolonged indwelling catheter time, use of local anesthesia, and electrical injury by a stray current.[16,17]

Mechanical urethral mucosa damage

Endoscopic instrumentation is one of the most common causes of strictures of the urethra. TURP inevitably causes a degree of mechanical urethral stress due to the application of a metal resectoscope sheath. Some studies have shown that an improper relationship between instrument size and the urethral meatus diameter would cause mechanical damage to the meatus mucosa and lead to the formation of meatus stricture.[16,17] In China, many resectoscopes are imported from the West with inappropriate instrument diameters when applied to the Chinese population. We observed several cases of serious urethral mucosa damage due to the improper relationship between the caliber of the resectoscope sheath and the lumen of the urethra (unreported). Mamoulakis *et al*.[8,9] detected changes in the urethral mucosa at the end of the TURP, such as injury to proximal bulbous urethra by compression from the resectoscope sheath and multiple narrow rings in the penile urethra, which could develop into strictures. In a prospective randomized trial, Erturhan and colleagues found that a large-diameter resectoscope (27F) caused partial rupture of the bulbomembranous urethra occurring at the first entrance, which contributes to urethral stricture formation after TURP.[18]

To investigate whether resectoscope size plays a role in the formation of urethral strictures following TURP, Günes *et al*.[19] retrospectively compared the urethral stricture rates in patients undergoing TURP with resectoscope sizes of 24F and 26F and found a statistically significant higher incidence of bulbar stricture in patients undergoing TURP with a 26F resectoscope than in those undergoing TURP with a 24F resectoscope (11.4% *vs* 2.9%, $P = 0.018$). Additionally, the use of a noncontinuous resectoscope shaft causes increased meatal stricture incidence due to the reciprocation of the shaft in the axial axis. In addition to the oversized resectoscope and mechanical stress from inappropriate axial and rotating movements of the resectoscope, mucosal damage may also result from longer operative time and longer catheterization time.[12,19]

According to the urethral stricture formation model postulated by Mundy and Andrich,[20] urethral mucosa damage due to mechanical stress will cause inflammation and ischemia, which can lead to subepithelial fibrosis and, if circumferentially confluent, will lead to luminal contracture over time.

Electric current leakage

The leakage of electric current can provoke stenosis. Given the difference in the arrangement of the return electrode between M-TURP and B-TURP, B-TURP can be performed in conductive solution because the resectoscope itself is used as the return electrode. In the process of resecting with conventional TURP or B-TURP, the incidence of a short circuit between the active electrode and the metal sheath or other metal parts integrated in the sheath can lead to a high current density in the urethra, which may induce the risk of electrothermal injury in the corresponding urethral mucosa.[21] The current misconduction may occur when the cutting loops are broken, or there are insulation defects on the sheath, or the trapped carbonized resection materials on the loop create direct contact between the resection loop and the sheath.[21] In addition to electrical power, the conductivity and quality of the lubricant gel should be considered as another important factor that can lead to electrothermal injury of the urethra. When using lubricant with lower conductivity than that of the urethral mucosa, the leaking current may pass from the surface of the sheath to the surrounding urethra at sites where the lubricant film is relatively thin or has been totally displaced.[21] In a randomized trial comparing B-TURP using the TURis system with conventional M-TURP, 136 patients were followed up for 36 months. There was a significantly higher urethral stricture rate in the TURis group compared with the M-TURP group in patients with a prostate volume >70 ml.[13] There are few reports showing a correlation between urethral stricture and larger prostate volume in laser enucleation. Komura *et al.*[13] postulated that a correlation exists between the distinct electrical current flow and the incidence of urethral stricture after TURP, and the results showed that the larger prostate volume and longer operation time could be important predictors of the occurrence of urethral stricture in patients treated with TURis.

The main drawback of bipolar resection is the higher cutting current, generally 270 W, compared with 175 W in conventional monopolar techniques.[12] In fact, the internal high-frequency current during transurethral resection (TUR) can also lead to thermal damage to the urethra, especially for the TURis system, in which the passive electrode is incorporated into the outer sheath. Therefore, a high cutting current should be avoided in M-TURP and B-TURP.[12]

Infection

Insufficiently managed urinary infections may be another risk factor leading to the development of urethral stricture after TURP. Historically, recurrent gonococcal urethritis accounted for the majority of anterior urethral strictures due to internalized gonococci with phagocytic vacuoles, which evoke a brisk inflammatory response and inflammatory infiltrates in the submucosa that ultimately lead to spongiofibrosis and stricture.[22,23] Infections after TURP may mimic the same pathologic process and cause stricture formation. A retrospective study reviewed the data of 917 patients undergoing TURP to evaluate the relationship between pathologically confirmed prostatic inflammation and reoperation rates due to urethral stricture or bladder neck contracture after TURP. The results showed that the

indications for reoperations were urethral stricture (n = 29, 76.3%) and bladder neck contracture (n = 9, 23.7%). The reoperation rate in the prostatic inflammation group was significantly higher than that in the noninflammation group. The authors concluded that prostatic inflammation is an independent variable affecting the development of urethral stricture or bladder neck contracture.[22,23] Another theory postulated that bacterial infection can induce squamous metaplasia in the epithelium of the urethral mucosa, similar to several other factors, such as chemical, physical, or biological, that are not necessary for the further development of the stricture.[20]

Other factors

In addition to mechanical urethral mucosa damage and current leakage, infection, ischemic urethral mucosa, and prolonged indwelling catheterization, the temperature of the irrigation solution may play a role in the pathophysiology of TURP stricture. Park *et al.*[16] compared the effect of warm and room temperature irrigation solution on the incidence of urethral stricture after TURP by a retrospective study. The patients were divided into a warm irrigation solution group (36°C) and a room temperature irrigation solution group (20°C). The 6-month follow-up urethral stricture rate was 21.3% versus 6.3% for room temperature and warm irrigation solution, respectively. Thus, colder irrigation solution may lead to the constriction of blood vessels in the urethra with a higher risk of urethral stricture formation.[16]

Resection time has been identified as a cofactor for developing urethral stricture,[24] not only by exposing the urethra to more electrical energy during the long operation time but also by multiplying the number of instrument sheath movements. Another study showed that a larger prostate volume requiring a longer resection time was an important predictor for the development of urethral stricture after TURP.[13] In summary, main results of studies involving the etiology of TURP strictures are listed in **Table 2**.

MANAGEMENT

Treatment of urethral stricture following TURP includes minimally invasive endoscopic management, including urethral dilation and direct visual incision, or open surgical procedures with varying techniques of urethroplasty.

Urethroplasty techniques include end-to-end anastomosis, augmented urethroplasty with buccal mucosal grafts, and perineal urethrostomy. As we chose an appropriate procedure for patients with TURP strictures, a general point to emphasize is that scientific studies focusing on TURP strictures are relatively limited and sparse. However, we can apply the principles of urethral stricture management before making decisions on individual TURP stricture treatments.

Dilation and urethrotomy

The goal of urethral stricture dilation is to stretch and tear open the partial fibrosis of the corpus spongiosum using plastic dilators over a guidewire in a controlled fashion.

Optical or direct vision internal urethrotomy (DVIU) utilizes a metallic cystoscope sheath to drive a blade into the stricture (and healthy spongiosum, either deliberately or with other surgeons accidentally) usually at 6 o'clock, thereby opening the constricted urethral caliber. Traditionally, DVIU is not performed for strictures >1 cm, and better results are reported for short first-time strictures of the thick-walled bulbar urethra.[25,26] Recent reports have shown that success rates after primary DVIU range from 9% to 60%.[27,28] A randomized study evaluated urethral dilation versus DVIU and found no statistically significant difference in outcomes between the two procedures.[27,29]

Michielsen and colleagues reported 10 cases of US after M-TURP or B-TURP, all of which required a second intervention, including 6 DVIU, 2 external meatotomy, and 2 repeat dilatations.[12] In a retrospective study of 71 patients undergoing TURP with at least 1 year of follow-up, 8 cases of US were detected. Again, all patients required a second intervention, which included DVIU in 5 patients, external meatotomy in 3 patients, repeat dilation in 2 patients, and one patient was managed with urethroplasty.[19]

These series showed that most urologists manage TURP strictures by endoscopic interventions with an associated high recurrent stricture rate. With increasing stricture length, the recurrence rates are even higher.[27,29]

Urethroplasty for TURP strictures

For patients in whom dilation or urethrotomy is inappropriate because of frequent significant stricture recurrence, urethroplasty may be considered.[20,30] However, in many patients after TURP, multiple segments of the urethra are affected by instrumentation trauma, limiting the feasibility and success of the open reconstructive approach.

Table 2: Main results of studies involving the etiology of transurethral resection of the prostate strictures

Author	*Publishing year*	*Main results*
Günes *et al.*[19]	2015	Mechanical urethral mucosa damage: the use of small-diameter resectoscope shafts may cause a reduction in the incidence of urethral strictures in relation to urethral friction and mucosa damage
Erturhan *et al.*[18]	2007	Mechanical urethral mucosa damage: observation of injuries (2.5%) occurred at the first entrance with the big size resectoscope
Faul *et al.*[21]	2008	Electric current leakage: the incidence of a short circuit between the active electrode and the metal sheath or other metal parts integrated in the sheath can lead to a high current density in the urethra, which may induce the risk of electrothermal injury in the corresponding urethral mucosa
Komura *et al.*[13]	2015	Electric current leakage: there was a significantly higher urethral stricture rate in the TURis group compared with the M-TURP group in patients with a prostate volume >70 ml; the larger prostate volume and longer operation time could be important predictors of the occurrence of urethral stricture in patients treated with TURis
Michielsen and Coomans[12]	2010	Electric current leakage: because the passive electrode is incorporated into the outer sheath, a high cutting current during TUR can lead to thermal damage to the urethra
Doluoglu *et al.*[23]	2012	Infection: recurrent gonococcal urethritis accounted for the majority of anterior urethral strictures due to internalized gonococci with phagocytic vacuoles that evoke a brisk inflammatory response and inflammatory infiltrates in the submucosa that ultimately lead to spongiofibrosis and stricture
Park *et al.*[16]	2009	Temperature of the irrigation solution: colder irrigation solution may lead to the constriction of blood vessels in the urethra with a higher risk of urethral stricture formation
Tan *et al.*[24]	2017	Resection time: resection time has been identified as a cofactor for developing urethral stricture, not only by exposing the urethra to more electrical energy during the long operation time but also by multiplying the number of instrument sheath movements

M-TURP: monopolar transurethral resection of the prostate; TUR: transurethral resection

Short bulbar stricture

In general, for short strictures of the bulbar urethra, good results have been achieved using a tension-free end-to-end anastomosis technique with long-term success rates of approximately 90%,[31] but this technique is associated with a reported risk of sexual dysfunction in 18%–22.5% of patients.[32] The SIU/ICUD consultation on urethral strictures recommended that end-to-end anastomosis is an option for short bulbar urethral strictures, regardless of etiology or previous treatment.[33] However, this technique cannot be used for penile strictures, as it would lead to ventral penile curvature during erection.[34]

Long bulbar stricture

The degree of spongiofibrosis in patients with urethral stricture after TURP is usually limited to approximately 10% of the thickness of the urethral wall.[35] Because the dorsal aspect of the bulbar urethra has a thin corpus spongiosum, dorsal stricturotomy can be performed with limited bleeding and preservation of spongiosal blood flow ventrally. This dorsal stricturotomy approach exposes the stricture segment and allows the surgeon to evaluate true stricture length intraoperatively. Very short, membrane-like strictures are suitable for a "Heinke-Mikulicz"-type stricturoplasty, whereas long stricture segments can be augmented with an appropriately sized buccal mucosal-free graft. Some strictures are short enough to achieve a mucosal anastomosis and primary horizontal closure of the dorsal stricturotomy, whereas in other slightly longer but near obliterative strictures, a hybrid anastomosis with buccal graft augmentation can be performed. All technical variations commonly show that the urethra is not transected (unlike the classical end-to-end anastomotic approach), thereby preserving the ventral spongiosal blood flow of the urethra, which has benefits in an elderly population. Bugeja *et al.*[32] reported that selecting the most appropriate operative technical variation of the "dorsal nontransecting bulbar urethroplasty approach" according to the individual intraoperative finding achieved a radiologic success rate of 96.9% in 67 patients with not only idiopathic but also bulbar TURP urethral strictures.

Penile strictures

A number of different tissue transfer techniques are used in penile urethroplasty, including penile skin flap, oral, bladder, and colonic mucosa-free grafts and extragenital skin grafts (dermatome from the upper thigh or lower abdomen). In contemporary practice, oral mucosa grafts, including buccal mucosa and lingual mucosa, are used most commonly in anterior urethroplasty.[36–38] Oral mucosa is tough, resilient, and easy to harvest. This tissue has a thick epithelium with a thin lamina propria and a dense panlaminar vascular plexus, which allows early inosculation between the graft and the corresponding bed. Buccal mucosa is harvested from the inner surface of the oral cavity and lingual mucosa is harvested from the under surface of the tongue. To avoid complications, the parotid gland duct should be identified to prevent unintentional injury to it. A series of studies confirmed that graft substitution urethroplasty with lingual mucosa appeared to be equivalent that with buccal mucosa.[36–39]

Kulkarni *et al.*[40] performed a prospective study for the management of post-TURP stricture. Out of 170 patients, 165 were treated with oral mucosa urethroplasty. The mean (range) buccal mucosa graft length was 6.25 (4–8) cm, and the width was 1.5 (1.3–1.8) cm. The overall success rate was 82.43%. Although controversy exists when considering the choice of a graft or flap for urethroplasty, some research has shown that there is no advantage of a flap over a graft in terms of the stricture recurrence rate.[39,40] However, the advantage of a penile skin flap over a scrotal skin flap is obvious in terms of complications, so a ventral onlay flap of penile skin can be especially helpful for anterior urethral stricture after TURP in some circumstances.[33] Based on the orientation of the skin island and related fascial pedicle, a number of flap designs have been described. Although urethroplasty with penile skin or flaps is technically more demanding than substitution urethroplasty using oral mucosa grafts, ventral onlay techniques with penile skin flaps, especially the Orandi technique, are particularly useful in the management of nonobliterative strictures within the penile shaft after TURP.[41–44]

Perineal urethrostomy

Long multisegment strictures after TURP affect the meatus/fossa, penile, and bulbar urethra, which are very common. Kulkarni *et al.*[40] reported a series of post-TURP strictures and found that 11.2% of panurethral stricture patients had stricture lengths as long as 16.75 cm. These patients, who are usually elderly, may prefer a perineal urethrostomy over interval dilatation management or self-dilatation. Perineal urethroplasty utilized an inverted "U" shaped perineoscrotal skin flap that was sutured into the opened ventral bulbar urethrotomy to create a skin funnel opening at the perineoscrotal junction. This technique is usually a simple and effective procedure for a complex urethral stricture problem. Barbagli *et al.*[45] performed a quality of life assessment for patients treated with perineal urethrostomy for anterior urethral stricture disease. Although a repeat intervention is necessary in as many as 30% of patients, 135 patients (78%) were satisfied with the results obtained with surgery and 33 (19.1%) were very satisfied. As benign prostatic hyperplasia (BPH) is an age-related condition, for elderly patients with multiple comorbidities and severe or panurethral stricture disease, performing perineal urethrostomy is a wise option to provide normal voiding function, with the price of sitting down to void.

TURP STRICTURE PREVENTION

Urethral strictures related to TURP are a significant risk to the patient, and patients are often not fully aware of the potential life-long consequences. More rigorous indications for BPH surgery are the obvious and best prevention of operative complications. Medical device technology of the 20th century relies on prostatic tissue resection or ablation utilizing various amounts of electrical current or laser energy and generally requires a large instrument access sheath, which is the main cause for urethral trauma and subsequent stricture formation.

In the recent 21st century, less invasive device technology innovations are coming into more widespread clinical use (Urolift, Rezum) with the hope that smaller access sheaths and shorter procedure time will lead to reduced functional complications and reduced urethral stricture rates.[46]

As a well-recognized major complication, urethral stricture after TURP is a leading cause of iatrogenic urethral stricture. The management of these patients is challenging, and we should be familiar with the exact etiology of such disease and consider measures of how to protect the integrity of the urethra mucosa when performing the resection. The management of TURP strictures varies widely. With an associated high recurrent stricture rate, endoscopic interventions may not always be effective, especially in patients with long or severe strictures. Actually, oral mucosa grafts, including buccal mucosa and lingual mucosa, are most commonly used in anterior urethroplasty. For elderly patients with multiple comorbidities and severe or panurethral stricture disease, a perineal urethrostomy is not only a clinically expedient treatment but a wise option to provide normal voiding function to these patients.

AUTHOR CONTRIBUTIONS

JWW carried out the design of the review, searched and selected papers related to the review, analyzed the references, and drafted the manuscript. LBM carried out the design of the review. Both authors read and approved the final manuscript.

COMPETING INTERESTS

Both authors declared no competing interests.

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