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MR urethrography versus X-ray urethrography compared with operative findings for the evaluation of urethral strictures

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Abstract

Purpose We compared the accuracy of magnetic resonance (MR) urethrography and X-ray urethrography with operative findings for urethral strictures and observed their effects on treatment.

Materials and methods A total of 87 male patients (10–85 years of age) treated from January 2015 to December 2016 were included in the study. X-ray and MR urethrograms were performed for all patients to determine the location, length, and degree of urethral strictures and the organizational structure around the urethra, and the results were compared with the operative findings. One-way analysis of variance (ANOVA) was performed to compare the lengths of the urethral strictures determined by the two methods with the operative findings. A value of $P<0.05$, calculated using GraphPad software, indicated statistical significance.

Results Urethral stricture was more clearly shown on MR urethrography than on X-ray urethrography. The stricture length measured by conventional X-ray urethrography [(2.17 ± 0.65) cm] was much longer than that measured by MR urethrography [(1.68 ± 0.67) cm]. The surgical findings [(1.66 ± 0.70) cm] were significantly different from X-ray urethrography findings ($F=24.660$, $P=0.000$), but no significant difference was observed between the surgical findings and the stricture length measured by MR urethrography ($F=0.040$, $P=0.842$).

Conclusion Urethral strictures can be displayed more clearly and accurately by MR urethrography than by X-ray urethrography. MR urethrography is expected to become a necessary and standard procedure for the preoperative examination of urethral strictures.

Keywords Urethral stricture · Magnetic resonance imaging · X-ray urethrography

Introduction

Urethral stricture refers to any abnormal narrowing or obliteration of the anterior or posterior urethra, which is a challenging condition for urologists due to its complexity and recidivity [1]. Significant advancements in the treatment of urethral stricture have occurred in the past 20 years, which is attributed to increased understanding of the pathology and implementation of imaging technique that have improved surgical procedures [2].

Urethral dilation and direct vision internal urethrotomy (DVIU) are regarded as initial treatment options for most urethral strictures, but have no cost-effective or beneficial harvest for those patients with high recurrence rates [3, 4]. The surgical management of stricture is complex and challenging, because multiple factors should be taken into account [5]. Location, degree, length and aetiology of urethral stricture are considered as important factors to designate the treatment methods [3, 6]. Among them, the etiology is more closely related to the recurrence of urethral stricture on account of the inflammatory tissue and regenerative fibrous scar tissue in and around the urethral wall in most conditions [2, 5]. If the situation of urethral stricture is shown clearly by imaging technique preoperatively, surgeons could plan the surgical strategy of the lesions on the workstation rather than in the operation room [7, 8].

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X-ray urethrography, including retrograde urethrography (RUG) and voiding cystourethrography, is considered as the "gold" standard for diagnosing urethral stricture [9]. This approach could show the approximate location and degree of the urethral stricture, but it has certain limitations for accurately detecting the length of the stricture, fibrosis around the urethra, and even an end dislocation [10]. Although ultrasonography is a very useful tool for determining the stricture length and assessing the degree of fibrosis, it is not recommended to be solely used for the assessment of strictures due to its small field of view and difficulty in delineation of the urethral lumen [11, 12].

Magnetic resonance imaging (MRI) is an imaging technique with high resolution of soft tissue. Magnetic resonance (MR) urethrography could not only delineate the accurate location and length of the urethral stricture but also distinguish the different organizations around the stricture [13]. However, MR urethrography in the voiding/retrograde condition is currently rarely used to diagnose and evaluate urethral strictures. Our research was to compare MR urethrography with X-ray urethrography in the consistent state to diagnose and evaluate urethral strictures according to the surgical findings.

Materials and methods

This study was approved by the Ethics Committee of The Affiliated Huai'an No. 1 People's Hospital of Nanjing Medical University, and informed consent was obtained from all participants. This prospective study was conducted from January 2015 to December 2016 and included 87 male patients (mean age 63.3 ± 13.7 years; 10–85 years of age) with dysuresia. Of them, 35 of patients were unable to urinate autonomously and could not be catheterized from urinary meatus, and then had suprapubic catheters used for urination.

X-ray urethrography and MR urethrography were performed for all patients 3 days before the treatments. Patients enrolled in this study did not have MR contraindications such as pacemakers and metal external fixators. The location (the anterior or posterior urethra or bladder neck), degree (narrowing or obliteration) and length of the urethral stricture were diagnosed from the X-ray and MR urethrograms, and the organizational structure (the scar tissue or oedema) around the urethra was estimated from the signal characteristics of MR images. These images' judgement was responsible by two radiologists with 10 years of experience in X-ray and MRI diagnosis.

X-ray urethrography

RUG

The patients were prepared in the position of 45° tilted and near-bed-side legs bent on the X-ray machine (BSX-200: SHIMADZU, China) and the penis was straightened vertically along the long axis of the body. The balanus was disinfected, a catheter was inserted from the external orifice of the urethra, and then the balanus was compressed. Alternatively, a syringe nipple was inserted directly from the external orifice of the urethra and then it was closed. 15–20 ml of contrast agent (10–25% meglumine diatrizoate, Xudong Haipu Pharmaceutical Company, Shanghai, China) was infused from the catheter or syringe. The X-ray examination was performed in the prepared position after the infusion of contrast agent. An antero-posterior (A-P) film had been obtained and the length of urethral stricture was measured with reference scale.

Voiding cystourethrography

300–400 ml of contrast agent was infused into the bladders through the suprapubic catheters until the patients had an urge to urinate. The patients were exposed on X-ray in the same position with RUG when they were asked to void. Also A-P films were obtained, and then it was measured of the length of urethral stricture or the distance between two disrupted ends of the urethra with reference scale.

All the patients were first examined by RUG. When the urethra was unobstructed, the contrast agent could enter the bladder. If the entire urethra was not completely displayed, the voiding cystourethrography was undergone after the contrast agent was infused to bladder through suprapubic catheters.

MR urethrography

MR urethrography was performed with every patient lying in a supine position using a six-channel abdomen coil with a 3.0 T MRI scanner (Verio: Siemens Healthcare, Erlangen, Germany). Every patient was told to avoid urination until they expressed a very strong desire to void, and patients with suprapubic catheters were infused with 250–350 ml saline solution for better imaging. 15–20 ml saline solution was slowly infused into the anterior urethra via meatus and then elastic bandage was used to ligate the end of the penis to prevent the leakage of urine through the meatus for every patient.

The patients were told to urinate at the beginning of MRI examination. The sequences of MR urethrography were as follows: (1) sagittal, axial and coronary turbo spin-echo fat-suppression (FS) T2-weighted imaging (T2-WI); (2) pre-contrast axial turbo spin-echo FS T1-WI; (3) post-contrast sagittal, axial and coronary turbo spin-echo FS T1-WI. GD-DTPA (Magnevist, Berkeley, NJ, USA) as a contrast agent was injected at a concentration of 0.1 mmol/kg (depending on the patient's weight) at 2 ml/s from the antecubital vein directly, and 2 min later the post-contrast FS T1-WI began to scan. The specific parameters of each sequence are shown in Table 1.

The scar tissue structure had signal characteristics of iso-intense signal on the pre-contrast T1-WI, low signal intensity on the T2-WI and abnormal enhancement on the post-contrast T1-WI. The oedema around the urethra manifested as low signal intensity on the T1-WI, high signal intensity on the T2-WI and no contrast enhancement on post-contrast T1-WI. The location, extent and length of the stricture could be clearly delineated on T2-WI when saline solution was used to dilate the urethra.

Treatment of the urethral stricture

The treatment methods of the urethral stricture mainly included urethral dilation and DVIU by endoscopy and excision and end-to-end anastomosis by the open surgery, which was appropriate to the patient according to the urethral situation demonstrated on X-ray and MR urethrography. In the length measurement of the urethral stricture, we measured from the near-point to the far-point of the narrow in accordance with unified regulations. When endoscopy was chosen to treat the urethral stricture, a catheter with a tick mark was used to measure the length of the stenosis. While in the open surgery, a scale was used directly to measure the length of the stenosis.

Statistical methods

The length measured by MR and X-ray urethrography was compared with the operative findings, respectively. GraphPad InStat version 6.0 for windows (GraphPad software, San Diego, CA, USA) was used for the statistical analysis. The parameters that conformed to the normal distribution were expressed as mean ± standard deviation ($\bar{x} \pm$ SD), and the parameters that did not conform to the normal distribution were shown with the median (quartile) [*M* (P25, P75)]. Paired *t* test was applied when the parameters satisfied the normality distribution and homogeneity of variance; otherwise, Mann–Whitney *U* test was used to analyse the parameters. The criterion of α value was 0.05. *P* value below α value was considered statistically significant.

Results

According to the clinical history, symptoms, laboratory examinations and surgical results, patients with urethral stricture in current study were caused by inflammation, benign prostatic hyperplasia (BPH), iatrogenic conditions and trauma. The corresponding locations of the urethral stricture were shown in Table 2.

Table 1 The sequence parameters of MR urethrography

Parameters	TSE T2-WI			Pre-contrast TSE T1-WI	Post-contrast TSE T1-WI		
	Sagittal	Axial	Coronary	Axial	Axial	Sagittal	Coronary
TR (ms)	6610.0	4500.0	4500.0	794.0	794.0	794.0	794.0
TE (ms)	87.0	96.0	96.0	20.0	20.0	20.0	20.0
FOV (mm × mm)	312 × 273	380 × 321	380 × 321	380 × 297	380 × 297	380 × 297	380 × 297
Slice thickness (mm)	3.0	3.0	3.0	3.0	3.0	3.0	3.0
No. of layers	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Slice gap (mm)	29	29	29	30	30	30	30
Fat suppression	SPAIR	SPAIR	SPAIR	SPAIR	SPAIR	SPAIR	SPAIR
Time (s)	127	87	87	60	60	60	60

TSE T2-WI turbospin-echo T2-weighted imaging, *TSE T1-WI* turbospin-echo T2-weighted imaging, *TR* repetition time, *TE* echo time, *FOV* Field of View

Table 2 The cause and location of urethral stricture

Pathology	Inflammation		BPH	Surgical history			Trauma	
Location	AU	BN	PU	AU	PU	BN	AU	PU
Cases	7	3	4	5	44	8	5	11

BPH benign prostatic hyperplasia, *AU* anterior urethra, *BN* bladder neck, *PU* prostatic urethra

The stricture, abruption and misalignment of the urethra were clearly shown in the pelvic T2-WI during voiding and the distended distal urethra filled with saline solution (Figs. 1a–c, 2a, c, 3a, b). The normal urethra was dilated by saline solution, and the strictured part of the urethra was not expanded after the saline solution was infused into the urethra. The scar tissue structure around the urethra demonstrated iso-intense signal intensity on the pre-contrast T1-WI and low signal intensity on the T2-WI. Post-contrast T1-WI clearly showed the urethral stricture and fibrosis around the urethra with significant abnormal contrast enhancement (Figs. 2b, d, 3c, d). The oedema around the urethra manifested as low signal intensity on the T1-WI and high signal intensity on the T2-WI. On post-contrast T1-WI, the oedema part showed no enhancement.

The urethral stricture was not clear on the conventional T2-WI (Fig. 2e). The extent of the stricture could be clearly delineated on T2-WI and contrast-enhanced T1-WI of MR urethrography when saline was used to dilate the urethra. Of thirty-five patients, urethral stricture length measured by X-ray urethrography (Figs. 1d, 3e, f) was 5 mm more than that by MR urethrography, and the results of two examinations of eight patients were consistent. In the early stage of research, the posterior urethra of 12 patients was not adequately filled with saline solution or urine. The location

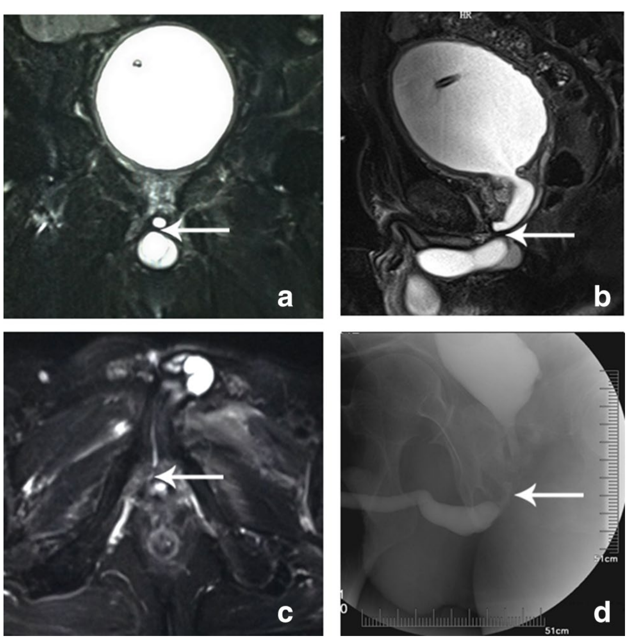

Fig. 1 A 55-year-old man had a suprapubic catheter for half a year after the pelvic trauma. **a**–**c** Coronal, sagittal and axial fat-suppressed (FS) T2-WI images of MR urethrography with the infusion of saline solution showing the urethral membrane was damaged seriously, the both broken ends of the urethra were dislocated and the scar tissue was hyperplasia. **d** X-ray urethrography showing there was no contrast agent infused in the urethral membrane and part of the urethral prostate

and the length of strictured urethra were detected from the axial T2-WI.

A total of 41 patients were treated using urethral dilation and DVIU due to the presence of a short (< 1.5 cm) urethral stricture and a frail condition. Excision and anastomosis of the urethra and the repair of the buccal mucosa were performed in 46 patients with a long urethral stricture or urethral obliteration. The long-term success rate of endoscopic treatment (13/41) was significantly lower than that of the excision and anastomosis of urethral strictures and the repair of the buccal mucosa, which had no repeated urethral strictures.

The stricture length measured on X-ray urethrography, MR urethrography and operation that is shown in Table 3 corresponded to normality assumptions and the statistical analysis was homogeneity of variance. The results of paired t test showed that the stricture length measured on operation was not significantly different from the stricture length measured on MR urethrography ($t = 1.47$, $P = 0.15$), but was significantly different from that measured on X-ray urethrography ($t = 22.71$, $P < 0.01$).

Discussion

There were four reasons for urethral stricture in our study. Anterior urethral stricture mostly resulted from trauma (straddle injury and iatrogenic instrumentation) and inflammation, while posterior urethral stricture was caused by pelvic trauma and iatrogenic instrumentation. This conclusion was consistent with El-Ghar MA's experience [14]. Some authors have noted that the common aetiologies of urethral stricture were idiopathic and iatrogenic in developed countries, whereas trauma was the common cause in developing countries [15]. In our study, iatrogenic urethral stricture has occupied the majority of all urethral strictures. This result reflected the improvement in the socioeconomic level and the ageing population in our country.

Urethral stricture had a strong impact on patients' quality of life and it was necessary to accurately diagnose the condition of urethral stricture and then select the appropriate operative methods preoperatively [16]. In our study, it was found that MR urethrography could demonstrate morphology of the urethral stricture including the location, degree and length more accurately than X-ray urethrography according to the surgical findings, which was consistent with other results [17, 18]. Obviously, morphology of the urethral stricture was a critical factor that could determine the reasonable choice of surgical treatment. It was found that endoscopic treatment in bulbar stricture of less than 1 cm had the highest success rate [19]. For patients with short urethral stricture, urethral dilation and DVIU had long-term outcomes with success rate of 75%

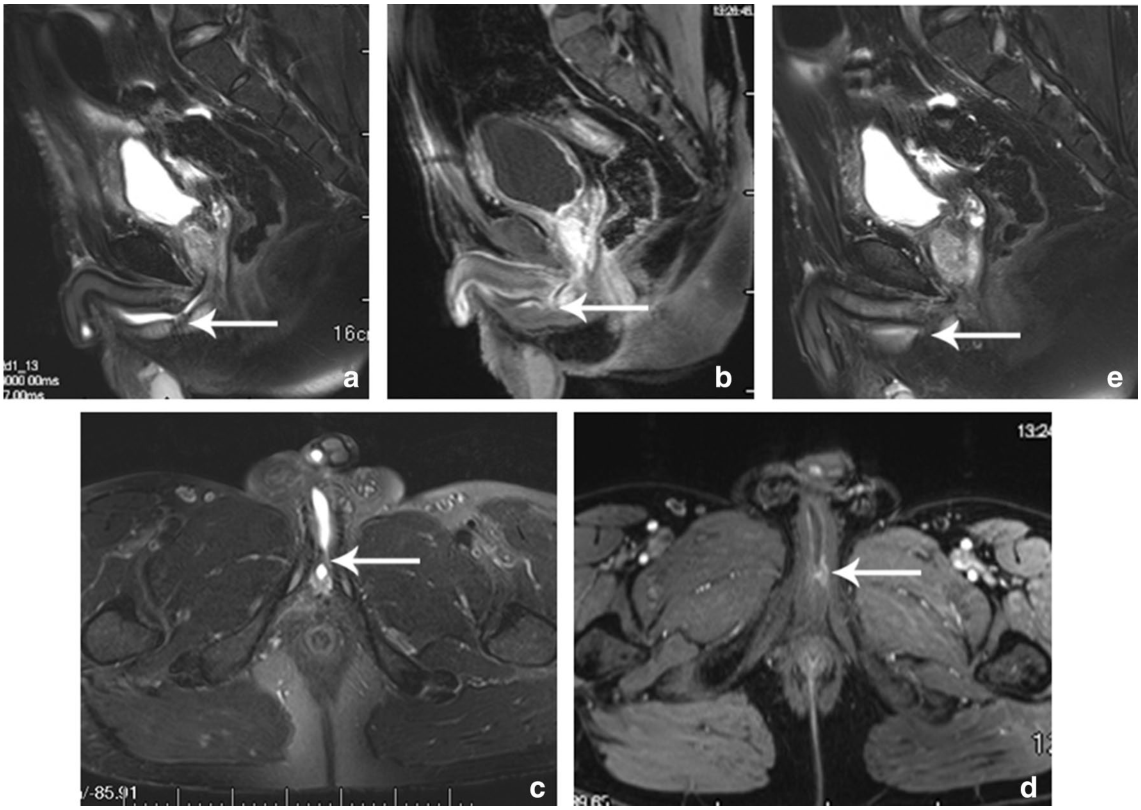

Fig. 2 A 53-year-old male had multiple urination difficulties for more than a year after a cross-injury of his perineum. **a**, **c** Sagittal and axial FS T2-WI images of MR urethrography showing the mucosa of urethral bulb was damaged and the scar tissue around urethra was formed. **b**, **d** Sagittal and axial contrast-enhanced FS T1-WI of MR urethrography showing the damaged mucosa of urethra and abnormal strengthening of the scar tissue around urethra. **e** The urethral stricture is not seen clearly in the conventional sagittal FS T2WI

[20]. If the urethral stricture length was more than 1.5 cm, it was necessary to choose excision and end-to-end anastomosis [21]. Therefore, the morphology of urethral stricture determined the methods of urethral stricture surgery and their success rate.

In addition, MR urethrography had obvious advantages in displaying the scar tissue around the urethra [22, 23], while X-ray urethrography had no ability to display any scar tissue. One important reason for the failure of urethral stricture surgery was the inadequate removal of the scar tissue around the urethra. [24] Excision, end-to-end anastomosis and buccal mucosal graft were best choice if scar tissue around the urethra was thick and long [25]. Scar tissue could determine the difficulty of surgery preoperatively and lead to recurrence of urethral stricture postoperatively [26]. In current study, scar tissue around the urethra was accurately identified with multi-parametric MRI. With the recognition of scar tissue, steroid hormones were used to inhibit the regeneration of scar tissue after the surgery of urethral stricture [26, 27]. Therefore, for patients with urethral stricture, MRI urethrography could not only guide the selection of surgical methods and evaluate the difficulty of surgery, but also evaluate the therapeutic effect.

In addition, MR urethrography could be performed many times without ionizing radiation, whereas the dose of the ionizing radiation should be controlled for X-ray urethrography. Although an ultrasound examination could show the scar tissue in the anterior urethra, it cannot accurately display the other anatomical structures of the posterior urethra, traumatic pelvic and so on. [28] Furthermore, the accuracy of the ultrasonic inspection results depends on the experience of the operator, and ultrasound images are not as intuitive as MR images.

MR urethrography was first proposed by Sung et al. [13], who used a sterile lubricating gel that was infused retrogradely into the urethra to dilate urethra. El-Bab et al. [18] used a sterile gel in their MR urethrography. In our study, saline solution was used in the sterile lubricating gel. Saline solution had several advantages. First, we found that saline solution was enough to dilate urethra to display the position of the narrowing. Second, it was a common sterile reagent in the clinic and had no side effects on the human body. Furthermore, saline solution could show good signal difference with other tissues in MRI.

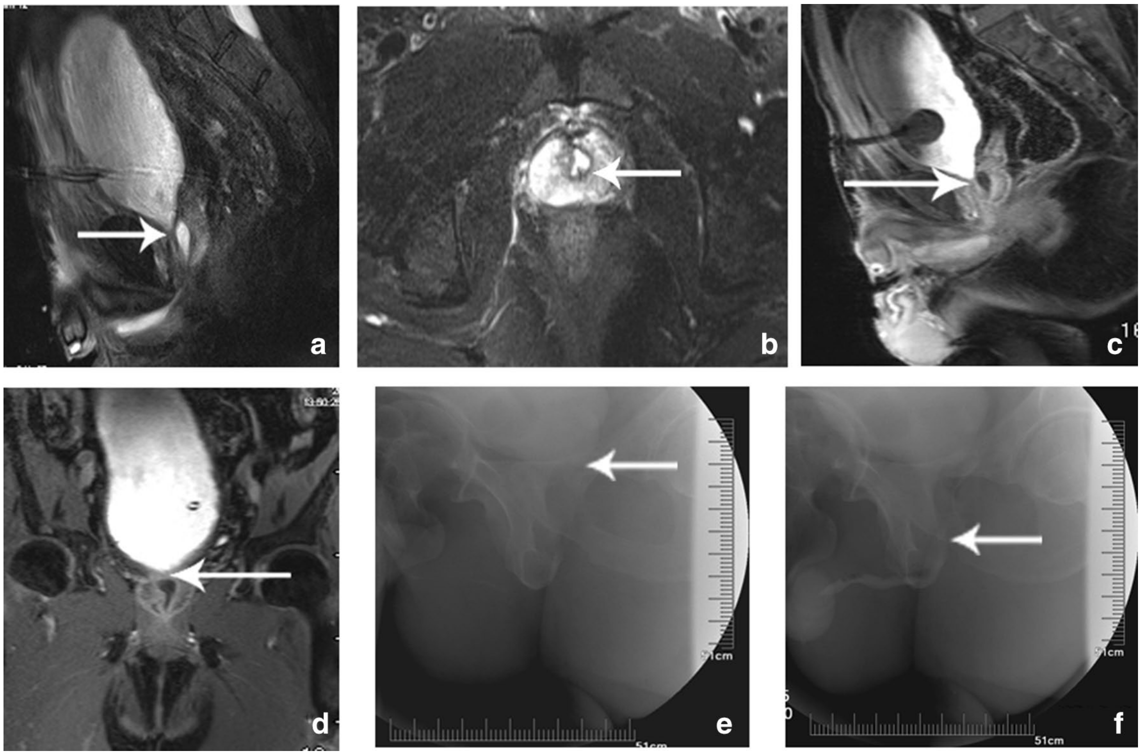

Fig. 3 An 81-year-old man had progressive dysuria for 1 week with a history of prostatic hyperplasia surgery 3 months ago. **a**–**b** Sagittal and axial FS T2-WI of MR urethrography showing a membranous stricture between the neck of the bladder and the inner urethra and a diverticulum structure in the prostatic part of the urethra. **c**, **d** Sagittal and coronal contrast-enhanced FS T1-WI of MR urethrography showing that the contrast agents in the bladder could not enter the urethra. **e**, **f** X-ray urethrography images showing that the neck of the bladder was blocked and there was stenosis in the posterior urethra

Table 3 The length of urethral stricture demonstrated on X-ray urethrography, MR urethrography and operation

Method	Urethral stricture length (cm)	*t*	*P*
X-ray urethrography	2.17 ± 0.65	22.71*	< 0.01*
MR urethrography	1.68 ± 0.67	1.47#	0.15#
Operation	1.66 ± 0.70		

*The statistical analysis of the length measured on X-ray urethrography and operation

#The statistical analysis of the length measured on MR urethrography and operation

There were some limitations in this research. First, in the early stage of study, the posterior urethra of 12 patients was not adequately filled with saline solution or urine, which could be overcome using axial T2-WI. However, in the late-stage study, it was found that better images could be obtained when patients were full relaxed. Additionally, the scanning time of MR urethrography was longer than that of X-ray urethrography. Lastly, the cost of MRI examination was higher than that of X-ray examination.

Conclusion

Overall, MR urethrography has advantages in the imaging of urethral stricture and may become a standard and necessary preoperative examination for urethral stricture.

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Compliance with ethical standards

Conflict of interest The authors declare no competing financial interests.

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