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BRIEF REPORT

Title:

Advancing Intraoperative Assessment of Urethral Stricture Anatomic Variation: a Prospective Proof-of-concept Study

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Short Title: Intraoperative Urethral Stricture Assessment

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ABSTRACT

Introduction:

Urethral strictures, particularly those refractory to endoscopic interventions, are commonly treated through open urethroplasty. However, predicting recurrence in homogeneous patient populations remains challenging.

Methods:

To address this, we developed an intraoperative urethral stricture assessment tool aiming to identify comprehensive risk predictors. The assessment includes detailed parameters on stricture location, length, urethral bed width, spongiosum thickness, obliteration grade, and spongiofibrosis extension. The tool was prospectively implemented in 106 men with anterior one-stage augmentation urethroplasty 04/2020 to 10/2021.

Results:

An intraoperative granular assessment of intricate stricture characteristics is feasible. Comparative analyses revealed significant differences between bulbar and penile strictures. Bulbar strictures exhibited wider urethral beds and thicker spongiosum compared to penile strictures (all $P<0.001$). The assessment showed marked variations in the degree of obliteration and spongiofibrosis extension.

Conclusion:

Our tool aligns with efforts to standardize urethral surgery, providing insights into subtle disease intricacies and enabling comparisons between institutions. Notably, intraoperative assessment may surpass the limitations of preoperative imaging, emphasizing the necessity of intraoperative evaluation. While limitations include a single-institution study and limited sample size, future research aims to refine this tool and determine its impact on treatment strategies, potentially improving long-term outcomes for urethral strictures.

INTRODUCTION

Urethral strictures commonly manifest in the anterior urethra [1] and are effectively treated through open urethroplasty, particularly when refractory to endoscopic interventions [2]. Clinical adverse metrics, such as pelvic irradiation, lichen sclerosus, or prior hypospadias repair, have been associated with treatment failure. Notably, predicting recurrence in homogeneous populations of patients with anterior strictures, lacking such complicating factors, remains exceedingly challenging [3]. Although mid-term success rates of non-transecting excision and primary anastomosis or augmentation urethroplasty (AU) for anterior strictures can reach up to 90%, identifying patients at higher risk of failure during surgery can be complex.

METHODS

To address this challenge, we have developed an intraoperative urethral stricture assessment tool. This tool aims to gather and identify parameters not previously considered, potentially serving as missing metrics essential for comprehensive risk prediction. The assessment encompasses detailed depiction of stricture location and length, the width of the urethral bed and corpus spongiosum, and evaluation of the extension of spongiofibrosis. This evaluation is conducted utilizing the six-grade scale introduced by Jordan and Devine, which comprises the following criteria: A – mucosal fold; B – iris constriction; C – full-thickness involvement with minimal fibrosis in the spongy tissue; D – full-thickness spongiofibrosis; E – inflammation and fibrosis involving tissues outside the corpus spongiosum; F – complex stricture complicated by a fistula [4]. Additionally, it includes measurements of graft length and width, as well as degree of obliteration, modified based on suggestions by McAninch [5] and Chiou [6]. Supplementary details concerning surgical technique, type of graft, and grafting approach are systematically collected to facilitate categorization within an institutional data template (Fig. 1).
To evaluate the feasibility and applicability of this novel tool, we prospectively implemented the intraoperative assessment on a precursor population of men undergoing anterior one-stage AU at our institution between 04/2020 and 10/2021. The assessment was conducted by the operating surgeon, macroscopically and through haptic tissue evaluation, after opening the urethra in the stricture area. Objective measurements of graft and urethral metrics were taken using a surgical ruler, with the procedural data simultaneously recorded by the supervising nurse. The characteristics of bulbar and penile strictures were compared using suitable statistical tests, including Mann-Whitney U, Fisher's exact, and chi-squared tests.

RESULTS

Out of 106 men, 94 (89%) underwent bulbar and 12 (11%) penile urethroplasty. Among these, 91 (86%) received a ventral onlay [3] and 15 (14%) a dorsal inlay [7]. Additionally, 25 (24%) underwent mucomucosal anastomotic non-transecting augmentation (MANTA) urethroplasty [8]. The median stricture length was 40 mm, showing no significant difference between penile and bulbar locations ($p>0.9$). Bulbar strictures exhibited wider urethral beds (median 10 mm vs. 7 mm) and thicker corpus spongiosum (median 5 mm vs. 3 mm) compared to penile strictures (all $p<0.001$). The degree of obliteration was mild (<⅓ lumen) in 10 (9.4%) men, moderate (⅓–½ lumen) in 43 (41%), and severe (>½ lumen occluded) in 53 (50%) men, with no significant difference between bulbar and penile locations ($p=0.3$). Of the participants, 58 men (55%) showed no more than epithelial scarring or minimal spongiofibrosis, while 48 (45%) exhibited at least full-thickness spongiofibrosis (Table 1).

DISCUSSION

Recently, there has been a surge in efforts to standardize urethral surgery, aiming to match the strides made in urologic oncology. The latter has consistently led in terms of data quality, high-quality trials, and standardizing outcomes. However, reconstructive urology is rapidly advancing. Breakthroughs in research have led to advancements in the classification of strictures, enabling uniform reporting of their location, segment, and etiology [9]. Additionally, defining treatment success, a historically contentious issue, has seen progress [10,11]. Our intraoperative assessment tool aligns with these developments and represents a step forward in how we collect and standardize data for disease assessment. This standardization enables comparisons between institutions, enhancing our understanding of subtle disease intricacies. Such insights may clarify why one patient responds favorably while another, seemingly similar in terms of known stricture characteristics, does not.
The rationale behind our definitive intraoperative assessment, as opposed to relying solely on preoperative imaging, stems from the limitations of current imaging modalities such as (sono)urethrography or urethroscopy. These methods often fail to capture anatomic intricacies like spongiofibrosis or the true extent of remaining healthy, vascularized urethral tissue. According to European Association of Urology (EAU) guidelines, patients

should be informed that the final treatment decision is made intraoperatively, potentially deviating from initial preoperative counseling [2]. This emphasizes the limitations and imperfections of available preoperative diagnostics, as we cannot entirely grasp the nature of the stricture. Therefore, the evident challenge in accurately predicting risk before surgery underscores the increasing importance of intraoperative evaluation. Our proof-of-concept study demonstrates the feasibility of a novel intraoperative assessment of detailed urethral stricture characteristics. Notably, within a seemingly homogeneous group of men undergoing one-stage AU, we identified distinct differences in anatomic and morphologic features that may impact treatment success. Another aspect is the new assessment tool's capacity for standardized measurement and enhancement, particularly for future multicenter studies employing a uniform template. Utilizing a graphic representation that delineates precise urethral anatomy facilitates the identification of the exact stricture location intraoperatively. The intuitive documentation of this information is achieved through the graphical interface of the assessment tool. Eventually, this data can be transformed into innovative classification systems, such as a male anterior urethral stricture classification system introduced by the Trauma and Urologic Reconstructive Network of Surgeons (TURNS) [9]. However, our study has limitations, primarily because it was conducted at a single institution, where only the operating surgeon performed the intraoperative assessment, limiting insights into interrater variability. Moreover, the potential impact of objectively and distinctly assessing stricture characteristics on influencing the selection of a particular surgical technique over another (and its success) will be the focus of forthcoming research endeavors. Furthermore, due to the high success rates of anterior urethroplasty (approximately 90%), our sample size was insufficient to correlate differences in the assessed intraoperative stricture characteristics with treatment success. We are currently pursuing multi-institutional research to further advance this assessment tool. This includes integrating the updated EAU stricture classification [2] and exploring additional technical maneuvers, such as graft quilting or fenestration, commonly employed to enhance surgical outcomes. Ultimately, future research aims to determine whether a tool like the one presented will aid in refining treatment strategies, ultimately improving long-term subjective and objective outcomes.

STATEMENTS

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None.

STATEMENT OF ETHICS

This study was reviewed and approved by the local ethics committee Hamburg, approval number PV5634. Written informed consent from participants was not required in accordance with local laws (intraoperative deidentified data collection; Hamburgisches Krankenhausgesetz [HmbKHG] §12.1).

CONFLICT OF INTEREST STATEMENT

All authors declare no conflict of interests.

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No funding was received for this study.

AUTHOR CONTRIBUTIONS

Conceptualization:	Marks, Engel, Vetterlein
Investigation:	Marks, Daniels, Ding, Engel, Soave, Vetterlein
Formal Analysis:	Vetterlein
Writing - Original Draft Preparation:	Marks, Vetterlein
Writing - Review and Editing:	Dahlem, Klemm, Kühnke, Kranzbühler, König, Fisch
Visualization:	Vetterlein
Supervision:	Vetterlein

DATA AVAILABILITY STATEMENT

All data generated and analyzed for this article have been included. For additional inquiries, please contact the corresponding author.

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FIGURE LEGEND

Fig. 1 Intraoperative urethral stricture assessment tool for standardized assessment of anatomic, morphologic, and surgical characteristics.

Patient label

Universitätsklinikum Hamburg-Eppendorf

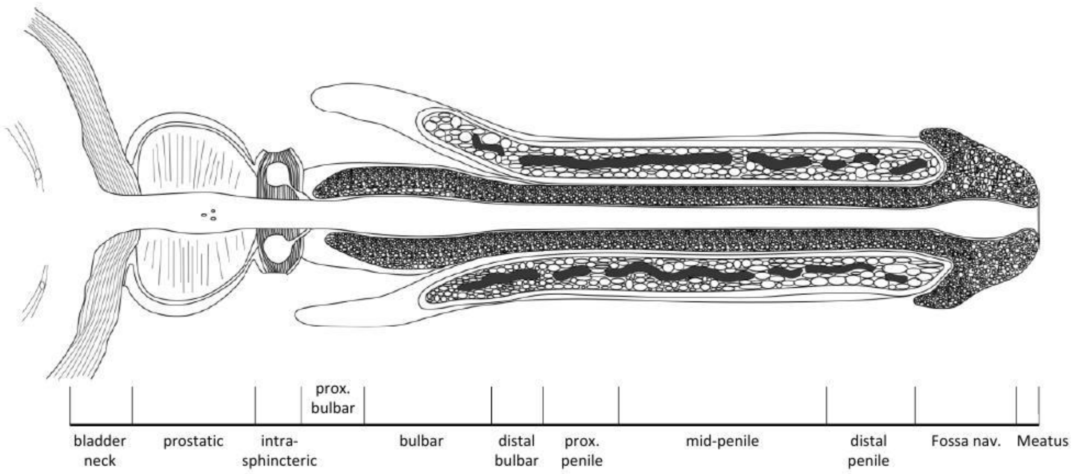
Department of Urology
Reconstructive Urology Research Unit

Intraoperative Urethral Stricture Assessment

Version 1 – 04/2020

Date of surgery: ___________________________

Stricture location (tick all that apply):



Stricture length	____ mm
Width of urethral bed	____ mm
Thickness of corpus spongiosum	____ mm
Spongiofibrosis (Jordan degree A-F) **A** ☐ **B** ☐ **C** ☐ **D** ☐ **E** ☐ **F** ☐	
Length of graft	____ mm
Width of graft	____ mm
Grade of obliteration (modified after McAninch and Chiou)	
Mild: < ⅓ lumen occluded	☐
Moderate: ⅓ to 50% lumen occluded	☐
Severe: > 50% lumen occluded	☐

Operative technique

One-stage ☐ Staged ☐

1. stage ☐ 2. stage ☐

Comments: ______________________

Graft

Oral mucosa ☐ Meshgraft ☐

Other ☐ ____________________________

Grafting technique

Ventral onlay ☐ Dorsal onlay ☐ Inlay ☐

Other

EPA ☐ Mucomucosal anastomosis ☐

EPA = excision and primary anastomosis

Table 1 – Surgical and intraoperative stricture characteristics in 106 men undergoing anterior one-stage augmentation urethroplasty between 04/2020 and 10/2021.

	Overall 106 (100)	Bulbar 94 (89)	Penile 12 (11)	*p* value
Age (yr), median (IQR)	52 (35-62)	51 (35-64)	53 (33-59)	0.7
Intraoperative stricture characteristics				
Stricture length (mm), median (IQR)	40 (30-50)	40 (30-50)	40 (28-50)	>0.9
Width of urethral bed (mm), median (IQR)	10 (9-12)	10 (10-12)	7 (5-9)	**<0.001**
Thickness of corpus spongiosum (mm), median (IQR)	5 (4-8)	5 (4-8)	3 (2-3)	**<0.001**
Degree of urethral obliteration, modified after McAninch [5] and Chiou [6], *n* (%)				0.3
Mild: < 1/3 lumen occluded	10 (9.4)	7 (7.5)	3 (25)	
Moderate: 1/3 – 1/2 lumen occluded	43 (41)	39 (41)	4 (33)	
Severe: > 1/2 lumen occluded	53 (50)	48 (51)	5 (42)	
Grade of spongiofibrosis, after Jordan [4], *n* (%)				0.2
A: no spongiofibrosis, epithelial flap	0 (-)	0 (-)	0 (-)	
B: epithelial scar with minimal spongiofibrosis	16 (15)	12 (13)	4 (33)	
C: full thickness involvement with minimal spongiofibrosis	42 (40)	36 (38)	6 (50)	
D: full-thickness spongiofibrosis	28 (26)	27 (29)	1 (8.3)	
E: inflammation and spongiofibrosis involving tissue outside the corpus spongiosum	18 (17)	17 (18)	1 (8.3)	
F: spongiofibrosis occupies entire corpus spongiosum and potential fistula formation	2 (1.9)	2 (2.1)	0 (-)	
Graft length (mm), median (IQR)	40 (38-50)	40 (40-50)	40 (30-55)	0.4
Graft width (mm), median (IQR)	15 (11-15)	15 (12-15)	10 (10-15)	**0.032**
Grafting technique, *n* (%)				**<0.001**
Ventral onlay	91 (86)	91 (97)	0 (-)	
Dorsal inlay	15 (14)	3 (3.2)	12 (100)	
MANTA urethroplasty [8], *n* (%)	25 (24)	25 (27)	0 (-)	**0.032**

IQR = interquartile range; MANTA = mucomucosal anastomotic non-transecting augmentation.