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Learning curve of various type of male urethroplasty

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Purpose: To determine the number of cases required to achieve a specified recurrence-free rate (>80%) among urethroplasty types.

Materials and Methods: A retrospective analysis of consecutive patients, who underwent urethroplasty performed by a single surgeon between April 2013 and January 2019, was conducted. Urethroplasty subtypes were divided according to stricture location: penile, bulbar, and posterior. If there was no recurrence for >6 months after surgery, the surgery was considered to be a success. The average success rates among quintile groups were compared to determine the learning curve for each type.

Results: Of 150 patients who underwent urethroplasty, 112 were included in this study. The overall success rate was 89.7% in penile, 97.8% in bulbar, and 74.1% in posterior urethroplasty. Bulbar urethroplasty reached the target success rate in the first quintile group (1–9 cases). Penile urethroplasty also achieved the target success rate in the first quintile group (1–8 cases), and the success rate gradually increased until the fifth quintile group (32–39 cases). In posterior urethroplasty, the target success rate was achieved in the fifth quintile group (20–27 cases).

Conclusions: Bulbar urethroplasty had the fastest learning curve, and posterior urethroplasty the slowest.

Keywords: Learning curve; Reconstructive surgical procedures; Urethral stricture

INTRODUCTION

Urethroplasty is the gold standard treatment for urethral stricture; however, it is a technically complex operation. Compared with other intraabdominal procedures, urethroplasty has different anatomical approaches with complex anastomosis procedures, and the urologist may have to use substitution materials [1]. Additionally, there are different surgical approaches to the urethra, depending on the anatomical location. Urethroplasty can be divided into anterior and posterior; furthermore, anterior can be divided into penile and bulbar depending on the location. Excision and primary anastomosis (EPA) and substitution urethroplasty involve radically different procedures. Moreover, buccal mucosa grafts are divided into dorsal onlay and ventral onlay, with each method having its learning curve.

Urologists have long been interested in the learning curves for urethroplasty due to its surgical difficulty and relatively high failure rate compared with other urological operations. Approximately 10% to 20% of patients have been reported to experience recurrence after urethroplasty [2]. Previous reports have described learning curves in adult and pediatric patients [3,4]. Faris et al. [5] reported the anterior urethroplasty learning curve of six surgeons and set clini-

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cal proficiency at >90% success. Fossati et al. [6] described a prospective study of one-stage anterior urethroplasty. Both studies defined the recurrence-free rate as the primary endpoint and demonstrated that the success rate increased with the number of cases. Spilotros et al. [7] compared bulbar urethroplasty techniques by dividing patients into quartiles. Success rates may vary and depend on the definition of success, the use of parameters (such as uroflowmetry) to define success, and the observation period; therefore, it is particularly challenging to establish a learning curve for each technique.

Given the complex anatomy, posterior urethroplasty is one of the most challenging procedures for the reconstructive surgeon. According to our literature search, no study has compared the learning curves for the entire anatomy of the urethra, including the posterior urethra. However, by comparing the success rate of operations performed by a single surgeon, it is possible to observe the learning curve for different anatomical locations objectively. Accordingly, we defined the learning curve as the time to reach a specified success rate (>80%) and conducted this study to determine the number of cases required to achieve this rate among selected urethroplasty types.

MATERIALS AND METHODS

1. Patients

Prior to analysis, data of all patients were anonymized. The Institutional Review Board of Samsung Medical Center (Seoul, South Korea) approved this study (IRB no. 2019-03-116). Methods were carried out in accordance with the Declarations of Helsinki. Written informed consent was given by all participants at the time of surgery for recording their clinical data. When it is difficult for the patient to agree because of a medical condition, the consent of the primary caregiver (parent or spouse) was obtained. A retrospective analysis of consecutive patients who underwent urethroplasty performed by a single surgeon was conducted. Medical records were reviewed to identify patients who underwent urethroplasty at the authors' hospital between April 2013 and January 2019. The majority of patients had an indwelling Foley catheter for three weeks after urethroplasty. We put suprapubic cystostomy with urethroplasty. After removal of the Foley catheter, voiding cystourethrogram (VCUG) was routinely performed to assess periurethral leakage and if there is no problem after 1 or 2 weeks, then removed cystostomy. The patients were followed-up at 1, 2, 6, and 12 months and annually thereafter, using uroflowmetry.

2. Outcome measures

Recurrence was defined as clinically significant urethral stricture in the operative location, through which it was not possible to pass a 17 Fr cystoscope, with voiding symptoms including dysuria, weak stream, or acute urinary retention. If stricture recurrence was clinically suspected, cystoscopy or retrograde urethrography was performed to confirm the diagnosis. Majority cases of recurrence were treated with repeat urethroplasty. However, some strictures were simply surrounded by membranes, such as mucosal web, and were treated with direct vision internal urethrotomy.

Patients who were followed-up for >6 months and experienced recurrence within that period were included. Urethroplasty was divided into three subtypes according to stricture location: penile, bulbar, and posterior. When the stricture location was pan-urethra, or penile and bulbar strictures were present, the subject was placed in the penile subtype according to stricture length. Penile and bulbar strictures were categorized into EPA and substitution types. Substitution urethroplasty included dorsal or ventral onlay buccal mucosal graft, Orandi technique, and distal penile circular fasciocutaneous flap.

If there was no recurrence for >6 months after surgery, the urethroplasty was considered to be a success. The average success rate in the quintile groups was compared in an attempt to determine the learning curve for each type of urethroplasty. Estimated blood loss (EBL) and operation time were also compared among the urethroplasty groups. Additionally, risk factors for stricture recurrence within six months were also investigated.

3. Statistical analysis

All results are expressed as median (range). The Kolmogorov–Smirnov statistic was used to analyze continuous variables for normality. The Mann–Whitney U test was used to compare descriptive variables. Logistic regression analysis was used to analyze factors affecting recurrence. Data were analyzed using IBM SPSS Statistics ver. 21.0 (IBM Corp., Armonk, NY, USA) and R: A Language and Environment for Statistical Computing version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria). All statistical tests were two-sided, and statistical significance was defined at $p<0.05$.

RESULTS

Of 150 patients who underwent urethroplasty in the specified study period, 112 were included in this analysis. Thirty-four patients who were not followed-up for >6

Table 1. Basic clinical characteristics

Characteristic	Penile (n=39)	Bulbar (n=46)	Posterior (n=27)	p-value
Age (y)	63.0 (30.0–85.0)	60.5 (11.0–87.0)	50.0 (8.0–77.0)	0.004
Stricture length (mm)	35 (10–150)	19.5 (7–55)	20 (10–40)	<0.001
Cause of stricture				<0.001
Idiopathic	5 (12.8)	10 (21.7)	0 (0.0)	
Trauma	3 (7.7)	19 (41.3)	27 (100.0)	
Iatrogenic	29 (74.4)	15 (32.6)	0 (0.0)	
Infection	2 (5.1)	2 (4.3)	0 (0.0)	
Operation time (min)	134 (60–341)	117 (60–182)	159 (96–297)	0.001
EBL (mL)	100 (10–650)	100 (0–600)	400 (100–1,000)	<0.001
Hospital day	5 (3–18)	6 (4–25)	6 (5–14)	0.746
Foley indwelling period (d)	22 (11–63)	20 (15–68)	21 (15–39)	0.362
Follow-up duration (mo)	16.7 (6.2–47.3)	21.8 (6.0–63.2)	12.8 (2.5–56.6)	0.049

Values are presented as median (range) or number (%).
EBL, estimated blood loss.

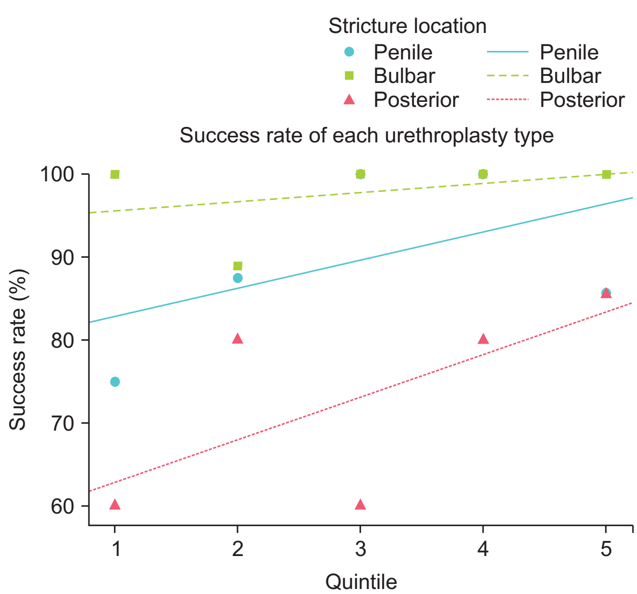

Fig. 1. The success rate of each urethroplasty subtype. In all three groups, the success rate increased as the number of cases increased. Bulbar urethroplasty had the fastest learning curve, while posterior urethroplasty was the slowest.

months were excluded; four patients who underwent perineal urethrotomy were also excluded. The median age of the patients was 57.0 years, and the mean follow-up duration was 21.3 months. Patients in the posterior urethroplasty group were the youngest, had the longest operation time, and the highest EBL. The length of hospital stay and the Foley catheter indwelling period were comparable among the groups (Table 1). The causes of stricture were categorized. Iatrogenic causes included strictures caused by Foley catheter, cystoscopy, ureteroscopy, previous hypospadias surgery, holmium laser enucleation of the prostate, transurethral resection (TUR)-B or TUR-P. Infection included strictures caused by sexually transmitted disease, urethritis, or penile abscess(es).

The overall success rate was 89.7% in penile, 97.8% in bulbar, and 74.1% in posterior urethroplasty. The learning curve of each subtype of urethroplasty is shown in Fig. 1. Bulbar urethroplasty reached an 80% success rate within the first quintile group (1–9 cases), and the high success rate was maintained. In bulbar urethroplasty, EPA had only a single failed case, and substitution urethroplasty achieved the target success rate in the first quintile group (1–17 cases). Penile urethroplasty achieved the target success rate within the first quintile group (1–8 cases), and the success rate gradually increased until the fifth quintile group (32–39 cases). In the posterior urethroplasty subtype, the 80% success rate was achieved within the fifth quintile group (20–27 cases), and the success rate gradually increased. The operation time within the three groups gradually decreased as the number of cases increased (Fig. 2). EBL in the posterior group decreased from the third quantile, while the other two groups did not demonstrate a notable difference (Fig. 3). Of the anterior urethroplasty, there were a total of 31 EPA cases, with a success rate of 96.8% (30/31). There were 54 substitution urethroplasty cases, with a success rate of 83.3% (45/54). There was a total of 13 cases of recurrence (penile=5, bulbar=1, posterior=7), and the median recurrence period was 2.4 (interquartile range, 1.6–4.7) months. Eight of the 13 cases underwent re-do urethroplasty (61.5%), while five cases (38.5%) underwent direct-vision internal urethrotomy (DVIU) only. There were two cases (25.0%) of DVIU before the re-do urethroplasty, and 50% of the re-do urethroplasty used substitution material. In our analysis of the urethroplasty

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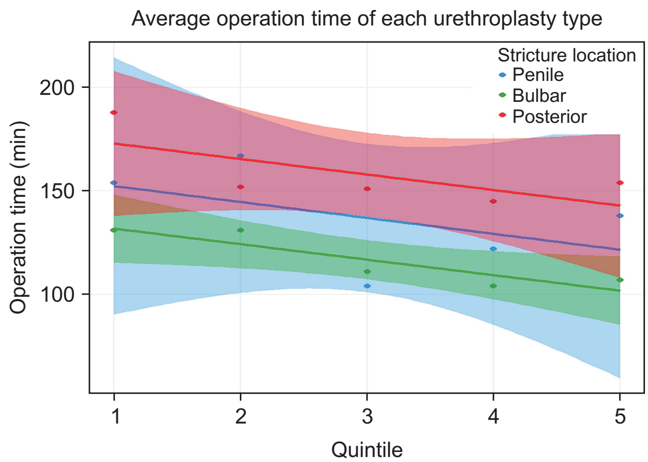

Fig. 2. Operation time for each urethroplasty subtype. In all three groups, the mean operation time decreased as the number of cases increased.

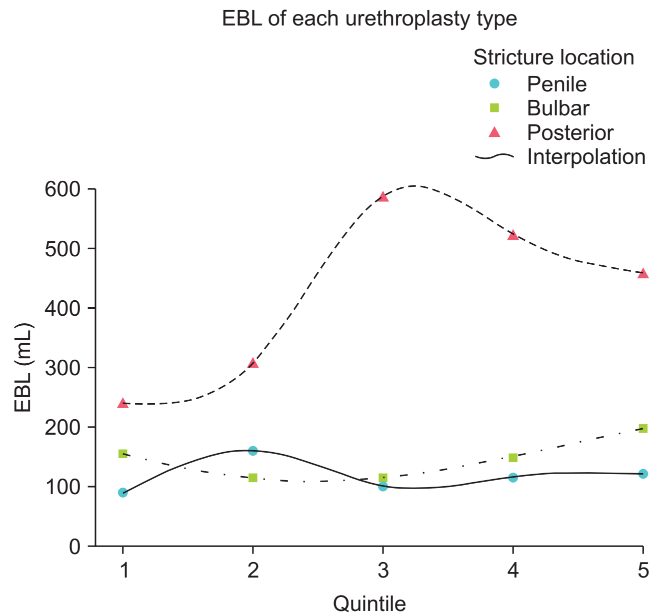

Fig. 3. Estimated blood loss (EBL) for each urethroplasty subtype. Patients in the posterior urethroplasty group had the highest EBL, which gradually decreased after the third quantile (12–18 cases).

series, posterior urethroplasty was identified as the only risk factor for recurrence in univariate (hazard ratio [HR], 17.143) and multivariate (HR, 11.493) analyses (Supplementary Table 1).

DISCUSSION

We conducted this study to compare the learning curves for urethroplasty subtypes according to the anatomical location. The learning curve is influenced by the surgeon's attitude, self-confidence, and experience [8]. We divided the cases into quintiles to determine how many cases were required to achieve the target success rate (>80%). The learning curve can substantially vary depending on target outcomes, which include success rate, mean operation time, specific EBL, or complication rate.

The criteria usually used to define learning curves vary among optimal operation time, time to decreased adverse effects, or time to achieve long-term functional outcomes [8]. We set criteria based on the recurrence-free rate. We believe that an acceptable success rate for urethroplasty is ≥80%, given that reported success rates vary from 75% to 95% according to location and technique [9,10]. In our study, bulbar urethroplasty had the fastest learning curve and is regarded as the simplest type of urethroplasty [7]. If a surgeon endeavors to start urethroplasty, choosing and beginning with these types of cases can improve the success rate, after which more complicated cases can be performed.

Interestingly, the rate of operation time reduction was very similar among the three groups as the number of cases increased. Depending on the anatomical location, the success rate and operation time were different; however, the time reduction was very similar among the three groups. This pattern suggests that surgical proficiency mainly affects operating time. Lacy et al. [11] reported that longer operation times were associated with increased rates of complications. During urethroplasty, surgeons may reduce operation time by performing the harvest themselves or not closing the buccal mucosa [12].

Characteristically, there was a sudden increase in the amount of EBL in the third quintile (11–15 cases) for posterior urethroplasty, which is believed to be caused by the surgeon's implementation of inferior partial pubectomy from that time and it was implemented in 9 of 27 posterior urethroplasty cases. Portions of the ischiopubic rami were excised at the time of inferior partial pubectomy and which allows exposure of the apical prostatic urethra. EBL had decreased again as the number of cases increased. Similarly, EBL in penile urethroplasty increased slightly in the second quintile (9–16 cases), which coincided with the start of the penile circular fasciocutaneous flap.

Posterior urethroplasty is one of the most challenging reconstructive surgeries due to its deep location in the pelvis, the association with the pelvic ligaments and the relation to complex anatomical structures including the prostate and external sphincter [1]. It is known that a posterior location does not affect *de novo* erectile dysfunction compared with anterior urethroplasty [13,14]. Furthermore, Urkmez et al. [15] suggested that urethroplasty surgery itself does not significantly affect erectile function, orgasmic function, and general sexual satisfaction, regardless of the type of surgery. Gomez and Scarberry [1] emphasized the importance of the surgical plan and transport to specialized tertiary referral centers.

Many studies have reported the cause or clues to urethral stricture recurrence after urethroplasty. First, it was reported that an initial voiding trial failure might be a key to identify individuals who experience early recurrence [16]. Second, Ekerhult et al. [17] suggested that a finding of sclerosis (severe fibrosis with thickening and hardening) on histology is a significant predictive factor for recurrence. Third, Rapp et al. [18] demonstrated that obesity is not associated with recurrence. We speculated that stricture length and previous urethroplasty would be related to the recurrence rate; however, this was not revealed in our analysis.

To ensure that there is no leakage in the anastomosis area, a peri-catheter urethrogram (R.U.G) is typically performed three weeks after the operation [7,19]. However, we implement a VCUG in most cases because we believe that the pressure received in the urethra and anastomosis area when VCUG more closely resembles natural urination. We believe that R.U.G provides more pressure and can cause small iatrogenic damage if the physician is not adept with this procedure. Moreover, Haider and Mahmud [20] claimed that a urethrogram is not essential in tension-free urethroplasty; nevertheless, a large-scale study is necessary to generalize this argument.

One particular strength of this study is that it objectively assessed each surgical method by comparing the learning curves according to the anatomical position with the procedure being performed by a single surgeon. The institution in which the study was performed is a large-scale tertiary hospital, and a single surgeon performs all urethroplasties. Thus, the interval between operations generally did not exceed one month, and interaction with long surgical intervals was minimized. As such, this study provides meaningful information about the learning curve, including the reduction of EBL and operating time when a certain number of urethroplasty procedures are performed continuously by a single surgeon.

In the present study, posterior stricture was the sole risk factor for recurrence. Generally, stricture length, stricture cause, whether it is a revision or repair, or the number of previous procedures are known to be essential factors predicting stricture recurrence [5,18]. However, in our study, stricture location was more of a critical risk factor than any others. The odds ratio of the previous urethroplasty was measured relatively high in multivariable analysis. Still, it may not have obtained statistical power, and the surgeon used substitution material in 54.1% of the total patients, which may have contributed to reducing recurrence.

There were several limitations to this investigation. First, the general perception of the learning curve is that the success rate stabilizes after the early cases; however, our study did not reach such a case number. Second, we set a six-month time point for judging success in urethroplasty, which is rather short compared with that used in other studies [21]. Third, our research intended to identify the patterns of success rate changes through the trend line. Unfortunately, although there is a considerable number of urethroplasty as a single surgeon, statistical significance was not reached as a result. Fourth, we did not assess complications, such as post-micturition incontinence, known to be common after anterior urethroplasty [22]. Questionnaires such as patient-reported outcome measures (PROMs) could be used to quantify the quality of life or erectile function after urethroplasty. Erectile function or ejaculatory function can also be significant parameters after urethroplasty. The complications experienced by patients in our study included hematuria, urethro-cutaneous fistula, cellulitis, and wound dehiscence. We plan, however, to perform a quantitative analysis of the complications in a future study.

CONCLUSIONS

Bulbar urethroplasty demonstrated the fastest learning curve, while posterior urethroplasty was the slowest. The posterior urethroplasty group had the highest EBL, but it gradually decreased to the third quintile (12–18 cases). As the number of cases increased, the operation time decreased in all three groups. Posterior urethroplasty was the only risk factor for failed surgery.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

AUTHORS' CONTRIBUTIONS

Conceptualization: Hyun Hwan Sung. Data curation: Joongwon Choi and Chung Un Lee. Formal analysis: Joongwon Choi and Hyun Hwan Sung. Methodology: Joongwon Choi. Supervision: Hyun Hwan Sung. Writing: Joongwon Choi and Hyun Hwan Sung.

SUPPLEMENTARY MATERIAL

Supplementary material can be found via https://doi.

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