

Original Article

Int Neurourol J 2025;29(2):125-134

<https://doi.org/10.5213/inj.2550016.008>

pISSN 2093-4777 · eISSN 2093-6931



Transurethral Sphincterotomy and an Artificial Urinary Sphincter – A Novel 2-Stage Surgery for Refractory Bladder Emptying Disorders: A Proof-of-Concept Study

Kyung Tak Oh¹, Avelyn Noble Lim^{1,2}, Alwadai Raed Ibrahim^{1,3}, Jang Hwan Kim¹

¹Department of Urology and Urological Science Institute, Yonsei University College of Medicine, Seoul, Korea

²Subsection of Urology, Department of Surgery, University of Santo Tomas Hospital, the Philippines

³Department of Urology, King Abdullah Hospital, Bishah, Saudi Arabia

Purpose: We developed an innovative 2-stage procedure combining transurethral sphincterotomy (TURS) with artificial urinary sphincter (AUS) implantation to restore voiding in patients with refractory bladder emptying disorders. This proof-of-concept study evaluated its safety and efficacy.

Methods: We retrospectively reviewed clinical data from patients who underwent combined TURS and AUS implantation between April 7, 2021, and October 31, 2024. Eligible patients had neurogenic bladder with refractory emptying, irreversible neurogenic disease, and no mechanical obstruction (e.g., urethral strictures). In the TURS stage, the entire inner urethral segment corresponding to the external sphincter was resected to induce intrinsic sphincter deficiency; this was followed by AUS placement. We analyzed patient demographics, preoperative and postoperative daily pad usage, clean intermittent catheterization (CIC) frequency, patient-reported outcomes (Life Quality [LQ], International Consultation on Incontinence Questionnaire [ICIQ], Sandvik Severity Index [SAND]), postvoid residual (PVR) urine volume, estimated glomerular filtration rate (eGFR), abdominopelvic ultrasonography, and postoperative complications.

Results: Four out of 6 patients (66.7%) successfully achieved CIC-free status, with effective self-voiding achieved through AUS activation and abdominal pressure generation. Significant improvements were documented in LQ scores ($P=0.042$), ICIQ scores ($P=0.004$), and SAND scores ($P=0.039$). Median PVR significantly decreased from 237.5 mL (interquartile range [IQR], 112.5–317.5 mL) preoperatively to 1.5 mL (IQR, 0–85.8 mL) postoperatively ($P=0.028$). No patient demonstrated upper-tract damage or significant eGFR change. One patient developed an AUS infection requiring explantation; another remained CIC-dependent due to insufficient abdominal pressure.

Conclusions: Combining TURS with AUS implantation is a safe and effective surgical option for refractory bladder emptying disorders, yielding significant improvements in voiding autonomy and quality of life while reducing catheter dependence. Future studies with larger cohorts and longer follow-up are warranted to validate safety, long-term durability, and broader applicability. These findings may shift current paradigms in neurogenic bladder management.

Keywords: Urinary bladder, Neurogenic; Urinary sphincter, Artificial; Intermittent urethral catheterization

- **Grant/Fund Support:** This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.
- **Research Ethics:** The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of Yonsei University College of Medicine (4-2023-1649). The Institutional Review Board of Yonsei University College of Medicine waived the requirement of obtaining informed consent because this study retrospectively reviewed anonymous patient data and did not include the use of human tissue samples.
- **Conflict of Interest:** No potential conflict of interest relevant to this article was reported.

Corresponding author: Jang Hwan Kim  <https://orcid.org/0000-0002-9056-7072>
Department of Urology, Severance Hospital, Urological Science Institute, Yonsei University College of Medicine, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea
Email: jkim@yuhs.ac

Submitted: January 8, 2025 / **Accepted after revision:** March 31, 2025



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INTRODUCTION

Pioneered by Lapides et al., clean intermittent catheterization (CIC) has revolutionized the management of bladder emptying disorders associated with neurogenic and nonneurogenic lower urinary tract dysfunctions [1, 2]. CIC is widely recognized as an effective and safe method. In conditions such as acontractile detrusor, detrusor overactivity with impaired contractility, and detrusor underactivity, CIC is routinely performed to prevent urinary tract infections and upper urinary tract damage, as well as to improve quality of life (QoL) [3–5]. However, unlike healthy individuals, patients using CIC may experience a significant reduction in QoL, activity limitations, and considerable psychological distress [6]. Additionally, many patients encounter substantial challenges in adapting to or accepting CIC. Various strategies have been developed to help patients more effectively adopt and implement CIC [7]. Beyond these challenges, urinary incontinence represents another significant issue for these patients. Persistent incontinence during CIC usage notably increases depression and anxiety, severely reducing QoL [8].

For patients experiencing difficulties with CIC, we have developed a novel surgical approach combining transurethral sphincterotomy (TURS) and artificial urinary sphincter (AUS) implantation. The concept for this procedure arose from clinical experiences involving patients with emptying disorders requiring CIC, who concurrently had prostate cancer. Following radical prostatectomy, these patients became incontinent and subsequently received AUS implantation. Postoperatively, they no longer required CIC, expressed high satisfaction, and achieved successful self-voiding via AUS activation.

TURS, a surgical technique first described in 1958 [9], involves surgical resection of the external sphincter to reduce bladder outlet resistance, facilitating low-pressure bladder emptying in patients with spinal cord injuries and detrusor-sphincter dyssynergia [10]. AUS implantation is an effective treatment for stress urinary incontinence (SUI) due to intrinsic sphincter deficiency (ISD) [11]. The AUS device includes a pump located in the scrotum, which relaxes the cuff that constricts the urethra, effectively replacing sphincter function. In our approach, TURS is deliberately performed to induce ISD and complete incontinence, followed by AUS implantation to enable voiding without residual urine and simultaneously restore continence. While TURS and AUS procedures are individually established surgical methods, combining these 2 pro-

cedures to manage bladder emptying disorders represents, to the best of the authors' knowledge, an unprecedented approach. This proof-of-concept study aimed to evaluate the efficacy and safety of this novel combined surgical technique.

MATERIALS AND METHODS

Study Populations and Indications for Surgery

This study was conducted with approval from the Institutional Review Board. Patients who underwent TURS combined with AUS implantation between April 7, 2021, and May 31, 2024, were included, and clinical data up to October 31, 2024, were utilized for the analysis. The indications for surgery were as follows: a history of CIC for at least 5 years, a strong desire to discontinue CIC, the presence of irreversible neurogenic diseases requiring lifelong CIC, confirmation of a refractory emptying disorder (e.g., neurogenic acontractile detrusor, underactive bladder, or detrusor hyperactivity with impaired contractility [DHIC]) via urodynamic study (UDS) demonstrating normal compliance, and the confirmed absence of mechanical obstruction such as benign prostatic hyperplasia or urethral stricture. For patients with DHIC, only those demonstrating detrusor overactivity on UDS but requiring CIC due to inability to achieve bladder emptying were included. Preoperative cystoscopy was performed to verify the absence of mechanical obstructions. All patients provided informed consent. Patients with less than 3 months of follow-up after AUS activation were excluded from the study.

Transurethral Sphincterotomy

The conventional TURS technique involves making an incision at the bulbous-membranous urethral junction at the 12 o'clock position using a diathermy knife electrode or laser ablation [10, 12]. However, the primary objective of the traditional approach is not to induce complete incontinence. The classic TURS facilitates voiding by utilizing detrusor overactivity as the driving force; however, when detrusor overactivity is insufficient, bladder emptying can worsen, leading to TURS failure [13]. In contrast, the goal of our study was to achieve complete incontinence. Therefore, the entire inner urethral segment around the external sphincter, distal to the verumontanum, was completely resected. Fig. 1 illustrates this TURS procedure. This approach ensures that even if residual sphincter muscle contraction occurs, coaptation of the urethral sphincter is prevented, thus reliably inducing ISD.

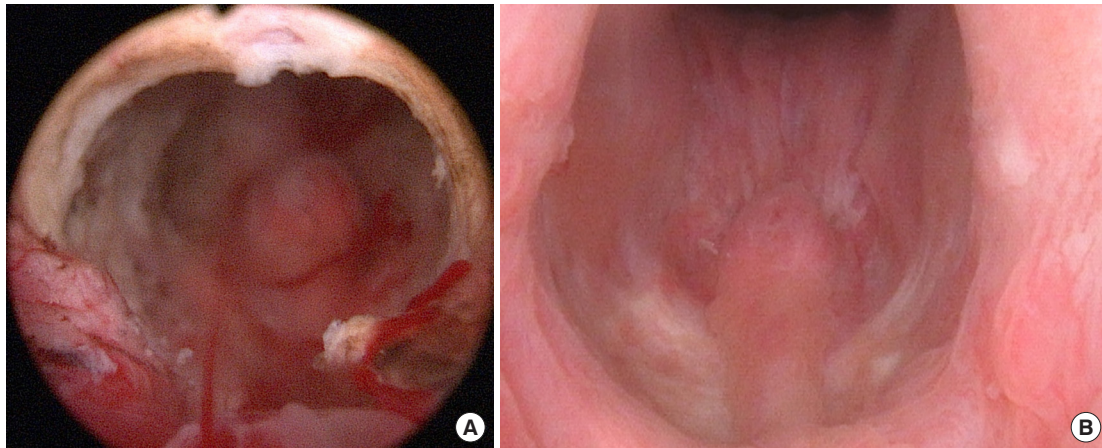


Fig. 1. Transurethral sphincterotomy (TURS). (A) Immediate post-TURS image, demonstrating the entire inner segment of the urethra corresponding to the circumferential region of the rhabdosphincter was resected. (B) Post-TURS image taken 3 months later, demonstrating a well-healed urethra with mucosa appropriately covering the sphincterotomy site. Upon confirming the well-healed state of the urethra, as shown in (B), the subsequent step of artificial urinary sphincter implantation was planned.

Patients were discharged 1 day after the procedure with a Foley catheter in place. At the 1-week postoperative follow-up, patients chose to either maintain the Foley catheter, use a penile clamp, or wear diapers, according to their preference, due to the complete incontinence achieved by surgery. The postoperative follow-up protocol after TURS consisted of an initial outpatient clinic visit 1 week after surgery, followed by monthly follow-up appointments. During these outpatient visits, cystoscopy was performed to assess urethral healing status. Bladder filling with penile clamping, uroflowmetry (UF), and postvoid residual (PVR) measurements were also conducted to evaluate bladder emptying function.

AUS Implantation

The timing of AUS implantation was determined after cystoscopy confirmed complete healing with adequate mucosal coverage of the urethra and successful bladder emptying. AUS implantation was performed through 2 incisions: 1 perineal and 1 suprapubic [11]. The sphincterotomy site of TURS is located at the external urethral sphincter or rhabdosphincter, between the distal verumontanum and the membranous urethra. The AUS cuff was placed more distally at the bulbar urethra. When measuring urethral circumference and selecting cuff size, a looser fit rather than a snug one was intentionally chosen, given that neurogenic patients typically have poorer vascularity and are at higher risk for infection and erosion. Fig. 2 illustrates the entire surgical process combining TURS with AUS implantation. All

patients were discharged the day after AUS implantation surgery.

Data Collection and Statistical Analysis

Data on baseline patient characteristics, as well as pre- and postoperative assessments, were collected. These assessments included daily CIC frequency, daily pad usage, Life Quality (LQ) score from the International Prostate Symptom Score, International Consultation on Incontinence Questionnaire - Short Form (ICIQ) score, Sandvik Severity Index (SAND), PVR, estimated glomerular filtration rate (eGFR), and abdominopelvic ultrasonography findings. The eGFR was calculated using the Chronic Kidney Disease Epidemiology Collaboration equation [14]. UDS was performed at 6 months postoperatively and annually thereafter. Postoperative clinical data were collected as midterm results approximately 6 months after surgery, as well as separately for the last follow-up results. Postoperative complications were categorized and analyzed using the Clavien-Dindo classification [15]. Statistical analyses were conducted using IBM SPSS Statistics ver. 23.0 (IBM Co.). Descriptive statistics summarized patient characteristics and clinical data. Due to the small sample size and relatively large standard deviations compared to the mean, normality was assessed using the Shapiro-Wilk test. If variables satisfied normality assumptions, the paired t-test was conducted; otherwise, the Wilcoxon signed-rank test was applied. A P-value of less than 0.05 was considered statistically significant.

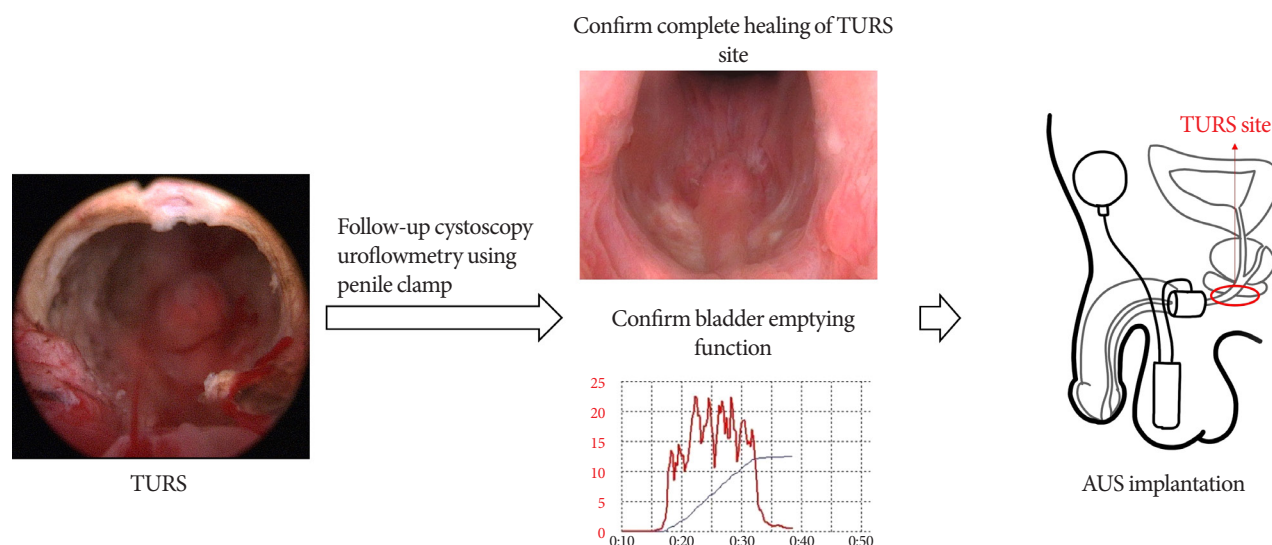


Fig. 2. The entire process and protocol schematic of transurethral sphincterotomy (TURS) combined with artificial urinary sphincter (AUS) implantation.

RESULTS

Patient Characteristics

From the first surgery on April 7, 2021, through October 31, 2024, a total of 6 patients underwent the procedure. The median patient age was 37 years (interquartile range [IQR], 24–61.5 years), and the median follow-up duration was 15.5 months (IQR, 13.2–20.7 months). Patient numbers 1, 5, and 6 had histories of spinal cord injuries at the L1 level due to a fall, and at the T4 and L3 levels due to motor vehicle accidents, respectively. Patient No. 1 also had diabetes mellitus and stable angina. The other 3 patients had spina bifida with no additional significant medical history. Patient No. 2 had previously undergone bilateral ureteroneocystostomy for vesicoureteral reflux and augmentation ileocystoplasty with a bladder-neck rectus fascia sling for SUI. The remaining spina bifida patients had no significant past medical history. Except for Patient No. 5, SUI was the primary type of preoperative incontinence. Patient No. 5, diagnosed with DHIC, primarily experienced overflow incontinence. Regarding surgical indications, patient numbers 1 and 4 required CIC once and twice daily, respectively; despite their relatively low CIC frequency and PVR volumes, their International Prostate Symptom Score LQ scores exceeded 4 points, indicating a strong desire to discontinue CIC. Baseline demographics for each patient are presented in Table 1.

Outcomes of Surgery

The median operative time for TURS was 52.0 minutes (IQR, 27.8–59.8 minutes), and the median operative time for AUS implantation was 145 minutes (IQR, 106.3–188.5 minutes). The median interval between the TURS and AUS procedures was 4.3 months (IQR, 3.7–6.9 minutes). Comparing pre- and postoperative outcomes, 4 out of 6 patients (66.7%) achieved CIC-free status. In these 4 CIC-free patients, voiding was successfully performed by activating the AUS pump and utilizing abdominal pressure, with PVR volumes consistently below 50 mL. The 2 patients who did not achieve CIC-free status were patient numbers 5 and 6. Patient No. 5 had preoperative DHIC identified via UDS, with frequent urgency but inability to self-void, thus requiring CIC. Postoperatively, patient No. 5 could void only with assistance from another person manually compressing the suprapubic area after activating the AUS but was unable to self-void independently due to difficulty performing the Valsalva maneuver and generating adequate abdominal pressure. Patient No. 6 required AUS removal due to device infection.

Clinical data before and after surgery are presented in Table 2. Fig. 3 illustrates postoperative UF results for each of the 4 successful patients. Preoperative median PVR decreased significantly postoperatively, from 237.5 mL (IQR, 112.5–317.5 mL) to 0 mL (IQR, 0–126.5 mL), reflecting improved bladder emptying function ($P=0.028$). Furthermore, significant improve-

Table 1. Demographic characteristics and raw clinical data of patients

Characteristic	Patient number					
	1	2	3	4	5	6
Age (yr)	65	26	22	37	58	24
Etiology of neurogenic bladder	SCI (L1)	Spina bifida	Spina bifida	Spina bifida	SCI (T4)	SCI (L3)
Other comorbidities	DM Stable angina	None	None	None	Hypertension	None
Preoperative UDS	Normal compliance	Normal compliance	Normal compliance	Normal compliance	Normal compliance	Normal compliance
	NA	NA	NA	NA	DHIC	NA
	MC 600 mL	MC 463 mL	MC 482 mL	MC 593 mL	MC 306 mL	MC 418 mL
	VLPP 182 cm H ₂ O	CLPP 48 cm H ₂ O	CLPP 72 cm H ₂ O	VLPP 118 cm H ₂ O		CLPP 63 cm H ₂ O
Midterm postoperative UDS	Normal compliance	Normal compliance	Normal compliance	Normal compliance	N/A ^{a)}	N/A ^{b)}
	NA	NA	NA	NA		
	MCC 735 mL	MCC 556 mL	MCC 488 mL	MCC 480 mL		
	PVR 4 mL	PVR 0 mL	PVR 5 mL	PVR 0 mL		
Last postoperative UDS	No incontinence	No incontinence	No incontinence	No incontinence		
	Normal compliance	Normal compliance	Normal compliance	Normal compliance	N/A ^{a)}	N/A ^{b)}
	NA	NA	NA	NA		
	MCC 609 mL	MCC 705 mL	MCC 448 mL	MCC 382 mL		
Main type of preoperative incontinence	PVR 0 mL	PVR 0 mL	PVR 14 mL	PVR 5 mL		
	No incontinence	No incontinence	No incontinence	No incontinence		
	CLPP 211 cm H ₂ O					
Follow-up duration (mo)	20.5	20.9	12.0	15.5	14.5	8.5
Interval from TURS to AUS implantation (mo)	3.8	5.8	4.3	3.6	8.0	4.1
Daily CIC catheter usage count	1/0	8/0	7/0	2/0	4/4	5/5
LQ	5/0	4/0	5/1	4/1	5/4	5/5
ICIQ	20/4	15/4	16/4	15/1	18/11	20/18
SAND	7/4	7/4	6/0	7/2	7/4	7/7
PVR	54/3	225/0	132/0	250/0	284/250	418/31
eGFR	69/68	125/134	121/124	115/112	112/118	157/153
Daily pad usage count	10/0.33	10/0	3/0	3/0	2/2	3/3

Values are presented as preoperative/postoperative values at last follow-up visit.

DM, diabetes mellitus; UDS, urodynamic study; NA, neurogenic acontractile detrusor; TURS, transurethral sphincterotomy; AUS, artificial urinary sphincter; CIC, clean intermittent catheterization; DHIC, detrusor hypersensitivity with impaired contractility; MC, maximal capacity; VLPP, Valsalva leak point pressure; CLPP, cough leak point pressure; SUI, stress urinary incontinence; LQ, Life Quality score of International Prostate Symptom Score; ICIQ, International Consultation on Incontinence Questionnaire - Short Form; SAND, Sandvik Severity Index; PVR, postvoid residual urine volume; eGFR, estimated glomerular filtration rate.

^{a)}Postoperative UDS was not performed in patient No. 5, as the patient declined further invasive evaluations due to disappointment related to continued reliance on CIC postoperatively, despite initial high expectations for achieving CIC-free status. ^{b)}Postoperative UDS was not performed in patient No. 6 because AUS was removed due to infection.

ments were observed in the LQ score, ICIQ score, and SAND score ($P=0.042$, $P=0.004$, and $P=0.039$, respectively). Comparisons between midterm and last follow-up results revealed no significant differences for any measured variables. Similarly, postoperative UDS findings showed no noteworthy differences between midterm and last follow-up assessments. In patient No. 1, new-onset SUI with a cough leak point pressure of 211 cm H₂O was identified; however, the patient maintained social

continence, requiring fewer than 1 pad per day.

In terms of surgical safety, no statistically significant difference was observed in the eGFR, with median preoperative values of 118.0 mL/min/1.73 m² (IQR, 101.25–133.0 mL/min/1.73 m²) and postoperative values of 121.0 mL/min/1.73 m² (IQR, 101.0–138.8 mL/min/1.73 m²) ($P=0.528$). Regular abdominopelvic ultrasonography performed during follow-up visits starting at least 3 months after AUS activation showed no evidence

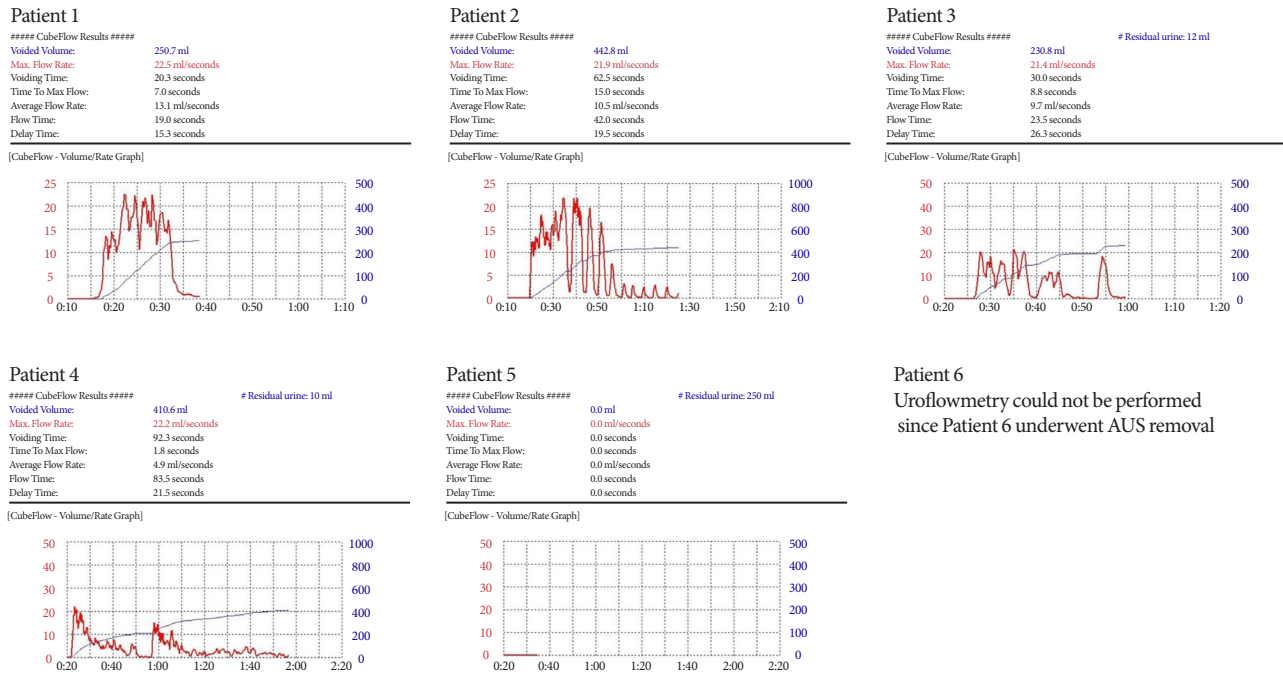


Fig. 3. Uroflowmetry of each patient after transurethral sphincterotomy (TURS) combined with artificial urinary sphincter (AUS) implantation.

Table 2. Clinical outcomes before, 6 months after (midterm), and at last follow-up after transurethral sphincterotomy (TURS) combined with artificial urinary sphincter (AUS) implantation

Value	Preoperation	Midterm result at 6 months	P-value [†]	Last follow-up result	P-value [‡]	P-value [§]
CIC-free status	-	4/6 (66.7)		4/6 (66.7)		
LQ	5.0 (4.0–5.0)	2.0 (0.8–5.0)	0.066	1 (0–1.0)	0.042	0.102
ICIQ	17.0 (15.0–20.0)	4.5 (3.5–11.3)	0.003 ^{a)}	4.0 (3.3–12.8)	0.004 ^{a)}	1.000 ^{a)}
SAND	7.0 (6.8–7.0)	4.0 (2.0–5.5)	0.041	4.0 (1.5–4.75)	0.039	0.655
PVR	237.5 (112.5–317.5)	0 (0–60.0)	0.028	1.5 (0–85.8)	0.028	0.180
Daily pad usage count	3.0 (2.8–10.0)	0.2 (0–2.3)	0.066	0.2 (0–2.3)	0.066	N/A ^{b)}
eGFR	118.0 (101.3–133.0)	119.0 (100.5–138.3)	0.562 ^{a)}	121.0 (101.0–138.8)	0.468 ^{a)}	0.732 ^{a)}
Clavien-Dindo classification grade ≥ II	-	1 (16.7)		1 (16.7)		

Values are presented as number (%) or median (interquartile range).

CIC, clean intermittent catheterization; LQ, Life Quality score of International Prostate Symptom Score; ICIQ, International Consultation on Incontinence Questionnaire - Short Form; SAND, Sandvik severity index; PVR, postvoid residual urine volume; eGFR, estimated glomerular filtration rate.

^{a)}This variable satisfied the normality assumption and was analyzed using the paired t-test, while the remaining variables did not meet normality and were analyzed using the Wilcoxon signed-rank test. ^{b)}Wilcoxon signed-rank test was not applicable since differences between paired observations were zero for all samples.

[†]Preoperation vs. midterm result at 6 months. [‡]Preoperation vs. last follow-up result. [§]Midterm result at 6 months vs. last follow-up result.

of upper urinary tract damage in any patient. According to the Clavien-Dindo classification, 1 patient (patient No. 6) experienced AUS infection requiring device removal (Clavien-Dindo

Classification grade III). The remaining 5 patients experienced no complications classified as grade II or higher related to either TURS or AUS.

DISCUSSION

This study demonstrated favorable outcomes, particularly regarding bladder emptying function. Notably, 4 of the 6 patients (66.7%) became free from the need for CIC following surgery. The procedure enabled these patients to independently manage voiding by activating the AUS at will, indicating not only positive functional outcomes but also substantial psychological satisfaction. Particularly significant were the improvements observed in patients who previously anticipated lifelong reliance on CIC, allowing them now to achieve voluntary voiding. This was especially meaningful for the 3 patients with spina bifida, who had depended on CIC since childhood and experienced CIC-free life for the first time. No longer needing to carry CIC supplies when outside significantly enhanced their daily social and functional activities and markedly improved their QoL. The surgical outcomes regarding urinary incontinence were also favorable. This surgical approach specifically targets patients with refractory bladder emptying disorders. Since the goal of TURS is to induce total incontinence to the extent that bladder filling no longer occurs, it may be applicable regardless of preexisting sphincter function. Additionally, patients with preoperative SUI may experience further improvement in their incontinence symptoms. The average number of daily pads used decreased postoperatively, and significant improvements were observed in the ICIQ and SAND scores. Importantly, all 4 successful patients used fewer than 1 pad per day after surgery, achieving social continence.

Patient No. 5 did not achieve CIC-free status primarily due to the inability to exert adequate abdominal pressure caused by a spinal cord injury at the T4 level. Postoperatively, the AUS function was confirmed through cystoscopy, demonstrating smooth cuff movement without evidence of strictures or obstruction. Although this patient could void with assistance through manual compression of the suprapubic area after activating the AUS, the inability to independently perform the Valsalva maneuver ultimately resulted in failure of strain-induced voiding during daily life. Nonetheless, some improvements in incontinence symptoms were noted, suggesting that additional training in Crede voiding techniques might enable recovery of bladder emptying function. The key lesson from this case is that the inability to perform an effective Valsalva maneuver preoperatively should be considered a relative contraindication for the combined TURS and AUS procedure.

Although this study did not implement a specific method for

objectively measuring the effectiveness of the Valsalva maneuver in enrolled patients, future studies should assess the patient's ability to perform the Valsalva maneuver by evaluating increases in intra-abdominal and intravesical pressures during UDS before AUS implantation. Additionally, some patients may be unable to perform the Valsalva maneuver effectively due to neurological conditions resulting in insufficient muscle strength or the inability to adequately increase intra-abdominal pressure. It is also important to consider circumstances in which performing the Valsalva maneuver might cause complications due to coexisting comorbidities. Conditions such as coronary artery disease, recent myocardial infarction, heart failure, cerebral aneurysm, intracranial hypertension, glaucoma, and hernia may be exacerbated by the Valsalva maneuver [16, 17]. Therefore, these conditions should be considered relative contraindications for surgery.

Regarding surgical safety, particularly concerning potential upper urinary tract damage, the AUS poses a theoretical risk of increased bladder pressures. However, this study observed no significant changes in eGFR, and no cases of urinary tract infections occurred postoperatively. Additionally, regular postoperative kidney ultrasonography indicated no abnormalities in the upper urinary tract. Nonetheless, given the relatively short follow-up period, additional research is needed to evaluate long-term outcomes. If future studies anticipate or identify upper urinary tract damage, deactivating the AUS and resuming CIC should be considered. If this approach is not feasible, suprapubic cystostomy may be an alternative. Patients should be thoroughly informed about these potential outcomes. Postoperative complications were minimal according to the Clavien-Dindo classification, with no grade II or higher complications reported except for 1 patient. Patient No. 6 required AUS removal due to infection. Infection or erosion of the AUS device represents one of the most clinically significant potential complications. Patients with neurogenic bladder conditions are particularly at risk due to CIC usage, a higher incidence of bladder stones, and frequent urinary tract infections. Furthermore, the mechanical durability of the AUS tends to be lower in these patients, necessitating a higher frequency of revision surgery [18]. Therefore, these risks must be carefully considered before proceeding with the combined TURS and AUS procedure. Based on the study results, we propose the following surgical indications: a strong desire to discontinue CIC; confirmed neurogenic acontractile detrusor, detrusor underactivity, or DHIC associated with significant PVR; bladder compliance within normal

limits; the ability to effectively perform a Valsalva maneuver; no issues operating the AUS; and verified absence of mechanical obstruction.

The urethral sphincter muscles are among the least understood in the human body due to their inaccessibility and small size. It is known that the sphincter anatomy consists of 2 distinct components: the internal sphincter (lissosphincter) and external sphincter (rhabdosphincter), with ongoing debate regarding their respective roles in continence maintenance [19, 20]. Koraitim et al., based on observations from various sphincter excision scenarios, inferred that the lissosphincter primarily contributes to passive continence, while the rhabdosphincter predominantly contributes to stress-related continence [20]. In this study, the TURS procedure primarily targeted the rhabdosphincter, deliberately inducing damage to disrupt its continence-maintaining function. Further research and deeper understanding of the urinary sphincter mechanisms could potentially lead to more effective strategies for inducing total incontinence.

By reducing bladder outlet obstruction, the conventional TURS technique facilitates reflex voiding at lower bladder pressures, thereby reducing urinary tract infections and protecting the upper urinary tract. Additionally, TURS can decrease the incidence of autonomic dysreflexia [10, 21]. Nevertheless, TURS is associated with various potential complications. Causes of TURS failure include abnormalities in bladder contractions, bladder-neck contractures, and urethral strictures [22]. In particular, urethral strictures can occur due to iatrogenic trauma during surgery, catheter-related injuries, or recurrent infections. Long-term complications, such as upper urinary tract deterioration, have also been reported [23]. Juma et al. [23] observed that approximately 50% of such complications occurred during long-term follow-up periods exceeding 2 years, emphasizing detrusor leak point pressure as a reliable urodynamic risk parameter. Further anatomical research into the urethral sphincter could potentially enable external sphincter excision while minimizing interference with the urethra, possibly through robotic surgery. If reproductive or sexual function is not a concern, robotic prostatectomy with concurrent sphincterectomy might also become a viable option. Such an approach could permit 1-step AUS implantation without intruding into the urethra, thereby reducing the risk of urethral strictures.

In this study, surgeries were performed exclusively on male patients, as TURS combined with AUS implantation has not yet been attempted in female patients. Females have distinct functional sphincter anatomy, and due to their shorter urethra, per-

forming TURS presents technical challenges. Additionally, the technical complexity of AUS implantation in females is greater than in males. However, this novel procedure may potentially be applicable to females with similar voiding dysfunctions in the future, contingent upon further research and technical advancements.

Several limitations should be noted in this study. First, it involved only 6 patients, resulting in a limited research sample. Such a small sample size limits the generalizability of these findings. Second, as a proof-of-concept study, there is a possibility of confirmation and selection biases. The primary objective of demonstrating initial feasibility may have influenced result interpretation due to preconceived expectations or the specific selection of patients. Third, the short-term follow-up period limits available data on potential long-term complications. Since this surgical approach replaces CIC with Valsalva voiding—which increases abdominal pressure to facilitate bladder emptying—long-term data on upper urinary tract safety are essential. Thus, the reliability of long-term outcome predictions remains uncertain, emphasizing the need for extended follow-up studies. Fourth, given that this is the first report of our novel surgical approach, it was impossible to fully anticipate all potential negative outcomes related to patient selection. However, based on our current results, future studies can refine patient selection criteria. Despite these limitations, this study successfully demonstrated the potential of the surgical approach, meeting its proof-of-concept objectives and producing promising outcomes. Future research involving more extensive patient populations, multicenter studies, and longer follow-up periods is essential to validate the effectiveness and safety of this surgical approach on a broader scale. Additionally, comparative evaluations of QoL and safety outcomes between neurogenic bladder patients undergoing standalone AUS implantation with ongoing CIC use versus those undergoing combined TURS and AUS implantation could provide valuable insights, further clarifying the clinical advantages and applicability of this novel surgical technique.

This study holds substantial significance as the first investigation of a novel surgical approach—TURS combined with AUS implantation. As an unexplored technique, it has the potential to initiate a paradigm shift in managing both neurogenic and non-neurogenic bladder emptying disorders. Being an innovative strategy, this approach represents a pivotal milestone that could revolutionize neurogenic bladder management.

In conclusion, this study provides the first exploration and

proof-of-concept evaluation of a novel 2-stage surgical approach, combining TURS with AUS implantation. Our findings demonstrate the feasibility and effectiveness of this procedure, successfully achieving CIC-free status in 66.7% of patients and significantly improving QoL. These outcomes highlight the potential of TURS combined with AUS as a viable treatment option for patients with refractory bladder emptying disorders. Based on this study, we propose the following indications for this procedure: a strong desire to discontinue CIC, confirmed neurogenic acontractile detrusor or DHIC with normal bladder compliance, adequate capability to perform the Valsalva maneuver, absence of mechanical obstruction, and the ability to operate the AUS pump. Although these early results are promising, the small sample size and relatively brief follow-up period limit the generalizability of the findings. Further research involving larger patient cohorts, multicenter studies, and extended follow-up durations is required to establish the long-term safety, durability, and broader applicability of this innovative surgical technique. Specifically, long-term follow-up studies are crucial to comprehensively evaluate potential late complications, including upper urinary tract deterioration and AUS-related adverse events. Nevertheless, this study lays essential groundwork for advancing treatment strategies in this challenging patient population.

AUTHOR CONTRIBUTION STATEMENT

- Conceptualization: *KTO, JHK*
- Data curation: *KTO, ANL, ARI*
- Formal analysis: *KTO, ANL, ARI*
- Methodology: *KTO*
- Visualization: *KTO*
- Writing - original draft: *KTO*
- Writing - review & editing: *KTO, JHK*

ORCID

Kyung Tak Oh	0000-0003-3681-6629
Avleyn Lim	0009-0005-8724-0502
Alwadaï Raed	0009-0009-4371-7822
Jang Hwan Kim	0000-0002-9056-7072

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