Original Article

Comparison of bladder autoaugmentation by transurethral vesicomyotomy and hydrodistention for ketamine cystitis

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Background: To illustrate the bladder autoaugmentation by transurethral vesicomyotomy (BATV) and compare the efficacy and safety of BATV to bladder hydrodistention (BH) for managing ketamine cystitis (KC).

Methods: We retrospectively analyzed clinical data for 53 patients with KC who received surgical intervention between 2014 and 2019 at our hospital. Of these, 41 (77.4%) underwent BH and 12 (22.6%) were subjected to BATV, with a minimum of 1-year follow-up. These groups were compared with reference to urodynamic parameters, subjective symptom scores as well as all complications.

Results: Both groups were matched in age, addiction time, preoperative urodynamic parameters, postvoid residual urinary volume (PVR), and symptom scores. All urodynamic parameters including maximum cystometric capacity (MCC), maximum detrusor pressure ($P_{det\ max}$), compliance, maximum urinary flow rate (Q_{max}) and symptom scores had improved significantly in two groups whether at 3 or 12 months. Moreover, the MCC was significantly increased after BATV than BH, at a mean [standard deviation (SD)] of 281.0 (25.7) *vs.* 213.5 (35.6) mL (P<0.001) at 12-month follow-up. The Q_{max} and the Pelvic Pain and Urgency/Frequency (PUF) symptom score were still noted better in the BATV group at 3 months after surgery. Additionally, patients in both groups had similarly low rates of complications.

Conclusions: BATV is superior to BH with increased bladder capacity and urodynamic outcomes, although showing equivalent in symptom relief and a similar rate of complications.

Keywords: Ketamine; cystitis; bladder autoaugmentation; vesicomyotomy; hydrodistention

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Introduction

Ketamine, an antagonist of the N-methyl-D-aspartic acid (NMDA) receptor complex, is largely used for anesthesia and as a therapy for mental disorders (1). With increasing ketamine abuse in adolescents as a recreational drug, ketamine cystitis (KC), one of its adverse health effects, has become a new clinical problem affecting the genitourinary tract. Pelvic pain, hematuria and lower urinary tract symptoms (LUTS) characterized by dysuria and urinary frequency/urgency have occurred globally in 26.6%

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of ketamine abusers (2). In addition, some severe cases progressed to bladder contracture and vesicoureteral reflux, leading to hydronephrosis of the upper urinary tract and ultimately impaired renal function (3).

Conservative treatments including behavior therapy and medication have provided little relief despite the cessation of ketamine (4,5). Surgical interventions including hydrodistention, augmentation cystoplasty, autoaugmentation, ureteric re-implantation, and cystectomy with neobladders have been reported sporadically for patients with intractable and relapse KC (6-8). Bladder hydrodistention was first suggested for interstitial cystitis/bladder pain syndrome (IC/BPS) in 1922 and also reported short-term improved bladder capacity as well as relieved LUTS for KC in spite of the limited experience (8,9). As treatment efficacy of hydrodistention decreased with long-term follow-up, more aggressive surgeries like bladder augmentation by cystoplasty have been performed and shown sustainably effective for KC, but is also associated with a high risk of complications and failure rates (6,7,10,11). Thus, BATV, which was initially used for contracted bladder, strives to offer a novel and stable therapeutic response to KC as minimally invasive alternatives along with a lower risk of adverse events (12). Here, we present 1-year retrospective results comparing BATV and BH as treatments for KC with regard to symptom relief and improvements in urodynamic outcomes. We present the following article in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/tau-21-188).

Methods

Participants

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Xiangya Hospital, Central South University (NO.: 202008101) and individual consent for this retrospective analysis was waived. Between 2014 and 2019, we retrospectively reviewed 61 patients with KC who underwent surgical intervention in our institution. All of these patients were unresponsive to conservative treatment preoperatively including anticholinergic medication, pelvic floor therapy and/or intravesical treatments. Indications for surgery included upper tract deterioration, maximum cystometric capacity (MCC) <150 mL, bladder compliance <30 mL/cmH_2O, refractory and/or relapse KC. No patients treated firstly by BH then BATV were enrolled in the study. Besides, 4 of patients with difficulty in transurethral operation and 4 with missing data were excluded. Overall, the study identified 53 patients, of whom 41 (77.4%) underwent BH and 12 (22.6%) were treated by BATV. There has been no standardized diagnose of KC. All patients provided a detailed history of ketamine use and underwent physical examination as well as urodynamics testing. Preoperative cystourethroscopy and biopsy are performed on initial assessment of KC. All excluded other pathology such as IC/BPS, neurogenic bladder or tuberculosis affecting the bladder and confirmed the typical pathological changes containing denuded mucosa, inflammation with lymphocyte and monocyte infiltration, and fibrosis of the bladder wall (6). Additionally, KC associated LUTS were quantitatively evaluated by Pelvic Pain and Urgency/Frequency (PUF) symptom score, Visual Analogue Scale/Score (VAS), O'Leary-Sant IC Symptom Index (ICSI), IC Problem Index (ICPI), and Quality of Life (QoL) score. The urinary tract was determined by computerized tomography (CT) scans while postvoid residual urinary volume (PVR) by immediate transurethral bladder drainage, and urodynamic testing was applied to assess MCC, maximum detrusor pressure ($P_{det\ max}$), compliance and maximum urinary flow rate (Q_{max}). Peri- and postoperative outcomes measured in two groups included operative time, duration of catheterization, hospital stay and complications. The catheter was subsequently removed after the urine turned reddish or clear, and patients were discharged 48 hours after removal of the catheter. All patients were evaluated for bladder capacity, LUTS and adverse events along with imaging and urodynamic assessment at the 3- and 12-month follow-ups.

Interventions

A single experienced surgeon at our site conducted all procedures using general anesthesia in the operating suite. BATV was performed using an Olympus cystoresectoscope (Japan, A22001), and patients were placed in a lithotomy position. During the operation, the surgeon examined the walls, neck and trigone of bladder and marked bilateral ureteric orifices aiming to avoid iatrogenic injury. Next, the mucosa and detrusor of bladder were incised longitudinally and latitudinally under resectoscope to create the diverticulum until perivesical fat was vaguely visible. The depth of incision varies from 1 to 2.5 mm due to the thickness of the bladder wall. Urethral catheter drainage

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was instituted and then the catheter was removed until postoperative hematuria receded.

Since there have been no standard methods of hydrodistention, we suggest performing low-pressure and short-duration BH similar to that described by Hanno (13). After general anesthesia was administered in each case, an initial cystoscopic examination was performed and urine obtained for cytology. The tube was subsequently inserted into the bladder meanwhile its tail connected a pressure monitor. A saline serum pouch was then suspended 60 to 80 centimeters above the operating table. The perfusion procedure began and continued to ensure the pressure was maintained approximately at 60 cmH_2O for 10 minutes without rest intervals. While inactive bleeding was recorded in a re-examined cystoscopy, the bladder was later continuously rinsed through the indwelling F22 3-way silicone catheter.

Statistical analysis

Pearson's Chi-squared and Fisher's exact tests were used for categorical characteristics as appropriate. Mann-Whitney U test was used for continuous variables as a comparison between baseline and 3–12 months. A value of $P<0.05$ was considered statistically significant(two-tailed). Data analysis was conducted using SPSS, version 22.0 (SPSS Inc., IBM Corp, USA).

Results

Baseline

The mean age (25.0±5.1 *vs.* 25.2±3.8 years), addiction time (3.0±0.9 *vs.* 3.3±1.7 years) and gender (75.0% *vs.* 73.2% of men) were not different between the BATV and BH groups (*Table 1*). The mean [standard deviation (SD)] preoperative MCC was 92.2 (12.3) mL before BATV surgery, compared to 93.2 (19.1) mL in the BH group. Besides, other urodynamic parameters, PVR and LUTS scores were similar between the two groups. Cystoscopy and histology show denuded mucosa, submucosal edema, microvascular damage, inflammation with lymphocyte and monocyte infiltration, and fibrosis of the bladder wall.

Operative characteristics

With reference to the perioperative data, operative time in the BATV group was significantly longer than BH (90.3±12.5 *vs.* 52.7±12.4 min, $P<0.001$). The estimated blood loss was not high enough to be evaluated in both groups because of the minimal invasion. In addition, the hospital stay and catheterization time showed similarities between the two groups (*Table 1*).

Treatment efficacy

As shown in *Tables 2,3*, all functional outcomes including MCC, Q_{max}, and symptom scores were significantly improved in both groups compared to baseline at 3- and 12-month follow-up. In comparison with 3-month, the mean MCC and Q_{max} were not further increased at 12-month in both groups. Also, the symptom scores at 12-month follow-up were not noted a remarkable reduction than at 3-month. Nevertheless, a significant increase in PVR was observed at 12-month follow-up than baseline after BATV (46.3±3.6 *vs.* 15.4±5.2 mL).

The MCC in the BATV group was notably higher than in the BH group (281.0±25.7 *vs.* 213.5±35.6 mL, $P<0.001$) at 12-month follow-up. The BATV still provided better improvements in compliance and $P_{det\ max}$. Furthermore, the BATV group achieved a better outcome in PUF scores and Q_{max} ($P=0.005$, $P=0.021$ respectively) at 3-month follow-up while showed insignificant difference at 12-month compared to the BH group. But the BATV group was demonstrated a more increased PVR at 12-month after surgery (46.3±3.6 *vs.* 15.9±4.7 mL) (*Table 2*, *Figure 1*). Regarding any other follow-up parameters to evaluate the efficacy of both approaches, there were no significant differences between two groups within 12 months of follow-up.

Patients with preoperative MCC <100 mL show more significant improvement in MCC, compliance and $P_{det\ max}$ after BATV than MCC ≥150 mL (*Figure 2*). Cumulative percentages of patients achieving various improvements in bladder capacity and Q_{max} in both groups are expressed in *Figure 3*. The increase in bladder capacity after BATV shows better than BH at 12 months from baseline (189.1±16.8 *vs.* 119.6±31.7 mL, $P<0.001$) while the changed volumes of PVR in two groups differ significantly (30.7±4.0 *vs.* −0.3±6.4 mL, $P<0.001$) (*Table 2*, *Figure 2*). Beyond that, the changes in Q_{max} and subjective symptom scores had no significant differences.

Complications

Thirteen patients (26.5%) of all encountered complications

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Table 1 Baseline characteristics and perioperative outcomes of the included patients

Characteristics	BH (n=41)		BATV (n=12)		P value
	No. Pts (%)/mean (SD)	Median (IQR)	No. Pts (%)/mean (SD)	Median (IQR)	
Male	30 (73.2)	–	9 (75.0)	–	1.000
Age (year)	25.2 (3.8)	25.0 (23.0–27.0)	25.0 (5.1)	23.5 (21.0–29.5)	0.536
Addiction time (year)	3.3 (1.7)	3.0 (2.5–4.0)	3.0 (0.9)	2.8 (2.1–3.8)	0.688
MCC (mL)	93.2 (19.1)	97.0 (82.5–104.0)	92.2 (12.3)	95.0 (80.8–97.8)	0.573
Compliance (mL/cmH_2O)	12.0 (3.4)	12.0 (9.5–14.0)	11.0 (2.6)	10.5 (9.0–13.5)	0.392
$P_{det\ max}$ (cmH_2O)	37.5 (7.9)	40.0 (32.5–43.0)	36.7 (7.0)	38.5 (32.5–41.8)	0.587
Q_{max} (mL/s)	9.7 (1.9)	8.9 (8.5–10.6)	9.2 (1.1)	9.2 (8.3–10.2)	0.741
PVR (mL)	16.1 (5.7)	15.0 (11.5–19.0)	15.4 (5.2)	14.0 (11.0–20.8)	0.670
PUF	17.8 (2.0)	18.0 (16.0–19.0)	17.3 (2.0)	17.5 (15.3–19.0)	0.526
VAS	7.7 (0.9)	8.0 (7.0–8.0)	7.8 (0.9)	8.0 (7.0–8.8)	0.596
ICSI	17.0 (1.8)	17.0 (15.0–19.0)	16.3 (1.2)	16.0 (15.3–17.0)	0.235
ICPI	12.6 (1.5)	13.0 (11.0–14.0)	12.9 (1.2)	13.0 (12.0–14.0)	0.551
QoL	5.3 (0.5)	5.0 (5.0–6.0)	5.5 (0.5)	5.5 (5.0–6.0)	0.324
Operative time (min)	52.7 (12.4)	49.0 (46.0–61.0)	90.3 (12.5)	87.5 (79.8–99.5)	<0.001
Catheterization time (d)	4.3 (0.9)	4.0 (4.0–5.0)	4.5 (0.9)	4.0 (4.0–5.0)	0.498
Hospital stay (d)	7.4 (1.1)	7.0 (7.0–8.0)	7.2 (1.2)	7.0 (6.3–8.0)	0.544

BH, bladder hydrodistention; BATV, bladder autoaugmentation by transurethral vesicomyotomy; Q_{max}, maximum urinary flow rate; MCC, maximum cystometric capacity; $P_{det\ max}$, maximum detrusor pressure; PVR, postvoid residual urinary volume; PUF, the Pelvic Pain and Urgency/Frequency; VAS, Visual Analogue Scale/Score; ICSI, O'Leary-Sant IC Symptom Index; ICPI, IC Problem Index; QoL, quality of life.

except 4 patients lost to follow-up within 12 months. Complications were classified using the Clavien-Dindo scale (grades I–IV) and most of these were Clavien grade I and II (*Table 4*). In the BH group, recurrent or persistent LUTS was the predominant complication while the rate of which was not significantly higher than in the BATV group. Moderate complications including bladder perforation and stone formation were present respectively in one patient and another after BATV (9.1%, P=0.224). Correspondingly, prolonged catheterization and transurethral cystolitholapaxy and lithotripsy were offered. Chronic urinary retention, acute kidney injury, and venous thromboembolism (VTE) were noted in 1 patient from each group, and these cases were treated with subsequent treatment including clean intermittent catheterization, diuretics along with hemodynamic management, and anticoagulant respectively. In addition, 3 (7.9%) patients in the BH group reported urinary tract infections (UTIs) than 1 (9.1%) in the BATV group, and one patient after BH developed sepsis requiring culture-based antimicrobial. Four (10.5%) and 2 (18.2%) of patients who underwent BH and BATV respectively had hypogastric pain and demanded analgesics. No patient after BATV and 4 (10.5%) patients after BH received continuous bladder irrigation due to gross hematuria. Overall, there was no significant difference in the incidence of complications in two groups.

Discussion

According to recent studies, cessation of ketamine is the mainstay of relieving LUTS, improving bladder capacity and avoiding further deterioration of renal function in spite of its difficulty for frequent users (14,15). Previous reports have suggested unsatisfactory results of conservative managements and that surgical interventions have been considered suitable for these patients who had contracted bladders, refractory and recurrent symptoms or upper tract compromise (6,7,15). Sihra *et al.* (7) reviewed ketamine abusers treated with urinary tract reconstruction such as augmentation cystoplasty, total cystectomy with orthotopic

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Table 2 Functional outcomes at 3 and 12 months of follow-up

Scale/time point	BH			BATV			P value
	N	Mean (SD)	Median (IQR)	N	Mean (SD)	Median (IQR)	
MCC (mL)							
Baseline	41	93.2 (19.1)	97.0 (82.5–104.0)	12	92.2 (12.3)	95.0 (80.8–97.8)	0.573
3 months	39	218.2 (39.1)	211.0 (189.0–256.0)	12	287.3 (38.2)	290.0 (260.0–310.0)	<0.001
12 months	38	213.5 (35.6)	211.5 (183.0–234.3)	11	281.0 (25.7)	280.0 (267.0–300.0)	<0.001
Difference		119.6 (31.7)	120.0 (90.5–145.3)	11	189.1 (16.8)	184.0 (181.0–205.0)	<0.001
Compliance (mL/cmH_2O)							
Baseline	41	12.0 (3.4)	12.0 (9.5–14.0)	12	11.0 (2.6)	10.5 (9.0–13.5)	0.392
3 months	39	16.6 (4.2)	17.0 (14.0–19.0)	12	22.0 (5.2)	21.5 (18.3–23.0)	0.001
12 months	38	15.9 (4.2)	16.0 (13.0–19.0)	11	23.2 (5.6)	23.0 (18.0–27.0)	<0.001
Difference		3.7 (3.0)	3.0 (1.0–5.0)		12.0 (6.1)	12.0 (9.0–19.0)	<0.001
$P_{det\ max}$ (cmH_2O)							
Baseline	41	37.5 (7.9)	40.0 (32.5–43.0)	12	36.7 (7.0)	38.5 (32.5–41.8)	0.587
3 months	39	25.1 (6.8)	23.0 (21.0–30.0)	12	18.4 (2.9)	18.5 (16.0–20.8)	0.001
12 months	38	26.2 (6.4)	25.0 (21.8–30.3)	11	17.3 (4.1)	16.0 (14.0–21.0)	<0.001
Difference		–11.2 (8.3)	–10.0 (–15.5 to –5.0)		–18.6 (6.2)	–21.0 (–23.0 to –13.0)	0.010
Q_{max} (mL/s)							
Baseline	41	9.7 (1.9)	8.9 (8.5–10.6)	12	9.2 (1.1)	9.2 (8.3–10.2)	0.741
3 months	39	16.7 (2.0)	16.8 (15.2–18.1)	12	18.1 (1.4)	18.0 (17.4–19.5)	0.021
12 months	38	17.5 (1.8)	17.6 (16.5–18.7)	11	17.5 (1.1)	17.5 (16.9–18.5)	0.943
Difference		7.7 (2.0)	8.0 (6.3–9.2)		8.2 (1.0)	8.1 (7.2–9.0)	0.581
PVR (mL)							
Baseline	41	16.1 (5.7)	15.0 (11.5–19.0)	12	15.4 (5.2)	14.0 (11.0–20.8)	0.670
3 months	39	16.4 (4.8)	15.0 (13.0–21.0)	12	14.5 (4.0)	14.0 (10.8–17.3)	0.204
12 months	38	15.9 (4.7)	14.5 (13.8–19.0)	11	46.3 (3.6)	47.0 (43.0–48.0)	<0.001
Difference		–0.3 (6.4)	0.0 (–3.0 to 4.0)		30.7 (4.0)	31.0 (28.0–34.0)	<0.001

BH, bladder hydrodistention; BATV, bladder autoaugmentation by transurethral vesicomyotomy; Q_{max}, maximum urinary flow rate; MCC, maximum cystometric capacity; $P_{det\ max}$, maximum detrusor pressure; PVR, postvoid residual urinary volume.

neobladder formation and heterotopic neobladder with Mitrofanoff, and deemed that they developed significant higher rate of postoperative complications than patients who underwent these surgeries for other benign diseases like refractory IC/BPS (71.4% *vs.* 37%). Some severe complications requiring surgical interventions remarkably impaired QoL of patients with KC who were afterward deprived of further managements and thus must be carefully selected and appropriately counseled for reconstructive surgery.

In the last decade, BH, BATV and other alternative surgery such as bladder autoaugmentation by inflatable silicone balloon and autoaugmentation by vesicomyotomy have emerged as minimally invasive approaches for patients with contracted bladder or intractable LUTS caused by KC, IC/BPS or neuropathic bladders after failed conservative therapy (8,12,16,17). Both Yang *et al.* (8) and Zeng *et al.* (9) have suggested their clinical outcomes of 18 and 36 patients

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Table 3 Comparison of subjective symptom questionnaires

Scale/time point	BH			BATV			P value
	N	Mean (SD)	Median (IQR)	N	Mean (SD)	Median (IQR)	
PUF							
Baseline	41	17.8 (2.0)	18.0 (16.0–19.0)	12	17.3 (2.0)	17.5 (15.3–19.0)	0.526
3 months	39	14.2 (1.9)	14.0 (13.0–15.0)	12	12.4 (1.7)	13.0 (11.3–14.0)	0.005
12 months	38	14.5 (2.2)	15.0 (13.8–16.0)	11	13.8 (1.6)	14.0 (13.0–15.0)	0.158
Difference		–3.3 (2.1)	–3.0 (–5.0 to –2.0)		–3.4 (1.4)	–3.0 (–4.0 to –2.0)	0.715
VAS							
Baseline	41	7.7 (0.9)	8.0 (7.0–8.0)	12	7.8 (0.9)	8.0 (7.0–8.8)	0.596
3 months	39	4.2 (1.1)	4.0 (3.0–5.0)	12	4.2 (1.1)	4.0 (3.0–5.0)	0.871
12 months	38	4.2 (1.0)	4.0 (3.0–5.0)	11	4.1 (1.1)	4.0 (3.0–5.0)	0.841
Difference		–3.5 (1.0)	–3.0 (–4.0 to –3.0)		–3.7 (1.4)	–3.0 (–5.0 to –3.0)	0.737
ICSI							
Baseline	41	17.0 (1.8)	17.0 (15.0–19.0)	12	16.3 (1.2)	16.0 (15.3–17.0)	0.235
3 months	39	13.6 (1.2)	14.0 (13.0–14.0)	12	13.4 (1.2)	13.0 (12.3–14.8)	0.498
12 months	38	14.0 (1.7)	14.0 (13.0–15.0)	11	13.6 (2.0)	14.0 (12.0–15.0)	0.679
Difference		–2.9 (2.0)	–3.0 (–4.0 to –1.8)		–2.6 (1.6)	–3.0 (–4.0 to –1.0)	0.752
ICPI							
Baseline	41	12.6 (1.5)	13.0 (11.0–14.0)	12	12.9 (1.2)	13.0 (12.0–14.0)	0.551
3 months	39	9.7 (1.5)	9.0 (9.0–11.0)	12	10.1 (1.2)	10.0 (9.0–11.0)	0.355
12 months	38	10.0 (1.4)	10.0 (9.0–11.0)	11	10.2 (1.3)	10.0 (9.0–11.0)	0.816
Difference		–2.7 (1.4)	–2.0 (–4.0 to –2.0)		–2.9 (0.7)	–3.0 (–3.0 to –2.0)	0.361
QoL							
Baseline	41	5.3 (0.5)	5.0 (5.0–6.0)	12	5.5 (0.5)	5.5 (5.0–6.0)	0.324
3 months	39	3.8 (0.8)	4.0 (3.0–4.0)	12	3.8 (0.7)	4.0 (3.0–4.0)	0.884
12 months	38	4.0 (0.5)	4.0 (4.0–4.0)	11	4.2 (0.4)	4.0 (4.0–4.0)	0.394
Difference		–1.3 (0.6)	–1.0 (–2.0 to –1.0)		–1.4 (0.7)	–1.0 (–2.0 to –1.0)	0.797

BH, bladder hydrodistention; BATV, bladder autoaugmentation by transurethral vesicomyotomy; PUF, the Pelvic Pain and Urgency/Frequency; VAS, Visual Analogue Scale/Score; ICSI, O'Leary-Sant IC Symptom Index; ICPI, IC Problem Index; QoL, quality of life.

with KC who underwent BH respectively and confirmed increased bladder capacity and subjective symptom relief in short-term follow-up. Nevertheless, there is still some study (18) shows their failure to achieve efficacy of BH for treating KC and presumably attributed it to inadequate damage to detrusor and mucosal afferent nerve endings, which followed the similar principle previously used in IC/BPS (8,19).

Autoaugmentation was firstly described as a method to improve bladder compliance and capacity by Cartwright and Snow (20,21) and modified by numbers of surgeons, each of whom named the procedure differently depending on whether the detrusor muscle was incised or excised. Stothers *et al.* (22) concluded that autoaugmentation by vesicomyotomy offered no advantage over vesicomyotomy in 12 patients with neurogenic bladder. Also, they revealed a mean 40% increase in bladder capacity as well as minor complications in patients who underwent vesicomyotomy.

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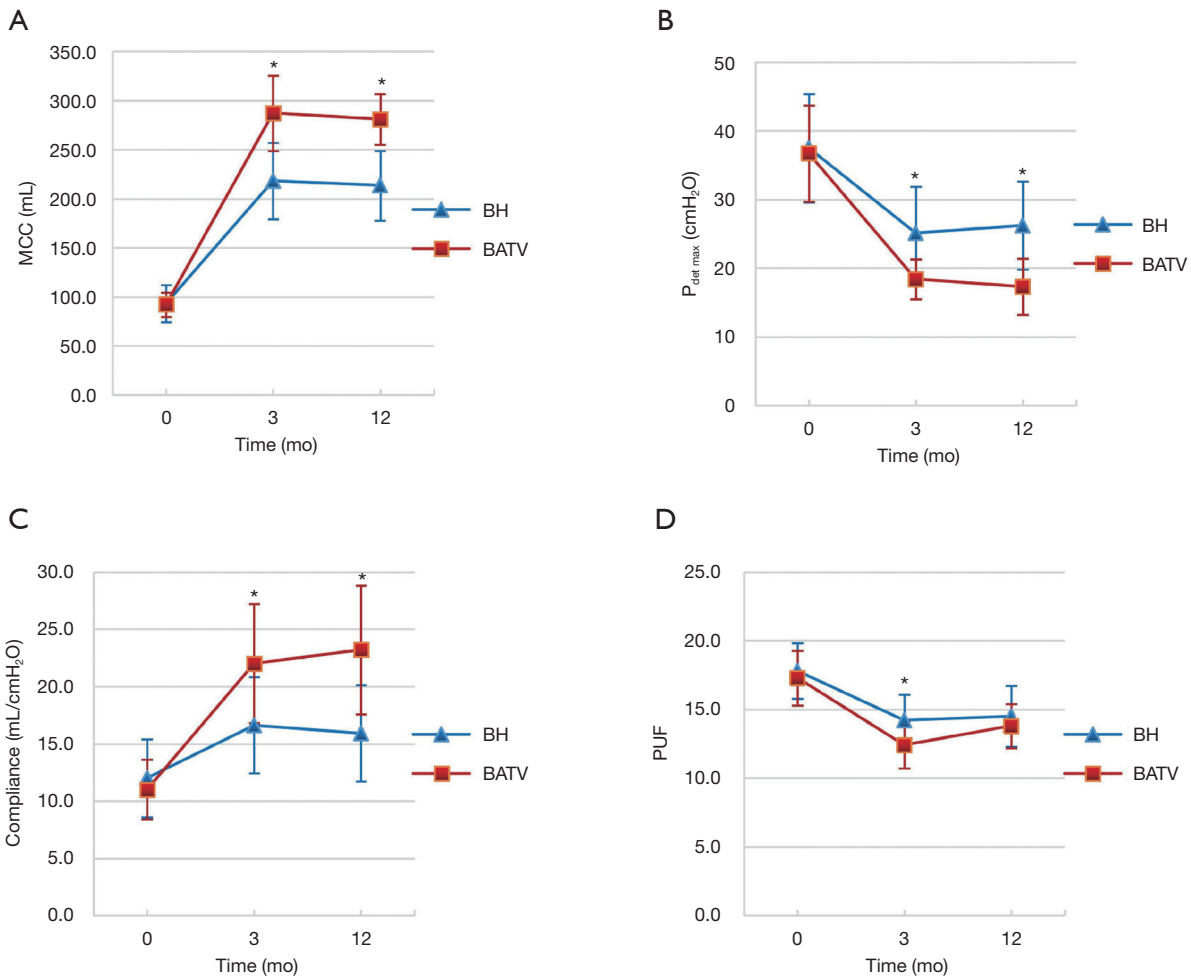

Figure 1 Outcomes following intervention with BH and BATV were assessed in terms of maximum cystometric capacity (A), maximum detrusor pressure ($P_{det\ max}$) (B), compliance (C), the Pelvic Pain and Urgency/Frequency (PUF) (D) within 12 months. The mean with 95% confidence interval of each parameter is indicated. * shows significant difference in two groups. BH, bladder hydrodistention; BATV, bladder autoaugmentation by transurethral vesicomyotomy.

Akin to treatment strategy to small and poorly compliant neurogenic bladders, BATV was performed as an intervention to KC in our series which showed similar short-term improvement in urodynamic parameters. This study is important and groundbreaking since systematic assessment of efficacy and safety of both BATV and BH procedure applied to KC is still rarely reported.

The present study shows urodynamic improvement along with decreases in symptom scores including PUF, ICSI, ICPI, VAS, QoL in both groups at 3-month and which were maintained for the duration of 1-year follow-up. In addition, the comparison appears to slightly favor patients treated with BATV when analyzing urodynamic outcomes. But as clearly shown, PVR was significantly increased after BATV at the 12-month follow-up while there was no significant change in BH group at any follow-up interval. The acquired bladder diverticula with short diameter were found initially after BATV due to the incision of detrusor muscle and the incisional fibrosis of the bladder wall. And the advantage of post-operative Q_{max} at 3-month follow-up after BATV disappeared at 12-month along with significantly increased PVR volume, which was presumably attributed to the expansion of bladder diverticulum and the fibrotic contracture of bladder inner wall. However, this was still acceptable since the mean (SD) PVR volume in BATV group at 12-month follow-up was 46.3 (3.6) mL

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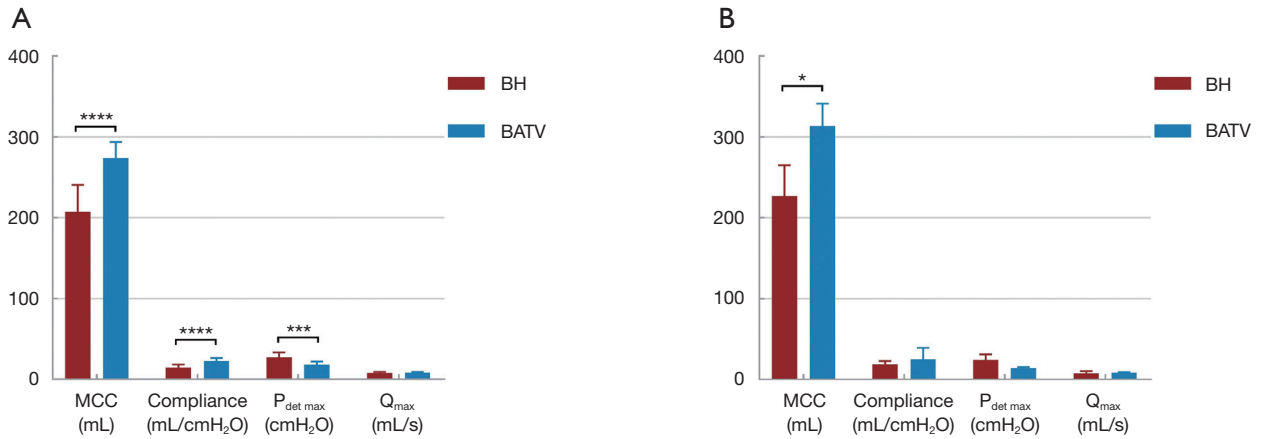

Figure 2 Comparison of urodynamic parameters at 12-month follow-up in patients with preoperative MCC <100 mL (A), and patients with preoperative MCC ≥100 mL (B). Compared with the BH group, *, P<0.05; ***, P<0.001; ****, P<0.0001. BH, bladder hydrodistention; BATV, bladder autoaugmentation by transurethral vesicomyotomy; Q_{max}, maximum urinary flow rate; MCC, maximum cystometric capacity; $P_{det\ max}$, maximum detrusor pressure.

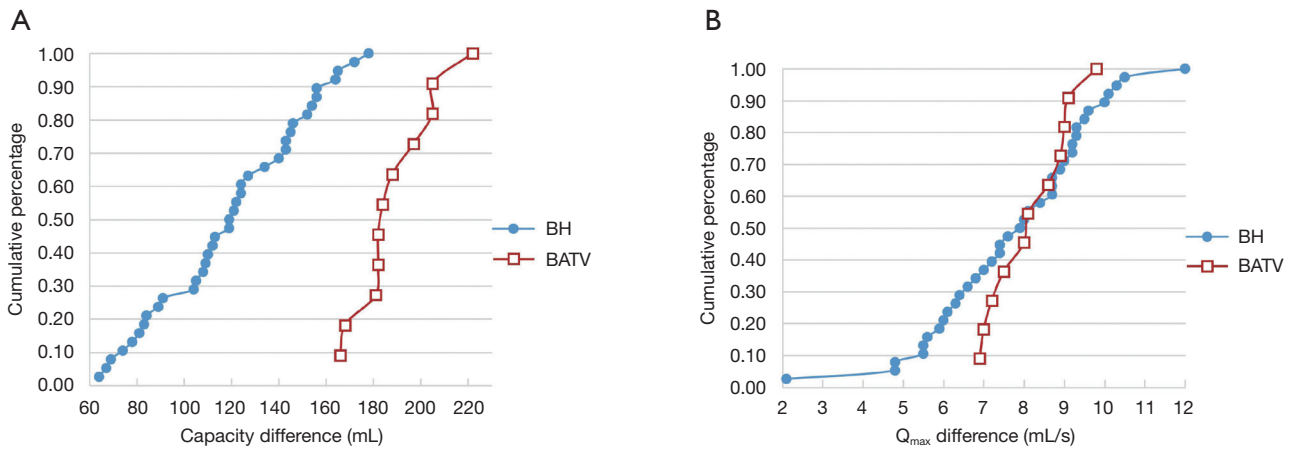

Figure 3 Cumulative percentages of changes in (A) maximum cystometric capacity and (B) maximum urinary flow rate (12 months after surgery vs. baseline) in the BH and BATV groups, e.g., half the patients received an increase in bladder capacity ≥120 mL after BH compared to 180 mL after BATV. BH, bladder hydrodistention; BATV, bladder autoaugmentation by transurethral vesicomyotomy.

and also lower than reported volume of other alternative surgery for KC [for instance, 82.6 mL of augmentation enterocystoplasty reported by Jhang *et al.* (15)]. Besides, in our series, where patients with slightly increased PVR, renal function had still not been implied in long-term follow-up the same as the surgical intervention for KC reported by Sihra *et al.* (7).

In a recent study of 81 patients who underwent hydrodistention and augmentation for treating KC, Wu *et al.* (23) found a significant lower PUF score in augmentation group (11.5±1.6 *vs.* 17.2±3.6). Similarly, we found that BATV resulted in better PUF score than BH at 3 months in the present study (12.4±1.7 *vs.* 14.2±1.9, P=0.005). This may be related to severer vesicomyotomy-induced lesions to afferent nerve endings than other approaches. Postoperative cystoscopy showed that the bladder volume was significantly improved and the bladder filling time was prolonged at same low flow and pressure than preoperative examination. Furthermore, the hypervascular reddened mucosal areas were reduced as well

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Table 4 Treatment-related complications after BATV and BH stratified by Clavien-Dindo classification grade

Complications	No. BH (%)	No. BATV (%)	P value	Interventions
Clavien-Dindo grade I				
Chronic urinary retention	1 (2.6)	1 (9.1)	0.402	Clean intermittent catheterization
Acute kidney injury	1 (2.6)	1 (9.1)	0.402	Diuretics/haemodynamic management
Gross hematuria	4 (10.5)	0	0.562	Continuous bladder irrigation
Hypogastric pain	4 (10.5)	2 (18.2)	0.873	Analgesics
Recurrent/persistent LUTS	7 (18.4)	2 (18.2)	1.000	Anticholinergic medications
Clavien-Dindo grade II				
Venous thromboembolism	1 (2.6)	1 (9.1)	0.402	Anticoagulant
Urinary tract infections	3 (7.9)	1 (9.1)	1.000	Culture based antimicrobial
Sepsis	1 (2.6)	0	1.000	Culture based antimicrobial
Clavien-Dindo grade IIIa				
Bladder perforation	0	1 (9.1)	0.224	Prolonged catheterization
Clavien-Dindo grade IIIb				
Bladder stone formation	0	1 (9.1)	0.224	Transurethral cystolitholapaxy and lithotripsy
Total	10 (26.3)	3 (27.3)	0.614	
Complications in patients with preoperative MCC <100 mL	6 (23.1)	3 (33.3)	0.421	–
Complications in patients with preoperative MCC ≥100 mL	4 (33.3)	0	0.495	–

BH, bladder hydrodistention; BATV, bladder autoaugmentation by transurethral vesicomyotomy; LUTS, lower urinary tract symptoms; MCC, maximum cystometric capacity.

as the fibrous scar after both surgeries. But the cystoscopic superiority has not been found in the remission of chronic inflammation of the bladder wall after BATV than the BH group. Comparing the subjective symptom scores after interventions in two groups, there were no significant differences at long-term follow-up as well. Persistent pan-urothelial or neurogenic inflammation with ischemia due to preoperative high and prolonged ketamine exposure may be some reason for this similarity despite the improved MCC and the incised overactive detrusor between the two groups.

Regarding postoperative complications, the overall rate of which was not significantly different between BATV group (27.3%) and BH group (25.6%), and was consistent with previous reports (8,12,17,20,22-24). The total complication rate in both groups thus strikingly lower than other bladder augmentation approaches such as cystoplasty, the rate of which ranged between 71% and 90% (7,10,11). Moreover, both procedures were minimally invasive with low morbidity in Clavien grade III + complications as well as relatively uncomplicated interventions. It was speculated that the reason may be the absence of invasive urinary tract reconstructive procedure along with higher grade adverse events such as anastomotic leaks, strictures or bowel obstruction. And the patients with preoperative MCC <100 mL demonstrated non-inferiority in safety after BATV while showed better urodynamics to the BH groups. Small bladder with thick fibrous wall may benefit more from BATV than BH, possibly because of the inadequate expansion of bladder under the pressure of 60 cmH_2O during hydrodistention.

BATV seems slightly superior to BH in terms of preventing post-operative gross hematuria although the difference between two groups was not statistically significant. The BATV electrode enables the surgeon to coagulate any bleeding when detrusor muscle was incised and thus provided excellent visibility during the operation. Additionally, the rate of UTIs appears analogue (7.9% *vs.* 9.1%) together with similar duration of catheterization

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(4.3 *vs.* 4.0 days) between two groups. And one patient after BH developed sepsis and subsequently treated with culture-based antimicrobial. However, unlike catheter-induced UTIs, some patients with pre-operative bacteriuria caused by prolonged urinary dysfunction may be the main pathogenesis of UTIs after surgery. Similar to our experience, both Chu *et al.* (3) and Yang *et al.* (8) revealed that almost all patients suffered from KC combined with pre-operative bacteriuria and elevated urinary leukocytes. Therefore, adequate preoperative urinalysis and prophylactic use of culture-based antibiotics are necessary to prevent postoperative UTIs for KC after surgery.

There are several limitations in the present study and the main one exists in its retrospective design. Moreover, the insufficient sample size enrolled in this study combined with short-term follow-up weakens the significance of data. A more accurate elucidation to the efficacy and safety of BATV and BH warrants larger pool of cases, prospective and randomized controlled design as well as long-term follow-up. Nevertheless, this study provides satisfactory peri-operative and 12-month follow-up data and systematically analyzes the differences in outcomes between BATV and BH procedures in spite of above drawbacks. Therefore, the findings will be helpful in selecting appropriate surgical approaches for KC.

Conclusions

BATV is a safe and efficacious procedure as a minimally-invasive alternative in treating KC. Besides, 1-year follow-up data shows BATV is superior to BH in terms of increasing urodynamic outcomes, and has similar rate of complications as well as symptom relief. Whilst it may not have broad indications in treatment of KC, it provides an option for patients situated in the cure pathway between conservative therapy and urinary tract reconstruction.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Xiangya Hospital, Central South University (NO.: 202008101) and individual consent for this retrospective analysis was waived.

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