



Prediction of urinary retention after surgery for rectal cancer using voiding efficiency in the 24 h following Foley catheter removal

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Abstract

Purpose Postoperative urinary retention is a common adverse effect after rectal surgery. Current methods for assessing postoperative urinary retention (residual urine volume) are inaccurate and unable to predict long-term retention. Voiding efficiency is an effective indicator of postoperative urinary retention in urological and gynaecological fields, but not in colorectal surgery. We aimed to determine whether voiding efficiency in the initial 24 h after urinary catheter removal was more effective in predicting the incidence of postoperative urinary retention than residual urine volume.

Methods In this retrospective, observational study using prospectively collected data from patients who visited the colorectal department of a single institution, 549 patients who underwent rectal cancer surgery between April 2012 and May 2016 were initially enrolled, of which 46 were excluded and 503 finally included.

Results The incidence of postoperative urinary retention was 18.5% (93/503). Multivariable logistic regression analyses revealed that the association of postoperative urinary retention with voiding efficiency < 50% was stronger than that with residual urine volume ≥ 100 mL (odds ratio, 38.30 (residual urine volume) and 138.0 (voiding efficiency)). Voiding efficiency was significantly lower in patients with long-term than in those with short-term postoperative urinary retention (adjusted p value = 0.02), whereas residual urine volume was not different between the two groups. Multivariable logistic regression analysis for long-term postoperative urinary retention showed the strongest association with voiding efficiency < 20% (odds ratio, 25.70).

Conclusions Voiding efficiency is a more effective predictor of postoperative urinary retention than residual urine volume in rectal cancer patients.

Keywords Rectal cancer · Postoperative urinary retention · Long-term postoperative urinary retention · Voiding efficiency · Residual urine volume

Introduction

Postoperative urinary retention (PUR) is a common adverse effect of rectal surgery [1–4]. The incidence of PUR after

rectal surgery is reported to range from 4 to 29%, and many factors are proposed to be associated with PUR, including old age, male sex, low rectal tumours, longer operative time, aggressive fluid resuscitation, early urinary catheter removal and pelvic autonomic nerve resection [5–10].

Generally, PUR is characterised by the need for urethral catheterisation for postoperative self-voiding difficulty [8–12]. If patients need urethral catheterisation after discharge, they are required to master self-management of clean intermittent self-catheterisation (CIC) or indwelling Foley catheter during hospitalisation. Residual urine volume (RUV) is routinely used to assess PUR at discharge; however, the accuracy of predicting PUR using RUV is not sufficient. Chaudhri et al. reported that even when a patient's RUV was high after catheter removal, voiding difficulties were improved by the tenth postoperative day in 80% of cases [13].

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Moreover, according to previous studies, the cut-off value of RUV for estimating PUR is not fixed and ranges from 50 to 400 mL [6, 7, 9, 13–15]. In our department, we use an RUV of 100 mL as the standard cut-off value because this value had been used commonly in various fields [14, 16–19].

In contrast, voiding efficiency (VE), which is the ratio of self-voiding volume to the total voiding volume, has been reported to be a good indicator for evaluating PUR in urological [20–22] and gynaecological fields [23–26]. We have considered that VE may be also a useful tool to assess PUR after colorectal surgery. Moreover, some patients with long-term PUR require prolonged catheterisation. Changichien et al. reported that 32.6%, 19.4% and 7.8% of colorectal cancer patients had PUR 1, 3 and 6 months after surgery, respectively [2]. Sterk et al. reported that 46.7% of rectal cancer patients with PUR needed catheterisation for more than 3 months after the surgery [5]. However, there have been no reports investigating the predictors for long-term PUR. Therefore, in this study, we examined whether VE in the initial 24 h after urinary catheter removal was more effective than RUV of more than 100 mL in predicting PUR after rectal surgery. We also evaluated the predictability of long-term PUR (PUR lasting over 3 months) using VE.

Methods

Study design and patients

This study was a retrospective, observational study using prospectively collected data and it was approved by the Institutional Review Board of the National Cancer Centre Hospital in Chiba, Japan (No. 2017-089). The study and manuscript adhere to the STROBE guidelines for observational studies.

In the department of colorectal surgery of our institution (National Cancer Centre Hospital East), clinical and pathological information is prospectively recorded in a single database. From this database, we first extracted the data of patients with middle and low rectal cancer who had undergone rectal surgery between April 2012 and May 2016. The exclusion criteria were patients who underwent concurrent cystectomy or prostatectomy and local excision only, had urinary system injury during surgery or severe postoperative complications and urinary tract fistula after surgery and had lack of declaration of self-voiding. Patients' urinary status was evaluated at 1, 3, 6 and 12 months after surgery using questionnaires on medication, CIC and indwelling Foley catheter.

We conducted a retrospective review of the database and patients' medical records. Data on the following clinical factors were collected: demographics, history of diabetes mellitus or benign prostatic hyperplasia, preoperative RUV (pre-RUV), distance of the tumour from the anal verge, clinical T

stage, preoperative therapy, surgical approach, surgical method, lateral lymph node dissection (LLND), pelvic autonomic nerve preservation, operative time, bleeding and postoperative hospitalisation day.

Postoperative urinary management and definition of PUR

To define the incidence of PUR, the standard clinical flow of postoperative urinary management at our institution is shown in Fig. 1. For most patients, the Foley catheter was removed 5 days after surgery (day 5), as recommended in previous reports [27, 28]. At day 5, the self-voiding urinary volume and RUV were measured at each self-voiding time in patients who had self-voiding after Foley catheter removal. If the patients could not urinate by themselves, RUV was measured every 5–6 h using bladder ultrasonography (BVI-6100 BladderScan, Verathon Inc., Bothell, WA, USA). When RUV was ≥ 100 mL on measurement using BladderScan in both patients who could and could not urinate, we confirmed the actual RUV by bladder-emptying catheterisation. When we confirmed that the RUV was 100 mL or higher in three or more consecutive measurements, treatment with oral medication, such as alpha-blockers and/or cholinergic was started [29]. When the patient's RUV did not reach the criterion for RUV (< 100 mL after oral medications), we suspected the incidence of PUR and offered patients a choice between CIC and Foley catheter re-insertion (RUV ≥ 100 mL flow in Fig. 1). When RUV was less than 100 mL in three consecutive measurements, with a self-voiding volume of 100 mL or higher, the patient was regarded as 'non-PUR', and then the RUV measurements were stopped (RUV < 100 mL flow in Fig. 1). When RUV was 100 mL or higher, we monitored the patient's RUV continuously, and if it decreased to less than 100 mL over three consecutive measurements, with a self-voiding volume of 100 mL or higher, the patient was regarded as 'non-PUR', and then the RUV measurements were stopped (the patients' RUV changed to < 100 mL flow in Fig. 1). However, in patients whose RUV was less than 100 mL but increased and in whom RUV increased to 100 mL or higher in three or more consecutive measurements, treatment with oral medication was started as mentioned above (patients' RUV changed to ≥ 100 mL flow in Fig. 1).

A patient was regarded as 'PUR' when CIC or indwelling Foley catheter was needed at the day of hospital discharge. In patients with PUR, long-term PUR (long PUR) was defined as the necessity for catheterisation more than 3 months after surgery [5, 10], and short-term PUR (short PUR) was defined as the necessity for catheterisation within 3 months after surgery. Self-voiding volume and RUV within 24 h after Foley catheter removal were recorded in our database.

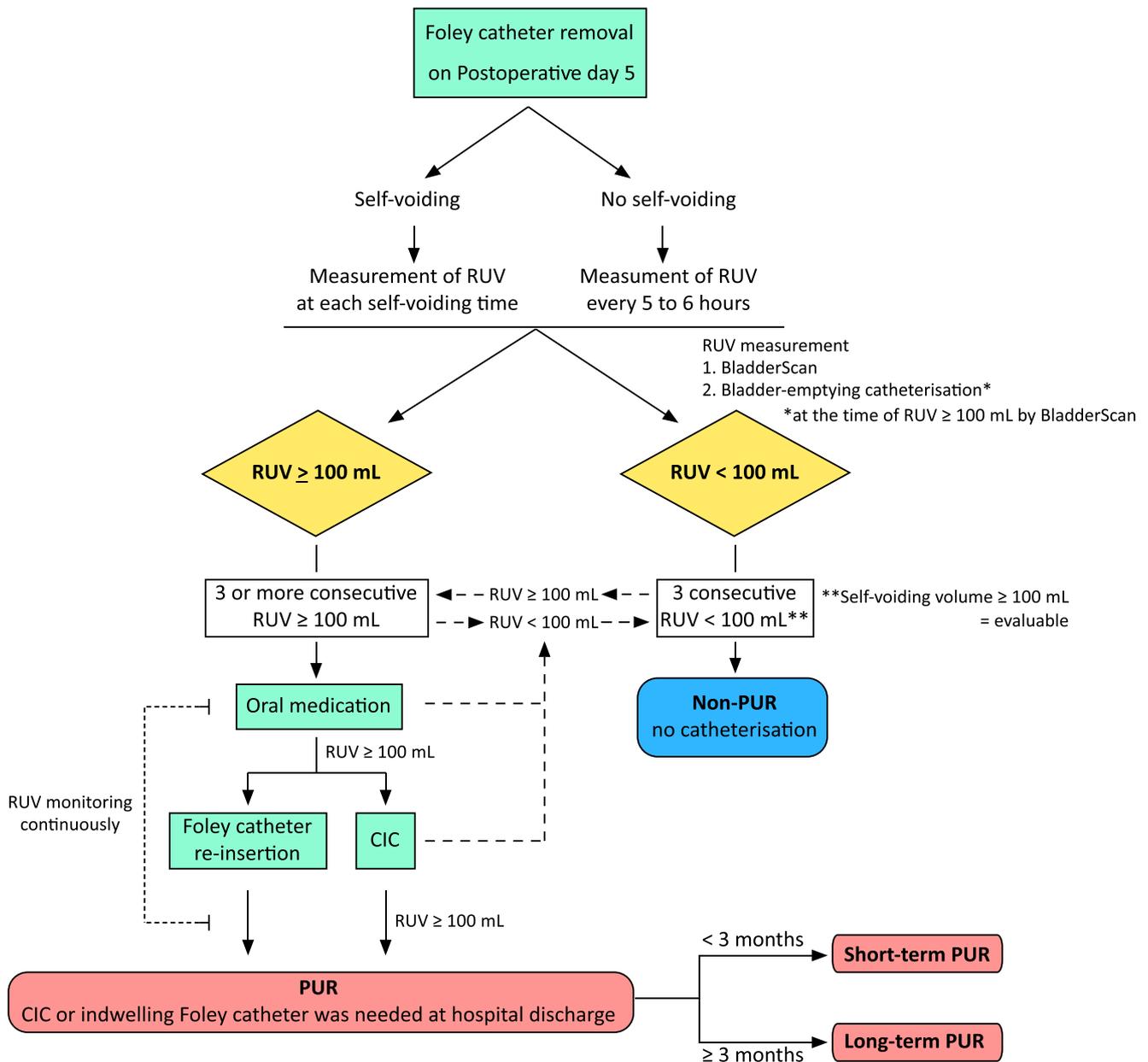


Fig. 1 Algorithm of the postoperative urinary management protocol RUV = residual urine volume, CIC = clean intermittent self-catheterisation, PUR = postoperative urinary retention

Calculation of 24-h VE

VE was calculated using the following formula: voiding efficiency (VE) = [total self-voiding volume/(total self-voiding volume + total RUV)] × 100 (%). Total self-voiding volume and total RUV were the sums of the volumes recorded within 24 h after Foley catheter removal [30].

Statistical analysis

Receiver operating characteristics (ROC) curves of continuous VE and RUV were drawn using a univariable logistic model and

compared by bootstrapping the original dataset. The cut-off values of VE for predicting PUR or long PUR were determined from the ROC curves. For RUV, a cut-off value of 100 mL (standard cut-off point in our institution) was used. Potential predictive factors for PUR or long PUR were selected on the basis of significant associations (*p* < 0.05) in the univariable logistic regression model. For multivariable regression analysis, RUV and VE were independently assessed by adjusting the selected potential predictive factors, considering a correlation between RUV and VE. The distributions of RUV and VE were compared using a Steel-Dwass test for multiple comparisons among the three groups (non-PUR, short PUR and long PUR).

P values less than 0.05 were considered statistically significant. All statistical analyses were performed using EZR ver 2.2–5 (Saitama Medical Centre, Jichi Medical University, Saitama, Japan), a modified version of R Commander that is designed to add statistical functions, which are frequently used in biostatistics [31], and R ver 3.3.1 (The R Foundation for Statistical Computing, Vienna, Austria).

Results

Patient characteristics and frequency of PUR

In this study, 549 patients with middle and low rectal cancer were identified. However, 9 patients who underwent concurrent cystectomy or prostatectomy and local excision only, 17 patients who had urinary system injury during surgery or severe postoperative complications and urinary tract fistula after surgery because they did not fit our standard flow of postoperative urinary management for long-term indwelling Foley catheter and 20 patients with missed measurements of RUV because of lack of declaration of self-voiding were excluded. Finally, 503 patients were included in the study (Fig. 2).

Patient characteristics are shown in Table 1. Among the 503 patients, the median value of RUV (interquartile range [IR]) was 64.0 mL (25.0, 184.0) and that of VE (IR) was 83.7% (53.8, 93.2) within 24 h after Foley removal. PUR was observed in 93 (18.5%) patients. PUR was managed by CIC in 75 patients and by Foley catheter re-insertion in the remaining 18 patients. All patients completed evaluation of their urinary status at 1, 3 and 6 months after surgery; however, the evaluation was discontinued in two patients at 12 months because of loss to follow-up and mortality, respectively.

Effectiveness and cut-off value of VE for predicting PUR

ROC analysis revealed that VE predicts PUR more accurately than RUV (area under the curve [AOC], 0.971 vs. 0.932, $p < 0.001$, calculated by bootstrapping the original dataset for 2000 replications) (Fig. 3). The best cut-off value of VE for predicting PUR was determined to be 50% because it was closest to the top-left corner in the ROC plot (the cut-off values of VE for PUR in male or female cases were similar at values close to 50%). Classification with RUVs (cut-off value, 100 mL) showed a sensitivity, specificity and accuracy

Fig. 2 Flowchart of included and excluded patients RUV = residual urine volume, TME = total mesorectal excision, TSME = tumour-specific mesorectal excision

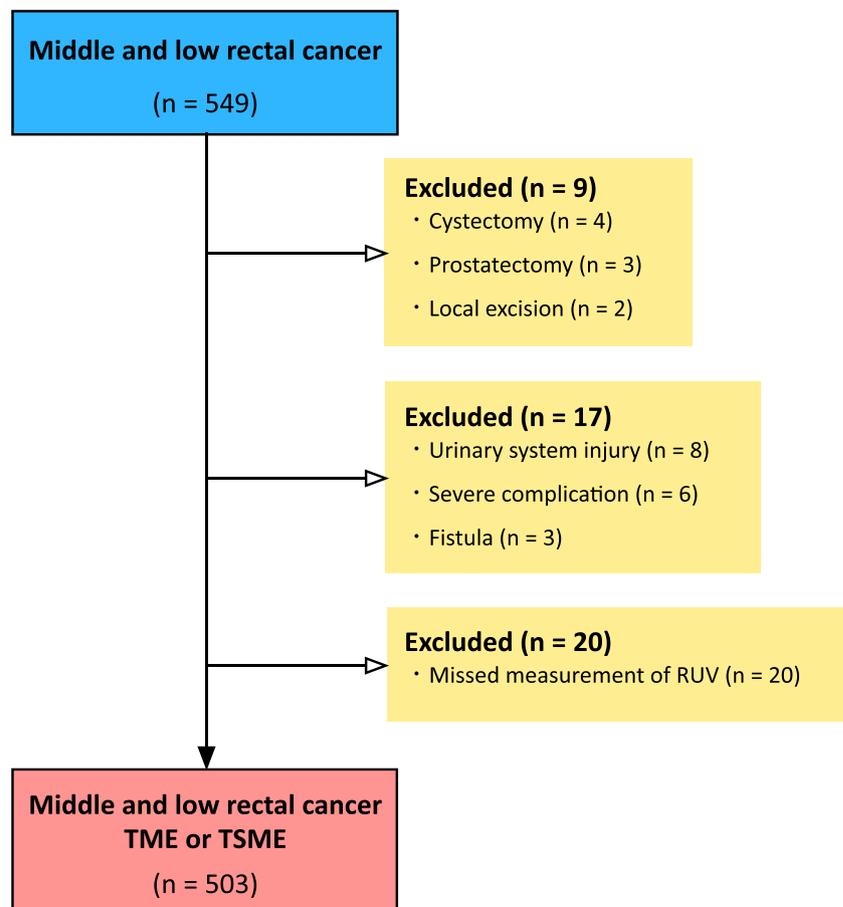


Table 1 Patient characteristics

Characteristics (<i>n</i> = 503)		<i>n</i>	%
Age (years), median (range)		63 (27-86)	
Sex	Male	329	65.4
	Female	174	34.6
History of DM		66	13.1
History of BPH*		20	6.1
Preoperative residual urine volume (mL)	< 50	394	78.3
	≤ 50, < 100	53	10.5
	≤ 100	21	4.2
	No data	35	7.0
Distance of the tumour from the anal verge (cm)	≤ 5	200	39.8
	< 5, ≤ 10	246	48.9
	10 <	57	11.3
Clinical T stage	T1	105	20.9
	T2	93	18.5
	T3	273	54.3
	T4	32	6.4
Preoperative therapy	Chemotherapy	90	17.9
	Chemoradiotherapy	9	1.8
Surgical approach	Open	64	12.7
	Laparoscopic	422	83.9
	Robotic-assisted	17	3.4
Surgical method	High anterior resection	27	5.4
	Low anterior resection	250	49.7
	Intersphincteric resection	189	37.6
	Abdominoperineal resection	27	5.4
	Others	10	2.0
Lateral lymph node dissection		208	41.4
Autonomic nerve partial/total resection**	Total preservation	311	61.8
	Hypogastric nerve	38	7.6
	Pelvic plexus/splanchnic nerve	98	19.5
	Neurovascular bundle	152	30.2
Operative time (min), median (range)		286 (93-709)	
Bleeding (mL), median (range)		65 (0-9794)	
Postoperative hospitalisation day, median (range)		12 (5–53)	

DM diabetes mellitus, BPH benign prostatic hyperplasia

*Only male patients were included

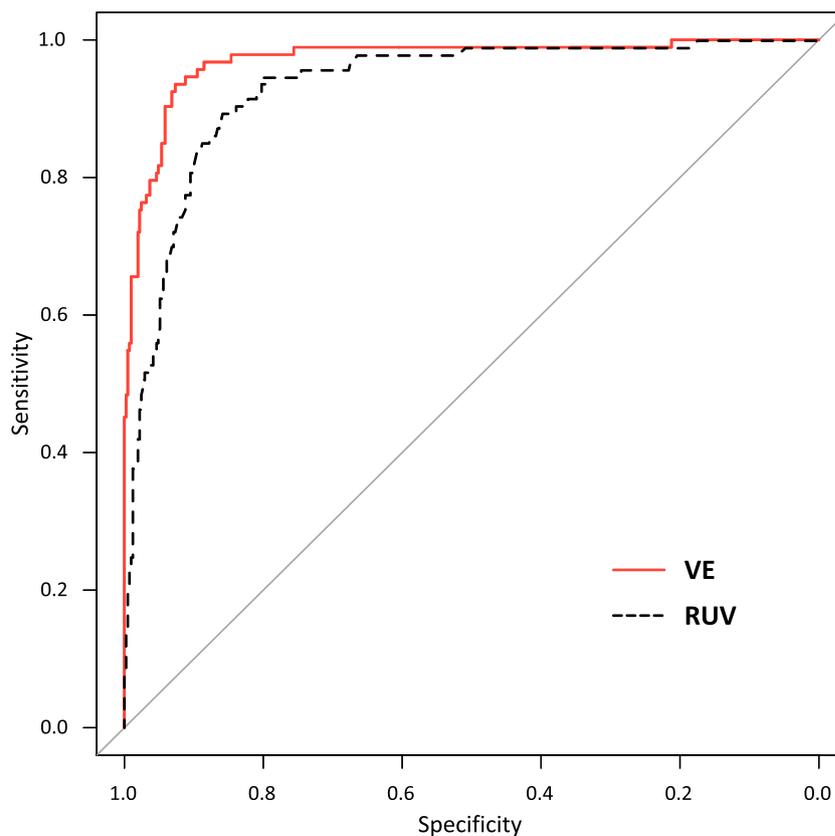
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of 94.6%, 75.1% and 78.7%, respectively. In contrast, classification with VE (cut-off value, 50%) showed a sensitivity, specificity and accuracy of 93.5%, 92.7% and 92.8%, respectively.

The univariable logistic regression analysis demonstrated that the following could be potential predictive factors of PUR: male sex, pre-RUV of ≥ 50 mL, clinical T3 or T4 stages, preoperative chemotherapy or chemoradiotherapy, open surgery, LLND, no hypogastric nerve preservation (no-HNP), no pelvic plexus/splanchnic nerve preservation (no-PSP), no

neurovascular bundle preservation (no-NVBP), operative time more than 300 min, bleeding more than 100 mL, postoperative hospitalisation day more than 14 days, RUV more than 100 mL and VE less than 50%. Multivariate logistic regression analysis adjusting the potential predictive factors showed that classification according to VE (cut-off, 50%) performed far better than that according to RUV (odds ratio (OR) and its 95% CI: RUV, 38.30, 14.40–102.0; VE, 138.0, 51.70–367.0), as shown in Table 2. When all patients had been divided into male or female groups, VE less than 50% was the

Fig. 3 Receiver operating characteristics (ROC) curves for voiding efficiency (VE) and residual urine volume (RUV) in the prediction of postoperative urinary retention (PUR). The accuracy in distinguishing patients with and without PUR was assessed by calculating the area under the curve (AUC). ROC curves were compared by bootstrapping the original dataset



independent significant predictive factor for PUR in the multivariate logistic analyses that included male or female patients (data not shown).

A difference in the distribution between RUV and VE is shown in Fig. 4. The cut-off line of RUV was set to 100 mL and that of VE was set to 50%, as previously mentioned. In 190 patients with RUV more than 100 mL, 74.3% (84/113) of patients with VE less than 50% had PUR. However, only 5.2% (4/77) of patients with VE and more than 50% had PUR (indicated as *Zone A* in Fig. 4).

Long course of PUR

Patients recovered from PUR gradually after surgery. At the time of discharge, the number of patients who had PUR was 93. However, it decreased to 64 patients (69%) 1 month after, 35 patients (38%) 3 months after, 19 patients (20%) 6 months after and 9 patients (10%) 12 months after the operation day. Of the 93 patients with PUR, 58 had short PUR and 35 long PUR. RUV within 24 h after Foley removal was not different between short PUR patients and long PUR patients (adjusted p value = 0.23 by Steel-Dwass test). On the contrary, the VE of long PUR patients was significantly lower than that of short PUR patients (adjusted p value = 0.02 by Steel-Dwass test) (Fig. 5). The ROC analysis revealed that VE predicts long PUR more accurately than RUV (AOC, 0.950 vs. 0.903, p =

0.01, calculated by bootstrapping the original dataset for 2000 replications) (Fig. 6). The best cut-off value of VE to predict long PUR was defined as less than 20%, which was closest to the top-left corner of the ROC (the cut-off values of VE for long PUR in male or female cases were similar at values close to 20%). RUV was not analysed for the cut-off value because it was not considered a useful indicator of long PUR, as shown in Fig. 5. Classification with VE (cut-off value, 20%) showed a sensitivity, specificity and accuracy of 82.9%, 91.0% and 90.5%, respectively.

The univariate logistic regression analysis demonstrated that the following can be potential predictive factors of long PUR: age \geq 70 years, clinical T3 or T4, preoperative chemotherapy or chemoradiotherapy, open surgery, LLND, no-HNP, no-PSP, no-NVBP, operative time more than 300 min, bleeding more than 100 mL, postoperative hospitalisation day more than 14 days and VE less than 20%. Multivariate logistic regression analysis after adjusting for the potential predictive factors showed that the independent predictive factors were as follows: age \geq 70 years, no-NVBP and VE $<$ 20%. VE $<$ 20% had the strongest association (OR, 95% CI: 25.70, 8.770–75.10) (Table 3). When all patients had been divided into male or female group, VE less than 20% was the independent significant predictive factor for long PUR in the multivariate logistic analyses that included male or female patients (data not shown).

Table 2 Predictive factors for PUR after rectal surgery in univariate and multivariate analyses

Predictive factors	<i>n</i>	PUR, <i>n</i> (%)	Univariate analysis		Multivariate analysis (included RUV)		Multivariate analysis (included VE)		<i>p</i> value
			OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value	
Age									
≥ 70 years	194	42 (21.6)	1.400 (0.887–2.200)	0.149	–	–	–	–	–
< 70 years	309	51 (16.5)	Reference						
Sex									
Male	329	73 (22.2)	2.200 (1.290–3.740)	0.004	1.690 (0.824–3.450)	0.153	1.560 (0.612–3.980)	0.352	
Female	174	20 (11.5)	Reference		Reference		Reference		
History of DM									
Yes	66	17 (25.8)	1.650 (0.900–3.020)	0.105	–	–	–	–	–
No	437	76 (17.4)	Reference						
History of BPH*									
Yes	20	4 (20.0)	0.870 (0.281–2.690)	0.808	–	–	–	–	–
No	309	69 (22.3)	Reference						
Preoperative residual urine volume									
≥ 50 mL	74	20 (27.0)	1.810 (1.020–3.200)	0.043	1.230 (0.551–2.750)	0.613	1.550 (0.541–4.460)	0.414	
< 50 mL or no data	429	73 (17.0)	Reference		Reference		Reference		
Distance of the tumour from the anal verge									
≤ 5 cm	200	42 (21.0)	1.310 (0.834–2.070)	0.239	–	–	–	–	–
> 5 cm	303	51 (16.8)	Reference						
Clinical T stage									
T3 or T4	305	78 (25.6)	4.190 (2.330–7.530)	< 0.001	1.820 (0.758–4.370)	0.180	1.920 (0.648–5.670)	0.240	
T1 or T2	198	15 (7.6)	Reference		Reference		Reference		
Preoperative therapy									
Chemotherapy or chemoradiotherapy	99	34 (34.3)	3.060 (1.860–5.030)	< 0.001	0.612 (0.276–1.360)	0.227	0.607 (0.211–1.750)	0.356	
No	404	59 (14.6)	Reference		Reference		Reference		
Open	64	35 (54.7)	7.930 (4.510–13.90)	< 0.001	1.780 (0.756–4.190)	0.187	1.280 (0.406–4.030)	0.673	
Laparoscopic or robotic-assisted	439	58 (13.2)	Reference		Reference		Reference		
Lateral lymph node dissection									
Yes	208	63 (30.3)	3.840 (2.380–6.200)	< 0.001	0.640 (0.221–1.850)	0.410	0.503 (0.124–2.040)	0.336	
No	295	30 (10.2)	Reference		Reference		Reference		
Hypogastric nerve preservation									
No	38	19 (50.0)	5.280 (2.670–10.50)	< 0.001	2.230 (0.810–6.120)	0.121	1.840 (0.479–7.060)	0.375	
Yes	465	74 (15.9)	Reference		Reference		Reference		
Pelvic plexus/splanchnic nerve preservation									
No	98	43 (43.9)	5.550 (3.380–9.120)	< 0.001	1.480 (0.694–3.150)	0.311	1.500 (0.557–4.040)	0.422	
Yes	466	50 (12.3)	Reference		Reference		Reference		
Neurovascular bundle preservation									
No	152	59 (38.8)	5.910 (3.660–9.570)	< 0.001	1.990 (0.973–4.060)	0.060	2.400 (0.972–5.920)	0.058	
Yes	351	34 (9.7)	Reference		Reference		Reference		
Operative time									
≥ 300 min	242	67 (27.7)	3.460 (2.110–5.670)	< 0.001	1.340 (0.486–3.720)	0.568	1.160 (0.340–3.990)	0.809	
< 300 min	261	26 (10.0)	Reference		Reference		Reference		
Bleeding									
≥ 100 mL	206	67 (32.5)	5.020 (3.060–8.260)	< 0.001	2.150 (0.923–4.980)	0.076	3.000 (0.999–9.000)	0.050	
< 100 mL	297	26 (8.8)	Reference		Reference		Reference		

Table 2 (continued)

Predictive factors	n	PUR, n (%)	Univariate analysis		Multivariate analysis (included RUV)		Multivariate analysis (included VE)	
			OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Postoperative hospitalisation day	171	55 (32.2)	3.670 (2.300–5.850)	<0.001	1.720 (0.895–3.310)	0.104	1.130 (0.480–2.660)	0.780
Residual urine volume	332	38 (11.4)	Reference		Reference		Reference	
Voiding efficiency	190	88 (46.3)	53.10 (21.00–134.0)	<0.001	38.30 (14.40–102.0)	<0.001		
	313	5 (1.6)	Reference		Reference			
	117	87 (74.4)	184.0 (74.20–455.0)	<0.001			138.0 (51.70–367.0)	<0.001
	386	6 (1.6)	Reference				Reference	

PUR postoperative urinary retention, OR odds ratio, CI confidence interval, DM diabetes mellitus, BPH benign prostatic hyperplasia

*Only male patients were included

Discussion

To the best of our knowledge, this is the first report to demonstrate the effectiveness of VE to assess PUR in colorectal surgery. We revealed that VE was more useful than RUV in predicting the necessity of CIC or Foley catheter detention after hospital discharge. Additionally, VE was capable of identifying patients who needed prolonged catheterisation for long PUR.

VE depends on the strength of bladder contractility against urethral resistance, and it is measured according to the degree of bladder emptying [30, 32]. There are two techniques to measure VE: the auto-fill technique and the backfill technique. The auto-fill technique involves waiting for a patient to void after catheter removal, followed by measuring RUV, and the backfill technique involves filling the bladder with 300 mL of sterile fluid through the Foley catheter before removing the catheter and measuring self-voiding volume and RUV [24, 25]. We used the auto-fill technique in this study because of its simplicity and ease of use compared with the backfill technique.

Calculating VE does not require additional costs or cause any additional discomfort to the patient because it requires only patient's self-voiding volume and RUV, which are usually measured in daily practice. VE has been introduced as a precise predictive tool for PUR in urological and gynaecological fields. In a previous urologic study, patients with postoperative VE $\geq 67\%$ had excellent outcomes. However, those with VE $< 33\%$ had poor surgical outcomes after transurethral bladder-neck incision [22]. Another report indicated that pre-treatment VE $< 87\%$ could be predictive of a poor response to Botox injections for overactive bladder syndrome [21]. For gynaecological surgery, a prospective study reported that VE after vaginal prolapse or continence surgery predicted normal bladder function adequately in patients with VE $\geq 68\%$ [23]. We decided on a cut-off value of VE for PUR of 50% by ROC analysis in this study. However, the cut-off value of VE was between 60 and 80% in previous urological and gynaecological studies [21, 23, 25, 26]. Our cut-off value was lower than that in previous urological or gynaecological studies, and this may be because patients are more likely to recover from postoperative urinary dysfunction after rectal surgery than after urological or gynaecological surgery because the detrusor muscle itself is almost normal in rectal cancer patients compared with that in male patients with detrusor underactivity and overactive bladder syndrome and also because rectal cancer surgery has a smaller effect on the female lower urinary tract than does gynaecological surgery.

Using VE as a predictor of PUR can reduce unnecessary treatments and cost after rectal surgery. Among patients in Zone A of the scatter plot in Fig. 4 (patients with RUV ≥ 100 mL and VE $\geq 50\%$), only 5.2% (4/77) showed PUR: this means that the other 73 patients would not need to be treated

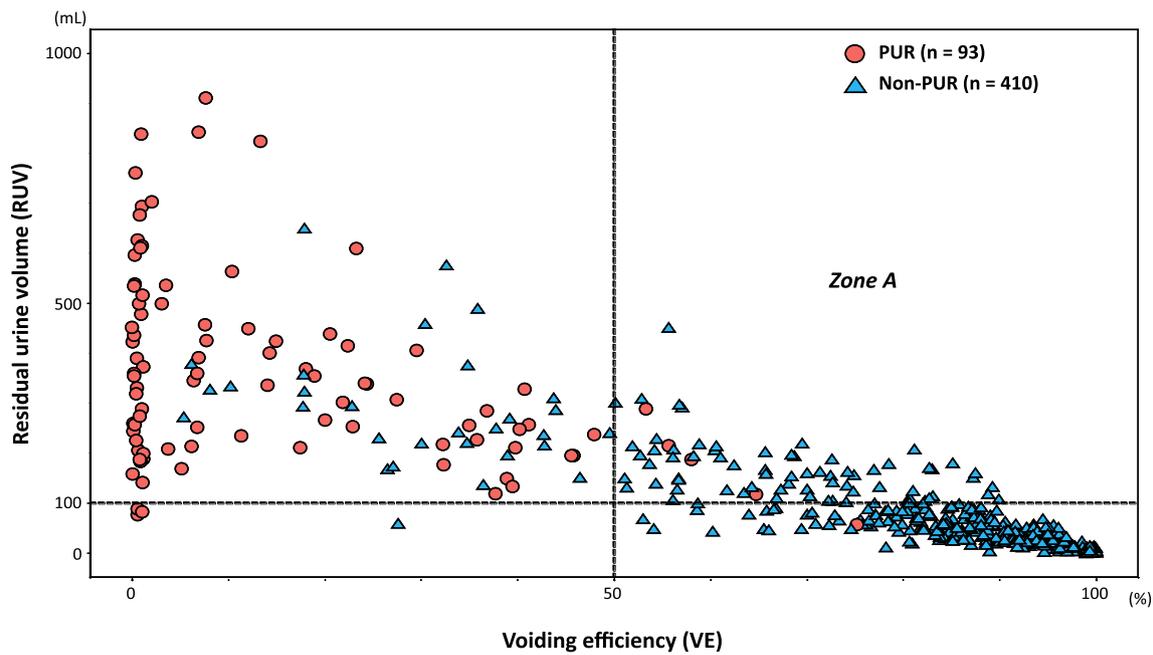


Fig. 4 Scatter plot of distribution between voiding efficiency (VE) and residual urine volume (RUV). Vertical and horizontal lines denote 100 mL RUV and 50% VE, respectively. Red circles and blue triangles

represent patients with postoperative urinary retention (PUR) and non-PUR, respectively. *Zone A* indicates patients who have an RUV of more than 100 mL and VE of less than 50%

by catheterisation or oral medication. However, they would have received treatment for voiding difficulty in this study, according to our previous protocol using RUV. If we use VE as a prediction tool for PUR, patients with high RUV but good VE (such as patients in *Zone A*) could avoid unnecessary medications or catheterisation that might be administered if

RUV is used as the predicting tool of PUR. Another advantage of using VE as a predictor is its potential to decrease medical resources. Medical staff could omit the catheterisation procedure, which we now realise is often unnecessary for such *Zone A* patients. However, the benefits of VE should be confirmed in a prospective study in the future.

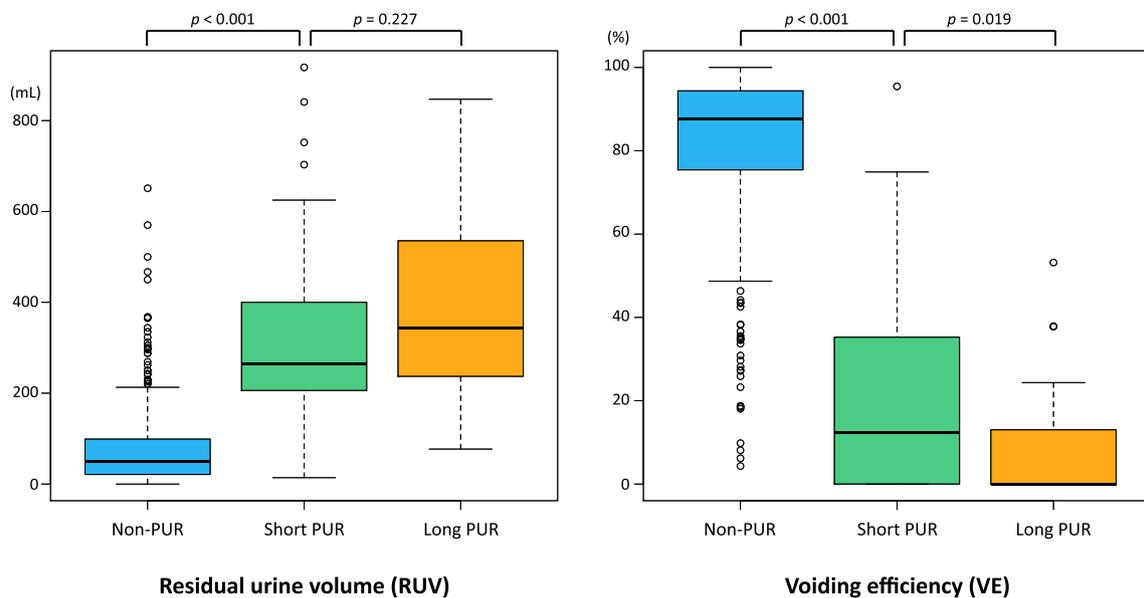
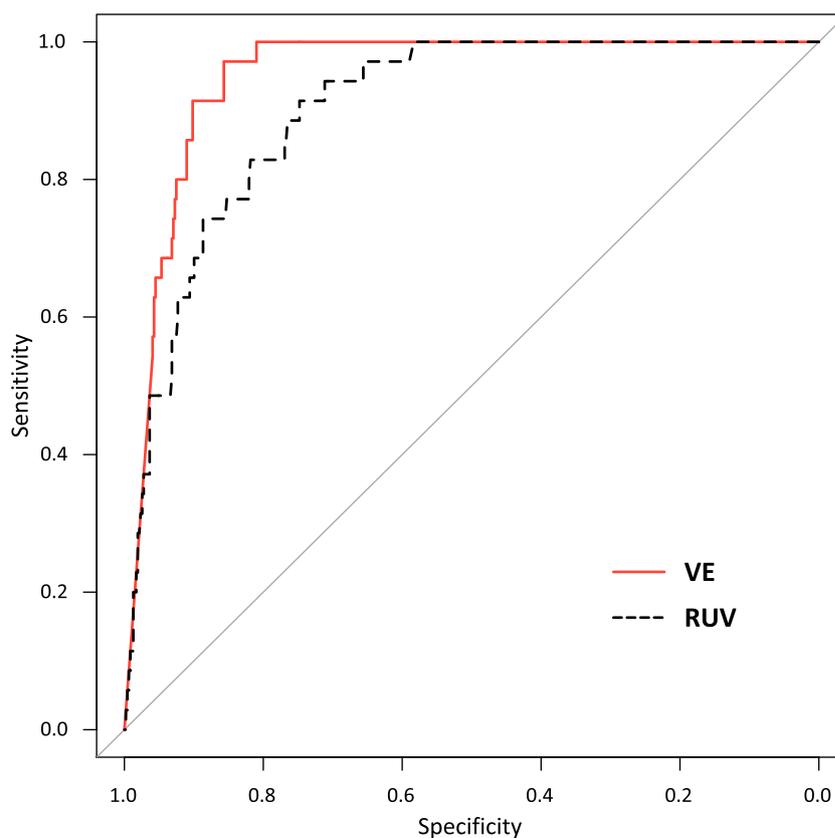


Fig. 5 Correlation of residual urine volume (RUV) and voiding efficiency (VE) among patients with or without postoperative urinary retention RUV and VE were compared using the Steel-Dwass test for multiple comparisons among the three groups (patients without postoperative

urinary retention (non-PUR), with short-term postoperative urinary retention (short PUR) and with long-term postoperative urinary retention (long PUR))

Fig. 6 Receiver operating characteristics curves (ROC) for voiding efficiency (VE) and residual urine volume (RUV) in the prediction of long-term postoperative urinary retention (long PUR). The accuracy in distinguishing patients with and without long PUR was assessed by calculating the area under the curve (AUC). ROC curves were compared by bootstrapping the original dataset



Moreover, the use of VE allows medical personnel to identify patients who need prolonged catheterisation for long-term PUR. Published studies have reported the frequency of long-term PUR [2, 5], but none have reported on predictive factors for long-term PUR in the early period following surgery. Our results showed that $VE < 20\%$ had a strong association with long PUR. However, RUV was not significantly different between short PUR and long PUR. Using VE, we can identify patients with long-term PUR and better explain what to expect during recovery as well as provide instructions about catheter management of CIC or Foley catheters in the early period following surgery.

Our study identified that no-NVBP and bleeding tended to be predictive factors for PUR, and older age and no-NVBP were independent predictive factors for long-term PUR. Although there has been no report of bleeding as a risk factor for PUR, we consider that occult injury to the pelvic nerves would occur when there is massive bleeding in the pelvis. We also thought that bleeding would be another result of intraoperative fluid volume loss. High intraoperative fluid resuscitation has been reported to be a risk factor of PUR because it causes urethral oedema and increased frequency of urination, which may lead to decreased bladder sensation and contractility [7, 8, 10]. Furthermore, the preservation status of the neurovascular bundle was a significant predictive factor of long-term PUR. Combined resection of the neurovascular

bundle causes frequent development of PUR and delayed recovery from PUR because the neurovascular bundle is located at the periphery of the pelvic nerves. On the contrary, in the univariate analysis, male patients developed PUR more significantly than female patients. The anatomical differences between male and female patients influence the technical difficulties of TME because male patients generally have narrow pelvic cavity and the pelvic plexus is closer to the lower rectum because of the absence of the vagina [33]. Furthermore, the long urethra may be the cause of PUR in male patients. However, in this study, we think that male sex was not an independent predictive factor because there would be confounding between sex and RUV or VE in the multivariate analyses. On LLND, the rate of PUR in the TME with LLND was equal to the TME without LLND in the Japanese randomised controlled trial [34]. Another report demonstrated that LLND has little influence on PUR, when bilateral pelvic nerves were preserved [6]. In our study, LLND was not an independent risk factor in the multivariate analysis; therefore, pelvic nerve preservation was considered more important than LLND for PUR.

In the conservative treatment of PUR, 5- α -reductase inhibitor (dutasteride) and 5-phosphodiesterase inhibitor (tadalafil), which has been reported to be useful in the treatment of urinary dysfunction related to BPH, may be effective apart from the drugs used in this study. These drugs may be

Table 3 Predictive factors for long-term PUR after rectal surgery in univariate and multivariate analyses

Predictive factors	<i>n</i>	Long-term PUR, <i>n</i> (%)	Univariate analysis		Multivariate analysis	
			OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value
Age	194	20 (10.3)	2.250 (1.120–4.510)	0.022	3.320 (1.220–9.060)	0.019
	309	15 (4.9)	Reference		Reference	
Sex	329	26 (7.9)	1.570 (0.720–3.440)	0.256	–	
	174	9 (5.2)	Reference		–	
History of DM	66	5 (7.6)	1.110 (0.416–2.980)	0.833	–	
	437	30 (6.9)	Reference		–	
History of BPH*	20	1 (5.0)	0.598 (0.208–4.650)	0.623	–	
	309	25 (8.1)	Reference		–	
Preoperative residual urine volume	74	9 (12.2)	2.150 (0.962–4.790)	0.062	–	
	429	26 (6.1)	Reference		–	
Distance of the tumour from the anal verge	200	16 (8.0)	1.300 (0.652–2.590)	0.457	–	
	303	19 (6.3)	Reference		–	
Clinical T stage	305	33 (10.8)	11.90 (2.820–50.10)	<0.001	3.110 (0.541–17.90)	0.203
	198	2 (1.0)	Reference		Reference	
Preoperative therapy	99	17 (17.2)	4.450 (2.200–8.990)	<0.001	2.470 (0.798–7.620)	0.117
	404	18 (4.5)	Reference		Reference	
Surgical approach	64	19 (29.7)	11.20 (5.370–23.20)	<0.001	2.740 (0.860–8.750)	0.088
	439	16 (3.6)	Reference		Reference	
Lateral lymph node dissection	208	26 (12.5)	4.540 (2.080–9.910)	<0.001	0.371 (0.065–2.130)	0.267
	295	9 (3.1)	Reference		Reference	
Hypogastric nerve preservation	38	8 (21.1)	4.330 (1.810–10.30)	0.001	0.848 (0.224–3.220)	0.808
	465	27 (5.8)	Reference		Reference	
Pelvic plexus/splanchnic nerve preservation	98	21 (21.4)	7.620 (3.710–15.60)	<0.001	2.240 (0.747–6.730)	0.150
	466	14 (3.5)	Reference		Reference	
Neurovascular bundle preservation	152	30 (19.7)	17.00 (6.460–44.80)	<0.001	6.230 (1.840–21.10)	0.003
	351	5 (1.4)	Reference		Reference	
Operative time	242	27 (11.2)	3.970 (1.770–8.920)	<0.001	1.030 (0.174–6.110)	0.973
	261	8 (3.1)	Reference		Reference	
Bleeding	206	28 (13.6)	6.520 (2.790–15.20)	<0.001	0.744 (0.150–3.690)	0.717
	297	7 (2.4)	Reference		Reference	
Postoperative hospitalisation day	171	22 (12.9)	3.620 (1.780–7.390)	<0.001	1.540 (0.555–4.280)	0.407
	332	13 (3.9)	Reference		Reference	
Voiding efficiency	71	29 (40.8)	49.00 (19.30–125.0)	<0.001	25.70 (8.770–75.10)	<0.001
	432	6 (1.4)	Reference		Reference	

PUR postoperative urinary retention, OR odds ratio, CI confidence interval, DM diabetes mellitus, BPH benign prostatic hyperplasia

*Only male patients were included

useful in patients with preserved pelvic nerve because of the decrease in the urethral resistance. Pelvic floor muscle training is a low-risk and low-cost treatment strategy for urinary dysfunction patients. These conservative treatments should be considered in the early postoperative period for patients at high risk for PUR with poor VE. As a surgical approach, sacral neuromodulation (SNM) was proved to be an effective treatment for an overactive bladder. However, there have been few reports of patients with an underlying neurological disorder including PUR [35]. Furthermore, in patients with no preserving pelvic nerves, the efficacy of SNM would not be expected. For such cases, regenerative treatment may be expected.

This study has some notable limitations. First, this was a retrospective review and a single-centre study. Second, the timing to define the PUR was different in each patient because of the variation in the length of postoperative hospitalisation. However, only one patient showed an improvement in PUR during the long hospitalisation, so the wide range of hospitalisation days had little influence on our results. Finally, our results require further validation; therefore, a multicentre study with a large cohort is required to validate our findings.

Conclusion

VE was a more effective tool than RUV in predicting the occurrence of PUR in rectal cancer patients. In addition, the use of VE allowed clinicians to predict which patients would require catheterisation for long-term PUR.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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