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Urinary incontinence is one of the most important complications of radical prostatectomy (RP), and has a negative impact on quality of life.[1] Some studies have examined the mechanism of incontinence after RP with regard to urethral sphincter and bladder storage functions. Urodynamic evaluations have also been performed to examine the continence status and reasons for incontinence after RP.[2-8]

Robot-assisted RP (RARP) is now performed worldwide. Systematic review and meta-analysis have shown improved recovery of urinary continence after RARP compared with conventional methods.[9] However, not all patients achieved continence status immediately after RARP. No previous studies have performed urodynamic evaluation of continence status immediately after RARP. In the current study, we evaluated continence status immediately after RARP, changes in urodynamic parameters before and after RARP, and prognostic factors for postoperative continence status. In addition, we performed filling cystometry (CM), urethral pressure profilometry (UPP), and abdominal leak point pressure (ALPP) to evaluate continence status immediately after RARP.

Urine loss ratio (ULR) calculated by dividing the total urine volume by the weight of urine loss after RP in the early postoperative period was reported to be a predictive factor for the recovery of postoperative urinary continence.[10,11] Demographic factors

and urodynamic parameters related to ULR before and immediately after RARP were also evaluated in this study.

MATERIALS AND METHODS

Patient Selection, Operative Technique, and Postoperative Evaluation

After receiving institutional ethics committee approval, patients with clinically localized prostate cancer undergoing RARP by one surgeon at Kanazawa University Hospital between December 2010 and May 2013 were included in this study. Ninety consecutive patients undergoing RARP who provided written informed consent were enrolled in this study. All patients were instructed in a pelvic floor muscle exercise; they began the exercise 1 month preoperatively and continued it postoperatively until urinary continence was recovered.

Prostatectomies were performed via a transperitoneal approach. A bilateral incision of the endopelvic fascia and nerve-sparing (NS) procedures were performed dependings on cancer status. The dorsal venous complex was divided athermally without ligation and sutured for hemostasis after division. Double layered posterior reconstruction was then performed before urethrovesical anastomosis.[12] The first layer was between the tissue

just below the urethra and the incision edge of the Denonvilliers' fascia, and the second layer was between the tissue just below the urethra and the posterior wall of the bladder, approximately 2 cm dorsocephalad to the bladder neck. Urethrovesical anastomosis was performed using a running suture with a double-armed 3-0 monocryl with RB-1 needle.[13]

The urethral catheter was removed 6–7 days postoperatively by cystography. CM, UPP, and ALPP were performed 1–2 days preoperatively, and 3–4 days after catheter removal. The micturition volumes (MVs) and weight of urine loss (UL) in the pads were measured separately for 24 h on the day of urodynamic evaluation. ULR was calculated by dividing the total urine volume (UL + MV) by MV. ULR was determined on the same day of urodynamic evaluation.

Continence status was evaluated using questionnaires regarding daily pad use (0 pads, 1 security pad, 1 pad, and 2 or more pads). No pad use and security pad use per day in daily activity were considered as continent, and pad use status was evaluated individually. Early continence was defined as achieving continence status within 3 months of surgery.

Urodymanic Evaluation

Filling CM was performed using a 6-F double-lumen Nelaton transurethral catheter with 37°C normal saline solution at a filling rate of 50 mL/min; abdominal pressure was monitored using a 10-F intrarectal balloon catheter. The maximal cystometric capacity (MCC), detrusor overactivity (DO), and bladder compliance (BC) were measured by filling CM. DO was defined as any involuntary bladder contraction over 15 cmH_2O. The transurethral catheter was withdrawn at 60 mm/min using an electronic puller with a perfusion rate of 2 mL/min to measure static UPP. The maximal closure urethral pressure (MUCP) and functional urethral length (FUL) were measured by UPP. Each relative decrease in MUCP and FUL was calculated by dividing MUCP or FUL after RARP by MUCP or FUL before RARP. The ALPP was measured at a volume of 150 mL (or half bladder capacity if the capacity was < 300 mL) by rectal monitoring after urethral catheter removal. Coughing or the Valsalva maneuver was performed at least five times, and the ALPP was defined as the lowest pressure inducing visible incontinence. If no incontinence was observed with an abdominal pressure >100 cmH_2O, the ALPP was defined as "negative." Urodynamic measurement and analysis were performed using the Solar Silver digital urodynamic apparatus (Medical Measurement Systems, Enschede, Netherlands). Urodynamic evaluation was performed and interpreted in accordance with the 2002 Good Urodynamics Practice Guidelines of

the International Continence Society.[14]

Statistical Analysis

Univariate and multivariate analyses were used to establish which predictor variables were significantly related to postoperative ULR. Pearson's correlation coefficient was calculated to assess correlations among factors. An unpaired *t*-test was used for categorical valuables of two levels, and ANOVA was used for the categorical variable of more than two levels. Tukey's HSD was used for multiple comparisons and post-hoc tests. Linear regression analysis was used for continuous variables; multivariate analysis was then performed including all predictor variables except for surgical margin status (because of the strong correlation with pathological stage, $r = 0.478$, $P < 0.001$) and bladder compliance (because of the strong correlation with MCC, $r = 0.484$, $P < 0.001$). In these analyses, the measured maximal abdominal pressure in all 12 patients without urine leakage in the ALPP test > 100 cmH_2O; the measured values were then used in calculations as the ALPP. All data analyses were performed using SPSS for Windows (SPSS Inc, Chicago, IL), and $P < 0.05$ was considered as statistically significant.

RESULTS

Three patients were excluded from this study because of minor leakage at urethrovesical anastomosis on cystograms after RARP. In the other 87 patients without anastomotic leakage, urethral catheters were removed 6 or 7 days postoperatively; these patients were then evaluated in this study. Patient characteristics and the results of univariate analysis comparing each variable with ULR are shown in Table 1. NS RARP was performed unilaterally in 41 patients (47%) and bilaterally in 14 patients (16%). The mean incontinence volume was 274 mL (range: 0–1652mL) and the mean ULR was 17.8% (range: 0%–100%). Early continence within 3 months of surgery, defined as no pad use per day, was observed in 41 patients (47%) and defined as no pad use and one security pad use per day was observed in 61 patients (70%). The correlation between ULR and an early continence rate was statistically significant ($r = –0.468$, $P < 0.001$ for no pad use, $r = –0.618$, $P < 0.001$ for no pad use and security pad use). In univariate analysis, NS status was the only predictive factor for ULR immediately after RARP (Table 1). In multivariate analysis, NS status was also the only predictive factor for ULR immediately after RARP ($P = 0.005$). Compared with non-NS, unilateral and bilateral NS had significant impacts on ULR (Table 1). Patients with higher NS tended to have decreased ULR ($P = 0.001$, when comparing non-NS with unilateral NS, and $P = 0.007$, when comparing non-NS with bilateral NS). However, no significant difference

was observed in ULR between unilateral and bilateral NS ($P = 0.957$).

The results of urodynamic evaluation before and immediately after RARP are shown in Table 2. No urine leakage was observed in any patients during the filling phase of CM. When the pre- and postoperative results by CM were compared, the mean MCC and the mean BC decreased from 341 mL and 28.4 cmH_2O to 250 mL ($P < 0.001$) and 17.8 cmH_2O ($P < 0.001$), respectively. Preoperative DO was present in 25% of patients; the rate of postoperative DO increased to 29%, but this was not statistically significant ($P = 0.442$). When the pre- and postoperative results of UPP were compared, MUCP and FUL decreased from 84.6 cmH_2O and 44.5 mm to 35.6 cmH_2O ($P < 0.001$) and 20.4 mm ($P < 0.001$), respectively. Relative decreases in MUCP and FUL were 46.6% and 48.8%, respectively. No urine leakage with cough or the Valsalva maneuver was observed in any patients preoperatively. However, urine leakage was observed in 75 patients (86%) postoperatively. The mean ALPP in these 75 patients was 47.7 cmH_2O (range: 5–98 cmH_2O).

The results of linear regression analysis to predict ULR by analyzing each urodynamic parameter after RARP are shown in Table 3. In univariate analysis, MCC, MUCP, FUL, and ALPP after RARP were predictive factors for ULR. Multivariate analysis was then performed, including all predictor variables. FUL was then no longer

a significant predictive factor. MCC, MUCP, and ALPP had significant predictive value for incontinence immediately after RARP. A linear correlation was found between ULR and MUCP after RARP (Figure 1A). No patients had preoperative urinary incontinence and the minimal MUCP before RARP was 37 cmH_2O. A linear correlation was also found between ULR and the ALPP after RARP (Figure 1B). No urine leakage was observed in 12 patients in the ALPP test after RARP, and ULRs in these individuals were very low. When NS status and urodynamic evaluation after RARP were compared, statistically significant correlations were found between NS status and MUCP (r = 0.247, P = 0.021) and between NS status and the ALPP after RARP (r = 0.254, P = 0.018).

COMMENT

The major reason for incontinence after RP is considered to be impaired function of the external sphincter, although DO, reduced BC, and decreased compliance are also considered to be causative factors. Urodynamic evaluations were performed pre- and postoperatively to investigate these factors.[2-8,15] To the best of our knowledge, this is the first report of urodynamic evaluation and precise urine loss immediately after RP as well as their correlation in RARP.

Previous studies demonstrated that MUCP and FUL decreased significantly at 2–6 months after RP compared with those obtained at preoperative evaluation.[3,5,7,15] Consistent with this, we performed evaluations immediately post surgery, and MUCP and FUL also decreased. MUCP was related to postoperative continence status, whereas FUL was not. Previous studies that performed evaluations 2–6 months after RP reported rates of postoperative MUCP ranging from 58%-81% compared with those of preoperative MUCP.[3,5,7,15] In the present study, the rate of postoperative MUCP was 46.6%, which was lower than that reported previously. MUCP did not change significantly over a long period (from 3 to 36 months) after RP in a previous report,[8] but did change over a short recovery period (from 1 week to 3 months).[16]

Here, we selected ULR immediately after surgery as an indicator of continence status, because previous reports suggested that ULR immediately after RP was a useful prognostic tool for continence recovery.[10,11] ULR was significantly related to the early recovery of continence (within 3 months after RARP) in the present study, regardless of the definition of continence ($r = –0.468$, $P < 0.001$ for no pad use: $r = –0.618$, $P < 0.001$ for no pad use and one security pad use). ULR showed a linear correlation with MUCP immediately after RARP, and a small number of patients exhibited a high incontinence rate with MUCP > 40 cmH_2O (Figure 1A). Stress incontinence may be the main reason

for post-RP incontinence and was affected by the activity and abdominal pressure of patients. No patients had with urinary incontinence or urine leakage in the ALPP test before RARP in our study, and the lowest MUCP among these patients before RARP was 37 cmH_2O. Only one patient (1.2%) had MUCP < 40 cmH_2O. The volume of urinary incontinence is believed to change depending on the activity and abdominal pressure of the patient, and postoperative MUCP of at least 40 cmH_2O MUCP may be necessary to maintain continence status during daily activity.

No standard procedure is available for measuring the ALPP. In the current study, the ALPP was measured without a urethral catheter because this method is believed to be more natural.[17,18] The correlation coefficient between the ALPP after RARP and ULR (r = -0.480, $P < 0.001$) was higher than that between MUCP after RARP and ULR (r = -0.409, $P < 0.001$) in the present study. MUCP is measured in the static state, and the ALPP is measured in the dynamic state with abdominal pressure. Therefore, the results of the ALPP test may reflect actual incontinence status better than the results of the MUCP test. The potential correlation between the ALPP and continence status after RP is controversial; one previous report indicated a significant correlation between the ALPP and daily pad use,[19] whereas another study did not.[20] The ALPP is believed to be useful to assess the intrinsic sphincter deficiency [4] and was significantly correlated with

ULR in the present study. However, it is impossible to measure the ALPP without incontinence, and no patients showed urine leakage in the ALPP test before RARP in the current study. Therefore, no leakage in patients with an abdominal pressure level > 100 cmH_2O was detected using the ALPP tests in the current study. Most patients without leakage and adequate abdominal pressure in the ALPP test immediately after RARP showed a small amount of postoperative urinary incontinence. Therefore, the ALPP test may be useful to objectively predict patients likely to achieve continence after RP.

Some preoperative and operative prognostic factors that predict urinary incontinence after RP were reported previously, including age, sexual function, and urinary function preopearatively.[21-23] In our patient population, NS status contributed to continence status immediately after RARP. Previously, MUCP before RP was reported to be a prognostic factor for postoperative urinary continence.[3,7] However, no significant correlation was found between MUCP before RARP and ULR (r = -0.016, P = 0.880) in the present study. Some reports suggested that the NS technique contributed to postoperative continence status.[21,24] For example, a correlation was reported between NS and MUCP 26 weeks after RP,[3] and higher NS status was significantly related to higher MUCP (r = 0.247, P = 0.021) and the ALPP (r = 0.254, P = 0.018) in the current study. This finding

suggests that the NS technique may contribute to continence status immediately after RARP.

This study had some limitations. For example, we evaluated only 87 patients. In addition, urinary incontinence was evaluated in hospitalized patients; therefore, the volume of urine leakage may not indicate normal incontinence status because activity in the hospital is reduced compared with that in normal daily life. Recently, several techniques to improve the functional outcome of RARP have been reported, for example, regional pelvic cooling during prostatectomy,[25] dissection of neurovascular bundles without tension and any use of electrocautery,[26] and a novel approach passing through the pouch of Douglas and avoiding the Retzius structures.[27] The results of these methods, particularly urinary continence, are usually determined according to pad use, pad tests of urinary leakage, and satisfaction questionnaires regarding continence status. However, these evaluations are influenced by the patients' activity and subjective feelings, and therefore may vary among patients. Urodynamic evaluation is a more objective method. Therefore, further studies of urodynamic data from a larger numbers of patients are required to establish an objective method for evaluating urinary function after RP.

CONCLUSIONS

MCC, MUCP, and ALPP in urodynamic evaluation immediately after RARP were predictive factors for urinary continence. The NS procedure contributed to continence status after RARP. Urodynamic evaluations after RP can objectively evaluate urinary continence status.

Figure 1 (A). Correlation between postoperative maximal closure urethral pressure and urine loss ratio (ULR). (B). Correlation between postoperative maximal closure urethral pressure and the ULR. The dark circle shows a patient without urine leakage in an abdominal leak point pressure (ALPP) test; the maximal abdominal pressure was then adopted as the ALPP value.

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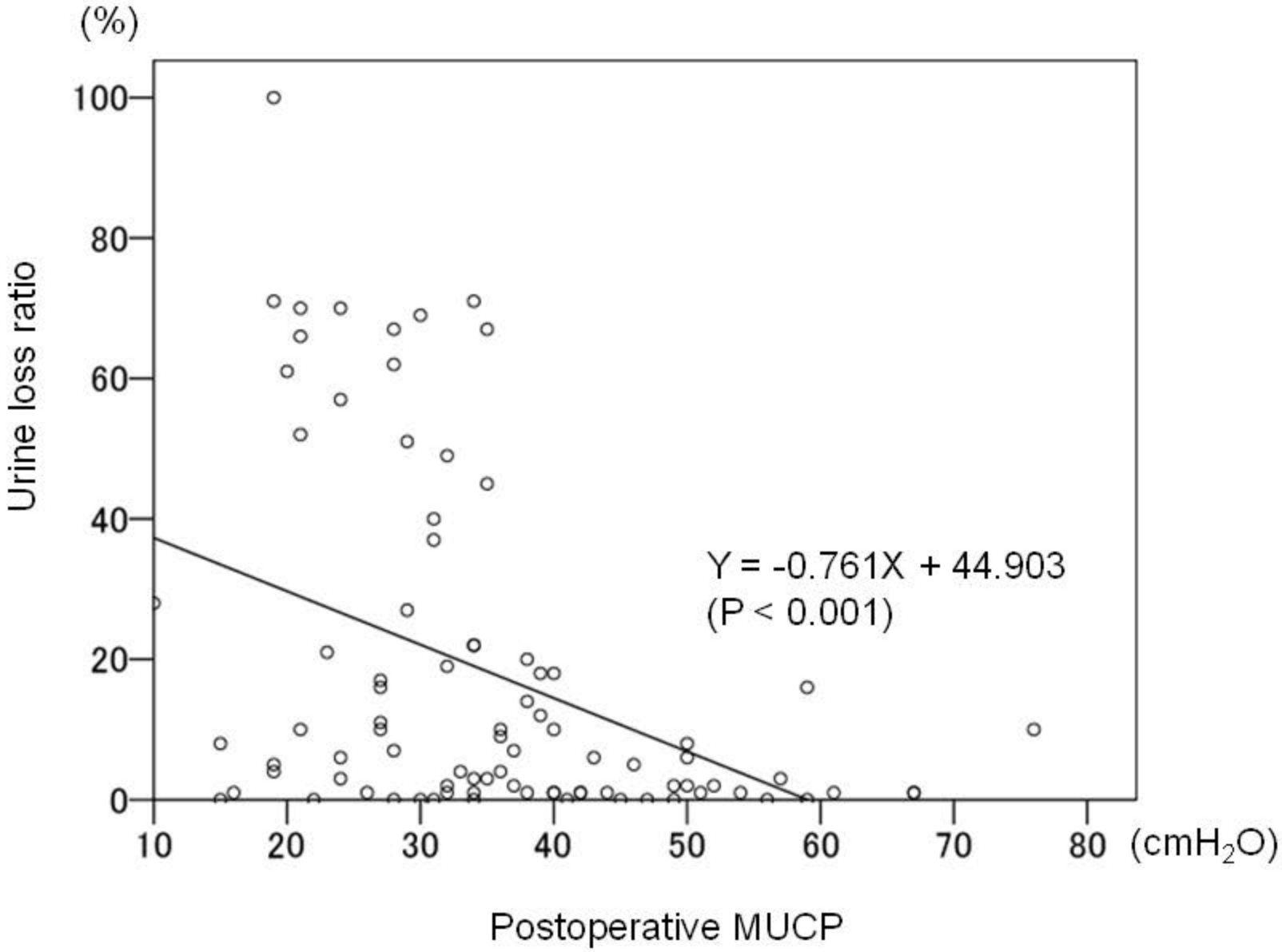
(%)
100
80
60
40
20
0
Urine loss ratio
Y = -0.761X + 44.903
(P < 0.001)
10
20
30
40
50
60
70
80
(cmH2O)
Postoperative MUCP

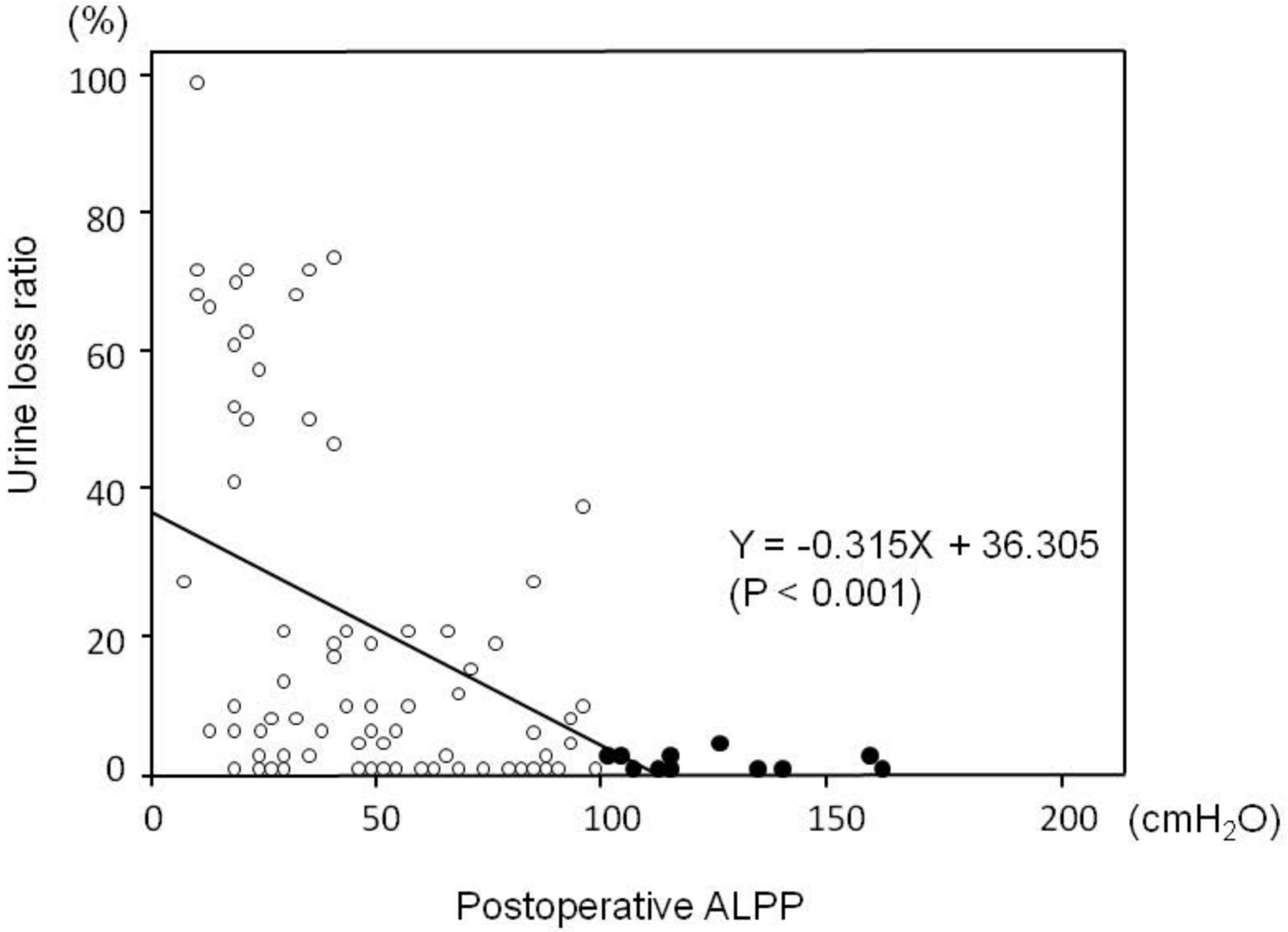
(%)
100
80
60
40
20
0
Urine loss ratio
Y = -0.315X + 36.305
(P < 0.001)
0
50
100
150
200
(cmH2O)
Postoperative ALPP

Table 1. Correlation of patient characteristics and preoperative urodynamic findings with postoperative urine loss ratio. P-values comparing each variable with urine loss ratio.

	All patients (n = 87)	Urine loss ratio (%)	P-value
Age	65.0 ± 5.3		0.729
Prior hormonal therapy			0.644
No	52 (60%)	16.9 ± 23.1	
Yes	35 (40%)	19.3 ± 26.0	
Nerve-sparing			< 0.001
non-	32 (37%)	30.9 ± 29.8	
unilateral	41 (47%)	10.7 ± 17.0	
bilateral	14 (16%)	8.8 ± 14.3	
Surgical margin status			0.954
Negative	70 (80%)	17.9 ± 23.8	
Positive	17 (20%)	17.5 ± 26.8	
Pathological stage			0.728
pT0	9 (10%)	20.2 ± 24.0	
pT2	60 (69%)	16.5 ± 23.2	
pT3-4	18 (21%)	21.2 ± 28.4	
Maximum cystometric capacity (mL)	341 ± 94		0.759
Bladder compliance (mL/cmH_2O)	28.4 ± 18.2		0.669
Detrusor overactivity			0.365
Negative	65 (75%)	16.5 ± 23.8	
Positive	22 (25%)	21.9 ± 25.7	
Maximum urethral closing pressure (cmH_2O)	84.6 ± 30.2		0.88
Functional urethral profile length (mm)	44.5 ± 12.3		0.376
Urine loss volume (mL)	274 ± 399		
Urine loss ratio (%)	17.8 ± 24.2		
Catheterization time (day)	7.0 + 0.2		

Continuous data are presented as mean ± standard deviation and discrete data as numbers of patients (%)

Table 2. Urodynamic findings before and after operation

	Preoperative	Postoperative	*P*-value
Maximum cystmetric capacity (mL)	341 ± 94	250 ± 72	< 0.001
Bladder compliance (mL/cmH_2O)	28.4 ± 18.2	17.8 ± 16.5	< 0.001
Detrusor overactivity	22 (25%)	25 (29%)	0.442
MUCP (cmH_2O)	84.6 ± 30.2	35.6 ± 13.0	< 0.001
FUL (mm)	44.5 ± 12.3	20.4 ± 5.8	< 0.001
Valsalva urine leakage	0 (0%)	75(86%)	< 0.001
Abdominal leak point pressure (cmH_2O)	-	47.7 ± 25.5	
Relative decrease in MUCP (%)	-	46.6 ± 19.3	
Relative decrease in FUL (%)	-	48.8 ± 17.7	

MUCP, Maximum urethral closing pressure;
FUL, Functional urethral profile length
Continuous data are presented as mean ± standard deviation and discrete data as numbers of patients (%)

Table 3. Results of linear regression analysis to predict urine loss ratio by analyzing each postoperative urodynamic parameter.

Postoperative urodynamic parameter	Univariate *P*-value	Multivariate *P*-value, B (95%CI)
Maximum cystmetric capacity (mL)	0.036	0.014, -0.080 (-0.143 to -0.017)
Bladder compliance (mL/cmH_2O)	0.108	0.390, -0.125 (-0.413 to 0.163)
Detrusor overactivity	0.385	0.094, -9.286 (-20.205 to 1.634)
Maximum urethral closing pressure (cmH_2O	< 0.001	0.002, -0.579 (-0.946 to -0.212)
Functional urethral profile length (mm)	0.007	0.115, -0.654 (-1.451 to 0.157)
Abdominal leak point pressure (cmH_2O)	< 0.001	0.001, -0.210 (-0.337 to -0.083)