Pre- and Postoperative Parameters on Magnetic Resonance Imaging Predict Continence Recovery after Laparoscopic Radical prostatectomy

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Abstract

Background: To evaluate the association between pre- and postoperative parameters on magnetic resonance imaging (MRI) and continence recovery after laparoscopic radical prostatectomy (LRP). To develop a risk scoring system for predicting continence recovery after LRP.

Methods: 73 patients who underwent LRP were retrospectively reviewed. Demographic characteristics, clinicopathologic outcomes and several MRI parameters before and after surgery were evaluated. Continence was defined as no pad per day. Early continence recovery was defined as continence recovery within 3 months. Kaplan-Meier analyses and log-rank test were used to compare time to continence recovery. Cox proportional-hazards regression analyses were performed to identify independent predictors of continence recovery.

Results: Patients with smaller prostatic volume, shorter intravesical prostatic protrusion length (IPPL), shorter preoperative membranous urethral length (MUL), lower MUL-removal rate, triangular vesicourethral anastomosis (VUA) and neurovascular bundle sparing experienced a faster continence recovery (All, $p < 0.05$). Multivariate analyses revealed IPPL (hazard ratio [HR]: 0.94, $p = 0.044$), preoperative MUL (HR: 1.10, $p = 0.032$), MUL-removal rate (HR: 0.91, $p = 0.007$) and shape of VUA (square vs. triangle, HR: 2.30, $p = 0.012$) were independent predictors of continence recovery. The four parameters were therefore used to develop a risk scoring system, termed Post-Prostatectomy Incontinence Score (PPIS) and ranging from 0 to 4. We observed early continence recovery in 100%, 84.6%, 27.8%, 0% and 0% of patients with a PPIS of 0, 1, 2, 3, 4, respectively.

Conclusion: IPPL, preoperative MUL, MUL-removal rate and shape of VUA were independently predictors of continence recovery. PPIS could accurately predict the early continence recovery after LRP.

Background

Radical prostatectomy (RP) is the main treatment option for localized prostate cancer, which obtains favorable oncological outcomes [1]. However, post-prostatectomy incontinence (PPI) is a bothersome complication with a significant negative effect on the health-related quality of life [2]. A systemic review showed that 4–31% of patients complain of urinary incontinence in 12 months after RP, with a “No Pad” definition of PPI [3].

Despite the etiology of PPI is multifactorial and complex, reduction of internal urethral pressure is the main factor. Several clinical parameters have been identified to be predictors of PPI, including age, body mass index (BMI), metabolic syndrome, prostate volume (PV), preoperative overactive bladder and neurovascular bundle (NVB) sparing [4–6]. Furthermore, urologists have proposed to predict continence recovery with preoperative anatomical parameters on magnetic resonance imaging (MRI) such as MUL and intravesical prostatic protrusion length (IPPL) [7,8]. However, the role of postoperative anatomical parameters in continence recovery has not been evaluated sufficiently. For better patient counseling and early intervention, it is important to identified the risk factors for PPI. The objective of the study was to

evaluate the association between pre- and postoperative anatomical parameters on MRI and continence recovery after laparoscopic radical prostatectomy (LRP), and to develop a risk scoring system to predict the early continence recovery.

Methods

Study population

The retrospective study was conducted in 74 patients treated with LRP for localized prostate cancer at our institute from January 2015 to April 2019 and was approved by the Institutional Review Board of Peking University Third Hospital. All patients underwent pre- and postoperative MRI to evaluate the pelvic anatomical parameters. None of the patients had undergone transurethral resection or holmium laser enucleation of the prostate. No patients had history of incontinence or urethral stricture. No patients received neoadjuvant hormone therapy or radiotherapy. The clinical and pathological data was reviewed in our collected database.

Surgical procedures

All patients received extraperitoneal LRP. After cutting part of the puboprostatic ligament, the deep dorsal vein was suture-ligated. NVB-sparing procedure was attempted to perform for all clinical localized prostate cancer. Reconstruction was performed using full-thickness interrupted sutures when needed. Urethro-vesical anastomosis was performed with 3-0 V-Loc sutures continuously.

MRI parameters measurement

MRI was performed on a 3.0 Tesla magnetic resonance scanner. The mean interval from LRP to postoperative MRI was 12.9 ± 7.0 months. Parameters measurement was performed on T2-weighted MRI images. PV was calculated by the formula, i.e. $PV = 0.52 \times \text{length} \times \text{width} \times \text{height}$. IPPL was measured as the vertical distance from the tip of the protruding prostate to the base of the urinary bladder on the midsagittal image (*Fig 1*). Preoperative MUL was defined as the distance from the apex of prostate to the level of the urethra at penile bulb on the coronal image (*Fig 2a*). Postoperative MUL was defined as the distance from the bladder neck to the level of the urethra at the penile bulb on the coronal image (*Fig 2b*). MUL-removal rate was calculated by the formula, i.e. $\text{MUL-removal rate} = (\text{Preoperative MUL} - \text{Postoperative MUL}) / \text{Preoperative MUL}$. The shape of vesicourethral anastomosis (VUA) on the midsagittal image was classified into triangle and square (*Fig 3a and 3b*). PV, IPPL, pre- and postoperative MUL, and shape of VUA were evaluated by one observer who were blinded to the clinical results.

Continence evaluation

We routinely instructed the patients of pelvic floor muscle exercises to acquire the continence recovery after surgery. They were followed up by outpatient service or telephone interviews every 3 months. In the study, urinary continence was defined as freedom from using safety pad (0 pad/day). Early continence recovery was defined as continence recovery within 3 months.

Statistical analyses

All statistical analyses were conducted with SPSS statistics version 22.0 (IBM Corp, Armonk, NY, USA). Continuous variables were presented as the mean value and standard deviation. The comparison between discontinuous variables and continuous variables was evaluated by Chi-square test and Student's t test, respectively. Kaplan-Meier analyses and log-rank test were used to compare time to continence recovery between groups. Univariate and multivariate Cox proportional-hazards regression analyses were used to identify independent predictors of continence recovery after LRP. A risk scoring system based on the independent predictors was developed to classified patients according to the likelihood of the continence recovery, and the area under the receiver operating characteristic curve (AUC) on continence recovery was evaluated. All tests of significance were two sided, and $p < 0.05$ was considered statistical significance.

Results

The clinical and pathological characteristics of patients are summarized in *Table 1*. The mean age was 69.8 ± 7.7 years. Patients with an mean BMI of 25.0 ± 3.2 kg/m². The mean operation time was 227 ± 68 min, and the mean estimated blood loss was 106 ± 123 ml. Non-, unilateral, and bilateral NVB sparing LRP was performed in 22 (30.1%), 4(5.5%) and 47(64.4%) patients, respectively. There were 5(6.8%), 27(40.0%) and 41(56.2%) patients with Gleason score 6, 7 and ≥ 8 , respectively. 32(43.8%) patients suffered a positive surgical margin. The mean PV was 39.6 ± 22.3 ml, the mean IPPL was 2.8 ± 4.6 mm, the mean preoperative MUL was 13.1 ± 3.2 mm and the mean MUL-removal rate was 6.0%. There were 50(68.5%) patients with triangle VUA, 23(31.5%) patients with square VUA on the postoperative MRI.

In the study 57.5% (42/73) of patients achieved early continence recovery after LRP. Continence recovery was achieved in 78.1% (57/73) and 97.3% (71/73) of patients within 6, and 12 months after LRP, respectively. Patients achieving early continence recovery had significant shorter operation time (210 min vs. 249 min, $p = 0.024$), less estimated blood loss (75 ml vs. 148 ml, $p = 0.029$), smaller PV (33.7 ml vs. 47.5ml, $p = 0.008$), shorter IPPL (0.9 mm vs. 5.4 mm, $p < 0.001$), longer preoperative MUL (14.3 mm vs. 11.6 mm, $p < 0.001$), lower MUL-removal rate (1.9% vs. 11.7%, $p < 0.001$), higher prevalence of triangle VUA ($p < 0.001$) and NVB sparing ($p = 0.014$) (*Table 1*).. There was no significant difference between the two groups in age, BMI, PSA, and pathological characteristics such as Gleason score, pathological T stage and positive surgical margin (*Table 1*)..

Kaplan-Meier analyses and log-rank test revealed that NVB sparing status (yes vs. no, $p = 0.005$), PV (<40ml vs. ≥ 40 ml, $p = 0.001$), IPPL (≤ 5 mm vs. ≥ 5 mm, $p = 0.001$), preoperative MUL (≥ 15 mm vs. <15mm, $p < 0.001$), MUL-removal rate (<10% vs. $\geq 10\%$, $p < 0.001$) and shape of VUA (square vs. triangle, $p < 0.001$) were all significantly associated with continence recovery (*Supplemental Fig 1*).. Univariate Cox proportional analyses revealed NVB sparing status ($p = 0.021$), PV ($p = 0.016$), IPPL ($p = 0.002$), preoperative MUL ($p = 0.004$), MUL-removal rate ($p < 0.001$) and shape of VUA ($p < 0.001$) were predictors of continence recovery after LRP (*Table 2*).. On the multivariate analyses, only IPPL (hazard ratio [HR]: 0.94, 95% confidence interval [CI]: 0.88–1.00, $p = 0.044$), preoperative MUL (HR: 1.10, 95% CI: 1.01–1.19, $p = 0.032$), MUL-removal rate (HR: 0.91, 95% CI: 0.86–0.98, $p = 0.007$) and shape of VUA (square vs. triangle, HR: 2.30, 95% CI: 1.21–4.39, $p = 0.012$) were identified to be independent predictors of continence recovery after LRP (*Table 2*)..

IPPL (≤ 5 mm = 0 score, ≥ 5 mm = 1 score), preoperative MUL (≥ 15 mm = 0 score, <15mm = 1 score), MUL-removal rate ($\leq 10\%$ = 0 score, $\geq 10\%$ = 1 score) and shape of VUA (triangle = 0 score, square = 1 score) were then summed to develop a risk scoring system, termed Post-Prostatectomy Incontinence Score (PPIS) that ranges from 0 to 4 (*Table 3*).. We observed early continence recovery in 100%, 84.6%, 27.8%, 0% and 0% of patients with a PPIS of 0, 1, 2, 3, 4, respectively. The PPIS achieved a satisfactory AUC of 0.93 (95% CI: 0.87–0.99) for predicting early continence recovery after LRP (*Fig 4*).. AUCs of 0.89 (95% CI: 0.80–0.97) and 0.92 (95% CI: 0.83–1.00) for predicting continence recovery within 6 and 12 months, respectively.

Discussion

Incontinence remains to be one of the most significant factors affecting quality of life after RP. In the present study, 57.5% of patients achieved early continence recovery, which was consistent with previous studies [4,9]. With the advances in knowledge of urinary continence mechanism, the main structure in continence is considered the external striated sphincter, which maintains a urethral closure pressure greater than bladder pressure. Sphincteric incompetence after RP may be a result of shorter MUL, loss of neural innervations, muscle damage and loss of the surrounding support tissue [10]. Though PPI is usually a temporary symptom, the lack of information predicting continence recovery leads to anxiety in patients and prevents early treatment for PPI. Therefore, to identify possible predictors of PPI and develop a risk scoring system can contribute to patient counseling and early intervention of PPI.

Advanced age has been proposed as an important predictor of continence recovery after surgery by some studies [4,11,12]. In contrast, our study revealed that there was not significant difference on ages between patients with and without early continence recovery. NyarangiDix et al [13] suggested that continence recovery in elderly men does not differ from younger men undergoing robot-assisted radical prostatectomy. Patient characteristics, surgeon experience and surgical techniques play an important role in continence recovery after RP. NVB sparing was confirmed to be an effective surgical technique for improving continence recovery [14,15]. Our study also revealed that patients treated with NVB sparing achieved significant better continence recovery.

We identified that preoperative MUL was an independent predictor of continence recovery. Coakley et al [16] firstly revealed that longer preoperative MUL was associated with faster continence recovery. The study reported 89% of patients with a MUL > 12 mm achieved continence recovery compared with 77% of patients with a preoperative MUL $\leq$ 12 mm in 12 months after surgery. A meta-analysis containing one randomized controlled trial and 12 cohort studies demonstrated that a longer preoperative MUL is significantly and positively associated with continence recovery after RP [17]. Matsushita et al [18] reported that the addition of preoperative MUL increased the AUC of model for predicting continence recovery, but the AUC was not good enough. Longer MUL including a greater amount of external striated sphincter, play an important role in maintaining and increasing the urethral closure pressures.

RP leads to damages in the structure and function of membranous urethra. However, the MUL-removal rates can vary greatly between different patients and surgeons. The postoperative MUL may be a more accurate parameter for predicting continence recovery than preoperative MUL. Since MRI is not routine performed after RP, only a few studies revealed that longer postoperative MUL was associated with a faster continence recovery after PR [7,9,19]. Postoperative MUL measured on cystourethrography was also identified to be an important predictor of continence recovery [20]. Kohjimoto et al [21] examined 179 prostate specimens of RP and identified that MUL removed with prostate was an independent predictor of continence recovery. Our study revealed that patients with higher MUL-removal rate suffered a significantly longer period of PPI. Therefore, blunt dissection of the urethra distal to the prostatic apex should be carried out for sparing the membranous urethra, which could contribute to improving continence recovery after RP [22].

In recent studies, several MRI parameters such as IPPL, bladder neck width were identified to be predictors of continence recovery after RP [8,9]. Lee et al. [8] reported that significant improvement in continence recovery was observed in patients with IPPL < 5 mm at all periods compared with those with IPPL $\geq$ 5 mm. In a cohort of 821 patients who underwent robot-assisted radical prostatectomy, IPPL measured by transrectal ultrasound was also identified to be a powerful predictor of continence recovery [23]. Our previous study also confirmed that patients achieved early continence recovery after LRP had a significant shorter IPPL [24]. The core condition of urinary continence is the balance of detrusor contractility and urethral pressure. Intravesical prostatic protrusion was identified to be associated with lower urinary tract symptoms and overactive bladder [25,26]. It is supposed that longer IPPL contributes to pathophysiological changes of bladder detrusor such as detrusor hyperactive, detrusor instability and subsequent bladder dysfunction, and then leads to a delay in continence recovery after RP. Furthermore, the impact of intravesical prostatic protrusion on more surgical damage of the internal sphincter during bladder neck dissections put forward as a possible contributor [25]. However, the underlying mechanisms by which IPPL affects continence recovery after RP remains unclear.

On the other hand, we revealed that square UVA was a strongly negative predictor of continence recovery after RP. The risk of PPI for patients with square UVA was 2.3 times higher than those with triangle UVA. However, the mechanisms resulting in the difference on the shape of UVA is unclear. It may be related to the procedure of dissociation proximal urethra and vesical-urethral anastomosis. We proposed that

patient with square UVA may suffered more damage such as scarring and fibrosis to the membranous urethra, which may be caused by high tension anastomosis, subsequent tissue ischemia and mechanical damage to sphincter [27]. Compared to the triangle UVA, square UVA may be an important signal of insufficient urethral closure pressure. Haga et al [19] found that patients with triangle bladder neck had better urinary continence, but it failed to showed significant difference. Further research on the association between the shape of UVA and continence recovery after RP is necessary. Finally, we develop the PPIS with the independent predictors of continence recovery after LRP in our study. It presented a satisfied ROC for predicting continence recovery after LRP. To the best of our knowledge, PPIS is the first risk scoring system based on pre- and postoperative MRI for predicting continence recovery after LRP. And the external validation studies are needed to be carried out.

The present study has some limitations. The retrospective nature of the study and the selection of patients with postoperative MRI could have generated unanticipated biases. The postoperative MRIs were performed in different intervals after surgery, which may affect the urethral parameters. Furthermore, the present study included a relatively small number of patients. Finally, the surgeon experience was not adjusted which may affect continence recovery after RP.

Conclusion

Our study identified that IPPL, preoperative MUL, MUL-removal rate and shape of VUA were independently predictors of continence recovery after LRP. PPIS is an MRI-based risk scoring system, which could accurately predict the continence recovery after LRP. The use of PPIS can help urologists to stratify patients who underwent LRP into subgroups with different risks of PPI.

Abbreviations

MRI: magnetic resonance imaging; LRP: laparoscopic radical prostatectomy; IPPL: intravesical prostatic protrusion length; MUL: membranous urethral length; VUA: vesicourethral anastomosis; PPIS: Post-Prostatectomy Incontinence Score; RP: radical prostatectomy; PPI: post-prostatectomy incontinence; BMI: body mass index; PV: prostate volume; NVB: neurovascular bundle; AUC: area under the receiver operating characteristic curve.

Declarations

Ethics approval and consent to participate

This study received institutional board approval at Peking University Third Hospital Medical Science Research Ethics Committee (IRB M2020235).

Consent for publication

The manuscript is approved by all authors for publication.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

All authors declare no potential conflicts of interest.

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Not applicable.

Authors' Contributions

LLM, YH (Yi Huang) and FZ proposed the protocol. BY, FZ, YCH (Yichang Hao) and YY contributed to data collection and management. BY contributed to data analysis and statistical analysis. BY and FZ contributed to manuscript writing. LLM and YH (Yi Huang) revised the manuscript. All authors have read and approved the manuscript.

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Tables

Table 1 Clinical and pathological characteristics of total patients and groups according to the early continence recovery after laparoscopic radical prostatectomy				
Variables	Total n=73	Early continence recovery		P value
		Yes (n=42)	No (n=31)	
Age, mean $\pm$ SD (years)	69.8 $\pm$ 7.7	68.8 $\pm$ 7.8	71.1 $\pm$ 7.6	0.210
BMI, mean $\pm$ SD (kg/m ²)	25.0 $\pm$ 3.2	24.8 $\pm$ 2.6	25.2 $\pm$ 3.9	0.577
PSA, mean $\pm$ SD (μ g/L)	25.5 $\pm$ 41.6	19.0 $\pm$ 28.6	34.3 $\pm$ 53.8	0.159
Operation time, mean $\pm$ SD (min)	227 $\pm$ 68	210 $\pm$ 52	249 $\pm$ 81	0.024
Estimated blood loss, mean $\pm$ SD (ml)	106 $\pm$ 123	75 $\pm$ 51	148 $\pm$ 172	0.029
Gleason score				0.406
6	5 (6.8)	2	3	
7	27 (40.0)	18	9	
$\geq$ 8	41 (56.2)	22	19	
Pathological stage				0.736
T2	37 (50.7)	22	15	
$\geq$ T3	36 (49.3)	20	16	
Positive surgical margin				0.250
No	41 (56.2)	26	15	
Yes	32 (43.8)	16	16	
NVB sparing status				0.014
No	22 (30.1)	7	15	
Unilateral	4 (5.5)	3	1	
Bilateral	47 (64.4)	32	15	
PV, mean $\pm$ SD (ml)	39.6 $\pm$ 22.3	33.7 $\pm$ 17.7	47.5 $\pm$ 25.6	0.008
IPPL, mean $\pm$ SD (mm)	2.8 $\pm$ 4.6	0.9 $\pm$ 2.1	5.4 $\pm$ 5.8	<0.001
preoperative MUL, mean $\pm$ SD (mm)	13.1 $\pm$ 3.2	14.3 $\pm$ 2.7	11.6 $\pm$ 3.3	<0.001
postoperative MUL, mean $\pm$ SD (mm)	12.4 $\pm$ 3.3	14.0 $\pm$ 2.6	10.1 $\pm$ 2.9	<0.001
MUL-removal rate, (%)	6.0 $\pm$ 6.2	1.9 $\pm$ 3.7	11.7 $\pm$ 4.0	<0.001
Shape of VUA				<0.001
Triangle	50 (68.5)	38	12	

Square	23 (31.5)	4	19
SD, standard deviation; BMI, body mass index; LUST, lower urinary symptom; PSA, prostate specific antigen; PV, prostatic volume; IPPL, intravesical prostatic protrusion length; MUL, membranous urethral length; NVB, neurovascular bundle; VUA, vesicourethral anastomosis			

Table 2. Univariate and multivariate analysis of parameters predicting continence recovery after laparoscopic radical prostatectomy.			
Variables	Univariate	Multivariate	
	P value	HR (95% CI)	P value
Age (years)	0.186		
BMI (kg/m ²)	0.331		
Operation time (min)	0.229		
Estimated blood loss (ml)	0.108		
NVB sparing status (Yes vs. No)	0.021	0.74 (0.43-1.30)	0.297
PV (ml)	0.016	1.00 (0.99-1.01)	0.991
IPPL (mm)	0.002	0.94 (0.88-1.00)	0.044
Preoperative MUL (mm)	0.004	1.10 (1.01-1.19)	0.032
MUL-removal rate (%)	<0.001	0.91 (0.86-0.98)	0.007
Shape of VUA (square vs. triangle)	<0.001	2.30 (1.21-4.39)	0.012
BMI, body mass index; NVB, neurovascular bundle; PV, prostatic volume; IPPL, intravesical prostatic protrusion length; MUL, membranous urethral length; VUA, vesicourethral anastomosis.			

Table 3 The scoring criteria of Post-Prostatectomy Incontinence score (PPIS)		
PPIS	0 score	1 score
Intravesical prostatic protrusion length (mm)	≤5 mm	≥5 mm
Preoperative membranous urethral length (mm)	≥15mm	<15mm
Membranous urethral length-removal rate	≤10%	≥10%
Shape of vesicourethral anastomosis	Triangle	Square

Figures

Figure 1

The vertical distance from the tip of the protruding prostate to the base of the urinary bladder on the midsagittal image defined as intravesical prostatic protrusion length (IPPL).

Figure 2

The distance from the apex of prostate / bladder neck to the urethra at the level of the penile bulb on the coronal image defined as preoperative MUL (a) / postoperative MUL (b). MUL membranous urethral length.

Figure 3

The shape of vesicourethral anastomosis (VUA) on the midsagittal image of postoperative magnetic resonance imaging: Triangle VUA (a) and square VUA (b).

Figure 4

ROC curve of Post-Prostatectomy Incontinence Score predicting early continence recovery after laparoscopic radical prostatectomy. ROC receiver operating characteristic, AUC area under the ROC curve.

Supplementary Files

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