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Predictors of short and long term urinary incontinence after radical prostatectomy in prostate MRI: Significance and reliability of standardized measurements

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ABSTRACT

Purpose: To evaluate standardized measurements of the membranous urethra length (MUL), the membranous urethra angle (MUA) and the prostate's apex type (AT) among further clinical parameters as potential preoperative risk factors of urinary incontinence (UI) after radical prostatectomy (RP).

Method: Our institutional review board approved this retrospective single center study. 316 patients (mean age 65 years) underwent MRI at 3 T prior to prostatectomy. MUL, MUA and AT were measured according to a standardized approach on T2w- sagittal sequences. In a second reading the inter-rater agreement for the MUL was determined. Image findings and clinical data were correlated by logistic regression to UI as evaluated by a standardized questionnaire determining the number of necessary hygiene pads (HP) at three different time points with corresponding patient subsets (one week, six months and 12 months after RP).

Results: There was a significant impact of the MUL on postoperative UI with odds ratios (OR) of 0.8 [$p < 0.001$; confidence interval (CI) 0.73-0.91], 0.8 ($p = 0.01$; CI 0.68-0.94) and 0.7 ($p < 0.01$; CI 0.56-0.89) at the respective time points. No significant impact was demonstrated regarding the MUA and AT. Of all clinical parameters there was significant impact of the patients' age and the degree of nerve-sparing surgery. Inter-rater agreement with respect to the MUL was good with an intraclass correlation coefficient of 0.82. The mean deviation of raters measuring the MUL was 1.2 mm.

Conclusions: A shorter MUL in mpMRI should be considered as a risk factor of UI after RP. Standardized measurements enabling good inter-rater agreement should be considered for routine assessments to facilitate prospective classifications.

1. Introduction

Urinary incontinence (UI) is a severe functional complication of radical prostatectomy and a major risk factor to consider during decision making about the individual treatment of prostate cancer (PC). Reports about the prevalence of UI after prostatectomy vary, depending on the measurement and definition of continence [1]. Despite advances in surgical techniques incidences of UI are relevant and resemble a major source of postoperative life quality impairment [2]. Acknowledging the widening spectrum of treatment strategies mainly represented by radical prostatectomy (RP), active surveillance, radiation and focal therapy, one has to demand increasing accuracy of diagnostics in order to ensure optimal decision making. Besides multiple clinical parameters potentially impairing postoperative UI, there is increasing literature suggesting possible imaging parameters eligible to stratify the risks of surgery with regards to postoperative continence [3–8]. However, existing literature focuses on a clinical perspective and current radiologic assessments are predominantly confined to cancer detection. Established reporting standards such as the prostate imaging and reporting data system (PI-RADS) [9] do not offer insights into

Abbreviations: ADC, Apparent diffusion coefficient; AT, Apex type; CI, Confidence interval; DWI, Diffusion-weighted imaging; HP, Hygiene pads; LN, Lymph node; mpMRI, Multiparametric prostate MRI; MUA, Membranous urethra angle; MUL, Membranous urethra length; NSS, Nerve sparing surgery; PC, Prostate cancer; PI-RADS, Prostate Imaging – Reporting and Data System; RP, Radical prostatectomy; SP, Safety hygiene pads; UI, Urinary incontinence

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Table 1
Standardized mpMRI protocol. DCE: Dynamic Contrast Enhancement. DWI: Diffusion weighted Imaging. *b-Values = 0 + 800 + 1200.

Sequence	Field of view	Repetition time	Matrix	Pixel size (mm)	Flip angle(s) (degrees)	Section thickness (mm)	Acquisition time (min:sec)
T2-weighted sagittal	150 × 150	3497	384 × 384	0.4	90	3	02:36
T2-weighted axial	160 × 160	5781	432 × 432	0.4	90	3	05:32
T2-weighted coronal	150 × 150	3649	432 × 432	0.4	90	3	02:56
DWI*	130 × 130	3623	128 × 128	1	90	3	05:58
T1-weighted	160 × 160	618	224 × 224	0.7	90	3	02:57
T1-weighted DCE^2	262 × 262	3.3	256 × 256	1.0	10	3	05:08

potential functional assessments. Of many possible parameters, we chose the membranous urethra length (MUL), the urethra angle (UA) and the prostate apex type (AT) as previously proposed by Lee and coworkers. [10,11] for this investigation as the most promising and feasible to determine. Accompanied by the most relevant clinical parameters, we found these to be the most eligible to be evaluated in a standardized way. Considering the circumstance that UI may alter during the postoperative interval, we analysed both short- and long term outcomes with respect to our preoperative findings. Hereby, the aim of this study was to investigate a patient collective with up-to-date, standardized imaging and identify feasible and consistent approaches to assess the risk of UI in preoperative mpMRI.

2. Material and methods

2.1. Patient selection and characteristics

The local institutional review board approved our single center retrospective study and waived the requirement for informed consent. Of 1631 patients who had undergone mpMRI between July 2014 and January 2018, 316 were included in our study. Inclusion criteria were biopsy-proven adenocarcinoma of the prostate, preoperative examination with a standardized mpMRI protocol, subsequent RP (open radical or robot-assisted) with complete postoperative pathology, as well as pre- and postoperative assessment of continence with a standardized questionnaire. Exclusion criteria were preoperative incontinence and pre- or postoperative radiation therapy within one year of follow-up. Due to inconsistent response-rates of the questionnaires for the respective time points of continence assessment three different patient subsets were defined: [A] One week after catheter removal (232 patients), [B] six months (162 patients) and [C] 12 months after RP (133 patients).

2.2. Pre- and postoperative assessment and definition of urinary incontinence

Pre- and postoperative assessment of urinary continence was evaluated with a standardized, self-administrated questionnaire determining the amount of daily necessary hygiene pads at different time points: previous to therapy, one week after catheter removal, six months and one year after RP. Continence was measured by the necessary amount of hygiene pads (HP). Since many patients use hygiene pads for safety purposes only, the study distinguishes between clean safety hygiene pads (SP) and at least partly drenched HP. Continence was defined as none or maximum one dry SP per day ($\leq$1 SP), UI as one or more wet HP per day ($\geq$1 HP).

2.3. Multiparametric MR imaging

All patients underwent in-house standardized multiparametric MRI on a 3 T system (Ingenia, Philips Medical Systems, Best, The Netherlands) using a phased-array coil. Unless patients had contraindications they were administered scopolamine butylbromide (40 mg) intravenously prior to the examination. The MR imaging protocol consisted of an axial T1-weighted sequence, triplanar high-resolution T2-weighted sequences with 3 mm section thickness and diffusion-weighted imaging (DWI; b-values of 0 and 1200s/mm^2). Apparent diffusion coefficient (ADC) maps were gathered automatically by the scanner software. Dynamic contrast-enhanced (DCE) images in the axial plane were obtained dynamically before, during and after intravenous injection of gadoteric acid at a flow rate of 2 ml/s (0.1 mmol/kg body weight; Dotarem, Guerbet, Paris, France). Finally, maximum enhancement and area under the curve maps were obtained by automatic postprocessing with a commercial software workstation (Invivo DynaCAD Prostate Workstation, Software Version v2.1.0, Gainesville, FL, USA). Evaluation of MUL, MUA and the AT was performed within the sagittal T2-weighted sequence (3 mm slice thickness, no gap). Details of the mpMRI protocol are summarized in Table 1.

2.4. Standardized image interpretation and measurements

For every patient MUL, MUA and AT according to Lee et al. were determined in a standardized approach, which requires reproducible patient positioning on the scanner table: Supine, feet-first with a wedge-shaped cushion (7 cm thickness) underneath the knees. In T2w-saggital plane, a horizontal line underneath the symphysis was placed (Fig. 1). We intentionally did not use the pubococcygeal line as a reference to avoid unnecessary enlargement of the field of view. Another intersecting line parallel to the membranous part of the urethra defines the MUA. MUL is measured as the distance of two horizontals: [1] on the level of the deepest part of the prostate's apex and [2] on the highest visible part of the penile bulbous. At last the AT was determined as previously described by Lee et al. depending on the amount of overlapping of anterior and posterior parts of the prostate apex (Fig. 2). Furthermore T-staging, assessment according to PI-RADS Version 2 and the prostate volume by ellipsoid calculation were determined. Image reading was performed prospectively during clinical routine by a specialized genitourinary radiologist (*blinded for review*, 20 years of experience) in awareness of available oncologic clinical data (i.e. clinical stage, PSA level, previous biopsies). At this point, there was no data about the patient's continence available to the raters. The second reading of the MUL was performed by a second radiologist unaware of the previous readings (*blinded for review*, 5 years of experience in genitourinary radiology).

2.5. Surgical and histopathological examination

RP was performed in a high volume prostate cancer center by board-certified urologists according to local standards [12]. Depending on preoperative diagnostics, as well as intraoperative frozen-section analysis uni- or bilateral nerve-sparing surgery was realized. Specimens were processed according to the local whole-mount standard preparation procedure.

2.6. Statistical analysis

The Kruskal-Wallis test and the Pearson's Chi-squared test were used to test for statistical differences of the distribution of the mean and for independence of categorical distributions. Cut-off value analysis was done using a 2 × 2 contingency table and Fisher's exact test. For both

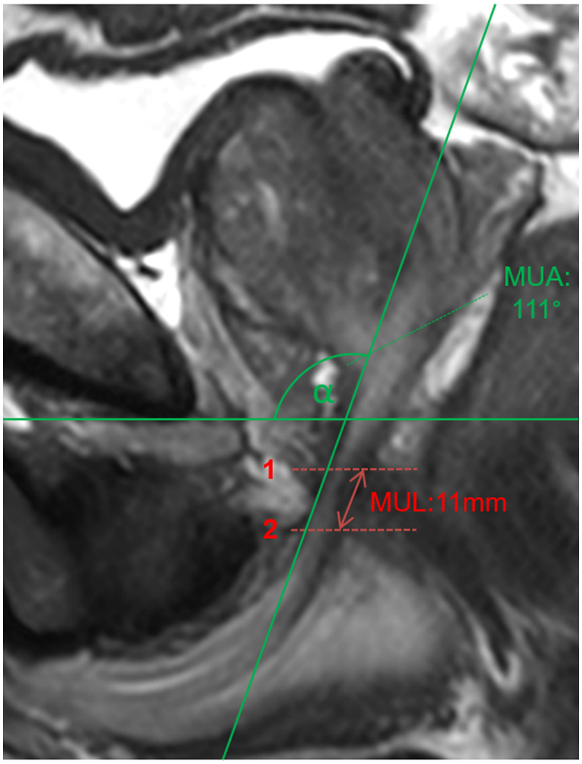

Fig. 1. Standardized measurements of membranous urethra length (MUL), angle (MUA) and apex type (AT). In T2w-sagittal plane a horizontal line underneath the symphysis was placed. Another intersecting line parallel to the membranous part of the urethra defines the MUA. MUL is measured as the distance of two horizontals: [1] on the level of the deepest part of the prostate's apex and [2] on the highest visible part of the penile bulbous.

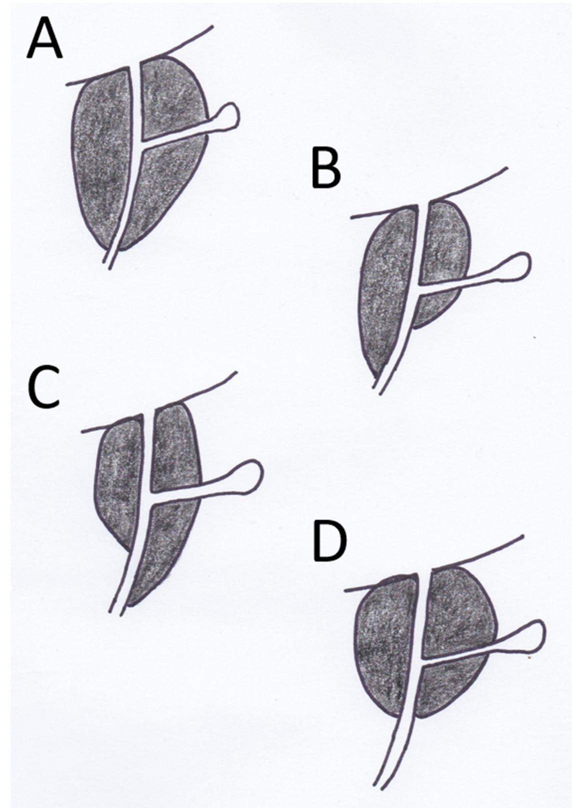

Fig. 2. Apex types (AT) according to Lee et al. Apex types as proposed by Lee et al. depending on the degree of anterior and/or posterior overlapping of the prostate apex [10].

clinical and MRI-parameters uni- and multivariable logistic regression models were performed to evaluate their association with short and long term UI. The intraclass correlation coefficient (ICC) was used to investigate the inter-rater agreement. An ICC > 0.75 was considered a good agreement [13]. The level of significance was set at $p \leq 0.05$. Analyses were performed using the R software (version 3.5.1) [14] and MedCalc (version 14.8.1, MedCalc Software bvba, Belgium).

3. Results

3.1. Patient collective and morphological data

The median age of all patients was 65 years (range 46–77 years). In the majority of cases there was no extracapsular extension with 203 tumors at stage T2 (64%), 62 at stage T3a (20%) and 51 at stage T3b/T4 (16%). Mean MUL and MUA of all patients were 10.5 mm (range 5.0 mm – 25.0 mm) and 122° (range 68°–153°), respectively. The dominating AT according to Lee et al. was "C" with 58%. The mean MUL of the respective AT differed significantly with "A" demonstrating the shortest mean MUL of 9.7 mm and "D" the longest with 14.7 mm (see Figs. 1 and 2; $p < 0.001$). Mean prostate volume was 47 ml (range 20 ml–160 ml). In 73% (230 patients) bilateral nerve-sparing surgery (NSS) was performed, while there was unilateral and bilateral extended resection in 20% (65 patients) and 7% (21 patients), respectively. Patients with and without NSS did not demonstrate significantly different mean MULs (10.8 mm [SD 3.2 mm], vs. 10.8 mm [SD 3.0]; $p = .40$). Details are summarized in Table 2.

Table 2
Patient Collective. AT: Apex type.

Parameter	value (range)
n	316
Mean Age (range)	65 (46–77)
Mean MUL in mm (range)	10.5 (5.0–25.0)
Mean MUA (range)	122° (68°–153°)
Prostate volume in ml (range)	47 (20–160)
AT according to Lee et al.	
A	71 (22%)
B	8 (3%)
C	184 (58%)
D	53(17%)
Nerve-sparing surgery	
Bilateral	230 (73%)
Unilateral	65 (20%)
None	21 (7%)
Tumor Stadium	
pT2	203 (64%)
pT3a	62 (20%)
pT3b/pT4	51 (16%)

3.2. UI one week after catheter removal (subset A: 232 patients)

Results are summarized in Table 3: One week after catheter removal UI was determined for 39% (90 patients), while 61% were continent (142 patients). There was a significant difference between the mean MUL in continent vs. incontinent patients (11.4 mm vs. 10.0 mm; $p < .001$). AT according to Lee et al. were distributed significantly differently. No significant difference was determined for the mean MUA in both patient groups. Uni- and multivariable logistic regression demonstrated significant impact on UI of MUL (Odd's ratio [OR]: 0.85; CI 0.76-0.93; $p < .001$), age (OR 1.1; CI 1.05–1.15; $p < .001$) and the type of nerve-sparing surgery with an increased OR of 3.9 in case of bilateral nerve resection (CI 1.14–15.9; $p = .04$). No significant impact was determined for the prostate volume.

Table 3

Urinary incontinence one week after catheter removal (Subset A: 232 patients). Comparison of means (I). Risk stratification by uni- (II) and multivariable logistic regression (III). AT: Apex type. CI: Confidence interval. HP: Hygiene pad. MUL: Membranous urethra length. MUA: Membranous urethra angle. NSS: Nerve-sparing surgery. OR: Odd's ratio. SP: Safety hygiene pad.

Parameter		0 ≤ 1 SP	≥ 1 HP	p =
(I) Comparison of means				
Subset A n = 232		142 (61%)	90 (39%)	
MUL in mm; mean (range)		11.4 (5.0–25.0)	10.0 (5.0–20.0)	< 0.001**
MUA; mean (range)		121° (68–153°)	121° (103–150°)	0.53
AT:	Sample (n = 316)			
A	71 (22%)	24 (17%)	32 (36%)	0.001**
B	8 (3%)	2 (1%)	4 (4%)	
C	184 (58%)	84 (59%)	45 (50%)	
D	53(17%)	32 (23%)	9 (10%)	
(II) Univariable logistic regression				
Parameter		**OR**	**95% CI**	**p =**
MUL		0.85	0.76–0.93	< 0.001**
MUA		1.0	0.97–1.02	0.73
(III) Multivariable logistic regression				
Parameter		**OR**	**95% CI**	**p =**
MUL		0.82	0.73–0.91	< 0.001**
Age		1.1	1.05–1.15	< 0.001**
Prostate volume		1.0	0.99–1.03	0.32
NSS:				
Bilateral		Reference		
Unilateral		2.0	1.03–3.8	0.04*
None		3.9	1.3–13.8	0.04*

3.3. *UI six months after radical prostatectomy (subset B: 164 patients)*

Results are summarized in Table 4: Six months after RP 19% (31 patients) demonstrated UI, while 81% (133 patients) were determined as continent. There was a significant difference of the mean MUL in continent vs. incontinent patients (11.1 mm vs. 9.4 mm; p < .01), while there were no significant differences regarding the mean MUA or the AT. In uni- and multivariable logistic regression significant impact on UI was confirmed for MUL (OR: 0.8; CI 0.68-0.94; p = .01) and age (OR 1.1; CI 1.0–1.16; p = .02). At this time point, there was no significant impact determined for the prostate volume or the type of nerve-sparing.

Table 4

Urinary incontinence six months after RP (Subset B: 164 patients). Comparison of means (I). Risk stratification by uni- (II) and multivariable logistic regression (III). AT: Apex type. CI: Confidence interval. HP: Hygiene pad. MUL: Membranous urethra length. MUA: Membranous urethra angle. NSS: Nerve-sparing surgery. OR: Odd's ratio. SP: Safety hygiene pad.

Parameter		0 ≤ 1 SP	≥ 1 HP	p =
(I) Comparison of means				
Subset A n = 164		133 (81%)	31 (19%)	
MUL in mm; mean (range)		11.1 (5–25)	9.4 (6–17)	< 0.01*
MUA; mean (range)		121° (68–153°)	121° (108–136°)	0.68
AT:	Sample (n = 316)			
A	71 (22%)	26 (19%)	10 (32%)	0.24
B	8 (3%)	3 (2%)	0 (0%)	
C	184 (58%)	78 (59%)	18 (58%)	
D	53(17%)	26 (20%)	3 (10%)	
(II) Univariable logistic regression				
Parameter		**OR**	**95% CI**	**p =**
MUL		0.83	0.70–0.95	0.02*
MUA		0.99	0.96–1.03	0.9
(III) Multivariable logistic regression				
Parameter		**OR**	**95% CI**	**p =**
MUL		0.8	0.68–0.94	0.01*
Age		1.1	1.0–1.16	0.02*
Prostate volume		1.0	0.98–1.03	0.59
NSS:				
Bilateral		Reference		
Unilateral		1.3	0.4–3.5	0.65
None		1.2	0.14–7.0	0.85

Table 5

Urinary incontinence one year after RP (Subset C: 133 patients). Comparison of means (I). Risk stratification by uni- (II) and multivariable logistic regression (III). AT: Apex type. CI: Confidence interval. HP: Hygiene pad. MUL: Membranous urethra length. MUA: Membranous urethra angle. NSS: Nerve-sparing surgery. OR: Odd's ratio. SP: Safety hygiene pad.

Parameter		0 ≤ 1 SP	≥ 1 HP	p =
(I) Comparison of means				
Subset A n = 133		111 (83%)	22 (17%)	
MUL in mm; mean (range)		11.3 (5–24)	8.9 (6–15)	< 0.001*
MUA; mean (range)		121° (68–153°)	122° (108–135°)	0.73
AT:	**Sample (n = 316)**			
A	71 (22%)	20 (18%)	5 (23%)	0.61
B	8 (3%)	3 (3%)	0 (0%)	
C	184 (58%)	68 (61%)	15 (68%)	
D	53(17%)	20 (18%)	2 (9%)	
(II) Univariable logistic regression				
Parameter		**OR**	**95% CI**	**p =**
MUL		0.73	0.57–0.88	0.004**
MUA		1.0	0.96–1.05	0.83
(III) Multivariable logistic regression				
Parameter		**OR**	**95% CI**	**p =**
MUL		0.7	0.56–0.89	0.006**
Age		1.1	1.02–1.23	0.02*
Prostate volume		0.99	0.97–1.02	0.78
NSS:				
Bilateral		Reference		
Unilateral		1.2	0.32–3.8	0.76
None		2.4	0.28–15.7	0.3

3.4. *UI 12 months after Radical Prostatectomy (subset C: 138 patients)*

Results are summarized in Table 5. 12 months after RP UI was detected in 17% (23 patients), 83% (111 patients) were continent. The mean MUL differed significantly with 11.3 mm vs. 8.8 mm in continent and incontinent patients, respectively. There was no significant difference regarding AT or MUA. Uni- and multivariable logistic regression confirmed a significant impact on UI of MUL (OR 0.7; CI 0.56-0.89; p < .01) and age (OR 1.1; CI 1.02–1.23; p = .02). There was no significant impact detected for prostate volume or the degree of nerve sparing. Application of a cut-off value of < 10 mm MUL, demonstrates significantly different incontinence rates one-year after RP (4% vs. 33%, respectively. p < .0001). Details are presented in Table 6.

3.5. *Inter-rater agreement in measuring the MUL*

The measurements of the MUL were repeated by a second reader blinded to the initial reports. The overall agreement between the two observers was good with an ICC of 0.82 (CI 0.75 - 0.87). The absolute

Table 6

Analysis of < 10 mm MUL cut-off value (Subset C: 133 patients). 2 × 2 contingency table evaluating the incidence of incontinence one-year after RP when dividing groups by a cut-off value (MUL < 10 mm). The association of grouping and outcome is statistically significant (p < .0001; Fisher's exact test). MUL: Membranous urethra length. HP: Hygiene pad. SP: Safety hygiene pad.

	Continent (0 ≤ 1 SP)	Incontinent (≥ 1 HP)	Σ
MUL < 10 mm	28	14	42
MUL ≥ 10 mm	66	3	69
Σ	94	17	111

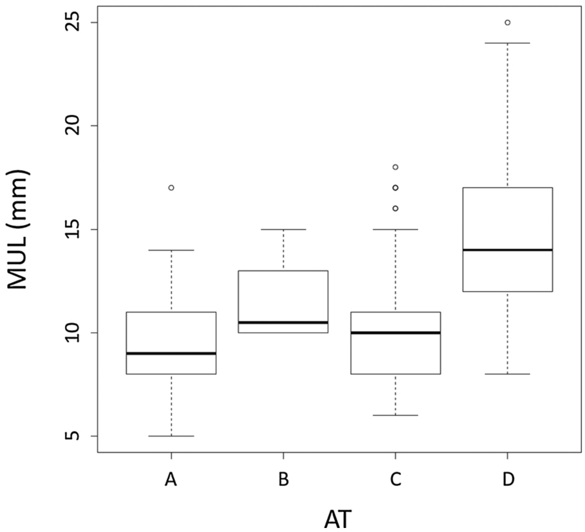

Fig. 3. Mean membranous urethra length (MUL) of the respective apex types (AT). The mean MUL of the respective AT: A 9.7 mm, B 11.5 mm, C 10.1 mm and D 14.7 mm. AT “A”, which overlaps the urethra both anteriorly and posteriorly (see Fig. 1) demonstrates a significantly smaller mean MUL than AT “D” without overlapping ($p < 0.001$).

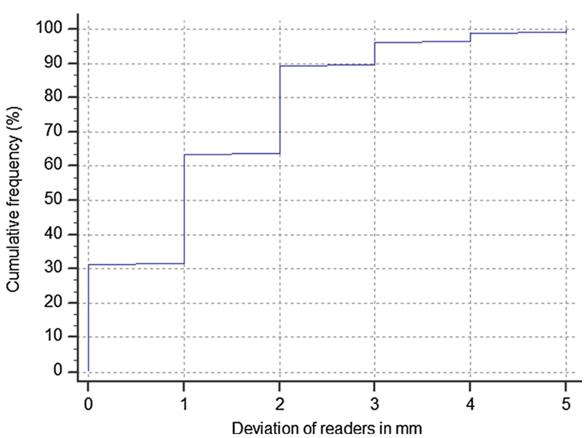

Fig. 4. Inter-rater correlation of the membranous urethra length (MUL) measurements: Absolute deviation of raters in mm. 0 mm: 31.3%, 1 mm: 32.0%, 2 mm: 25.9%, 3 mm 7.0%, 4 mm: 2.5%, 5 mm: 1.3%. The mean deviation was 1.2 mm (Standard deviation 1.1 mm).

deviation between both readers was 0 mm in 99 cases, 1 mm in 101 cases, 2 mm in 82 cases, 3 mm in 22 cases, 4 mm in 8 cases and 5 mm in 4 cases (mean = 1.21 mm). Results are visualized as a cumulative frequency plot in Fig. 4.

4. Discussion

The aim of our study was to evaluate a standardized approach to assess potential imaging markers predicting postoperative UI in mpMRI.

We found that, out of three investigated imaging parameters, only the MUL had a significant impact on UI, while no relevance of the MUA or the AT was detected. Standardized measuring of the MUL demonstrated a good inter-rater agreement.

Previous studies evaluated both clinical and imaging-associated parameters to estimate the risk of UI after RP [3–8]. However, the majority of them focusses on the urological context and despite increasing evidence, that MRI offers the capability to reveal potential risk factors of surgery, up to now, there is no relevance in everyday radiological routine [15]. In line with our results, Mungovan et al. reported in a meta-analysis a small, yet significant effect for every extra millimeter MUL on the return of continence after RP (OR: 1.09). The effect size seems comparable to our results, though we investigated the MUL’s effect on *incontinence* causing an inverse OR of 0.7 to 0.9 depending on the investigated time point. In our study the range of the MUL (min. 5 mm; max. 25 mm) demonstrated a maximum difference of 20 mm, accordingly a very relevant impact on postoperative incontinence has to be suspected especially for those patients with extreme values. For clinical application a statistically reliable cut-off value has to be determined in subsequent studies. So far, in clinical routine our group applies a “rule of thumb” threshold based on our available data which is < 10 mm MUL, which demonstrated a significant association with the incidence of long-term incontinence in this analysis. Future measurements certainly will gain precision and should benefit from technical advances such as recently proposed high resolution isotropic 3D acquisitions of T2-weighted which may offer improved reconstructions of the MUL [16].

Although there is increasing interest in pelvic floor anatomy, few studies have investigated the angle of the membranous urethra as a risk factor of UI. Soljanik et al. reported a significant wider MUA of incontinent patients after RP [6]. Though quick and easy to measure in standard MRI sequences, we could not determine a significant effect of the MUA in our markedly larger collective. Hence, we do not propagate the routine measurement of the MUA.

Introducing four different prostate ATs with a different degree of overlapping of the membranous urethra, Lee at al. demonstrated better postoperative continence recovery of the shape with the least overlapping [10]. During our measurements of this promising parameter, we assumed correlation of the AT with the MUL (i.e. more overlapping causes a shorter MUL), which seems to be confirmed by significantly different mean MULs (see Fig. 3) within the groups. In further analysis, we determined significantly different distribution for the ATs in incontinent vs. continent patients only in subset A. Due to limitations in the number of cases we were not able to perform reliable statistical analyses to confirm an association of AT with incontinence. In summary, we assume the correlation of the AT with the MUL to be the relevant effect on UI. This, and a follow-up study of the same initial group on robot-assisted RP patients denying a significant impact on UI of the proposed AT [11] causes us not to recommend evaluation of the AT in clinical routine.

Of all analyzed clinical parameters without surprise we determined a significant impact of the patient’s age on short- and long-term UI. In addition, there was a significant increase in short-term UI in patients without nerve-sparing prostatectomy. Presumably because of the uneven distribution of patients (93% received uni- or bilateral nerve-sparing) this impact was not demonstrated at long-term, previous studies, however, well depicted this effect [12,17]. There are inconsistent results regarding the prostate volume’s impact on UI. In this and several previous studies, no significant effect could be demonstrated [18,19]. Other studies demonstrate both postoperative disadvantages regarding the functional outcome [20] as well as challenging conditions for the surgeon [19]. Therefore, determining the prostate volume in MRI, as it is already routinely performed, still seems reasonable.

With small effects demanding precise measurements, we investigated precision and reliability by determining the degree of inter-rater agreement. With 96% of all deviations within ± 3 mm and a mean deviation of 1.2 mm, we think that our proposed approach is well reliable, even if Fig. 4 demonstrates cases of relevant discrepancy (max. 5 mm). The degree of agreement benefited from the fact that measurements of both readers were standardized through the specified criteria.

Our study has certain limitations. Although measurements were performed prospectively, the study is based on a retrospective, single center setup and prospective approaches are necessary to confirm our findings, especially in order to determine statistically reliable threshold values. Due to the incomplete response rate regarding our investigated time points the available data causes different subsets within our patient collective. Generally, there remains uncertainty about the evaluation and definition of incontinence with questionnaires and hygiene pads, however to our knowledge it is the most feasible and acceptable approach. Our results about the patient's functional outcome are not perfectly in line with the general collective of our center [17], presumably due to selection bias (e.g. obligatory in-house mpMRI). Though we demonstrated good inter-rater agreement in this study, one has to acknowledge the relevance of measurement deviation, especially in borderline cases, while evaluating the probability of post-operative incontinence.

5. Conclusions

In conclusion the MUL seems to be the most relevant imaging parameter with a rather small but consistent impact on postoperative UI. Measurements, when performed to defined standards, can be done with good inter-rater agreement. Up to now there are no established guidelines about the preoperative evaluation of imaging parameters to assess the postoperative functional outcome. Future clinical measurement of the MUL should be based on standards, similar to established criteria such as PI-RADS and MRI examinations should include sagittal T2-weighted imaging with small section thickness.

In order to facilitate increasing evidence, it is necessary to establish awareness among radiologists to gain standardized data, which might lead to absolute thresholds or classifications, that could be incorporated into the training procedures for mpMRI. Hereby, mpMRI has an increasing impact on the best decision about the optimal, individual treatment of PC.

Declaration of Competing Interest

None.

References

[1] V. Ficarra, G. Novara, W. Artibani, A. Cestari, A. Galfano, M. Graefen, et al., Retropubic, laparoscopic, and robot-assisted radical prostatectomy: a systematic review and cumulative analysis of comparative studies, Eur. Urol. 55 (5) (2009) 1037–1063 May 1 cited 2019 Jan 15. Available from: https://www.sciencedirect.com/science/article/pii/S0302283809000499.

[2] R.C. Chen, R. Basak, A.-M. Meyer, T.-M. Kuo, W.R. Carpenter, R.P. Agans, et al., Association between choice of radical prostatectomy, external beam radiotherapy, brachytherapy, or active surveillance and patient-reported quality of life among men with localized prostate cancer, JAMA 317 (11) (2017) 1141 Mar 21 [cited 2019 Jan 15] Available from: http://jama.jamanetwork.com/article.aspx?doi=10.1001/jama.2017.1652.

[3] S.F. Mungovan, J.S. Sandhu, O. Akin, N.A. Smart, P.L. Graham, M.I. Patel, Preoperative membranous urethral length measurement and continence recovery following radical prostatectomy: a systematic review and meta-analysis, Eur. Urol. 71 (3) (2017) 368–378 Mar [cited 2018 Sep 24] Available from: http://www.ncbi.nlm.nih.gov/pubmed/27394644.

[4] Y. Satake, Y. Kaiho, H. Saito, T. Yamada, N. Kawamorita, S. Yamashita, et al., Estimated minimal residual membranous urethral length on preoperative magnetic resonance imaging can Be a new predictor for continence after radical prostatectomy, Urology 112 (2018) 138–144 Feb [cited 2018 Sep 24] Available from: http://www.ncbi.nlm.nih.gov/pubmed/29158172.

[5] W. Song, C.K. Kim, B.K. Park, H.G. Jeon, B.C. Jeong, S. Seo IIet al., Impact of preoperative and postoperative membranous urethral length measured by 3 Tesla magnetic resonance imaging on urinary continence recovery after robotic-assisted radical prostatectomy, Can. Urol. Assoc. J. 11 (3–4) (2017) 93 Mar 16 [cited 2018 Sep 24]Available from: http://www.ncbi.nlm.nih.gov/pubmed/28360954.

[6] I. Soljanik, R.M. Bauer, A.J. Becker, C.G. Stief, C. Gozzi, O. Solyanik, et al., Is a wider angle of the membranous urethra associated with incontinence after radical prostatectomy? World J. Urol. 32 (6) (2014) 1375–1383 Dec 23 [cited 2019 Jan 7] Available from: http://www.ncbi.nlm.nih.gov/pubmed/24452450.

[7] D. Ikarashi, Y. Kato, M. Kanehira, R. Takata, A. Ito, M. Onoda, et al., Appropriate preoperative membranous urethral length predicts recovery of urinary continence after robot-assisted laparoscopic prostatectomy, World J. Surg. Oncol. 16 (1) (2018) 224 Nov 16 [cited 2018 Dec 21]; Available from: http://www.ncbi.nlm.nih.gov/pubmed/30445961.

[8] A. Tienza, M. Hevia, A. Benito, J.I. Pascual, J.J. Zudaire, J.E. Robles, MRI factors to predict urinary incontinence after retropubic/laparoscopic radical prostatectomy, Int. Urol. Nephrol. 47 (8) (2015) 1343–1349. Aug 7 [cited 2017 Aug 16] Available from: http://link.springer.com/10.1007/s11255-015-1019-8.

[9] American College of Radiology. 2015. Available from: https://www.acr.org/-/media/ACR/Files/RADS/Pi-RADS/PIRADS-V2.pdf.

[10] S.E. Lee, S.-S. Byun, H.J. Lee, S.H. Song, I.H. Chang, Y.J. Kim, et al., Impact of variations in prostatic apex shape on early recovery of urinary continence after radical retropubic prostatectomy, Urology 68 (1) (2006) 137–141 Jul 1 [cited 2017 Dec 5] Available from: http://www.sciencedirect.com/science/article/pii/S0090429506000872?via%3Dihub.

[11] H. Lee, K. Kim, S. Hwang II, H.J. Lee, S.-S. Byun, S.E. Lee, et al., Impact of prostatic apical shape and protrusion on early recovery of continence after robot-assisted radical prostatectomy, Urology 84 (4) (2014) 844–849 Oct [cited 2017 Aug 16] Available from: http://linkinghub.elsevier.com/retrieve/pii/S0090429514005949.

[12] Blinded for review.

[13] T.K. Koo, M.Y. Li, A guideline of selecting and reporting intraclass correlation coefficients for reliability research, J. Chiropr. Med. 15 (2) (2016) 155–163 Jun 1 [cited 2019 Feb 20] Available from: https://www.sciencedirect.com/science/article/pii/S1556370716000158?via%3Dihub.

[14] R Foundation for Statistical Computing, R: a Language and Environment for Statistical Computing, Available from: (2018) https://www.r-project.org/.

[15] M.S. Litwin, H.-J. Tan, The diagnosis and treatment of prostate Cancer, JAMA 317 (24) (2017) 2532 Jun 27 [cited 2019 Jan 15] Available from: http://jama.jamanetwork.com/article.aspx?doi=10.1001/jama.2017.7248.

[16] S.H. Polanec, M. Lazar, G.J. Wengert, H. Bickel, C. Spick, M. Susani, et al., 3D T2-weighted imaging to shorten multiparametric prostate MRI protocols, Eur. Radiol. 28 (4) (2018) 1634–1641. Apr [cited 2019 May 16] Available from: http://www.ncbi.nlm.nih.gov/pubmed/29134351.

[17] U. Michl, P. Tennstedt, L. Feldmeier, P. Mandel, S.J. Oh, S. Ahyai, et al., Nerve-sparing surgery technique, not the preservation of the neurovascular bundles, leads to improved long-term continence rates after radical prostatectomy, Eur. Urol. 69 (4) (2016) 584–589. Apr [cited 2019 Jan 15] Available from: http://www.ncbi.nlm.nih.gov/pubmed/26277303.

[18] A.P. Labanaris, V. Zugor, J.H. Witt, Robot-assisted radical prostatectomy in patients with a pathologic prostate specimen weight ≥100 grams versus ≤50 grams: surgical, oncologic and short-term functional outcomes, Urol. Int. 90 (1) (2013) 24–30 [cited 2019 Jan 14] Available from: http://www.ncbi.nlm.nih.gov/pubmed/23258076.

[19] J.A. Pettus, T. Masterson, A. Sokol, A.M. Cronin, C. Savage, J.S. Sandhu, et al., Prostate size is associated with surgical difficulty but not functional outcome at 1 year after radical prostatectomy, J. Urol. 182 (3) (2009) 949–955 Sep [cited 2019 Jan 14] Available from: http://www.ncbi.nlm.nih.gov/pubmed/19616260.

[20] P. Mandel, P. Weinhold, U. Michl, H. Huland, M. Graefen, D. Tilki, Impact of prostate volume on oncologic, perioperative, and functional outcomes after radical prostatectomy, Prostate 75 (13) (2015) 1436–1446 Sep [cited 2019 Jan 14] Available from: http://www.ncbi.nlm.nih.gov/pubmed/26074139.