Pre-operative Prostate MRI Predictors of Social Continence following Radical Prostatectomy

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Summary Statement

Membranous urethra length (MUL) on pre-operative prostate magnetic resonance imaging (MRI) is a significant predictor of social continence after radical prostatectomy (RP) both in univariate and multivariate logistic regression models, while the other MRI measures evaluated were not. Inter-rater agreement of the measure is stronger after measure-specific radiologist training.

Key Results

1. Longer MUL is a predictor of social continence at 3-, 6-, and 12-months post-RP.
2. Inner levator distance, outer levator distance, angle between membranous urethra and prostatic axis (aMUP), pubourethral angle, and prostate volume were not significant predictors of social continence post-RP.
3. Though not a statistically significant difference, multivariable logistic regression models to predict social continence seem strongest with combined clinical and MRI data.
4. Inter-rater agreement of MUL is stronger (ICC=0.620) among readers with measure-specific prostate MRI training compared to general abdominal radiologists (ICC=0.382).

Abbreviations

RP: radical prostatectomy

MUL: membranous urethra length
LD: levator distance

aMUP: angle between membranous urethra and prostatic axis

Background

Urinary continence after radical prostatectomy (RP) has a large impact on patient quality of life. Many clinical variables and measures on prostate magnetic resonance imaging (MRI) have been associated with continence outcomes, though the effect size and role in routine clinical practice is still unclear [1–5].

Purpose

To evaluate the inclusion of MRI-based anatomic prostate measures in multivariable models used to predict social continence post-RP and to determine the interrater agreement of these anatomic measures.

Methods

In this retrospective study, we evaluated continence outcomes in adult men who had prospectively reported continence data available (EPIC-26) and underwent RP at one quaternary care medical center. MRI-based anatomic measures were obtained retrospectively, by 4 trained abdominal radiologists, from each subject's pre-operative prostate MRI. Logistical regression models were developed at 3-, 6-, and 12-months post-RP with clinical variables alone, MRI variables alone, and combined clinical and MRI variables at each time point. Interrater agreement of measurements amongst radiologists was assessed using intraclass correlation coefficients.

Results

589 subjects were included, with subsets of the entire population used in each multivariable model depending on continence data availability. In all models, coronal MUL had a statistically significant odds ratio (OR) less than 1 (OR 0.79-0.89), indicating that a longer pre-operative MUL confers decreased risk for post-RP social incontinence. No other MRI variables (inner levator distance, outer levator distance, pubourethral angle, prostate volume, PIRADS score, median lobe size, and angle between membranous urethra and prostatic axis) were found to be significant across all time points. Age and urinary function baseline score were the only significant clinical variables at every time point. Combined clinical and MRI variable models had better discriminatory ability than the clinical-only or MRI-only models at each time point, but these differences were not statistically significant. We also found improved interrater agreement for coronal MUL among our trained readers (ICC=0.620) compared to agreement between the trained readers and the original clinical measurements (ICC=0.382).

Conclusions

Pre-operative coronal MUL is a valuable predictor of post-RP social continence. Our data supports the use of combined MRI and clinical variables to predict continence outcomes in this population. Interrater agreement is best among abdominal radiologists with measure-specific training.

References

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Disclosures

The authors have no pertinent disclosures or conflicts of interest.

Table 1. Patient demographic and clinical characteristics, N = 589 unless otherwise noted

Age at diagnosis, years, mean (SD)	**63 (7)**
BMI, kg/m², mean (SD)	**29.7 (4.7)**
Race, %	
Caucasian	89.4%
African American	5.9%
Other/Unknown	3.7%
Asian	0.8%
Initial PSA, ng/ml, median (IQR)	**6.5 (4.8,9.8)**
Biopsy Gleason score, # (%)	
6	129 (21.9%)
7	321 (54.5%)
8	58 (9.8%)
9	76 (12.9%)
10	3 (0.5%)
Unknown	2 (0.3%)
Grade Group, # (%)	
1	129 (21.9%)
2	214 (36.3%)
3	107 (18.2%)
4	58 (9.8%)
5	79 (13.4%)
Unknown	2 (0.3%)
PIRADS Score, # (%)	
3	40 (6.8%)
4	236 (40.1%)
5	250 (42.4%)
Not reported	63 (10.7%)
Clinical T Stage, # (%)	
T1	443 (75.2%)
T2	115 (19.5%)
T3	8 (1.4%)
Unknown	23 (3.9%)
Nerve Sparing Procedure, # (%)	
None	44 (7.5%)
Unilateral	46 (7.8%)
Bilateral	490 (83.2%)
Not reported	9 (1.5%)
Pelvic Lymph Node Dissection, # (%)	
None	24 (4.1%)
Unilateral	207 (35.1%)
Bilateral	355 (60.3%)
Not reported	3 (0.5%)
Pathologic N Stage, # (%)	
N0	540 (91.7%)
N1	27 (4.6%)
Not applicable/Unknown	22 (3.7%)
Extra-prostatic extension, # (%)	
Negative	331 (56.2%)
Focally positive	55 (9.3%)
Extensively positive	199 (33.8%)
Positive, extent unknown	4 (0.7%)
Seminal Vesicle Invasion, # (%)	
Not present	522 (88.6%)
Unilateral	36 (6.1%)
Bilateral	29 (4.9%)
Unknown	2 (0.3%)
Surgical Margin Status, # (%)	
Negative	481 (81.7%)
Focally Positive	68 (11.5%)
Extensively Positive	40 (6.8%)
Surgical Gleason Score	
6	14 (2.4%)
7	459 (77.9%)
8	19 (3.2%)
9	92 (15.6%)
Unknown	5 (0.8%)
EPIC Urinary Function baseline score, median (IQR)	**100 (86,100)**
Social Continence, # continent (%)	
Baseline/pre-operative, n=589	588 (99.8%)
3 months post-RP, n=529	384 (72.6%)
6 months post-RP, n=465	402 (86.5%)
12 months post-RP, n=425	388 (91.3%)
24 months post-RP, n=231	217 ((93.9%)
EPIC Sexual Function scores, median (IQR)	
Baseline/pre-operative, n=578	75 (47,92)
3 months post-RP, n= 523	27 (14, 54)
6 months post-RP, n=464	31 (17, 61)
12 months post-RP, n=421	39 (14, 67)
24 months post-RP, n=210	45 (17, 75)

Table 2. Univariable and multi-variable analyses of social continence at 3 months post-radical prostatectomy. Odds ratios below '1' indicate a lesser risk of incontinence. Reference for PI-RADS scores is PI-RADS 3. Reference for grade group is grade group 1.

MRI VARIABLES ALONE, N = 471				**C-STATISTIC = 0.702**
	Continent, mean (SD) / # (%)	**Incontinent, mean (SD) / # (%)**	**Univariable OR (95% CI, p-value)**	**Multivariable OR (95% CI, p-value)**
MUL, coronal (mm)	15.5 (3.7)	13.8 (3.7)	**0.88 (0.83-0.93, p<0.001)**	**0.89 (0.83-0.94, p<0.001)**
Inner LD (mm)	16.7 (2.9)	17.5 (3.1)	**1.09 (1.03-1.17, p=0.005)**	1.03 (0.93-1.13, p=0.606)
Prostate Volume	42.0 (21.2)	48.8 (27.4)	**1.01 (1.00-1.02, p=0.004)**	**1.02 (1.01-1.03, p<0.001)**
PIRADS 4	170 (78.3%)	47 (21.7%)	**0.45 (0.21-0.98, p=0.038)**	0.55 (0.24-1.29, p=0.158)
CLINICAL VARIABLES ALONE, N = 510				**C-STATISTIC = 0.690**
	Continent, mean (SD) / # (%)	**Incontinent, mean (SD) / # (%)**	**Univariable OR (95% CI, p-value)**	**Multivariable OR (95% CI, p-value)**
Age	61.7 (6.9)	65.1 (5.7)	**1.08 (1.05-1.12, P<0.001)**	**1.08 (1.04-1.12, P<0.001)**
Epic Urinary Baseline Score	93.1 (11.4)	86.7 (17.0)	**0.97 (0.96-0.98, P<0.001)**	**0.97 (0.96-0.99, P<0.001)**
Epic Sexual Baseline Score	71.2 (28.1)	61.4 (31.1)	**0.99 (0.98-1.00, P=0.001)**	1.00 (0.99-1.00, P=0.365)
MRI + CLINICAL VARIABLES, N = 455				**C-STATISTIC = 0.745**
	Continent, mean (SD) / # (%)	**Incontinent,mean (SD) / # (%)**		**Multivariable OR (95% CI, p-value)**
Age	61.7 (6.9)	65.1 (5.7)		1.07 (1.03-1.12, p=0.001)
Epic Urinary Baseline Score	93.1 (11.4)	86.7 (17.0)		0.98 (0.96-1.00, p=0.022)
MUL, coronal (mm)	15.5 (3.7)	13.8 (3.7)		0.86 (0.80-0.93, p<0.001)
Prostate Volume	42.0 (21.2)	48.8 (27.4)		1.01 (1.00-1.03, p=0.032)

Statistically insignificant variables in each model:
MRI alone: outer LD, aMUP, pubourethal angle, PIRADS 5 score, median lobe size
Clinical alone: BMI, initial PSA, grade group
Combined: BMI, initial PSA, grade group, Epic sexual baseline score, inner LD, outer LD, aMUP, pubourethal angle, PIRADS score, median lobe size

Table 3. Univariable and multi-variable analyses of social continence at 6 months post-radical prostatectomy. Odds ratios below '1' indicate a lesser risk of incontinence. Reference for PI-RADS scores is PI-RADS 3. Reference for grade group is grade group 1.

MRI VARIABLES ALONE, N = 414				**C-STATISTIC = 0.705**
	Continent, mean (SD) / # (%)	**Incontinent, mean (SD) / # (%)**	**Univariable OR (95% CI, p-value)**	**Multivariable OR (95% CI, p-value)**
MUL, coronal (mm)	15.3 (3.7)	13.5 (3.9)	**0.87 (0.81-0.94, p=0.001)**	**0.87 (0.79-0.95, p=0.003)**
CLINICAL VARIABLES ALONE, N = 452				**C-STATISTIC = 0.705**
	Continent, mean (SD) / # (%)	**Incontinent, mean (SD) / # (%)**	**Univariable OR (95% CI, p-value)**	**Multivariable OR (95% CI, p-value)**
Age	62.8 (6.7)	65.7 (5.6)	**1.07 (1.03-1.12, P=0.001)**	**1.09 (1.03-1.15, P=0.002)**
Epic Urinary Baseline Score	92.0 (13.1)	86.3 (17.2)	**0.98 (0.96-0.99, P=0.004)**	**0.98 (0.96-1.00, P=0.020)**
Epic Sexual Baseline Score	68.7 (28.7)	59.0 (31.5)	**0.99 (0.98-1.00, P=0.015)**	1.00 (0.99-1.01, P=0.372)
Grade group 3	82 (93.2%)	6 (6.8%)	0.38 (0.13-0.98, P=0.057)	**0.28 (0.09-0.77, P=0.017)**
MRI + CLINICAL VARIABLES, N = 403				**C-STATISTIC = 0.766**
	Continent, mean (SD) / # (%)	**Incontinent,mean (SD) / # (%)**		**Multivariable OR (95% CI, p-value)**
Age	62.8 (6.7)	65.7 (5.6)		**1.08 (1.02-1.15, p=0.016)**
Grade group 3	82 (93.2%)	6 (6.8%)		**0.19 (0.06-0.59, p=0.005)**
MUL, coronal (mm)	15.3 (3.7)	13.5 (3.9)		**0.86 (0.78-0.95, p=0.003)**
PIRADS 5	173 (82.0%)	38 (18.0%)		**6.99 (1.62-51.00, p=0.022)**

Statistically insignificant variables in each model:
MRI alone: inner LD, outer LD, aMUP, pubourethal angle, prostate volume, PIRADS score, median lobe size
Clinical alone: BMI, initial PSA, grade groups 2/4/5
Combined: BMI, initial PSA, grade groups 2/4/5, Epic urinary baseline score, Epic sexual baseline score, inner LD, outer LD, aMUP, pubourethal angle, prostate volume, PIRADS 4 score, median lobe size

Table 4. Univariable and multi-variable analyses of social continence at 12 months post-radical prostatectomy. Odds ratios below '1' indicate a lesser risk of incontinence. Reference for PI-RADS scores is PI-RADS 3. Reference for grade group is grade group 1.

MRI VARIABLES ALONE, N = 378				**C-STATISTIC = 0.706**
	Continent, mean (SD) / # (%)	**Incontinent, mean (SD) / # (%)**	**Univariable OR (95% CI, p-value)**	**Multivariable OR (95% CI, p-value)**
MUL, coronal (mm)	15.0 (3.7)	13.4 (3.2)	**0.88 (0.79-0.97, p=0.011)**	**0.83 (0.73-0.94, p=0.005)**
CLINICAL VARIABLES ALONE, N = 414				**C-STATISTIC = 0.806**
	Continent, mean (SD) / # (%)	**Incontinent, mean (SD) / # (%)**	**Univariable OR (95% CI, p-value)**	**Multivariable OR (95% CI, p-value)**
Age	62.5 (6.8)	66.3 (5.4)	**1.09 (1.04-1.16, P=0.002)**	**1.11 (1.04-1.19, P=0.002)**
Epic Urinary Baseline Score	92.2 (12.1)	81.3 (19.6)	**0.96 (0.94-0.98, P<0.001)**	**0.95 (0.93-0.98, P<0.001)**
MRI + CLINICAL VARIABLES, N = 369				**C-STATISTIC = 0.824**
	Continent, mean (SD) / # (%)	**Incontinent,mean (SD) / # (%)**		**Multivariable OR (95% CI, p-value)**
Age	62.5 (6.8)	66.3 (5.4)		**1.12 (1.03-1.22, p=0.008)**
Epic Urinary Baseline Score	92.2 (12.1)	81.3 (19.6)		**0.95 (0.92-0.97, p<0.001)**
MUL, coronal (mm)	15.0 (3.7)	13.4 (3.2)		**0.79 (0.67-0.91, p=0.002)**

Statistically insignificant variables in each model:
MRI alone: inner LD, outer LD, aMUP, pubourethal angle, prostate volume, PIRADS score, median lobe size
Clinical alone: BMI, initial PSA, Epic sexual baseline score, grade group
Combined: BMI, initial PSA, grade group, Epic sexual baseline score, inner LD, outer LD, aMUP, pubourethal angle, prostate volume, PIRADS score, median lobe size

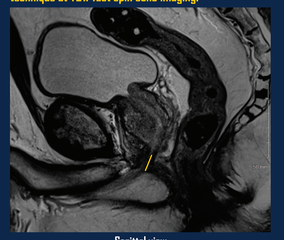
Table 5. Statistical comparison of continence model c-statistics. P-values reflect Delong's test.

3-month Models		**P**
Clinical alone (0.690)	MRI alone (0.702)	p = 0.756
Clinical alone (0.690)	Combined (0.745)	p = 0.134
MRI alone (0.702)	Combined (0.745)	p = 0.238
6-month Models		
Clinical alone (0.705)	MRI alone (0.705)	p = 0.999
Clinical alone (0.705)	Combined (0.766)	p = 0.201
MRI alone (0.705)	Combined (0.766)	p = 0.204
12-month Models		
Clinical alone (0.806)	MRI alone (0.706)	p = 0.100
Clinical alone (0.806)	Combined (0.824)	p = 0.725
MRI alone (0.706)	Combined (0.824)	p = 0.06

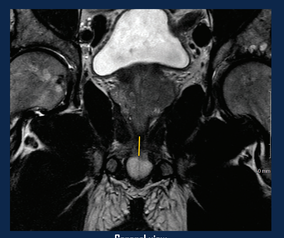
Table 6. Interrater agreement for MRI anatomic measures of continence predication. Data are intra-class correlation coefficients (ICC).

Among 4 trained experts		
Measure	N	ICC
Coronal MUL	19	0.620
Inner LD	20	0.774
Outer LD	20	0.503
aMUP	20	0.497
Pubourethral angle	20	0.820
Between clinical interpretation and 1 trained expert		
Coronal MUL	564	0.382

Figure 1. Membranous urethra length measurement technique at T2w fast spin echo imaging.

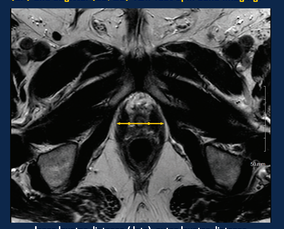


Sagittal view

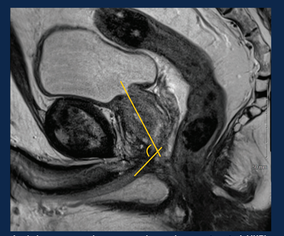


Coronal view

Figure 2. Anatomic measurement techniques at axial (2A) and sagittal (2B, 2C) T2w fast spin echo imaging.



Inner levator distance (dots), outer levator distance (arrow heads), axial.



Angle between membranous urethra and prostatic axis (aMUP).

Pubourethral angle