

# Pre-prostatectomy membranous urethral length as a predictive factor of post prostatectomy incontinence requiring surgical intervention with an artificial urinary sphincter or a male sling

Priyanka Oza<sup>1,2</sup>  | Nicholas Faure Walker<sup>3</sup>  | Giles Rottenberg<sup>4</sup> |  
Findlay MacAskill<sup>1</sup>  | Sachin Malde<sup>1</sup>  | Claire Taylor<sup>1</sup> | Arun Sahai<sup>1,2</sup> 

<sup>1</sup>Department of Urology, Guy's Hospital, Guy's and St Thomas' NHS Foundation Trust, London, UK

<sup>2</sup>Faculty of Life Sciences & Medicine, King's College London, London, UK

<sup>3</sup>Department of Urology, King's College NHS Foundation Trust, London, UK

<sup>4</sup>Department of Radiology, Guy's and St Thomas' NHS Foundation Trust, London, UK

## Correspondence

Consultant Urological Surgeon & Reader in Urology, Guy's Hospital & King's College London, Guy's Campus, Great Maze Pond, London SE1 1UL, UK.  
Email: [Arun.Sahai@gstt.nhs.uk](mailto:Arun.Sahai@gstt.nhs.uk)

## Abstract

**Aims:** To ascertain whether the membranous urethral length (MUL) is predictive of postprostatectomy incontinence (PPI) that requires surgery such as artificial urinary sphincter (AUS) or male sling (MS).

**Methods:** Men who had undergone AUS or MS for PPI were identified from a prospectively maintained database and compared to a control group of men who were continent at 12 months after radical prostatectomy. MUL in sagittal and coronal planes, sphincter height and width were measured on prebiopsy T2-weighted MRI scans. Sphincter volume was estimated as an ellipsoid cylinder.

**Results:** A total of 95 patients (64 AUS and 31 MS) were compared to 60 continent controls. There was no statistical difference in presenting PSA, prostate volume, and T-stage. The mean MUL in sagittal and coronal planes was 11.31 mm (*SD*: 2.6, range: 6–17 mm) and 11.43 mm (*SD*: 2.94, range: 5–17 mm) in patients who had AUS and MS, respectively; 15.23 mm (*SD*: 4.2, range: 8.25–25 mm) and 15.75 mm (*SD*: 4.1, range: 8–24 mm) in controls ( $p < 0.01$ ). No men in the PPI surgery group had an MUL >17 mm compared to 35% (20/57 sagittal, 20/58 coronal) of controls. The odds ratio for requiring surgery for PPI was 13.4 for sagittal MUL <9 mm and 3.2 if the MUL <12 mm.

**Conclusions:** Patients who had surgery for PPI had a significantly shorter MUL and sphincter volume than continent controls. Men with an MUL >17 mm are unlikely to require surgery for PPI whereas an MUL <12 mm significantly increases the risk of requiring surgery for PPI. MUL should be considered when discussing treatment options for prostate cancer.

## KEYWORDS

membranous urethral length, MRI, postprostatectomy incontinence, urinary incontinence

## 1 | INTRODUCTION

Urinary incontinence (UI) is a common complication following radical prostatectomy (RP) that is detrimental to quality of life.<sup>1</sup> It remains the most troublesome complication following RP and affects between 6% and 69% of patients<sup>2</sup> depending on the definition used. There is no standardised definition of postprostatectomy incontinence (PPI) and the use of heterogeneous outcome measures means comparison between studies is challenging.

Sphincteric dysfunction appears to be the most common cause of PPI.<sup>3</sup> However, damage to the muscles and nerves of the bladder, and detrusor underactivity can also lead to urinary retention and subsequent overflow incontinence, causing the symptoms of PPI. Furthermore, detrusor overactivity which may have been pre-existing or *de novo* can lead to urgency and urge UI postsurgery. Direct injury to the sphincter at the time of surgery, disruption to its innervation, ischaemia, shortening of the membranous urethra and fixation of the sphincter from surrounding scar tissue can all affect sphincteric function following RP, leading to stress incontinence.<sup>4</sup> Several other factors have been shown to impact PPI, including physical activity levels, body mass index, increasing age and preexisting lower urinary tract symptoms.<sup>5</sup>

Several imaging parameters have been assessed as to whether they are predictive of PPI and could hence help urologists and patients make more informed choices regarding their treatment for localised prostate cancer. These include prostate size,<sup>6</sup> shape of the prostatic apex,<sup>7</sup> urethral angle<sup>6</sup> and the membranous urethral length (MUL).<sup>1</sup> To date, the MUL is the only imaging parameter that has been shown to be predictive of PPI.<sup>1</sup> In a study by Ikarashi et al.,<sup>5</sup> it was concluded that an MUL >12 mm following robot-assisted laparoscopic prostatectomy (RALP) was predictive of early recovery to continence. Furthermore, in a systematic review by Y. Dubbelman and R. Bosch,<sup>8</sup> it was suggested that a preprostatectomy MUL greater than 12–14 mm is associated with a faster recovery to continence following RP. Every additional millimetre of MUL was associated with a faster recovery, with every extra 1-cm increasing the chance of recovery from continence by between 63% and 205%.<sup>1</sup> Interestingly, a shorter MUL before RP, is not a risk factor for preprostatectomy UI.<sup>9</sup>

PPI is normally managed conservatively in the first instance, with fluid management advice and pelvic floor muscle training.<sup>2</sup> Only a small proportion of patients suffering from PPI require surgical management, usually in the form of an artificial urinary sphincter (AUS) or male sling (MS). Although there is a proven link between

shorter MUL and increased recovery time to continence, no study to date has ascertained whether a shorter MUL is predictive of PPI that requires surgery such as MS or AUS.

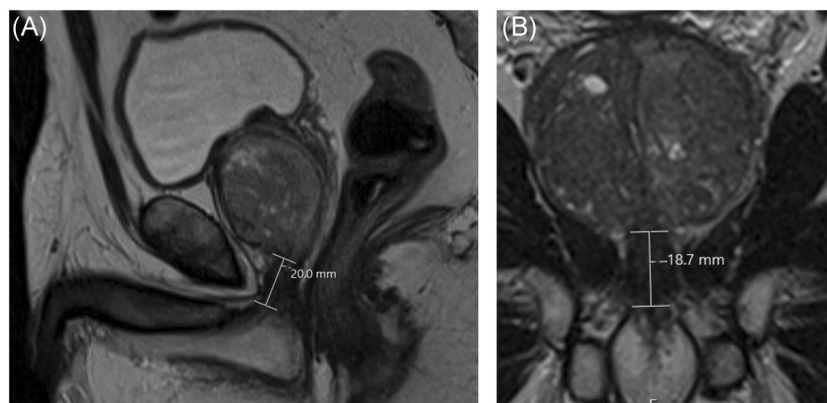
## 2 | MATERIALS AND METHODS

This study was registered as an audit within our hospital (project No. 7265). Subjects were identified from a database of patients who had undergone AUS or MS for PPI at our institution between April 2013 and February 2021. Patients with bothersome PPI were typically asked about pad use and worked up with a 24-h pad test, cystoscopy and video urodynamics. In all cases the AUS utilised was AMS 800™ Urinary Control System (Boston Scientific) with the cuff placed in the bulbar urethra and all MS cases utilised the Advance or Advance XP™ device (Boston Scientific). Patients were explained both options and the relative risks and benefits associated with an MS and AUS. In general, those with mild to moderate incontinence, without radiotherapy, were offered MS and those with moderate to severe incontinence or who had radiotherapy were offered an AUS, although this was not exclusively the case for all patients. Mild, moderate and severe PPI were considered in patients with 24 h pad tests of <100 g, 100–400 g, >400 g, respectively. Patients who had undergone surgical procedures for prostate removal other than primary and salvage RP including transurethral resection of the prostate (TURP) and holmium laser enucleation of the prostate (HoLEP) were excluded.

The control group was identified as the first 60 patients reported as continent at 1 year following RP at our hospital from a database of patients who had undergone RP in 2015 and matched for presenting PSA, prostate volume and clinical staging i.e. T-staging. Continence was defined as dry or the use of one safety pad a day or less at 12 months following RP. Initially, the number of cases and controls were matched, however, several controls were not included as their pre-prostatectomy MRI scans were not available.

Baseline data including patient age, presenting PSA, T stage, and 24-h pad weight were recorded. Pretreatment prostate MRIs were obtained from the hospitals where patients had undergone their original RPs. The measurements were taken from images obtained via the Sectra Picture Archiving and Communications image viewer. T2-weighted prostate magnetic resonance imaging (MRI) images in the sagittal, coronal, and axial planes were used to measure the prostate volume, MUL,

**FIGURE 1** T2-Weighted MRI images showing how the sagittal (A) and coronal (B) measurement of the membranous urethral length are taken. The images show that the exact definition of the MUL is the distance between the apex of the prostate and the bulb of the penis. MRI, magnetic resonance imaging; MUL, membranous urethral length



**TABLE 1** Baseline demographics for all patients included in the study

	AUS	MS	<i>p</i>	Combined	Continent controls	<i>p</i>
<b><i>n</i></b>	64	31		95	60	
Previous radiotherapy	21	4	0.02	25		
Median age (range)	65.4 (58–80)	64.0 (57–80)	0.14	65.0 (49–77)	60.20 (44–74)	0.07
Median PSA in ng/ml (range)	8.60 (2–50)	7.60 (4–39)	0.38	8.00 (2–50)	8.70 (3.6–50)	0.94
Median prostate volume in ml (range)	33.00 (10–90)	34.50 (13–105)	0.332	33.50 (10–105)	36.00 (15–224)	0.35
Pads (mean)/ <i>n</i>	4.13	2.64	<0.01			
Pad weight (mean)/g	529.02	197.5	<0.01			
<b>T stage (%)</b>						
T2	22 (%)	21 (81%)	<0.01	43 (57%)	32 (64%)	0.41
T3	26 (52%)	5 (19%)	<0.01	31 (41%)	17 (34%)	0.46
T4	2 (4%)	0 (0%)	0.08	2 (2%)	1 (2%)	0.52

Abbreviations: AUS, artificial urinary sphincter; MS, male sling.

sphincter height and width. For each patient, the MUL was defined as the distance between the apex of the prostate to the bulb of the penis,<sup>5</sup> as shown in Figure 1. The sphincter volume was estimated as an ellipsoid cylinder:  $V = \frac{1}{4}l(\pi \times r_1 \times r_2)$ , where  $l$  is the MUL in the sagittal plane, and  $r_1$  and  $r_2$  are the height and width measurements, respectively. Measurements were performed by a urologist and a uro-radiologist. MRI scans which were not measurable due to poor quality of the scan, or the presence of artefact were excluded from further analysis.

Data was collected and analysed using Microsoft Excel v16.51, Microsoft USA and SPSS. Medians and ranges were calculated for non-normally distributed data and differences were compared with the Mann–Whitney test. Normally distributed data was assessed using means, standard deviations and compared using the student *t* test.

### 3 | RESULTS

Review of the PPI database identified 95 patients (64 AUS, 31 MS). Review of the RP database identified 60 controls who were using one pad or less for continence control at 12 months following RP. Four patients were excluded as they had undergone TURP or HoLEP surgeries rather than RP. Twenty-six patients had undergone salvage radiotherapy and four cases were salvage RPs.

#### 3.1 | Baseline data

Baseline data is shown in Table 1. The median age of the AUS, MS, and control groups were 65.4, 64.0, and 60.2 ( $p = 0.07$ ) respectively. The median PSA in the AUS, MS, and control groups were 8.6, 7.6, and 8.7 ng/ml ( $p = 0.94$ ). The median prostate volumes in the AUS, MS,

and continent control groups were 33.00, 34.5, and 33.50 ml ( $p = 0.364$ ). The distribution of T2, T3, and T4 disease were similar between the groups.

The mean number of pads used in patients were compared between AUS and MS participants. The mean daily pad use was significantly higher in AUS participants (4.13) compared to MS patients (2.64) with  $p < 0.01$ . The 24-h pad weight was also significantly heavier in the AUS patients (529.02 g) compared to MS patients (197.5 g) with  $p < 0.01$ .

### 3.2 | Membranous urethra measurements

Of the 95 patients who had undergone PPI surgery, 87 (91.6%) had available sagittal section MRI scans and 83 (95.4%) were measurable. Coronal sections were available for 64 (67.4%) of PPI surgery patients and 59 (92.2%) of these were measurable. Within the continent control group, the MRI sagittal and coronal planes were available for 59/60 (98.3%) and 60/60 (100%) patients. Of these 57 (96.6%) and 58 (96.7%) were measurable. Results are shown in Table 2.

In PPI surgery patients the mean MULs in the sagittal and coronal planes were 11.31 mm ( $SD$ : 2.6, range: 6–17 mm) and 11.43 mm ( $SD$ : 2.94, range: 5–17 mm) respectively. In continent controls, the mean MULs were 15.23 mm ( $SD$ : 4.2, range: 8.5–25 mm) and 15.75 mm ( $SD$ : 4.1, range: 8–24 mm) in the sagittal and coronal planes, respectively. Sagittal and coronal MULs were significantly shorter in the combined AUS and MS surgical group compared to continent controls ( $p < 0.01$  and  $p < 0.01$ ). Results are shown in Table 2. There were no men in the surgical group with an MUL over 17 mm whereas 20/57 (35.0%) and 20/58 (34.4%) of the continent controls had an MUL of 17 mm or greater in the sagittal and coronal planes, respectively. Furthermore, 52/83 (62.7%) and 26/59 (44.1%) of men in the surgery group had an MUL  $\leq 12$  mm in the sagittal and coronal planes compared to 18/57 (31.6%) and 13/58 (22.4%) of the continent controls. The odds ratios for PPI requiring surgery were 13.4 for a sagittal MUL  $< 9$  mm and 3.2 for an MUL  $< 12$  mm.

The mean height and width of the membranous urethrae were 10.49 mm ( $SD$ : 1.77, range: 6.5–17 mm) and 11.21 mm ( $SD$ : 1.94, range: 7–18 mm) in the surgical group and 11.28 mm ( $SD$ : 1.58, range: 8–16.5 mm) and 11.59 mm ( $SD$ : 1.7, range: 9–17 mm) in the control group. The combined PPI surgery patients had a smaller sphincter height ( $p = 0.01$ ) than the continent controls but there was no significant difference in the widths ( $p = 0.24$ ).

The mean volume of the membranous urethra was 1.03 ml ( $SD$ : 0.48, range: 0–3 ml) in the surgical group and 1.57 ml ( $SD$ : 0.53, range: 0.75–3.02 ml) in the control group ( $p < 0.01$ ). Results are shown in Table 2.

## 4 | DISCUSSION

A shorter MUL has been shown to reduce the odds of returning to continence after RP.<sup>1</sup> Studies including those by Ikarashi et al.,<sup>5</sup> and Von Bodman et al.,<sup>10</sup> have concluded that a longer MUL is protective against prolonged UI. The link between MUL and PPI has not only been proven via MRI, but also using a transperineal ultrasound scan.<sup>11</sup> Although the MUL was only measured in a single plane, the midsagittal or coronal, there is still a strong association between a shorter MUL and worsening PPI. However, it has not been shown whether shorter MUL is associated with PPI that requires surgery such as MS or AUS. This study has shown that the MULs of men who underwent AUS or MS for PPI in our centre was 27% shorter than in men who were continent at 12 months after RP. A smaller sphincter volume and sphincter height was also associated with PPI requiring surgery. The sphincter volume calculation means the estimated volume is directly proportional to the sphincter length and height so this finding may reflect the MUL and height findings.

Interestingly, none of the patients in the PPI surgery group had an MUL over 17 mm in the sagittal or coronal plane. Within the control group, approximately 35% (20/57 sagittal, 20/58 coronal) of the group had an MUL greater than 17 mm. This suggests that having an MUL  $> 17$  mm can be protective against severe PPI, given that no patients in the surgery group had an MUL over 17. This corresponded to an odds ratio of 3.2 for requiring PPI surgery if the sagittal MUL was  $< 12$  mm. Furthermore, for men with an MUL  $< 9$  mm, the odds ratio was 13.4. This is in keeping with previous research including that by Ikarashi et al.,<sup>5</sup> who have concluded that a pre-operative MUL  $> 12$  mm is a reliable predictor, and a systematic review by Y. Dubbelman and R. Bosch<sup>8</sup> that a preprostatectomy MUL larger than 12–14 mm is also a marker of early recovery to UI following RALP.<sup>5,8</sup>

Prebiopsy MRI for the initial diagnosis of prostate cancer is becoming the standard of care in the United Kingdom particularly following the results of the PRECISION trial.<sup>12</sup> Clear margins between the prostate, urethra and bulb of the penis can sometimes be difficult to identify especially if patients have had previous pelvic surgery. Nevertheless, the MRI MUL in sagittal and coronal planes was measurable in over 92.2% of both PPI surgery and control groups in our study. The MRI MUL

**TABLE 2** Table showing the membranous urethral length and sphincter measurements after an incontinence surgery in all patients

	AUS Available				MS				All reconstruction				Continents										
	Available (%)	Measurable (%)	D/mm	SD	Range	p (vs control)	Available (%)	Measurable (%)	D/mm	SD	Range	p	Available (%)	Measurable (%)	D/mm	SD	Range						
Salvage Radical Prostatectomy Patients Included	60 (63.4)	57 (95.0)	11.30	2.61	6.0-17.0	0	27 (90)	26 (96.3)	11.33	2.65	6.0-16.0	0	87 (91.58)	83 (95.4)	11.31	2.6	6.0-17.0	0	59	57 (96.6)	8.5	4.20	8.5-25.0
	46 (48.9)	42 (91.3)	11.28	2.97	5.0-17.0	0	18 (60)	17 (94.4)	11.78	2.92	6.0-17.0	0	64 (63.37)	59 (92.2)	11.43	2.94	5.0-17.0	0	60	58 (96.7)	8	4.07	8.0-24.0
	59 (62.8)	57 (96.6)	10.28	1.7	8.0-17.0	0	28 (93.3)	26 (92.9)	10.94	1.87	6.5-15.0	0.4	87 (91.58)	83 (95.4)	10.49	1.77	6.5-17.0	0.01	60	58 (96.7)	8	1.58	8.0-16.5
	59 (62.8)	57 (96.6)	11.10	1.96	7.0-18.0	0.16	28 (93.3)	26 (92.9)	11.46	1.89	9.0-16.0	0.76	87 (91.58)	83 (95.4)	11.21	1.94	7.0-18.0	0.24	59	57 (96.6)	9	1.70	9.0-17.0
	59 (62.8)	56 (94.9)	0.99	0.47	0.0-3.0	0	26 (86.7)	25 (95.2)	1.11	0.49	0.0-1.94	0	85 (89.47)	81 (95.3)	1.03	0.48	0.0-3.0	0	60	56 (93.3)	0.75	0.53	0.75-3.02
Salvage Radical Prostatectomy Patients Included	35 (100)	35 (100)	11.38	2.33	6.0-16.0	0.00	25 (89.3)	24 (96.0)	11.22	2.55	6.0-15.2	0.00	60 (95.2)	59 (98.3)	11.31	2.40	6.0-16.0	0.00	59	57 (96.6)	15.23	4.20	8.5-25.0
	25 (71.43)	24 (96)	11.42	2.91	5.0-17.0	0.00	16 (57.1)	15 (93.8)	11.72	2.94	6.0-17.0	0.00	41 (85.1)	39 (95.1)	11.54	2.89	5.0-17.0	0.00	60	58 (96.7)	15.75	4.07	8.0-24.0
	34 (97.14)	34 (100)	10.01	1.21	8.0-12.0	0.00	26 (92.9)	24 (92.3)	10.83	1.87	6.5-15.0	0.28	60 (95.2)	58 (96.7)	10.35	1.56	6.5-15.0	0.00	60	58 (96.7)	11.28	1.58	8.0-16.5
	34 (97.14)	34 (100)	11.01	1.85	7.0-15.0	0.14	26 (92.9)	24 (92.3)	11.63	1.87	9.0-16.0	0.93	60 (95.2)	58 (96.7)	11.27	1.87	7.0-16.0	0.34	59	57 (96.6)	11.59	1.70	9.0-17.0
	34 (97.14)	34 (100)	0.98	0.28	0.48-1.59	0.00	26 (85.7)	23 (95.8)	1.10	0.51	0.0-0.51	0.00	60 (92.1)	57 (98.3)	1.03	0.39	0.0-1.94	0.00	60	56 (93.3)	1.57	0.53	0.75-3.02

Abbreviations: AUS, artificial urinary sphincter; MS, male sling.

urethral length would, therefore, appear to be a relevant imaging biomarker to include as standard on prostate MRI scan reports to help patients decide between treatment modalities for localised prostate cancer.

Finally, good patient counselling about treatment options for localised prostate cancer is key. Understanding the potential impact of MUL, especially if it is less than 12 mm for those considering RP can help contribute to these discussions. Such patients can be considered for alternatives to RP in these circumstances to try and avoid incontinence.

This study has several limitations including that of being retrospective in nature. A large prospective study would be needed to ascertain the true risk of requiring PPI surgery based on MRI MUL. This study is also reliant on preprostatectomy measurement as a predictor and therefore, does not consider how assessing the MUL can change with surgical technique or intraoperative complications such as fibrosis. This is pertinent as this study covers patients who may have also had their RP at different hospitals. Furthermore, the patients who underwent AUS and MS underwent their RPs at multiple different hospitals, whereas the continent control group all had RP at the same hospital. This also means that patients could have had preprostatectomy UI which was not known at the point of this study, due to incomplete data sets. There is also a risk of selection bias as the first evidence for the association between the MUL and PPI was emerging in 2015. The control group was hence chosen from earlier years to eliminate selection bias by surgeons performing RP who may have been aware of the link. It is also important to note that all patients undergoing an RP are given advice regarding pelvic floor muscle training after RP which could affect the level of incontinence experienced by patients. The control group was also found to be younger by approximately 5 years ( $p = 0.07$ ): median age for the combined surgical group was found to be 65.2 years compared to 60 years for the control group. Many studies have suggested that an advancing age is an independent risk factor of PPI following RP for example Shao et al.,<sup>13</sup> and Singla and Singla.<sup>14</sup> It is, however, unlikely that this 5-year difference explains the differences in MUL and continence.

## 5 | CONCLUSIONS

The preprostatectomy sagittal MRI MUL was found to be significantly shorter in patients who required artificial sphincter or MS surgery for PPI compared to continent controls. Men with an MUL before RP of over 17 mm are unlikely to require surgery for PPI whereas those with an MUL of less than 12 mm are at much higher risk of

requiring an AUS or MS. The MUL is a helpful imaging biomarker for men diagnosed with localised prostate cancer and should be included on pretreatment prostate MRI reports to allow clinicians to make more informed decisions with their patients regarding their treatment options.

## CONFLICTS OF INTEREST

Findlay MacAskill received funds via an unrestricted education grant by Boston Scientific. Sachin Malde received funds via an unrestricted educational grant by Boston Scientific & Metronic. Arun Sahai received funds via an unrestricted educational grant and has been paid lecturing fees by Boston Scientific. The other authors declare no conflicts of interest.

## AUTHOR CONTRIBUTIONS

*Study concept & design:* Arun Sahai. *Acquisition of data:* Priyanka Oza, Nicholas Faure-Walker & Giles Rottenberg. *Analysis & interpretation of data:* Priyanka Oza, Nicholas Faure-Walker, Findlay MacAskill & Giles Rottenberg. *Drafting of the manuscript:* Priyanka Oza, Nicholas Faure-Walker & Arun Sahai. *Critical revision of the manuscript for important intellectual content:* Nicholas Faure-Walker, Arun Sahai, Sachin Malde & Claire Taylor

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

## ORCID

Priyanka Oza  <http://orcid.org/0000-0002-7782-6180>

Nicholas Faure Walker  <http://orcid.org/0000-0002-7816-9426>

Findlay MacAskill  <http://orcid.org/0000-0001-9973-7368>

Sachin Malde  <http://orcid.org/0000-0002-3712-9460>

Arun Sahai  <http://orcid.org/0000-0003-4679-0506>

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