

**Review Article****Evaluation of image-based prognostic parameters of post-prostatectomy urinary incontinence: A literature review**Anna Colarieti,<sup>1,2</sup> Nikesh Thiruchelvam<sup>3</sup> and Tristan Barrett<sup>4,5</sup>

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**Abbreviations & Acronyms**

DTI = diffusion tensor imaging  
LRP = laparoscopic radical prostatectomy  
mpMRI = multiparametric magnetic resonance imaging  
MRI = magnetic resonance imaging  
MUA = membranous urethra angle  
MUL = membranous urethral length  
ORP = open radical prostatectomy  
PAL = prostate apex length  
PNF = periprostatic nerve fiber  
PPUI = post-prostatectomy urinary incontinence  
RARP = robot-assisted radical prostatectomy  
RP = radical prostatectomy  
TPUS = transperineal ultrasound  
US = ultrasound

**Abstract:** Prostate cancer is the second most common male cancer, and radical prostatectomy is a highly effective treatment for intermediate and high-risk disease. However, post-prostatectomy urinary incontinence remains a major functional side-effect in patients undergoing radical prostatectomy. Despite recent improvements in preoperative imaging quality and surgical techniques, it remains challenging to predict or prevent occurrence of this complication. The aim of this research was to review the current published literature on pre- and postoperative imaging evaluation of the prostate and pelvic structures, to identify added value in the prediction of post-prostatectomy urinary incontinence. A computerized bibliographic search of the PubMed library was carried out to identify imaging-based articles evaluating the pelvic floor and surrounding structures pre- and/or post-radical prostatectomy to predict post-prostatectomy urinary incontinence. A total of 32 articles were included. Of these, 29 papers assessed the importance of magnetic resonance imaging evaluation, with a total of 16 parameters evaluated. The most common parameters were intravesical protrusion, the membranous urethral length, prostatic volume and periurethral fibrosis. Preoperative membranous urethral length and its preservation after surgery showed the strongest correlation with urinary incontinence. Three studies evaluated ultrasound, with all carried out postoperatively. This technique benefits from a dynamic evaluation, and the results are promising for proximal urethral hypermobility and the degree of bladder neck funneling on the Valsalva maneuver. Several imaging studies evaluated the predictors of post-prostatectomy urinary incontinence, with preoperative membranous urethral length offering the most promise. However, the current literature is limited by the single-center nature of studies, and the heterogeneity in patient populations and methodologies used.

**Key words:** magnetic resonance imaging, membranous urethral length, prostate cancer, radical prostatectomy, ultrasound, urinary incontinence.

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**Introduction**

Prostate cancer is the second most common male cancer and the fifth leading cause of carcinoma death in men worldwide.<sup>1</sup> In intermediate and high-risk disease, the European Association of Urology guidelines recommend RP, external beam radiotherapy or external beam radiotherapy with brachytherapy boost and long-term androgen deprivation therapy.<sup>2</sup> RP is a highly effective treatment for prostate cancer, with a 97% 5-year survival post-surgery.<sup>3</sup> However, primary active treatments are associated with significant potential side-effects involving urinary, sexual and bowel function,<sup>4</sup> resulting in a reduced quality of life for patients and an economical burden for healthcare systems.<sup>5</sup>

Over the past 10 years, mpMRI has become an essential tool for lesion detection and preoperative staging of prostate cancer.<sup>6–11</sup> MRI-directed prostate biopsy has been shown to increase the detection of clinically significant prostate cancer and reduce the over-diagnosis of low-grade indolent disease.<sup>12–14</sup> This has enabled more appropriate risk stratification of patients, with low-risk patients managed conservatively, utilizing active surveillance as the preferred initial management strategy, and intermediate-to-high-risk patients undergoing radical therapy.<sup>8,15,16</sup>

MRI enables morphological assessment of the male pelvic floor and perineal anatomy both pre- and post-prostatectomy. MRI of the prostate has been shown to outperform clinical

nomograms, such as Partin tables for preoperative T staging of the prostate.<sup>17,18</sup> However, although specificity is approximately 90% for the detection of extracapsular extension and seminal vesicle invasion, sensitivity is low at approximately 50% for the presence of T3 disease.<sup>19–21</sup> As a result, innovative surgical techniques have been introduced to limit postoperative complications, including unilateral nerve-sparing approaches or adoption of “NeuroSAFE” intraoperative frozen section examination, particularly in patients at higher clinical risk, or when MRI is equivocal.<sup>22–24</sup>

Despite these improvements in imaging quality and surgical techniques, PPUI remains a major functional complication in patients undergoing RP and is present in up to 6–20% of patient at 1-year post-surgery.<sup>25</sup> The ability to predict patients at higher risk of developing such complications might help select patients for other management strategies for their prostate cancer or enable early postoperative interventions to minimize the impacts on quality of life. Several preoperative factors have been identified as potential risk factors for the development of PPUI; however, studies have included patient populations at differing risk, using mixed methodologies and have evaluated patients using different imaging modalities. It should also be noted that PPUI is typically a patient-reported outcome measure, which is subjective and will also depend on the assessment time-points and the evaluation scales used. The aim of the present study was to review the existing literature for imaging studies that evaluate the prostate and/or pelvic floor in either the pre- or postoperative setting to determine their value in predicting PPUI.

## Methods

### Objective

We reviewed the current literature for articles using imaging, in particular US and MRI, for the evaluation of the pelvic floor and surrounding structures before or after RP to predict PPUI.

### Search strategy

Data collection was carried out in accordance with the PRISMA statement. A comprehensive PubMed search was carried out for relevant articles published between January 2000 and June 2020. The search terms used were (radical prostatectomy OR robotic prostatectomy OR RARP, RALP OR robotic-assisted laparoscopic prostatectomy) AND post-prostatectomy AND (incontinence OR urinary incontinence) AND (imaging OR MRI, mpMRI OR ultrasound OR perineal ultrasound) AND (membranous urethral length OR bladder neck OR urinary sphincter OR urethral sphincter) AND (prostate volume OR pelvic floor OR pelvic floor thickness OR levator ani OR urethral stump length OR urethral angle OR urethral hypermobility).

### Review process

Study results were restricted to English-language articles. Studies carried out on animals, on benign conditions or on treatment of prostatic malignancy with approaches different

from RP were excluded, and studies published only as either abstracts or reports from meetings were not included for review. Papers were initially reviewed by relevancy of title and then by abstract. Non-excluded articles then had their full text reviewed against the inclusion and exclusion criteria. A total of 169 papers were retrieved and, after exclusions, 32 articles were included in the final review (Fig. 1).

### Risk of bias

The risk of bias and applicability of all studies was assessed using the QUADAS-2 criteria, including the presence of baseline confounding factors, bias in selection of patients and bias in imaging evaluation (Fig. 2, Table S1).

## Results

The 32 included studies are described in detail in Tables 1 and 2. The overall methodological quality was moderate, with 12 studies having a low risk of bias and applicability in all the assessed domains (Fig. 2, Table S1).

### MRI

Various preoperative patient-related risk factors that affect continence recovery have been reported. One of the first studies using MRI in the context of PPUI evaluated the degree of prostatic intravesicular protrusion, showing a correlation between a larger intravesicular protrusion and a higher rate of PPUI.<sup>26</sup> Several studies focused on the preoperative parameter of MUL, measured on T2-weighted images as the distance between the interior prostatic apex and the penile bulb (Fig. 3).

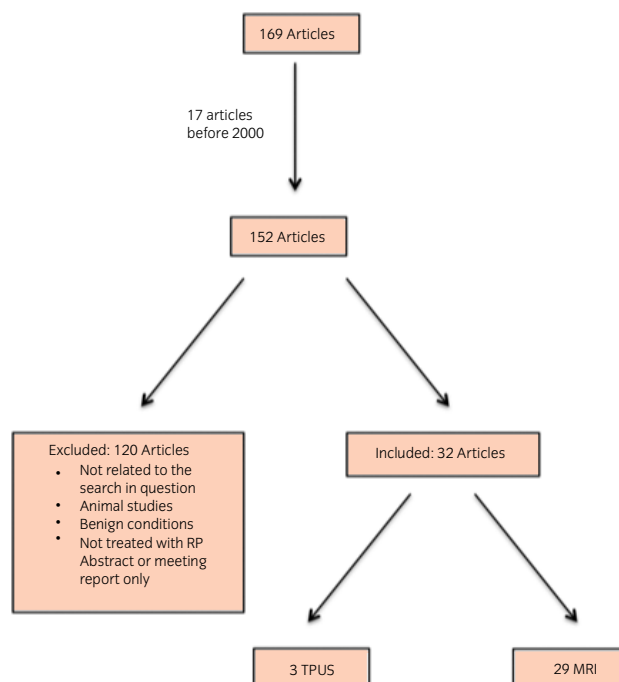
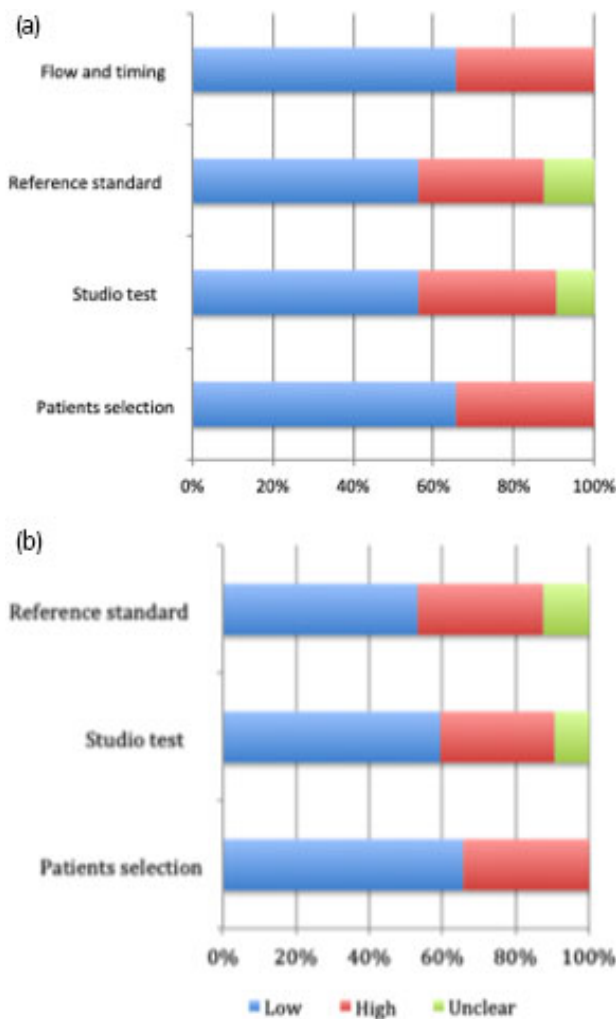


Fig. 1 Literature search.



**Fig. 2** Overall summary of risk of bias and applicability concerns across studies based on QUADAS-2 criteria. (a) Proportion of bias with low, high and unclear risk of bias. (b) Proportion of bias with low, high and unclear applicability of bias.

Several authors showed a correlation between increasing MUL and preservation of urinary continence after prostatectomy and, consequently, support MUL as a predictor factor

for recovery of urinary continence.<sup>27–43</sup> Indeed, several studies attempted to predict the probability of post-RP continence by using preoperative MRI measurements of MUL, with the largest retrospective study analyzing 602 men and showing a significant association between MUL and continence outcomes at 12 months post-RARP.<sup>28</sup> Some authors additionally evaluated the difference in MRI-measured MUL before and after surgery, and the percentage change of MUL (calculated as [(preoperative MUL – postoperative MUL) × 100] / preoperative MUL), showing these to significantly correlate with urinary continence after RP. Patients with longer postoperative MUL had a smaller removed urethra and these data correlate well with urinary continence after surgery.<sup>27,41,43</sup> More recently, Saur *et al.*<sup>41</sup> assessed 316 men with MRI pre- and post-surgery, measuring MUL, MUA (Fig. 4) and prostatic apex type, as proposed by Lee *et al.*,<sup>26</sup> depending on the degree of anterior and/or posterior overlapping of the apex of the gland. At 1-week post-surgery, there was a significant difference between the continent and incontinent groups in MUL (11.4 mm for continent men vs 10.0 mm, incontinent men), but no differences for MUA and apex type. These results were maintained at 6 months (MUL in the continent group was 11.1 mm vs 9.4 mm in incontinent one) and 12 months postoperatively (MUL 11.3 mm vs 8.8 mm, respectively).

In addition to the parameters reported above, Fuki *et al.*<sup>31</sup> assessed both prostate volume and pubic symphysis-PAL, showing PAL to be a predictive factor of PPUI at 3 months after RARP. Paparel *et al.* also showed that a high degree of periurethral fibrosis in the postoperative phase correlated with worsening continence. Nevertheless, due to technical difficulties in quantifying fibrosis, the authors were unable to find a statistical correlation between a higher grade of periurethral fibrosis and worsening postoperative continence (HR 0.64,  $P = 0.16$ ).<sup>43</sup>

More advanced MRI functional techniques, such as perfusion and diffusion, have been applied in the preoperative setting. Schmid *et al.* measured the perfusion quality of the levator ani muscle compared with the surrounding pelvic muscle structures in 42 patients, and found a significantly higher perfusion ratio in levator ani muscle versus surrounding pelvic muscles in the continent group compared with the

**Table 1** MRI and US features assessed for association with continence in men both pre- and postoperatively

	MRI	US
Preoperative	Prostatic bladder protrusion <sup>26</sup> MUL <sup>27,28,31–39,41–43,60–64</sup> MUA <sup>41,62,64</sup> Prostatic volume <sup>34,39,62</sup> Pubic symphysis-PAL <sup>61</sup> Muscle perfusion <sup>29</sup> Apex type <sup>41</sup> Number and length of PNF <sup>45,46</sup>	
Postoperative	Change in MUL <sup>27,30,35,43,61,63–65</sup> Change in MUA <sup>61,64,65</sup> Periurethral fibrosis <sup>43,61,65</sup> Number and length of PNF <sup>45,46</sup>	Proximal urethral mobility <sup>49–51</sup> Funneling of the bladder neck on Valsalva <sup>49–51</sup> Urethral angle <sup>49,50</sup> Periurethral fibrosis <sup>49</sup>

**Table 2** Prostatectomy technique used by each study and number of patients included

Study	Surgical techniques (RARP/LRP/ORP/RP)	No. patients
Lin <i>et al.</i>	RARP	602
Sauer <i>et al.</i>	ORP and RARP	316
Schmid <i>et al.</i>	RARP	42
Nakane <i>et al.</i>	RARP	73
Fuki <i>et al.</i>	RARP	270
Kitamura <i>et al.</i>	RARP	320
Siracusano <i>et al.</i>	RARP	26
Sadahira <i>et al.</i>	RARP	70
Kim <i>et al.</i>	RARP	529
Kadono <i>et al.</i>	RARP	185
Di Paola <i>et al.</i>	RARP	22
Satake <i>et al.</i>	ORP	121
Song <i>et al.</i>	RARP	186
Honda <i>et al.</i>	RARP	131
Tienza <i>et al.</i>	ORP and LRP	550
Matsushita <i>et al.</i>	RP (not specified)	2849
Haga <i>et al.</i>	ORP and LRP	53
Cameron <i>et al.</i>	ORP and RARP	26
Lee <i>et al.</i>	LRP	242
Soljakin <i>et al.</i>	ORP	34
Suskind <i>et al.</i>	RARP, LRP and ORP	21
Sohn <i>et al.</i>	ORP	13
Lim <i>et al.</i>	ORP	94
von Bodman <i>et al.</i>	ORP and LRP	600
Hakimi <i>et al.</i>	RARP	75
Mendoza <i>et al.</i>	RARP	80
Paparel <i>et al.</i>	ORP and LRP	64
Nguyen <i>et al.</i>	RARP	274
Coakley	RARP	211
Stafford <i>et al.</i>	ORP and RARP	42
Costa Cruz <i>et al.</i>	RP (not specified)	92
Kirschner-Hermanns <i>et al.</i>	RP (not specified)	33

In cases where more than one technique is listed, the proportion of patients undergoing each was not specified by the original authors.

incontinent group, as well as a positive association between the perfusion ratio and the MUL.<sup>29</sup> DTI, a technique able to map and quantify peripheral nerve fibre distribution around the prostate,<sup>44</sup> has shown potential for detecting early decreases in peripheral nerves after RP; however, this

relatively novel technique might prove to be more useful in predicting erectile dysfunction rather than PPUI.<sup>45,46</sup>

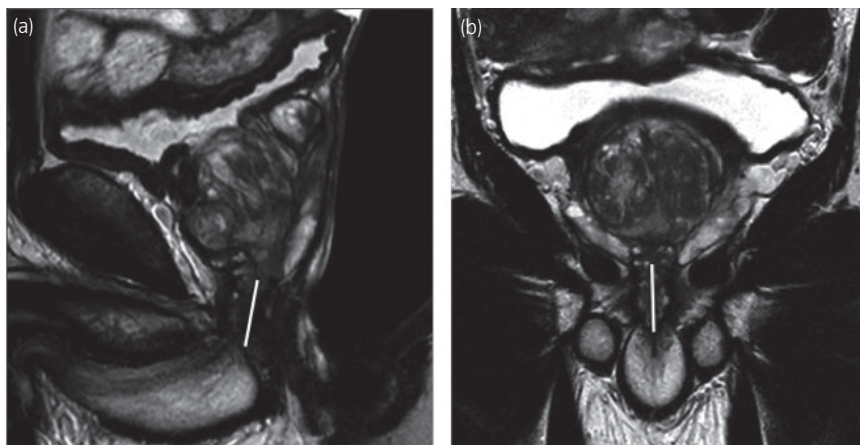
## Ultrasound

Perineal US is a well-established for assessing dysfunction of the female pelvic floor.<sup>47,48</sup> The modality has the advantage of dynamic imaging, with anatomy visualized both at rest and during induction of stress. More recently, such techniques have been adapted to analyze the anatomical and functional changes in the male pelvis after RP. Imaging can be carried out transrectally or non-invasively using a transabdominal or transperineal approach. To date, three studies have evaluated the technique, all using a transperineal approach and all within a postoperative setting (Figs 5,6).

Kirschner-Hermanns *et al.* evaluated the feasibility and reproducibility of TPUS in 33 men with and without PPUI after prostatectomy.<sup>49</sup> Good interobserver agreement was shown for the assessed parameters of proximal urethral mobility, funneling of the bladder neck on Valsalva maneuver, voluntary pelvic floor contraction before visual feedback and the presence of periurethral fibrosis. They concluded that hypermobility of the proximal urethra was only seen in men with incontinence, and that bladder neck funneling was more common in men with PPUI.

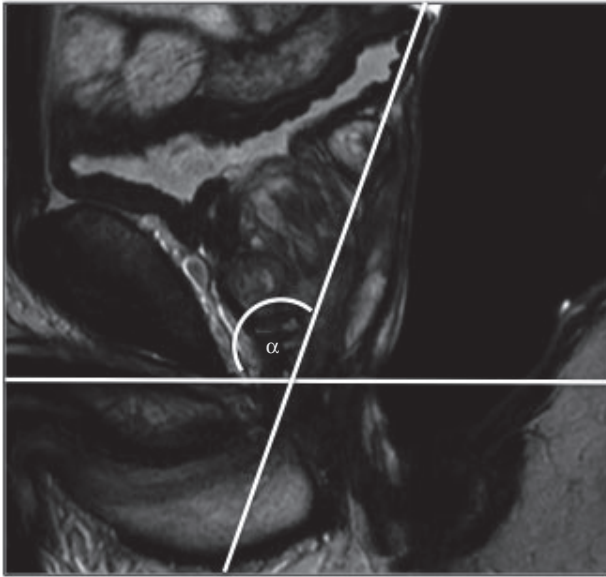
Costa Cruz *et al.* explored dynamic TPUS evaluation of the urethra and the pelvic floor in a population of 92 men post-RP at rest, during contraction and during the Valsalva maneuver.<sup>50</sup> They evaluated the degree of mobility of the proximal urethra, the measured urethral angle, presence of funneling of the bladder neck and voluntary pelvic floor contraction, concluding that urethral angles at rest in the incontinent group were significantly higher with a lower displacement of the anterior bladder neck during contraction than the continent group.

Stafford *et al.* analyzed the relationship between post-prostatectomy continence status and dynamic muscular features through the use of TPUS in 42 men, divided in two groups (continent vs incontinent).<sup>51</sup> US records were carried out during involuntary cough and maximal sustained voluntary contraction. The displacements of pelvic structures with the activation of puborectals, striated urethral sphincter,



**Fig. 3** Preoperative T2-weighted endorectal magnetic resonance images. The preoperative MUL is measured in the (a) sagittal and (b) coronal planes (distance from the prostatic apex to the level of the urethra at the penile bulb).





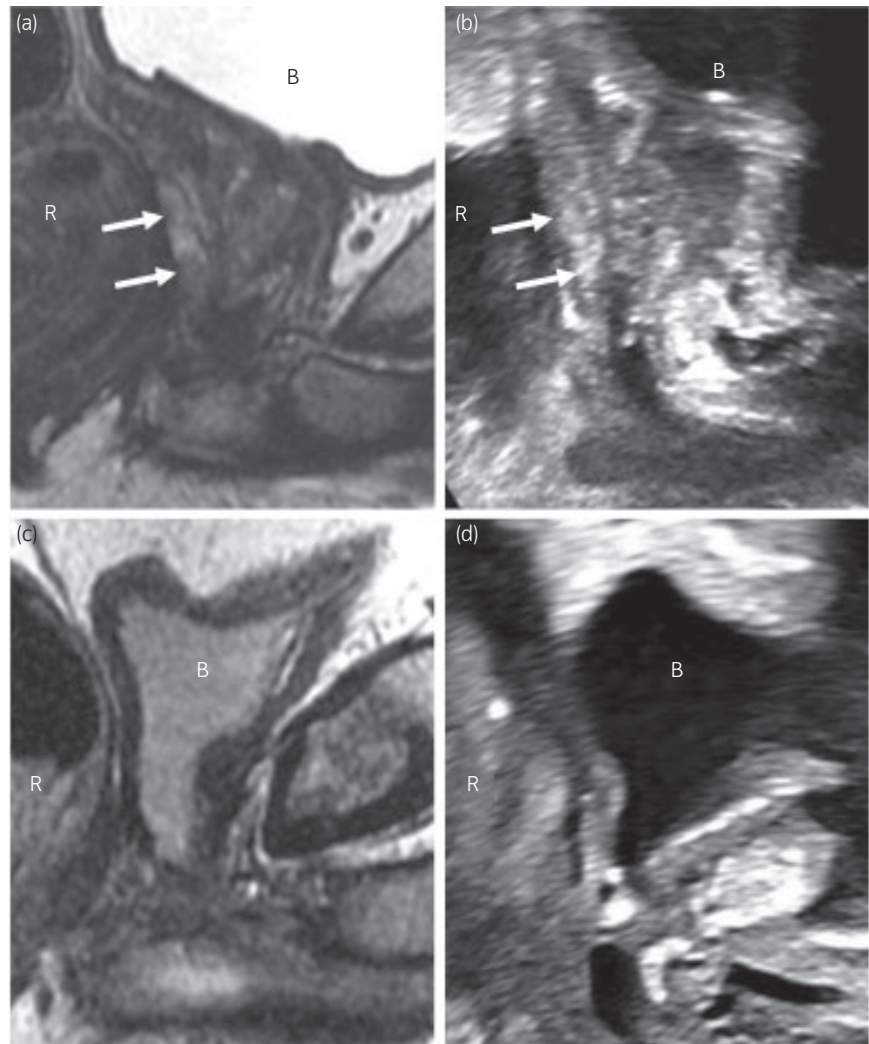
**Fig. 4** In a T2-weighted sagittal plane the horizontal line underneath the symphysis was placed. Another intersecting line parallel to the membranous part of the urethra defines the MUA.

bulbocavernosus muscles and the urethral length, and the resting position of the anorectal and urethra-vesical junctions were calculated. They found significant differences in the two groups, particularly in striated urethral activation, and bulbocavernosus and puborectals muscle activation.

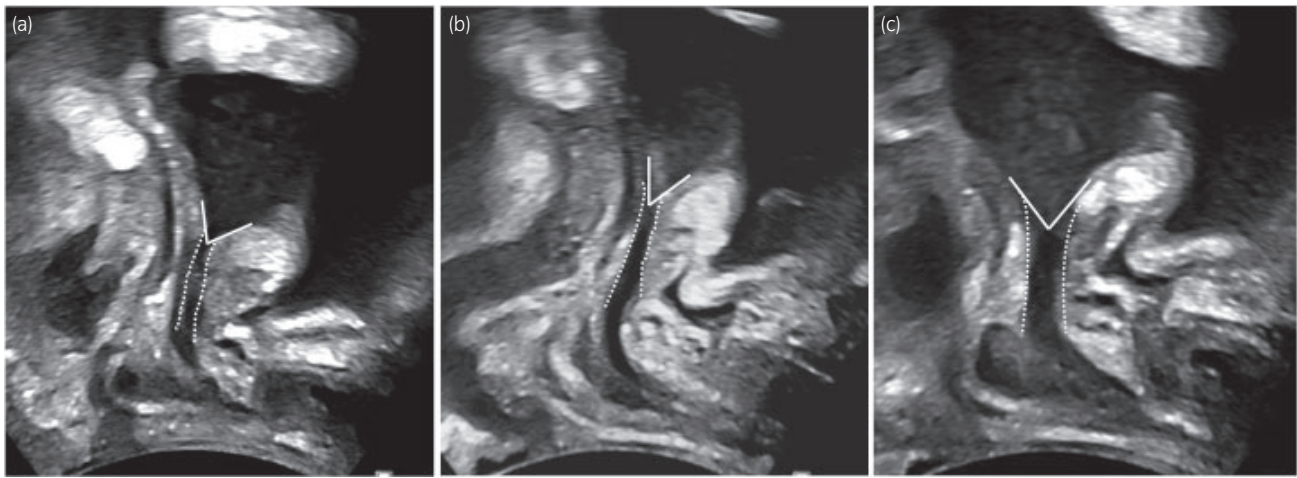
## Discussion

The most common side-effects of prostatectomy are functional deficits, such as incontinence and erectile dysfunction, with PPUI affecting up to 20% of men after surgery.<sup>25</sup> Several clinical factors are known to affect postoperative continence recovery including age, body mass index, preoperative sexual function and clinical stage, but to understand the pathophysiology of PPUI and/or predict its likely occurrence, several additional morphological and functional imaging parameters have been investigated. However, it should be noted that the studies used heterogeneous definitions of PPUI both in terms of assessment time-points and the evaluation scales used (EPIC, Pads, ICIQ), which makes direct comparison between studies challenging.

During the past 10 years, mpMRI has become the leading tool in the assessment of the prostate, providing information



**Fig. 5** MRI and TPUS images of the prostate. Top row: preoperative sagittal (a) MRI images and (b) equivalent longitudinal TPUS image in the same patient, arrows indicate the posterior margin of the prostate. Lower row: postoperative sagittal (c) MRI and (d) US images. B, bladder; R, rectum.



**Fig. 6** Dynamic TPUS images of the surgical bed post-prostatectomy. (a) Images at rest, dashed line indicates urethral outline, angle of the bladder neck indicated by solid lines. (b) Images after pelvic floor contraction in the same patient, the bladder neck moves superiorly and anteriorly, with closure of the bladder neck angle. (c) Images after Valsalva maneuver in the same patient, the bladder neck moves inferiorly with opening of the bladder neck angle, “funneling” is shown as widening of this angle and shortening of the distance to the apex of the opening.

on the location, size and local extension of prostatic lesions, and allowing a morphological preoperative evaluation of the gland.<sup>6,9,52,53</sup> However, it is important to note that several other parameters can only be obtained intra- or postoperatively, such as histological resection margins. A total of 22 articles identified in the present review process assessed the value of MUL measurement, with a significant correlation clearly identified between a longer length pre-surgery and continence after surgery (Table 1), suggesting that MUL might represent an independent predictor of early recovery from urinary incontinence.<sup>42</sup> Indeed, several surgical techniques have been developed to preserve MUL and increase periurethral suspension to maintain the integrity of the pelvic floor, further supporting the importance of MUL as a preoperative marker.<sup>54–56</sup> Furthermore, Mungoyan *et al.* in a recent systematic review and meta-analysis showed a significant and positive association between preoperative MUL and the return of continence after RP; in particular, the underlying importance of an extra millimeter in preoperative MUL on return to continence (OR 1.09, 95% CI 1.05–1.15,  $P < 0.001$  from the multivariate model).<sup>57</sup> However, it should be noted that just eight of the aforementioned studies were prospective, and all were single-center and with a small sample size of patients; furthermore, the majority of the studies did not report on intra- and inter-reader variation in the measurements, and it could represent an essential point to be considered for the next studies. Larger, prospective multicenter studies are required to explore the effect of MUL on PPUI, how reproducible this measurement is between readers and whether a cut-off MUL can be predefined for accurate prognostication.

Intravesicular prostatic protrusion is another potential preoperative anatomical feature that has been shown to correlate with continence;<sup>26</sup> however, this has only been assessed in a single retrospective study, wherein comorbidities and other risk factors for continence were not addressed.

Aside from morphological features, MRI has the potential to assess several functional parameters, either as part of a standard clinical mpMRI, or using novel research sequences. Di Paola *et al.*<sup>45</sup> and Siracusano *et al.*<sup>46</sup> prospectively

assessed DTI to map peri-PNF before and after prostatectomy. Although the decreased number of PNFs after surgery was statistically related to erectile dysfunction, no correlation was found between the number and the length of fibers and PPUI, suggesting the importance of other parameters involved in the development of PPUI. Both studies included small patient numbers, and did not have a model able to identify the course and direction of all fibers without the inclusion of non-nerve structures. DTI shows promise, and the ability to detect PNFs *in vivo* might complement the novel surgical technique of NeuroSAFE, which incorporates analysis of frozen section prostatic samples at the edges of the prostate perioperatively to help preserve nerve fiber integrity while ensuring clear margins.<sup>22</sup> However, DTI acquisition is time-consuming and expertise is required for interpretation, and any additional scanning time needs to be balanced against MRI availability and throughput of patients.<sup>58,59</sup>

US is another modality that has been utilized for assessment of the male pelvic floor. The technique is low-cost, available, quick, does not require expert interpretation and offers the advantage of dynamic assessment. Kirschner-Hemmanns *et al.*<sup>49</sup> and Costa Cruz *et al.*<sup>50</sup> both used static US to assess the differences between continent and incontinent men postoperatively compared with a control group with no history of surgery. Both studies showed that the continent group had a smaller urethral angle, and in the incontinent group there was a significantly reduced anterior displacement during contraction than in the continent men. The studies are limited by their small sample size and lack of a baseline evaluation, thus precluding comparison of pre- and post-surgical findings. Stafford *et al.* investigated the role of perineal US in the evaluation of dynamic features in pelvic floor muscles activation.<sup>51</sup> The results were encouraging, and suggested the potential impact of the assessment of these muscles in the recovery of continence after prostatectomy. Although reporting promising results in terms of sensitivity and specificity (84.2% and 91.3%, respectively), the study was limited in terms of patient selection and the choice of model regression, where the

variables were reduced from 14 to five and might have introduced a degree of bias.

Interestingly, despite the wide availability of both MRI and US, no study to date has compared the two techniques within the same patient population. Indeed, data potentially gained with the integration of the two modalities and incorporating both static and dynamic technique might offer additive benefit for the preoperative prediction of PPUI and could form the basis for future studies. It is also noteworthy that all US studies to date have been in the postoperative setting; however, there is no reason why US studies could not be carried out preoperatively, and this might be a further area for future work.

To the best of our knowledge, this is the first review of studies using multiple imaging tools to evaluate PPUI. Identified parameters could prove important in appropriately selecting patients for surgery. The static preoperative measurement of MUL by MRI has shown the most promise, given the widespread preoperative use of MRI, routine reporting of this parameter is a reasonable consideration to aid preoperative decision-making. However, it should be noted that inter-study comparisons are hindered by differences in the MRI protocols and US techniques used, small patient numbers, and a lack of a consensus on when to assess and how to define PPUI. Future multicenter prospective studies are required to establish the exact role of MUL, DTI, and other parameters in patient selection and preoperative planning to ensure satisfactory quality of life outcomes and to optimize healthcare resources.

## Conflict of interest

None declared.

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## Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

**Table S1.** QUADAS-2 assessment of included papers.