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TOPIC PAPER

Role of MRI in planning radical prostatectomy: what is the added value?

Jose Marenco[1] · Clement Orczyk[1,2] · Tom Collins[1] · Caroline Moore[1,2] · Mark Emberton[1,2]

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Abstract

Introduction The goal of radical prostatectomy is to eradicate oncological disease while achieving the best possible functional outcomes. In this regard, nerve sparing offers a greater chance of recovering potency after surgery. Accurately locating prostate cancer foci is instrumental for identifying good candidates for this approach whilst maintaining safe oncological margins. In addition to this, the length of membranous urethra is an independent predictor of time to, and extent of, continence recovery. The introduction of Mp-MRI allows visualising malignant tissue within the prostate gland, which could lead to image-directed surgery planning as with other solid-organ cancers such as kidney, pancreas, breast or testes.

Methods A narrative review of the available literature was performed.

Results Mp-MRI demonstrated moderate sensitivity and high specificity to detect extra-capsular extension, seminal vesicle involvement or T3 stage. Measurements of membranous urethral length have shown to be useful in predicting probability of achieving continence after surgery. Furthermore, image-guided surgery has shown to be accurate to determine surgical planes to safely preserve neurovascular bundles.

Conclusion The use of Mp-MRI for pre-surgical planning introduces a new scenario where the previously homogeneous radical prostatectomy can be tailored to suit patient and tumour features. This has the potential to improve functional outcomes whilst not compromising on surgical margins. Moreover, the introduction of Mp-MRI increases the ability to predict functional outcomes after surgery and allows for a more accurate local staging. This in turn provides more information to both patients and clinicians in the decision-making process regarding treatment.

Keywords Prostate cancer · MRI · Radical prostatectomy

Introduction

Radical prostatectomy (RP) is considered the standard surgical approach to localised prostate cancer. Traditionally, preoperative prostate cancer staging was performed based on nomograms [1]. The addition of preoperative Mp-MRI could allow a more accurate final pathological staging prediction [2], informing the most appropriate treatment selection.

The goal of RP is to achieve cure, whilst keeping the lowest possible rate of side effects. In this sense, there is a balance between wide excision, which will theoretically achieve the lowest rate of positive surgical margins, and a narrower excision with the aim of preserving structures that will determine functional outcomes. For this strategy, a reliable way to determine the likelihood of disease in the boundaries of the prostate is required. To address this dilemma, Mp-MRI has been shown to be effective in detecting and locating prostate cancer with a greater degree of certainty [3].

A pre-biopsy MRI strategy is beneficial to reduce the impact of post-biopsy artefact. Moreover, targeted biopsies can be more selective, allowing for greater rates of clinically significant prostate cancer detection [4] and reducing upgrading following surgery [5]. Further, Faria et al. demonstrated that this approach conferred an economical benefit against standard TRUS biopsy approach [6].

Another essential goal in radical prostatectomy is maintaining urinary continence. Greater preoperative maximal urethral length (MUL) is consistent with higher rates of

✉ Jose Marenco
jlmarencoj@gmail.com

[1] University College London Hospital, NHS Foundation Trust, 47 Wimpole Street, Marylebone, London W1G 8SE, UK

[2] Division of Surgery and Interventional Science, University College of London, London, UK

postoperative continence, thus preoperative MUL measurement could also be advisable [7].

Staging of localised prostate cancer

Local staging of prostate cancer is paramount in offering appropriate treatment. Previously, this was done using nomograms integrating PSA, Gleason score, number of positive cores and clinical stage based on digital rectal examination. This information is blind to size and location of tumour, as well as relation with surrounding organs. Moreover, digital rectal examination is subjective and operator dependant [8] and often underestimates tumour extent.

A reliable prediction of worse prognosis pathological findings is of paramount importance. Particularly given the recent trend towards selecting higher risk prostate cancer patients for radical prostatectomy [9]—where involvement of bladder neck, peri-prostatic fat or surrounding organs is not rare. However, the value of Mp-MRI in local staging is unclear. Whereas Feng et al. showed that the addition of Mp-MRI to clinical parameters improved the ability to predict extra-capsular extension [3] and Ryan et al reported that the addition of preoperative Mp-MRI increased the ability of clinical nomograms to predict extra-capsular extension, seminal vesicles invasion and lymph node involvement [10]; on a recent a recent systematic review, high specificity but inconsistent and generally low sensitivity was found for Mp-MRI to detect extra-capsular extension, seminal vesicle invasion and T_3 stage [11]. Therefore, whilst Mp-MRI is the best image method for local staging at present, it still seems to be a field for improvement.

Pre-surgical nodal evaluation

The most reliable way to assess lymph node involvement is a pelvic lymph node dissection (PLND); this is of course invasive and carries a significant degree of morbidity [12]. Therefore, identification of patients that will benefit from pelvic lymph node dissection, and the extent of this, provides another role where imaging in preoperative planning might change the current decision-making tools.

On a recent meta-analysis, the pooled sensitivity for detecting nodal metastasis for both CT scan and MRI scan was low at 0.42 and 0.39, respectively. Specificity was 0.82 for both tests. There was no statistical difference between the two tests; hence both have a similarly poor ability to detect nodal involvement. This is because both scans evaluate nodal involvement based on size criteria alone, and lack metabolic data [13].

Brembilla et al. found that adding clinical parameters to the MRI findings seems to increase the ability to predict LNI (AUC 0.956). Furthermore, tumour volume, tumour ADC value and tumour T stage were the most accurate independent predictors of LNI. Finally, the prevalence of nodal metastasis in patients with localised (T2 on MRI) tumours with tumour size < 1 cm was very low; therefore, the authors suggested that MRI could be used to triage which patients might avoid PLND [14].

Role of MRI to guide nerve-sparing radical prostatectomy

Preservation of neurovascular bundles (NVB) has shown to improve functional outcomes after radical prostatectomy [15]. Despite anatomical variations that make the degree of preservation hard to predict [16], NVB are considered to run posterolateral to the prostate from the base to the apex.

As discussed above, the gain in functional outcomes must be weighed against the risk of compromising surgical margins, thus increasing the risk of prostate cancer recurrence and the morbidity of adjuvant treatments. Therefore, to plan a narrower excision plane, it is desirable to ensure the absence of disease close to the posterolateral margins of the prostate. Schiavina et al. evaluated the role of Mp-MRI to decide the level of nerve spare and select patients for this approach. They performed an MRI scan on 137 men undergoing radical prostatectomy. The previous nerve-sparing strategy based on clinical data was revised with the MRI findings; in approximately half the cases, the nerve-sparing strategy was changed. Appropriateness of resection was considered, taking into account the presence of extra-capsular extension or positive surgical margins on the side where the NS strategy was changed. Overall, the change was reported to be appropriate in 75% of the cases. Moreover, they demonstrated lower positive margin rates on this cohort of patients when compared to a synchronous dataset of RARP [17].

Further to this, Panebianco et al. selected 125 patients who were deemed suitable for bilateral nerve-sparing radical prostatectomy (NS RP) based on clinical parameters and also performed an MRI scan. Patients were subsequently divided according to MRI findings into those eligible for bilateral NS and those where the strategy should change to either unilateral or no NS at all. In roughly 30% of men, the initial bilateral NS RP plan was changed. The authors claim that the use of preoperative Mp-MRI allowed choosing an appropriate level of excision in 95.9% and 87.5% of men in the bilateral and the unilateral or non-NS RP groups, respectively. Moreover, the rate of positive margins in the posterolateral region was low at 3.8% [18].

Measurement of membranous urethral length

Despite surgical advancements, incidence of urinary incontinence after radical prostatectomy is high, particularly in the early postoperative period. Recovery of continence is unpredictable and quite variable amongst different series [19]. Time to continence recovery is also variable with improvements reported up to 2 years after surgery.

Various patient-related risk factors have been reported to affect continence. Amongst these, membranous urethra length (MUL) has been hypothesised to have a positive correlation with better recovery of urinary continence [20]. Paparel et al. performed Mp-MRI pre- and post-operatively in 48 patients undergoing RP and observed that both preoperative MUL and ratio of MUL preservation positively correlated with likelihood of continence recovery. On the contrary, post-operative urethral fibrosis was associated with lower rates of continence [21].

In one recent meta-analysis, greater MUL (measured on T2 weighted images on preoperative MRI) correlated with better continence results at 3, 6 and 12 months. Furthermore, after statistical analysis every extra centimetre of MUL improved likelihood of continence recovery by more than 200% [7]. Therefore, measurement of MUL could be a standard preoperative evaluation, which will add valuable information when counselling patients.

Use of Mp-MRI for computer-assisted surgery (CAS)

Computer-assisted surgery is a broad term that entails the use of pre-surgical information to direct surgery. There are different concepts for achieving this purpose. In general terms, detailed preoperative imaging is performed and then interactive registration with intraoperative imaging is carried out to provide information and guidance to the surgeon during the procedure. Unlike, for example, in Neurosurgery, the application of CAS in Urology is inherently difficult due to the fact that the organs involved are prone to movement that can lead to registration errors. Nevertheless, surgical navigation has been described and applied in humans for a variety of procedures such as PCNL [22] and partial nephrectomy [23].

In relation to radical prostatectomy, different concepts have been proposed. Mohareri et al. [24] described the use of intraoperative TRUS setup using a brachytherapy stepper that rotated in response to the movements of the robotic arms. The images were displayed real time on the Tile Pro function of Da Vinci. The added value of this imaging was subjectively found to be useful for demarcation of the prostate–bladder delimitation during bladder neck dissection, identifying the seminal vesicles and their relation to the rectum as well as locating the distal limit of the apex. This strategy however, lacks information on tumour location. In an attempt to incorporate this information, Ukimura et al. [25] developed a 3D reconstruction of the prostate based on TRUS, superimposing MRI and biopsy information, as well as colour coding anatomical structures such as the urethra and nerve bundles. This information enables the surgeon to be aware of biopsy-proven cancer foci, as well as the theoretical location of the nerve bundles.

Augmented reality allows the surgeon to superimpose preoperative imaging findings onto the real-time surgical field. Simpfendorfer et al. [26] described their initial experience superimposing 3D reconstruction of the prostate and neurovascular bundles based on TRUS with real-time operative images. The use of needles inserted into the anterior surface of the prostate served as navigation aids to register organ movement and match the 3D reconstruction.

More recently, Porpiglia et al. [27] presented a novel software for augmented reality RARP (AR-RARP) that enables the surgeon to superimpose a high-quality 3D reconstruction of a prostate MRI onto intraoperative imaging. In their initial experience, MRI tumour locations were registered onto operative images; a metallic clip was placed in these areas. In all the cases (30/30), final pathology confirmed the presence of index lesions in the identified areas. Moreover, the mismatch was reported to be as low as 3 mm. These data suggest that AR-RARP could improve the precision of this surgery, further reducing the trade-off between oncological safety and functional outcomes.

Conclusion

Radical prostatectomy is the mainstay treatment for localised prostate cancer. Despite technological improvements, functional outcomes after radical prostatectomy are still variable and in some cases unpredictable. The introduction of preoperative imaging could lead to a more tailored radical prostatectomy incorporating patient and tumour information in pre-surgical planning. This could reduce the functional impact of the procedure without compromising oncological safety for a better-counselled patient.

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Compliance with ethical standards

Conflict of interest Mark Emberton receives research support from the United Kingdom's National Institute of Health Research (NIHR) UCLH/UCL Biomedical Research Centre. He has been an NIHR Senior Investigator since 2013. The remaining authors declare that they have no conflict of interest.

Ethical statement Ethical standard was locally reviewed for this trial.

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