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Review Article

# The role of MRI in BPH: clearing the waters

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**ABSTRACT**

**Background:** Benign Prostatic Hyperplasia (BPH) is common in ageing men. Traditional assessment involves a clinical history, flow studies, Digital Rectal Examinations (DRE), Prostate Specific Antigen (PSA) levels, International Prostate Symptom Score (IPSS), ultrasound (U,S), and histopathologic analysis (to exclude prostatic neoplasia). Magnetic resonance imaging (MRI), initially used to enhance neoplastic detection, is now emerging as a valuable tool in BPH classification and management.

**Objective:** This review aims to elucidate the role of MRI in diagnosing, classifying, and managing BPH and highlights its advantages over conventional imaging modalities.

**Methods:** A narrative review was conducted using current literature on prostate anatomy, BPH pathophysiology, and various imaging techniques, focusing on the evolving use of MRI.

**Findings:** While transabdominal ultrasound remains a key initial tool for assessing bladder wall thickness, post-void residual volume, and general prostatic anatomy, MRI offers superior imaging resolution. It provides detailed visualisation of prostate architecture and accurate prostate volume estimation, therefore informing targeted biopsies and guiding treatment decisions. Wasserman's MRI-based classification system for BPH – PIRADS – notably correlates with symptom severity and IPSS. MRI also shows promise in preoperative planning; for instance, improved outcomes in holmium laser enucleation have been associated with preoperative peripheral zone thickness on MRI once malignancy is excluded.

**Conclusion:** MRI is becoming increasingly valuable for diagnosing, classifying, and managing BPH. It enhances phenotypic characterization and guides therapeutic strategies with greater precision. Despite these benefits, MRI's cost and limited accessibility continue to hinder its routine use in managing BPH and remain a barrier to its widespread clinical adoption.

**Keywords:** Benign Prostatic Hyperplasia, Digital Rectal Examinations, Prostate Specific Antigen, International Prostate Symptom Score, Magnetic resonance imaging

## THE PROSTATE GLAND

The prostate gland is a vital component of the male urogenital system, located just below the bladder and encircling the urethra. It is primarily composed of glandular tissue and stroma. The glandular tissue of the prostate is organised into the peripheral zone (PZ), the central zone (CZ), and the transitional zone (TZ). The PZ takes up about 70% of the total prostate volume, leaving the remaining 25% and 5% for the CZ and TZ, respectively.(1) Although not glandular, the anterior fibromuscular stroma – sometimes called the anterior zone – forms a significant part of the prostate's anterior aspect and contributes to its structural integrity. In some classifications, the midline tissue between the lateral lobes – often involved in BPH – is called the "median-lobe" or "mid-lobe". The prostate glandular tissue consists of numerous secretory units arranged in lobules. These units comprise columnar and cuboidal epithelial cells, which produce seminal fluid when hormones and the autonomic nervous system are stimulated. The glandular tissue can be subdivided into the acinar and the ductal glands. The acinar glands are small sac-like structures that produce seminal fluid, while the ductal glands have larger ducts that direct the flow of seminal fluid towards the urethra to create semen. This seminal fluid from the prostate gland is typically rich in enzymes, proteins, and minerals that nourish sperm while enhancing their motility for optimal fertilisation.(2) Prostate-specific antigen (PSA) is a glycoprotein enzyme – specifically a serine protease – found in seminal fluid, secreted primarily by prostatic epithelial cells. It is clinically important for its physiological purpose in

liquefying semen and aiding sperm motility and its role as a biomarker. In the presence of prostate cell hyperplasia, inflammation, or malignancy, PSA levels can be elevated due to increased production and disruption in the normal functioning of the prostate gland.(3)

The fibromuscular stroma of the prostate is the most anterior portion of the gland and is crucial for its normal functioning.(4) It surrounds the glandular acini and ducts, providing structural support to the prostate and facilitating its organisation. The stroma comprises smooth muscle fibers, fibroblasts, and an extracellular matrix of components like collagen, elastin fibers, blood vessels, and nerves. (4) The smooth muscle contraction actively propels seminal fluid into the urethra during ejaculation. The shortening and lengthening of smooth muscle cells contribute to the urine flow by shaping the urinary stream – funnelling it to promote a smooth transition from turbulent to laminar flow – thereby facilitating healthy bladder emptying. In addition to the functioning of the prostate gland, its anatomical location means that any enlargement or change in its composition can significantly impact the normal urine flow.

## OVERVIEW OF BENIGN PROSTATIC HYPERTROPHY

BPH is a non-malignant enlargement of the prostate gland that is common in aging men. It is thought that early development of BPH can occur any time after the age of 40 years, with more than 50% of men over the age of 60 years affected by this condition.(4) Enlargement of the prostate gland is triggered most commonly by hormonal changes. With increasing age, the activity of 5-alpha-reductase in men increases. This enzyme converts testosterone into its more potent dihydrotestosterone (DHT) derivative. DHT has approximately 100 times increased binding strength to androgen receptors within the prostate gland, causing increased biological stimulation of glandular and stromal cells and subsequent hyperplasia.(5)

Various risk factors exist for the development of BPH, including those that are modifiable and those that are non-modifiable. Modifiable risk factors include lifestyle habits that are closely related to metabolic syndrome. These cluster of conditions, including obesity, hypertension, hyperlipidemia, and diabetes, can exacerbate already existing risk factors in BPH development due to chronic low-grade inflammation and hormonal imbalances.(6) Men with metabolic syndrome often exhibit a hypogonadotropic state with lower circulating testosterone levels. In contrast, despite this systemic deficiency, the prostate may experience increased local availability of DHT and other pro-growth factors, thus promoting stromal and epithelial cell proliferation. A diet high in saturated fats and red meat, excessive alcohol intake, smoking, and decreased physical activity should be considered when assessing contributing factors for BPH. In contrast, age and genetic predisposition are the most prominent non-modifiable factors in the development of BPH. A genome-wide association study found that approximately 60% of BPH presentations may be correlated to genetics.(7) A study at Sandford University found that BMP5 and CXCL13 genes were significantly upregulated (50-fold) in patients with BPH undergoing radical prostatectomies between 2011 and 2013.(8)

The increased physical size of the prostate gland in BPH is directly related to glandular enlargement, typically involving the TZ and the periurethral glands.(4) This enlargement, causing urethral obstruction, results in lower urinary tract symptoms (LUTS) and is called "the static effect." In contrast, "the dynamic effect" describes the stroma's physiological changes, including increased tone and contractility. When considering the combined impact of the static and dynamic effect, one can appreciate its compound influence on LUTS. The static effect provides a physical barrier to urine flow, while the dynamic effect exacerbates symptoms by increasing smooth muscle contraction.

The gradual worsening of LUTS over time highlights the progressive nature of BPH. In the early stages of the disease, men may experience mild weakening of the urine stream, increased frequency, nocturia, and the sensation of incomplete bladder emptying. With continued glandular enlargement, symptoms may worsen and potentially lead to complications such as retention, UTIs, visible haematuria, cystolithiasis, and potential renal failure. Different types of retention may exist: acute urinary retention (AUR) and chronic urinary retention (CUR). AUR is considered a urological emergency and requires immediate catheterisation to relieve pain and prevent further complications. (9) While not typically considered an emergency unless it presents with infection or renal dysfunction, CUR also requires medical attention and possible admission to prevent associated complications and identify the underlying cause of retention.(10)

Upon presenting with LUTS, patients should undergo a comprehensive assessment integrating thorough history taking, physical examination, and relevant investigations about the workup of suspected BPH and the exclusion of prostate cancer. Questionnaires such as the International Prostate Symptom Score (IPSS) may quantify symptom severity by assessing a patient's symptoms over a protracted period, thereby identifying functional decline (subjective or objective) that might suggest intervention. Patients who score 0-7 have mild symptoms; a score of 8-19 indicates moderate symptoms, and a score of more than 19 indicates severe symptoms.(11) On digital rectal examination, an enlarged, smooth, firm, non-tender prostate is typical. Anecdotally, the prostate is considered enlarged if the examiner is unable to get above the gland on palpation.

## IMAGING FOR BPH

After DRE and PSA analysis, traditional ultrasound or MRI imaging modalities play a critical role in diagnosing, classifying, and managing BPH because an increased prostatic volume may be appreciated. Although size

measurements vary depending on the patient's age and the imaging modality of choice, a healthy prostate is generally measured at <30ml.(12) The bullet and ellipsoid formulae are two examples that can be used to measure the volume of the prostate. The ellipsoid method assumes the prostate to be oval-shaped using the formula: transverse diameter x anteroposterior diameter x length x 0.52.(12) In 2009, the bullet formula was described as length x height x width x 0.65, assuming the prostate to be bullet-shaped.(13) Prostate volume measurements guide subsequent treatment options. Prostates measuring <30ml with associated urinary symptoms may respond best to alpha-adrenergic receptor blockers, while larger prostates will be better treated by 5-alpha-reductase inhibitors.(12) Transurethral resection of the prostate is indicated for patients with a prostate measuring up to 80ml with larger prostates requiring procedures such as simple prostatectomy or holmium laser enucleation, for example.(14)

The existing options for prostate imaging range from abdominal ultrasound (US) to transrectal ultrasound (TRUS) – both of which are advantageous in their utility at the bedside by a Urologist, as well as their use in renal assessment, bladder wall thickness, and functional assessment using a post-void residual volume (PVR); to computed tomography (CT) scans – which are not traditionally used for prostate assessment alone. Now, MRI is beginning to bare its head in the crowd of imaging modalities for BPH due in part for its utility in guiding diagnostic malignant evaluation. Abdominal US and TRUS are commonly used for BPH assessment as they are cost-effective, readily available, and provide information at the bedside.(15) Although more invasive, TRUS provides a more detailed view of the prostate zones, bladder, and seminal vesicles. Abdominal US is non-invasive and more comfortable for the patient. It is beneficial for analyzing bladder function and health, including measuring bladder wall thickness, the presence of trabeculations or diverticula, and measuring post-void residual volume. These measures aid in identifying possible bladder outlet obstruction, which may be secondary to BPH.

While not routinely used in BPH, CT scans are relevant in specific clinical scenarios. Several high-resolution, cross-sectional images are captured from the patient's pelvic area, allowing the anatomy of the lower urinary tract to be appreciated. Complications from BPH may be visualised, such as stones, hydronephrosis, and compression of adjacent organs secondary to prostate hypertrophy. CT imaging is advantageous when MRI might be contraindicated, for example, in a patient with a metallic implanted device where scatter artifacts might distort viewing.(15)

MRI is typically the imaging modality of choice for the workup of suspected prostate cancer. MRI is, however, becoming increasingly recognized as a valuable tool for the classification and management of BPH. Traditionally, BPH classification relied heavily on ultrasound and histopathologic analysis, but with the detailed imaging properties of MRI, there is a greater movement towards wider utilization of this imaging option.(4,16) Future studies defining both outcomes and the definitive surgical approach based on symptomatology and MRI features will soon emerge.

## MRI ASSESSMENT OF BPH

Dr. Randall classified BPH in terms of the regions of prostatic enlargement visualised on autopsy. Further to Randall's work, an ultrasound classification system was described for BPH (**Table 1**).(4) With MRI's detailed visualisation of prostate anatomy, a new proposed approach to classify BPH was developed by Wasserman based on its phenotypic properties (**Table 2**). These newly described classifications may improve treatment strategies with varying lobar involvements presenting with different symptoms and risk associations.(4)

To further aid the classification of the prostate using MRI, the introduction of automated prostate segmentation in MRI has enabled an accurate description of zonal hyperplasia. Advanced semiautomated and fully automated segmentation techniques may delineate the prostate gland from high-quality MRIs without requiring manual input. These algorithms have been designed to interpret a variety of prostate glands – complex and non-complex – while eliminating human error and calculating a prostate volume that is accurate and reproducible. By determining the affected zone involving BPH and the precise volume and structure of the gland, improved diagnosis and management can be achieved.(12)

The Prostate Imaging Reporting and Data System (PIRADS) uses multi-parametic MRI, including T2-weighted imaging, diffusion-weighted imaging (DWI), and dynamic contrast enhancement (DCE) imaging to create standardised reporting and interpretation for suspected prostate cancer.(17) Each abnormal lesion within

**Table 1:** (Randall vs. ultrasound classification of BPH)

| Type | Randall | Ultrasound |
|---|---|---|
| I | Simple bilateral lobe enlargement | Bilateral transition zone |
| II | Solitary commissural enlargement | Retrourethral lobe |
| III | Bilateral and commissural enlargement | Bilateral transition zone and rectourethral lobe |
| IV | Solitary sub-cervical enlargement | Solitary or multiple pedunculated |
| V | Bilateral and sub-cervical enlargement | Pedunculated with transition zone or retrourethral lobe |
| VI | Bilateral sub-cervical and commissural enlargement | Subtrigonal or ectopic |
| VII | Anterior enlargement | Other combinations |

**Table 2:** (Criteria for lobar classification of BPH)

| | |
|---|---|
| Type 1 | Bilateral transitional zone enlargement |
| Type 2 | Retrourethral enlargement |
| Type 3 | Bilateral transitional zone and retrourethral enlargement |
| Type 4 | Single pedunculated enlargement |
| Type 5 | Bilateral transitional zone with pedunculated enlargement |
| Type 6 | Subtrigonal enlargement |

**Table 3:** (PIRADS Version 2.1(2019))

| | | |
|---|---|---|
| PIRADS 1 | Clinically significant cancer is highly unlikely | 2% cancer detection rate |
| PIRADS 2 | Clinically significant cancer is unlikely | 4% cancer detection rate |
| PIRADS 3 | Clinically significant cancer equivocal | 20% cancer detection rate |
| PIRADS 4 | Clinically significant cancer is likely | 52% cancer detection rate |
| PIRADS 5 | Clinically significant cancer is highly likely | 89% cancer detection rate |

an enlarged prostate is scored between 1 and 5, directly correlating to its cancerous likelihood (**Table 3)**.(18) The PIRADS scoring system can indirectly assist in the analysis of BPH. By ruling out suspicious prostatic malignancy with a PIRADS score of 1 and 2, in conjunction with guidance from clinical history and PSA results, this may direct management towards likely BPH as opposed to pursuing invasive and unnecessary biopsies.(19)

## CLINICAL UTILITY OF MRI ASSESSMENT OF BPH

Guneyli et al. investigated the correlation between MRI-derived BPH patterns and IPSS in patients diagnosed with BPH and prostate cancer. The study included 61 patients and concluded that an MRI-calculated transitional zone volume (TZV) directly correlates with IPSS ($p = 0.001$). Additionally, IPSS-symptom scores (IPSS-ss) and IPSS-voiding symptoms (IPSS-vs) were significantly correlated to MRI-measured TZV ($p = <0.001$ and 0.03 respectively). These findings not only support IPSS as a valid clinical screening tool for symptom evaluation in the presence of prostate enlargement but also that MRI is a useful adjunctive tool for diagnosing clinically evident LUTS.(11)

Furthermore, specific BPH patterns demonstrated on MRI may also correlate with LUTS. Grivas et al. highlights MRI's usefulness in evaluating BPH patterns and their association with LUTS. The study found a significant association ($p < 0.001$) between prostates classified as Type 5 (**Table 2**) and a high IPSS score with a longer intravesical prostatic protrusion. Additionally, Type 5 prostates showed a higher IPSS than Type 1 prostates ($p = 0.001$).(20)

Some evidence exists for the role of MRI in guiding the interventional management of BPH. A retrospective analysis investigating 71 patients undergoing holmium laser enucleation of the prostate identified improved outcomes post-procedure for patients with thinner preoperative peripheral zone thickness (PZT) on MRI (PZT <9mm OR, 10.34; 95% CI, 3.45-31.39; $p < 0.001$).(21) However, in the field of prostatic artery embolization, another retrospective analysis of 71 patients with LUTS demonstrated no difference in improvement in IPSS or prostate volume loss based on BPH pattern (IPSS reduction post-procedure; $p = 0.60$ and volume reduction post-procedure; $p = 0.88$).(22)

Advancements in minimally invasive treatment options for BPH, such as Rezum, Aquablation, and Urolift, may also bring attention to the use of MRI in distinguishing patient selection for these novel procedures. With MRI's insight into zonal hypertrophy, prostate volume, and median lobe presence, treatment plans can be tailored to best suit patient-specific scenarios. For example, UroLift is most successful in patients with intermediate prostate volume (30–70ml) and lateral hypertrophy.(23) MRI and ultrasound can detect median lobe protrusion, which could contraindicate UroLift as a treatment option. According to Al-Singary et al., a prominent median lobe might prolapse into the bladder, obstructing and interfering with the UroLift's effectiveness of lateral lobe retraction.(24) However, Rukstalis et al. say otherwise and suggest that even with a protruding median lobe, UroLift's technique can be modified to ensure successful treatment.(25) Rezum targets lateral and median lobe hypertrophy of prostates no larger than 120ml,(26) which can be easily identified with MRI. Similarly, patients with larger prostates (80-150ml) or architecturally complex might benefit most from Aquablation done under image guidance or open subtotal resection.(27)

## CONCLUSION

In conclusion, MRI has emerged as a valuable tool in assessing, classifying, and managing BPH. Its detailed visualization of prostate anatomy, including zonal hypertrophy and volumetric analysis, enhances diagnostic precision and informs treatment decisions. Wasserman's classification system (**Table 2**) offers improved approaches to understanding BPH phenotypes, aiding symptom correlation and intervention outcomes. However, despite its advantages, MRI's routine use in BPH management is limited by its high cost and poor availability. Additionally, further work is required to standardise imaging protocols. Stabile A. et al. reviewed factors influencing MRI accuracy and highlighted that using an endorectal coil in mpMRI may improve anatomical detail. However, its use is limited

by already mentioned resource constraints. Also, radiologist experience enhances interpretation and reporting accuracy.(28) Overall, MRI has cemented its diagnostic role in Prostate cancer. Now, considering cases where malignancy is excluded, MRI is poised to play an increasingly pivotal role in the tailored management of BPH.(22)

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