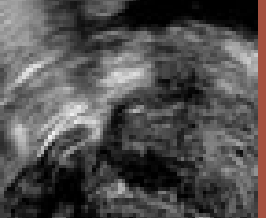

Prostate Cancer Imaging: Ultrasound, CT, MRI, and Nuclear Medicine Techniques

ABSTRACT

Prostate cancer is a common cancer in men worldwide, and early detection is key to improved patient outcomes. Diagnosis typically involves a combination of clinical examination, prostate-specific antigen blood testing, and imaging studies. Radiology plays an important role, aiding in treatment planning, confirming the diagnosis by directing biopsy, staging the patient, and following treatment course. Imaging modalities for prostate cancer diagnosis include ultrasound, CT, nuclear medicine, and MRI. While MRI is the most sensitive imaging modality, ultrasound is still the preferred modality for measuring the prostate volume. Prostate-specific membrane antigen PET imaging has shown to have superior sensitivity and specificity compared to conventional imaging modalities in the detection of prostate cancer, especially in the context of low PSA. Clinical pearls include performing ultrasound-guided biopsy under local anesthesia to improve patient comfort, and the use of fusion MRI and ultrasound images to facilitate MRI/TRUS fusion-guided biopsy.

KEYWORDS: Prostate cancer, imaging modalities, ultrasound, MRI, CT, PSMA PET.

Introduction:

Prostate cancer is the second most common cancer in men worldwide, with an estimated 1.4 million new cases diagnosed in 2020. The diagnosis of prostate cancer typically involves a combination of clinical examination with digital rectal examination, prostate-specific antigen (PSA) blood testing, and imaging studies. Radiology plays an important role, providing valuable information regarding the location and extent of the tumour, allowing confirmation of the diagnosis by directing biopsy, as well as aiding in treatment planning.

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Clinical History:

The clinical presentation of prostate cancer can vary widely, with many patients unfortunately remaining asymptomatic until the disease is advanced. Common clinical symptoms include urinary symptoms such as hesitancy, frequency, and urgency, as well as possible erectile dysfunction and back pain. A digital rectal examination (DRE) may reveal an abnormal prostate gland, such as the presence of a prostate nodule, and PSA blood testing is often used to screen for prostate cancer. Elevated PSA levels can indicate the presence of prostate cancer, but further imaging studies are usually necessary to confirm the diagnosis and to determine the extent of the disease. Discussing the controversies of prostate cancer screening is beyond the scope of this article.

Radiology Diagnosis:

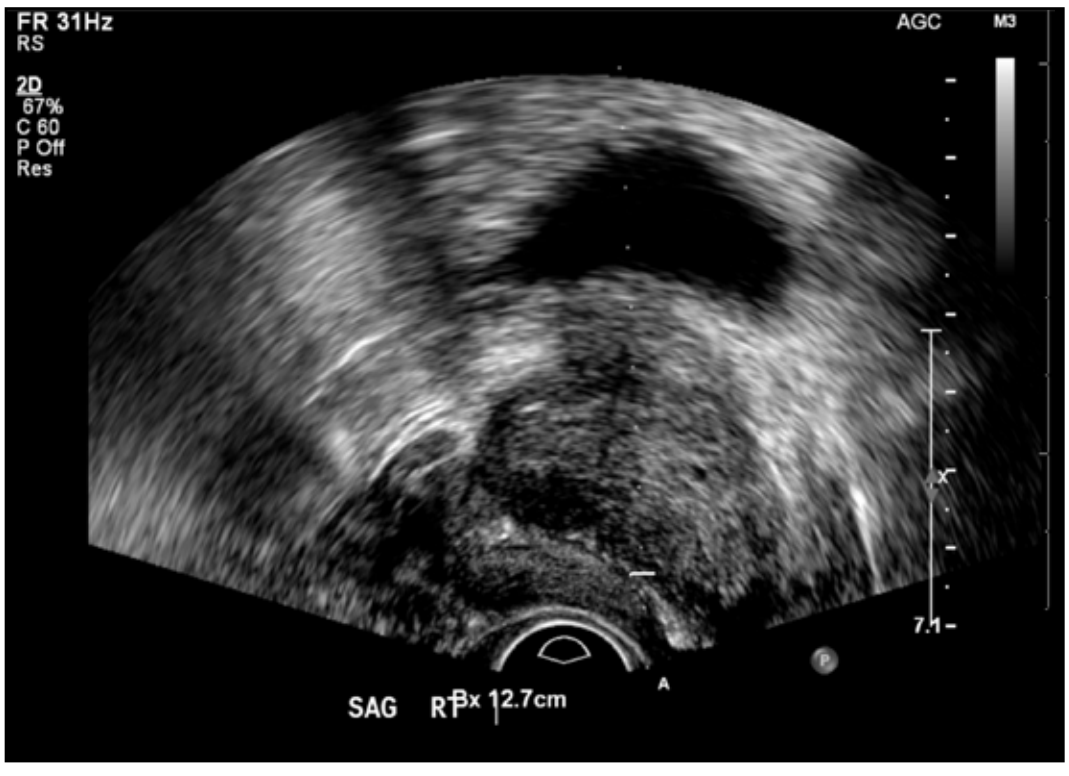
Imaging studies are an essential component of the diagnostic workup for prostate cancer. The most used imaging modalities include ultrasound, computed tomography (CT), nuclear medicine, and magnetic resonance imaging (MRI).

Ultrasound:

While MRI is more accurate than TRUS for determining the prostate volume, transrectal ultrasound (TRUS) is inexpensive, non-invasive, and almost as accurate as MRI. As a result, it is the preferred modality for measuring the prostate volume.

Ultrasound is also commonly used to guide prostate biopsy procedures, which involve taking approximately twelve x 18-gauge small tissue samples from the prostate gland for histological analysis. Ultrasound-guided biopsy is a minimally-invasive procedure that involves inserting a needle through the rectum via an ultrasound probe guide and into the prostate gland. The patient is treated with antibiotic prophylaxis before hand to decrease the risk of infection to approximately 1 in 100 patients. The ultrasound probe is used to visualize the prostate gland, allowing the physician to guide

Figure 1: A single image from an ultrasound-guided transrectal core biopsy of the same patient as the MRI.

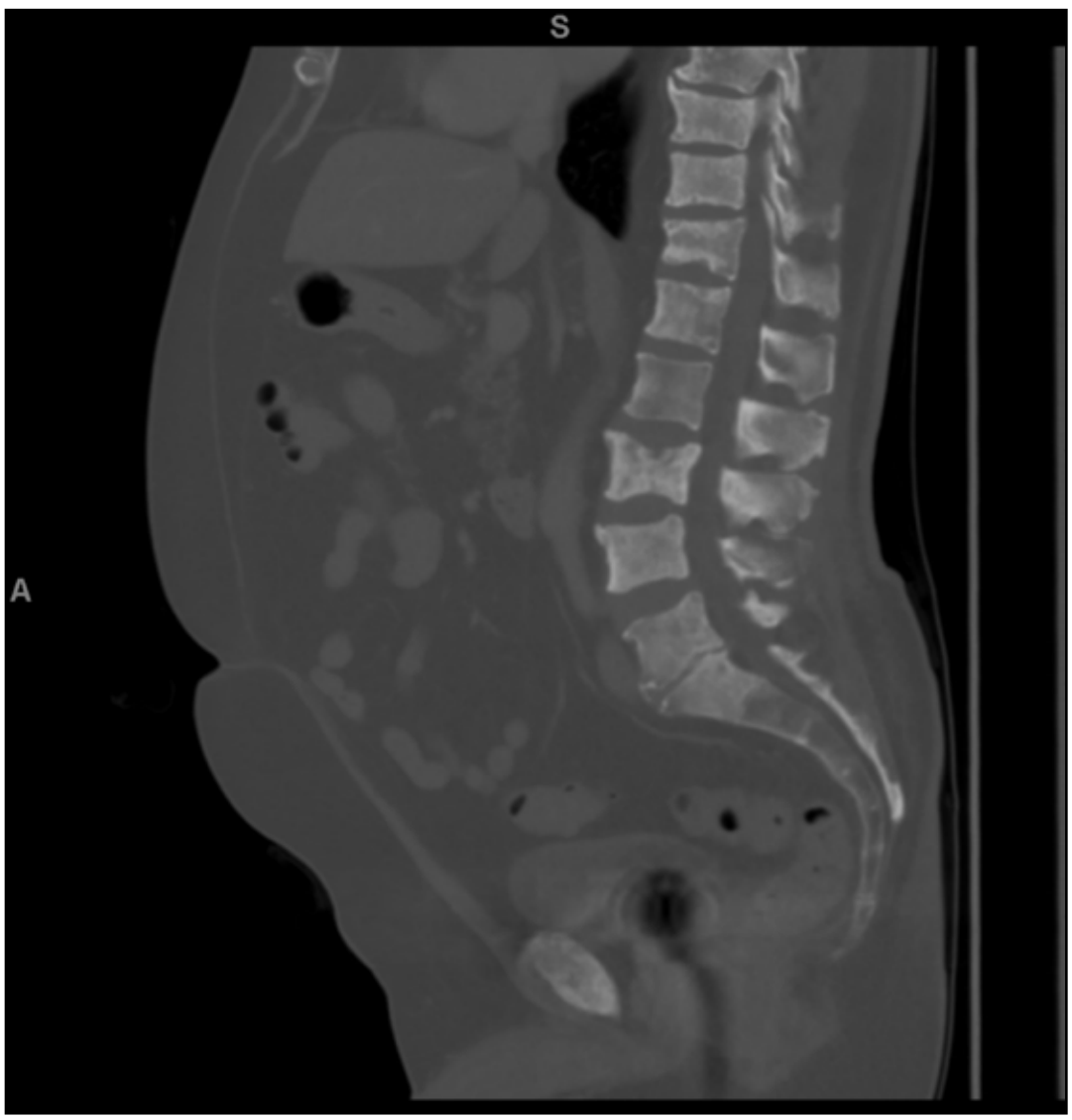


the needle to any area of interest. Ultrasound-guided biopsy is typically performed under local anesthesia, and patients are discharged the same day after a short period of observation in the radiology department, to ensure that there is no bleeding and that the patient can urinate normally.

CT Staging:

CT is a useful imaging modality for staging prostate cancer. This evaluates for the presence of metastatic disease. CT can detect enlarged lymph nodes in the pelvis and retroperitoneum, as well as bony metastases, which are often sclerotic. CT is also useful for evaluating the response to treatment, such as radiation therapy or chemotherapy. CT scans can be performed with or without intravenous contrast, and usually take less than 30 minutes.

Figure 2: A sagittal image of the CT of the abdomen and pelvis from the same patient as the bone scan demonstrates diffuse sclerotic bone metastasis with some mild compression fractures.



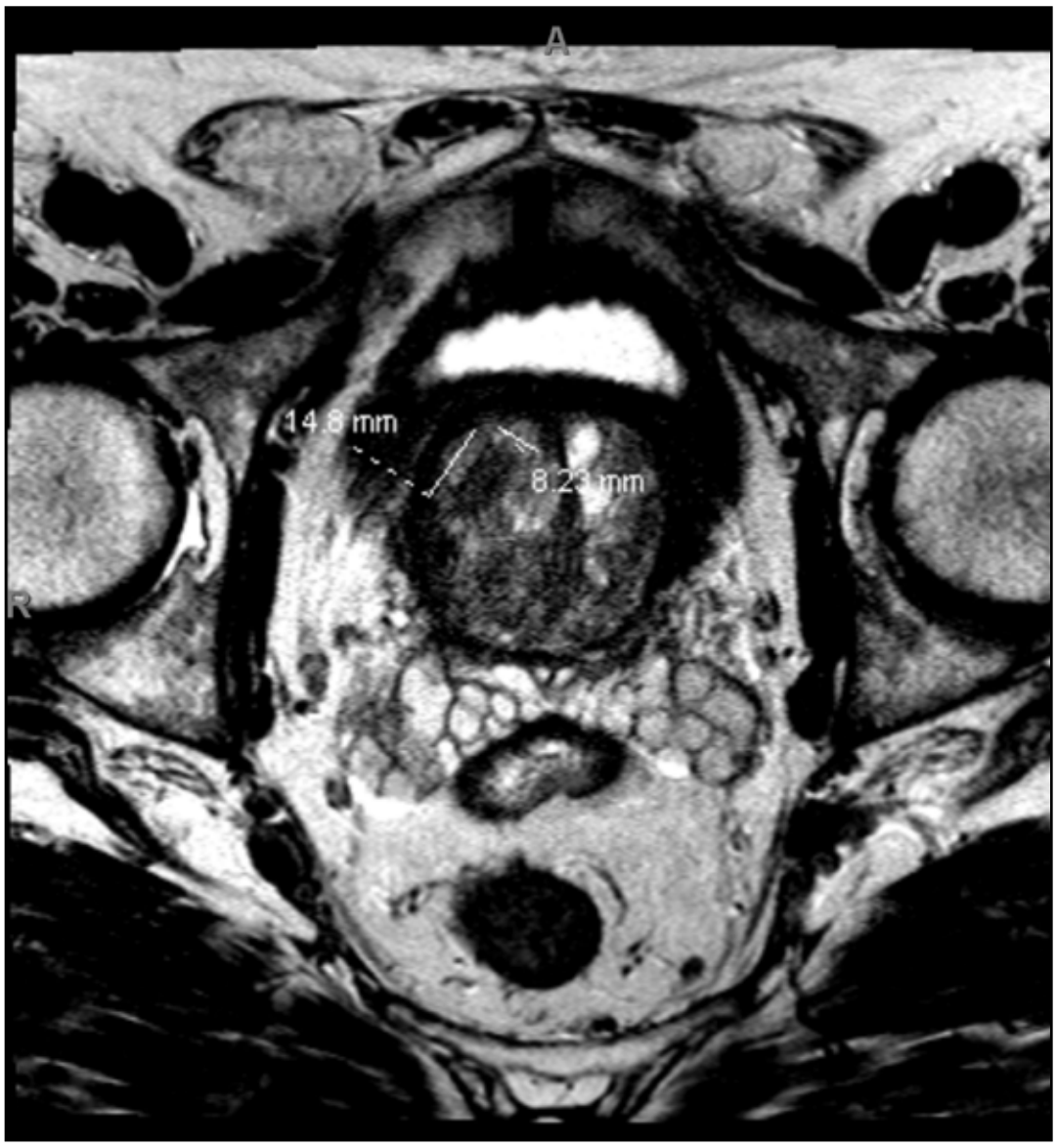
MRI Work-Up:

MRI is the most sensitive imaging modality for detecting prostate cancer as well as for evaluating the extent of the disease. MRI can potentially detect small tumours that may be missed on other imaging studies, as well as provide information about the tumour's location and size. MRI can also detect the presence of extra prostatic extension, which can help guide treatment planning. Prostate MRI typically involves the use of intravenous contrast agents, which can help distinguish between benign and malignant tissues.

MRI has also been used to identify suspicious areas in the prostate which could undergo ultrasound-guided biopsy. MRI and ultrasound images can be fused to facilitate this procedure with MRI/TRUS fusion-guided biopsy.

MRI-guided biopsy with in-bore MRI targeting is a relatively new technique that involves using MRI instead of ultrasound to guide biopsy procedures, which can potentially improve accuracy

Figure 3: Axial T2 weighted image of the prostate demonstrates a right-sided anterior transition zone prostate lesion at the level of the base of the prostate measuring 15 by 8 by 12 millimeters. This is a T2 hypointense lesion with spiculated, irregular margins demonstrating no restricted diffusion and no locally invasive features (PIRADS 5). This could be targeted under transrectal ultrasound biopsy as in Figure 1.



and reduce the need for repeat biopsies, but has limited availability at present.

Nuclear Medicine and Molecular Imaging:

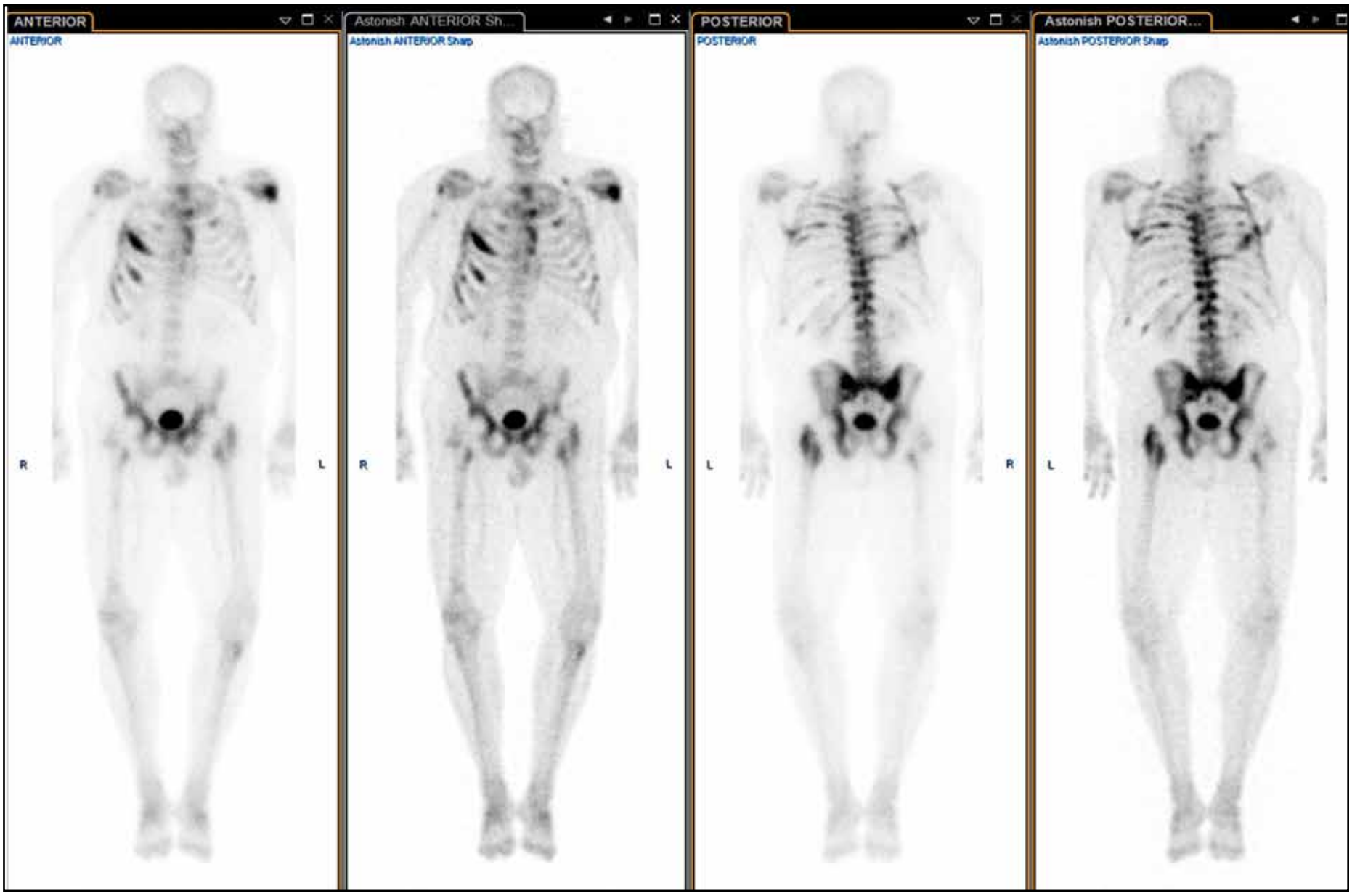
Nuclear medicine is a branch of medical imaging that uses small amounts of radioactive isotopes (radiopharmaceuticals) to diagnose and treat various diseases. Radiopharmaceuticals emit gamma rays that can be detected by specialized cameras, allowing physicians to visualize the distribution and function of various organs and tissues in the body.

A very common nuclear medicine imaging technique used in prostate cancer diagnosis is bone scintigraphy (bone scan) which uses a radiopharmaceutical (Technetium 99 methylene diphosphonate) that is taken up by metabolizing bone. Since prostate cancer very commonly metastasizes to bone and is metabolically active, bone scintigraphy can detect bone metastases, often before they become symptomatic.

A newer and more targeted nuclear medicine technique for prostate cancer diagnosis is prostate-specific membrane antigen (PSMA) positron emission tomography (PET) imaging. PSMA is a protein expressed on the surface of prostate cancer cells, and its expression increases as the disease progresses. PSMA PET imaging uses a radiolabeled PSMA-specific ligand that binds to PSMA on the surface of prostate cancer cells, allowing visualization of those cells throughout the body.

PSMA PET imaging has shown to have superior sensitivity and specificity compared to conventional imaging modalities in the detection of prostate cancer, especially in patients with low prostate-specific antigen (PSA) levels and possible biochemical recurrence after initial treatment. A recent meta-analysis of 52 stud-

Figure 4: Nuclear medicine bone scan. The patient with prostate cancer was injected with technetium pertechnetate. Subsequent imaging demonstrates extensive metastatic lesions with multiple foci of increased activity in the skeleton, including within the ribs, spine, pelvis, proximal femora, as well as the proximal humeri.



ies with 5,336 patients showed that PSMA PET imaging had a pooled sensitivity of 85% and a specificity of 96% in the detection of prostate cancer. PSMA PET imaging also has the potential to identify sites of metastatic disease, which can guide treatment decisions and improve patient outcomes, but has limited availability at present.

Conclusion:

Diagnostic imaging is a key component of the diagnostic and treatment algorithm for prostate cancer. Imaging studies, including ultrasound, CT, nuclear medicine, and MRI, provide valuable information about the location and extent of the tumour, aid in biopsy, treatment planning, and in the monitoring of disease progression. Ultrasound-guided biopsy and MRI-guided biopsy are minimally-invasive techniques that improve the accuracy of the biopsy procedure. With further advances in imaging technology, radiology will continue to play an important role in the diagnosis and management of prostate cancer.

SUMMARY OF KEY POINTS

Radiology plays a crucial role in prostate cancer diagnosis, aiding in treatment planning, confirming the diagnosis, and directing biopsy.

Imaging modalities for prostate cancer diagnosis include ultrasound, CT, nuclear medicine, and MRI.

MRI is the most sensitive conventional imaging modality for detecting prostate cancer.

Prostate-specific membrane antigen PET imaging has been shown to have superior sensitivity and specificity compared to conventional imaging modalities in the detection of prostate cancer, especially in context of low PSA.

Ultrasound is still the preferred modality for measuring the prostate volume.

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CLINICAL PEARLS

Ultrasound-guided biopsy is a minimally-invasive procedure that involves inserting a needle through the rectum via an ultrasound probe guide and into the prostate gland. It is performed under local anesthesia and patients are discharged the same day after a short period of observation in the radiology department.

MRI and ultrasound images can be fused to facilitate MRI/TRUS fusion-guided biopsy, which improves the accuracy of the biopsy procedure.

The use of antibiotic prophylaxis before ultrasound-guided biopsy decreases the risk of infection to approximately 1 in 100 patients.

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