Multiparametric MR Imaging for Prostate Cancer

- Relative indications for Prostate MRI
  - For local staging of prostate cancer that has already been diagnosed
  - When prostate cancer is suspected despite negative transrectal US and biopsy findings, and
  - To detect local recurrence after definitive treatment of prostate cancer

- Optimal MR images of the prostate are acquired with the combined use of an endorectal coil and a pelvic phased-array coil

- MRI is more sensitive for the detection of tumors in the peripheral zone than transitional or central zones; it can also detect extracapsular extension of tumors and seminal vesicle invasion

- Diffusion weighted MRI (DWI), and dynamic contrast enhancement (DCE) MRI increase the sensitivity and specificity of prostate cancer detection over that of T2 weighted imaging alone; the combination of these techniques is referred to as multiparametric MR imaging

Prostate cancer accounts for twenty-five percent of all male cancers in the United States and it is estimated that there are over 190,000 new cases and over 27,000 deaths a year from this disease. Because of the use of prostate specific antigen (PSA) testing, 91% of the new cases are detected when the disease is at a local or regional stage, when the 5-year survival rate is above 95%. However, management of prostate cancer is challenging because the disease has variable clinical and pathologic behavior and there are a number of treatment options to choose from.

Most prostate cancers are diagnosed with the aid of transrectal ultrasound and ultrasound-guided biopsy. However, up to 40% of prostate cancers are isoechoic with the surrounding tissue, limiting their detection, and the finding of a hypoechoic area within the peripheral zone is not specific. Therefore, random, systematic biopsy samples are obtained under ultrasound guidance from multiple sites within the prostate. Sampling errors are common and a single biopsy session has a sensitivity of 70-80% for the detection of cancer.

The role of CT in detection and staging of prostate cancer is limited because of poor soft tissue contrast. CT is only recommended when the patient’s PSA level is >20 ng/ml, Gleason score >7, and/or clinical tumor stage is T3 or higher for the purpose of nodal staging. The criterion for positive nodal disease on CT is based on node size (>1 cm diameter) and nodal enlargement due to metastases occurs relatively late in the progression of prostate cancer.

![Figure 1. Axial T2 weighted image in a patient with advanced local stage prostate cancer. On the axial image, the right peripheral zone tumor is seen as a hypointense region in contrast to the normal appearing hyperintense left peripheral zone, with tumor also showing extracapsular extension (arrow).](image-url)
The Role of MRI
MRI is recommended for staging of prostate cancer after diagnosis. MRI can determine whether there is extracapsular extension of tumors, involvement of the seminal vesicles, and/or whether there is enlargement of the lymph nodes due to prostate cancer spread to the lymph nodes. In cases in which prostate cancer is suspected from continuing elevation of prostate specific antigen (PSA) despite negative transrectal ultrasound and multiple biopsies, MRI may be useful for the detection of prostate tumors. In addition, MRI is indicated if PSA levels rise after definitive treatment for prostate cancer in order to assess for local disease recurrence, nodal involvement, and metastases to bone in the pelvis.

Patient Preparation
Ideally, prostate MRI should not be performed until at least six weeks after biopsy because hemorrhage may be present, which will interfere with accurate interpretation. Patients are asked to avoid sexual activity for three days prior to the prostate MR examination, because ejaculation distends the seminal vesicles and can make image interpretation more difficult. They should eat no more than a light meal and should avoid caffeine for four hours prior to the examination. Patients should self-administer a Fleet enema in the morning of the examination or two hours prior to the examination because optimal MRI requires the use of an endorectal coil in conjunction with a phased array pelvic coil.

The Prostate MRI Examination
The current MRI examination protocol at Mass General Imaging includes acquisition of T1- and T2-weighted axial images of the pelvic region, including the pelvic sidewalls, and small field of view axial, coronal, and sagittal views of the prostate region. The small field of view images have sub-millimeter resolution and are superior for local staging and can increase the sensitivity of prostate tumor detection. In addition, diffusion weighted imaging (DWI) and dynamic contrast enhanced (DCE) MRI, are performed to increase sensitivity of MR examinations.

In T2-weighted images, tumors appear as low signal intensity areas (Figures 1, 2, and 3A), which are seen more readily in the peripheral zone because it normally has higher signal intensity than the transitional and central zones (which are indistinguishable on MRI). The sensitivity of T2 imaging has been estimated to be 85.3% with a positive predictive value of 92.6% for tumors >1 cm, but only 26.2% and 75.9% for tumors <1 cm. MRI also permits the detection of extracapsular extension of tumors and involvement of the seminal vesicles (Figure 2). Extracapsular extension can be detected when there is asymmetry or envelopment of the neurovascular bundle, an irregular or spiculated margin, an angulated margin of the prostate gland, capsular retraction, a tumor-capsule interface >1 cm, or a breech of the capsule with evidence of tumor extension. Seminal vesicle involvement can be detected from the observation of disruption of the normal architecture of the seminal vesicle, low intensity regions within the seminal vesicle or ejaculatory ducts, obliteration of the angle between the prostate gland and seminal vesicle, or demonstration of direct tumor extension into and around the seminal vesicle.

DWI increases sensitivity of tumor detection because of the differences in the random Brownian motion of water, or diffusion. The normal prostate gland has an extensive branching configuration that allows water to move quite freely, whereas tumors have high cellularity and lack interstitial spaces, resulting in more restricted diffusion. Therefore, tumors appear as high signal regions in DWI images (Figure 3B) while those that map the apparent diffusion coefficient (ADC) show tumors as darker regions (Figure 3C). Adding DWI to T2 imaging has been shown to increase the sensitivity of detection from 50-54% to 73.2-81% and the positive predictive value from 65.7% to 74.8%.

DCE MRI takes advantage of differences in the vascularity of tumors and normal tissues. Like other tumors, prostate cancers induce angiogenesis, the formation of new blood vessels that have higher permeability than normal. As a result, both uptake and washout of contrast material is more rapid in tumor than in normal tissue. Specialized software is used to calculate features such as time to peak enhancement, relative peak enhancement, and washout rate in individual image voxels, the results of which are displayed as color-coded images, which draw attention to tumors (Figure 3D). DCE MRI is considered to be the most sensitive sequence for identification and staging of organ-confined peripheral zone or transition zone cancers while the addition of DWI adds to the sensitivity without loss of specificity.
Figure 3. Axial Multiparametric MR Images. A) T2-weighted, B) diffusion weighted (DWI), C) apparent diffusion coefficient (ADC) and D) dynamic contrast enhanced (DCE) images of a patient with prostate cancer. The tumor appears dark on the axial T2-weighted image (arrow); the corresponding area shows restricted diffusion on the DWI and ADC images as well as abnormal contrast enhancement on the DCE axial image (as evident from abnormal red color coding of the tumor).

Scheduling
MRI examinations are performed on the main MGH campus, MassGeneral West Imaging, Waltham, and MassGeneral Imaging, Chelsea. They may be scheduled online through Radiology Order Entry (http://mghroe) or by calling 617-724-9729(XRAY).

Further Information
For further questions on prostate MRI, please contact Mukesh Harisinghani, M.D., Director of Abdominal MRI, Abdominal Imaging and Intervention, Department of Radiology, Massachusetts General Hospital at 617-726-8396.

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References


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