Magnetic Resonance Imaging of Prostate Cancer

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Introduction

With a total of 192,280 new cases predicted for 2009, prostate cancer (PC) now accounts for 25% of all new male cancers diagnosed in the USA [1]. Furthermore, in their lifetime, one in six men will be clinically diagnosed with PC, although many more will be found to have histological evidence of PC at autopsy [2-4]. Presently, approximately one in ten men will die of PC [5, 6]. The ever-aging population and more widespread use of the blood prostate-specific antigen (PSA) test [7, 8], as well as the tendency to apply lower cut-off levels for this test [9], will further increase the diagnosis of PC [10].

An elevated PSA level, abnormal changes in PSA level and dynamics (such as PSA velocity or doubling time), or an abnormal digital rectal examination are biological indicators signaling an increased risk of PC. With the improvement and wider range of curative therapies, the detection and subsequent exact localization of PC have become increasingly important because of their influence on treatment strategy [11, 12], in particular, laparoscopic (robotic) radical prostatectomy and intensity-modulated radiation therapy (IMRT) [13]. The urologist’s inability to palpate the operating field during laparoscopic surgery makes it even more crucial to precisely localize the cancer. Moreover, the urologist must determine whether the cancer is near a neurovascular bundle since this affects the decision of whether or not to perform nerve-sparing prostatectomy [14]. IMRT also necessitates accurate PC localization. While the prostate receives a standard dose of radiation, a higher (boost) dose can be given to dominant intraprostatic lesion(s) since it is those lesions that regularly appear to be the sites of recurrent disease [15]. Furthermore, precision radiation dosimetry will decrease radiation complications, particularly rectal wall toxicity [16], thereby likely diminishing the development of post-radiation rectal cancer [17].

In order to determine the optimal treatment for each patient, it is necessary to thoroughly evaluate him and to determine the cancer’s characteristics. In this regard, laboratory values (PSA level and dynamics), the results of the digital rectal examination (clinical staging), and histopathological prostatic biopsy findings (Gleason score) are important aspects. Additionally, however, magnetic resonance imaging (MRI) can play an important role in detecting and localizing those areas most reflective of the actual aggressiveness of the cancer. This directly influences patient assessment and may lead to important changes in treatment strategy, which can mean the difference between treatment success and failure.

In the mid-1980s, the first prostate MRI examinations were performed. Since that time MRI has evolved from a promising technique into a mature imaging modality for PC imaging [18, 19]. Beside anatomical information, MRI provides functional tissue-characteristic information. Multiparametric MRI consists of a combination of anatomical T2-weighted imaging and functional MRI techniques such as dynamic contrast-enhanced MRI (DCE-MRI), diffusion-weighted imaging (DWI), and 1H MR-spectroscopic imaging (MRSI). Within a multiparametric MRI examination the relative value of its component techniques differ. In addition to T2-weighted MRI, which mainly assesses anatomy, MRSI [20] can add specificity for PC detection, while DCE-MRI [21] and DWI [22] are both very sensitive and very specific.

The clinical challenges in the work-up of patients with either suspected or proven PC include detection, localization, TNM staging, determination of cancer aggressiveness, follow-up of patients in active surveillance protocols, and determination of the site and extent of cancer recurrence after therapy.

This chapter reviews the MRI anatomy of the prostate and the basic MRI techniques that can be applied in PC, and discusses the clinical role of this imaging modality. At the end of this chapter, three clinically applicable protocols are provided.

Magnetic Resonance Imaging: Anatomy

In order to effectively apply the various MRI techniques, it is important to first understand the prostate’s normal anatomy and its intrinsic age-related changes. The superior part of the prostate is called the base while its most caudal part is referred to as the apex, analogous to the
anatomy of the heart. The prostate consists of three zones: (1) the peripheral zone, located posteriorly and caudally at its middle portion; (2) the transition zone, located interiorly, around the urethra; and (3) the central zone, which is posterior and superior to the transition zone. Ventral to the prostate is the anterior fibromuscular stroma.

In aging, an important frequent change in prostate zonal anatomy occurs, namely, the transition zone becomes hypertrophic (as in benign prostatic hyperplasia), thus compressing the central gland. Consequently, most men who are imaged for prostate cancer have only two identifiable compartments in the prostate, the hyperplastic transition zone surrounded by the peripheral zone (Fig. 1).

Up to 70-80% of PCs are located in the peripheral zone [23], with an overall analysis of these cancers showing that they are homogeneously distributed across the entire zone [24]. Additionally, over half of the prostates examined contained two or more distinct cancer foci [25]. Nevertheless, while up to 20-52% of all PCs originate in the transition zone, only a small percentage (3.6-25%) of these cancers occur solely in that zone [24, 26], and many such patients will have foci of concurrent peripheral-zone cancer [23, 27, 28]. Thus, a solitary transition zone cancer is rare in the general PC population.

Magnetic Resonance Techniques and Their Role in Detection and Localization

For evaluation of the prostate, anatomical (high-resolution) MRI can be combined with functional and metabolic information. DWI, dynamic MRI, and MRSI provide information about the motion of free water molecules and thus about cellular density (neo-)vascularization and metabolism, respectively. These different types of information can be combined into a multiparametric MRI examination.

T2-Weighted Imaging

Compared to CT computed tomography (CT) scanning, MRI has a high soft-tissue contrast resolution (Fig. 2). The use of a disposable endorectal coil combined with other external coils at 1.5 Tesla (T) increases the soft-tissue contrast significantly and is now the accepted clinical standard for MRI of the prostate, when information about submillimeter extracapsular penetration is of clinical importance [29]. A drawback is the extra time required for inserting and checking the position of the endorectal coil as well as the substantial expense and patient discomfort.