Clinicopathologic Significance of High Signal Intensity on Diffusion-weighted MR Imaging in the Ureter, Urethra, Prostate and Bone of Patients with Bladder Cancer

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Rationale and Objectives: The aim of this study was to determine the clinicopathologic significance of high-intensity areas in the ureter, urethra, prostate, and bone incidentally found on diffusion-weighted magnetic resonance imaging (DWI) for the staging of bladder cancer.

Materials and Methods: Axial and sagittal DWI and T2-weighted imaging of the pelvis were evaluated in 157 patients with bladder cancer. Two observers assessed T2-weighted imaging with DWI independently. The observers pointed out 67 areas showing abnormal high signal intensity on DWI in the ureter (n = 17), urethra (n = 8), prostate (n = 20), and bone (n = 22). Of the 67 high-intensity areas, 33 lesions were confirmed histopathologically (ureter, n = 10; urethra, n = 7; prostate, n = 16), and 22 bone lesions were diagnosed using T1-weighted imaging and follow-up computed tomography. Thus, 55 lesions were evaluable for correlation with DWI findings.

Results: Of the 55 high-intensity areas, 28 (53%) were synchronous or metastatic urothelial cancer or invasion of urothelial cancer. The remaining 27 (47%) were a ureteral clot in one, a ureteral stone granuloma in one, prostatic cancer in six, granulomatous prostatitis in three, and normal red bone marrow in 16.

Conclusions: DWI is useful to comprehend the extent of bladder cancer and to detect incidentally coexisting diseases. Other imaging, endoscopic, and clinical findings would be useful to reduce false positivity.

Key Words: Bladder cancer; diffusion magnetic resonance imaging; cancer staging.

In recent years, the usefulness of diffusion-weighted imaging (DWI) to detect various cancers, including those of the liver, breast, prostate, uterus, colorectum, and bone, has been reported (1–6). The usefulness of DWI to detect bladder cancer and determine the tumor stage has also been reported; the apparent diffusion coefficient (ADC) value of bladder cancer is low, and cancer shows high signal intensity (SI) on DWI (7–9). When interpreting pelvic DWI to determine the tumor stage of bladder cancer, abnormal high intensity is often found outside the bladder (eg, in the prostate, ureter, urethra, and bone). DWI high intensity may represent invasion or metastasis of bladder cancer, but it has not yet been clarified whether other malignant or nonmalignant lesions can also show such high intensity. Because the strategy for treating bladder cancer changes with the tumor site, extent, and stage, clarifying the clinical significance of such high-intensity areas would be very important. The purpose of this study was to evaluate the clinicopathologic significance of high-intensity areas in the prostate, ureter, urethra, or bone incidentally found on pelvic DWI performed for the purpose of staging bladder cancer.

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MATERIALS AND METHODS

Patient Population

The subjects of this study were 157 patients with bladder cancer undergoing pelvic magnetic resonance imaging (MRI) to determine the tumor stage and repeat computed

tomography (CT) of the pelvis to evaluate the node and metastasis stages between August 2006 and September 2009. All pelvic MRI studies included T2-weighted imaging (T2WI) and DWI. All patients underwent pelvic CT both at initial diagnosis and 3 to 9 months later. There were 118 men and 39 women aged 38 to 91 years (mean age, 71 years). Two abdominal radiologists reviewed 157 MRI studies and identified 67 areas that showed abnormally high SI in the ureter, urethra, prostate, or bone on DWI in 56 patients, on the basis of criteria described later. Of the patients, 29 underwent surgical intervention for areas showing high SI on DWI, including one-sided nephroureterectomy in nine, cystoprostatectomy in nine, prostatic biopsy in eight, ureteral biopsy in one, and urethral biopsy in two. From these surgical specimens, 33 high-intensity areas on DWI were histopathologically evaluable. One radiologist interpreted T1-weighted imaging (T1WI) and both computed tomographic images to diagnose 22 bony lesions on the basis of criteria described later. Finally, 55 areas in 45 patients (36 men, nine women; age range, 38–91 years; mean age, 71 years) were evaluable for correlation with DWI findings. The local institutional review board approved this retrospective study, and the requirement for patient informed consent was waived.

MRI Protocol

To moderately distend the bladder, all patients were prohibited from urination for about 1 hour before examination. To reduce bowel motion, 78 (50%) and 18 (11%) of the 157 patients received 20 mg scopolamine butylbromide (Mitsubishi Tanabe Pharma, Osaka, Japan) or 1 mg glucagon G novo (Novo Nordisk Pharma, Tokyo, Japan), respectively, before examination. The remaining 61 patients (39%) had contraindications to the drugs or refused antispasmodic agents.

MRI was performed using a 1.5-T scanner (Gyroscan Intera; Philips Medical Systems, Best, The Netherlands) with a maximum amplitude of the gradients of 33 mT/m and a maximum slew rate of 180 T/m/s, equipped with a radiofrequency coil (Quadrature body coil) and a phased-array five-channel sensitivity encoding cardiac coil. Turbo spin-echo T2WI and DWI were performed for axial and sagittal sections in all patients. Parameters for T2WI were as follows: repetition time, 4390 to 5424 ms; echo time, 120 ms; matrix size, 256 × 189; slice thickness, 4 mm; slice gap, 0.4 mm; number of slices, 19 to 24; acquisition time, 91 to 117 seconds; field of view, 23 cm; and sensitivity encoding factor, 1.5. Parameters for DWI were as follows: single-shot spin-echo echo-planar sequence with chemical shift selective fat-suppression techniques; b = 0 and 1000 s/mm^2 (with diffusion-weighted gradients applied in three orthogonal directions); repetition time, 2790 to 4560 ms; echo time, 88 ms; matrix size, 128 × 109; slice thickness, 4 mm; slice gap, 0.4 mm; field of view, 25 to 33 cm; number of slices, 19 to 24; number of signals acquired, 14; sensitivity encoding factor, 2; and acquisition time, 146 to 196 seconds. ADC maps were generated from DWI with b values of 0 and 1000 s/mm^2. For transverse T2WI and DWI, the scan range was from the symphysis pubis to the top of the bladder. For sagittal T2WI and DWI, the bladder was scanned with two to four extra slices. In these scan ranges, the sacral, pubic, and ischial bones were scanned completely, and the iliac bones were scanned partially. Spin-echo T1WI was also performed for axial sections in all patients. Parameters for T1WI were as follows: repetition time, 526 ms; echo time, 10 ms; matrix size, 352 × 245; slice thickness, 8 mm; slice gap, 0.8 mm; number of slices, 19 to 24; acquisition time, 99 to 117 seconds; and field of view, 35 cm. The total examination time was 573 to 743 seconds.

DWI Interpretation

All magnetic resonance image sets were reviewed in random order independently by two radiologists with 22 and 16 years of experience. They were notified that MRI had been performed to evaluate the stage of bladder cancer but were blinded to all other clinical information. Two observers initially assessed DWI and then referred to T2WI to identify the location of lesions after coregistering the two images using a workstation (Centricity RA1000; GE Medical Systems, Barrington, IL). Lymph nodes were not evaluated, because they show high intensity regardless of the presence of metastasis. Bowel walls, which often show high intensity because of susceptibility artifacts from bowel gas, were also excluded from evaluation. It has been reported that the normal ADC value of the transitional zone is lower than that of the peripheral zone and surrounding tissues, and the transitional zone shows relatively high SI on DWI (10). When interpreting DWI of the prostate, therefore, an isolated nodule in the prostate or bladder mass extending to the prostate and showing higher SI than the transitional zone was regarded as positive to reduce false positivity. Higher intensity than the gluteal muscle was regarded as a positive finding for diagnosing lesions in the ureter, urethra, and bone. The ADC values were not evaluated in this study, because there was a wide overlap between benign and malignant lesions in a preliminary analysis. Any discrepancy between the two radiologists was resolved by reaching a consensus. The longest diameter of an enhancing lesion and the diameter perpendicular to it were measured after appropriate magnification on the workstation by a radiologist.

Diagnostic Criteria

Prostatic, ureteral, and urethral lesions were confirmed histopathologically from the specimens obtained at surgery. Because no surgical procedure was performed for bone lesions, a low-intensity mass on T1WI that showed osteolytic or osteoblastic lesions on unenhanced CT was regarded as bone metastasis (6,11). When bone metastasis was judged to be absent, the finding was confirmed by follow-up CT in all patients. The observer with 22 years of experience interpreted