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Review article

Primary staging of urinary bladder carcinoma: the role of MRI and a comparison with CT

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Abstract. Since the introduction, pelvic MRI has been considered the best non-invasive technique for primary staging of urinary bladder cancer. Before using MRI an understanding of normal and pathological MR images of the urinary bladder is essential. This review therefore describes the MR anatomy of the urinary bladder as well as the appearances of carcinoma. MRI plays an important clinical role in staging the primary tumour. In superficial tumours, clinical staging, which includes transurethral biopsy, is the best technique. For invasive tumours, MRI is superior to other techniques such as CT scanning, transvesical ultrasonography and clinical staging. A limitation of both MRI and CT scanning is their inability to recognize minimal tumour growth in the muscle layer of the bladder wall, or to differentiate between post-transurethral resection oedema and tumour. Therefore, in all patients with urinary bladder cancer staging should preferably start with MRI followed by clinical staging. Unfortunately, however, because of the high cost of this strategy, MRI has to be reserved for staging deeply invasive and superficial poorly differentiated tumours.

Key words: MRI – Staging – Urinary bladder cancer

Introduction

Carcinoma of the urinary bladder is, after prostate cancer, the most common malignant tumour of the urinary tract in males and females, and accounts for 2 % of all malignancies. In 1993 in the United States 52300 cases were registered, and this number is expected to increase with ageing of the population. The mortality in 1993 was 9900. Bladder cancer is predominantly seen in elderly men. The male : female ratio is 4 : 1.

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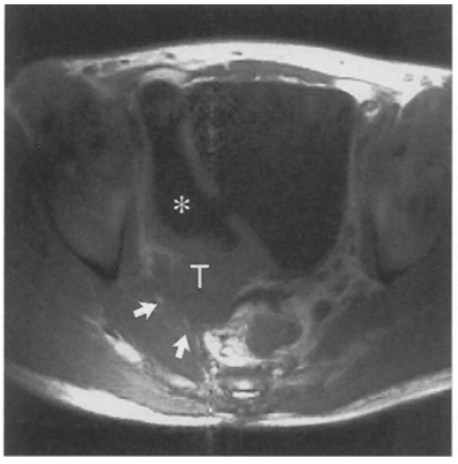
About 90 % of urinary malignancies are transitional cell carcinoma, 5–10 % consist of squamous cell and adenocarcinoma, and the remainder include predominantly sarcomas, and metastasis from other primary tumours. About two thirds of tumours are superficial and are usually papillary. One third of the tumours show infiltration in or beyond the muscular layer of the bladder wall.

The treatment and prognosis are largely determined by the depth of tumour infiltration, the degree of lymph node and distant metastases, and the histological tumour type [1]. Therefore, exact staging is imperative.

Since the introduction of pelvic MRI in 1983, several reports have attested to the superiority of this technique for staging urinary bladder carcinoma [2–16]. The appearance on MR images of the normal and pathological urinary bladder will be discussed. The role of MRI in primary staging of this disease will be reviewed and illustrated. Preoperative recognition of pelvic side wall infiltration and metastases is a very important clinical aspect of this technique, because patients with such a tumour extension are unsuitable for curative cystectomy.

MR anatomy of urinary bladder and bladder carcinoma

MRI provides an excellent insight into the anatomy and pathology of the urinary bladder. The bladder wall consists of four layers: the mucosa or epithelium, the lamina propria or subepithelial connective tissue, the muscle layer, and the serosa. On proton-density weighted images, the mucosa and the lamina propria can sometimes be distinguished from the muscle layer, because the mucosa and lamina propria have a higher signal intensity [12, 16–20]. Even on MR images of a cystectomy specimen the mucosa and lamina propria cannot be separated [12]. The muscle layer consists of bundles of smooth muscle tissue, and has an intermediate signal intensity, equal to skeletal muscle, on T1-weighted images and a low signal intensity on T2-weighted images. According to Narumi et al. [21] the muscular wall consists of two layers, the



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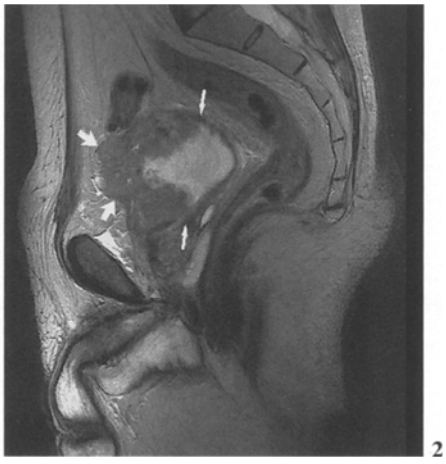

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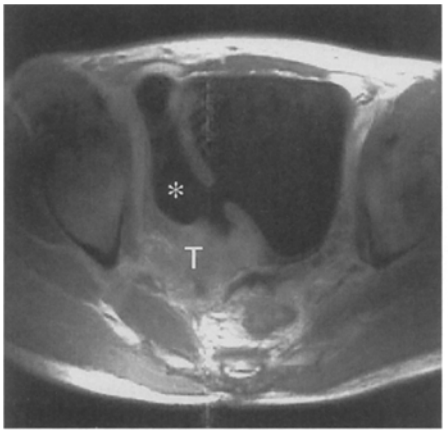
Fig. 1. T1-weighted 2D FLASH image in the axial plane in a patient with giant bladder diverticulum *(asterisk)* and infiltrative tumour. Both tumour *(T)* and bladder wall have intermediate signal intensity, equal to that of muscle. Tumour can be delineated from low signal urine, and high signal perivesical fat. There is infiltration of the pelvic side wall on the right side *(arrows)*

Fig. 2. Sagittal high-resolution T2-weighted turbo-SE image (1024 × 1024 matrix) shows tumour with invasion in perivesical fat on the ventral side *(large arrows)*. The low signal intensity bladder wall is disrupted at the tumour site *(small arrows)*, arguing for deep muscle invasion



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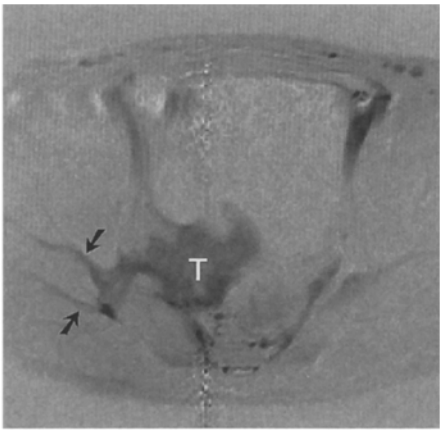

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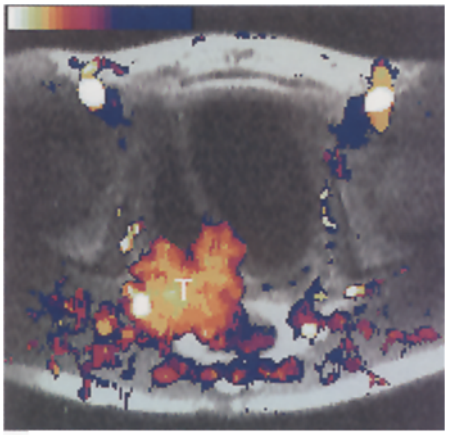

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Fig. 3. a Axial T1-weighted postcontrast 2D FLASH image (same patient as Fig. 1, same parameters) shows enhancement of tumour. **b** Subtracted image from Fig. 1 and Fig. 3a shows greater tumour enhancement, displayed as black, compared with surrounding tissues (e.g. bladder wall). On this image infiltration between the muscles can also be appreciated *(arrows)*. **c** Time image shows quantitatively the start of tumour enhancement relative to the start of arterial enhancement (femoral artery). Each colour represents 1.2 s. Tumour starts to enhance 2.4 s after arterial enhancement, whereas non-malignant structures start to enhance after 10.8 s

muscle fibres of the outer layer being looser and interspersed with loose collagen fibres, blood vessels and adipose tissue. Therefore, on T2-weighted in vitro MR images the signal intensity of the outer bladder wall is higher. However, these findings have only been reported on in vivo MR images in cases of bladder wall hypertrophy. At the site of the trigone, the wall consists of a extra triangular layer of muscle. Bundles from this layer link the ureteric ostia, forming the inter-ureteric ridge. The serosa is not a *bona fide* layer, since the term serosa is synonymous with peritoneal covering, which, in fact, is in contact with the bladder only at the dome – just a small part of the entire bladder surface. This "layer" is too thin to be recognized on MR images.

On T1-weighted images the urine has a low signal intensity, whereas the perivesical fat has a high signal intensity. As urinary bladder carcinomas have an intermediate signal intensity, equal to that of muscle, T1-weighted images are used for determination of tumour infiltration into the perivesical fat (Fig. 1), and to show the endoluminal tumour component. T1-weighted images are also most suitable for imaging lymph nodes, which have a signal intensity lower than the surrounding fatty tissue. However, normal and abnormal lymph nodes show no difference in signal intensity on these images. Therefore, a normal lymph node on MRI can be defined only by its size. Bone marrow metastases have a signal intensity equal to that of the primary tumour, and thus are best recognized on T1-weighted images, on which there is a good contrast between these metastases and the surrounding fatty bone marrow.

On T2-weighted images the perivesical fat has a low or a high signal intensity, depending on the type of sequence used. Urine has a high signal intensity. The zonal anatomy of prostate or uterus and vagina can be well recognized on these images. The tumour has an intermediate signal intensity, higher than that of bladder wall or late fibrosis and lower than that of urine. These images are used for determination of the depth of tumour infiltration into the bladder wall (Fig. 2), for assessment of invasion into the prostate, uterus or vagina, and to confirm bone marrow metastases seen on T1-weighted images.

After intravenous administration of gadolinium contrast agents, urinary bladder cancer shows early and

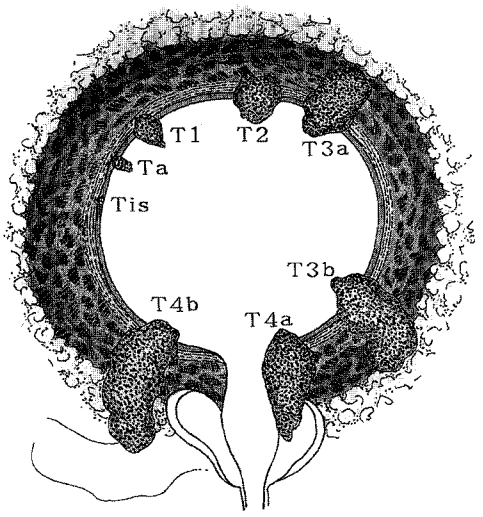

Fig. 4. T stages of urinary bladder cancer extension. (Courtesy of Janet Husband, Royal Marsden Hospital NHS Trust, UK)

Table 1. Comparison between the TNM classification [23] and the Jewett-Strong staging system [22]

Jewett-Strong	TNM	Histopathological findings
0	T0	No tumour
0	Tis	Carcinoma in situ
0	Ta	Papillary tumour, confined to epithelium (= mucosa)
A	T1	Tumour invades subepithelial connective tissue (= lamina propria)
B1	T2	Tumour invades superficial muscle (inner half)
B2	T3a	Tumour invades deep muscle (outer half)
C	T3b	Tumour invades perivesical fat
D1	T4a	Tumour invades surrounding organs
D1	T4b	Tumour invades pelvic or abdominal wall
D1	N1–3	Pelvic lymph node metastases
D2	M1	Distant metastases
D2	N4	Lymph node metastases above the bifurcation

more enhancement compared with the normal bladder wall and other non-malignant tissues (Fig. 3). Furthermore, enhancement of bladder cancer occurs earlier than that of oedema and granulation tissue.

Primary staging by MRI

To determine local tumour extension and metastases the International Cancer Association introduced a uniform clinical TNM staging method (Fig. 4, Table 1) [22]. In Table 1 the American, Jewett-Strong classification [1, 23] is also presented.

MRI is unsuitable for diagnostic screening for bladder cancer due to its high costs, and the most appropriate method of detecting a bladder tumour remains cystoscopy. Once a bladder tumour has been detected primary staging is needed to determine therapy and prognosis. Most important in this regard is the distinction between superficial tumours and tumours invading the muscular bladder wall. Clinical staging, which includes transurethral biopsy and bimanual examination, is the best technique for separating superficial (stage T1) from minimally invasive tumours (stage T2) [12, 24–29]. Transurethral biopsy also offers information about tumour histology. Currently, differentiation of stage T1 from stage T2 is difficult using MRI. Therefore staging usually begins with transurethral biopsy.

Patients with superficial tumours are treated with local endoscopic resection followed by intravesical installations of chemotherapeutic agents and/or BCG therapy. In these patients no additional staging techniques are needed. An exception could be made for stage T1 tumours with a high malignancy grade (grade III), because these tumours have a high risk of progressing to an infiltrative tumour or developing metastases. In these patients considerable oedema and granulation tissue may be present. As MRI provides good differentiation between the bladder wall and tumour, further staging and follow-up should be performed with MRI.

Patients with muscle invasion, with perivesical infiltration or with invasion into prostate, vagina or uterus (stages T2–T4b) may have radical lymphadenectomy and cystectomy, unless pelvic side wall infiltration or tumour extension into the abdominal wall (stage T4B) and/or metastases are present. In these patients palliative chemotherapy or radiation therapy will be given. Therefore preoperative recognition of pelvic side wall infiltration or metastases is very important. Although rare, recognition of bowel infiltration is also important preoperative information for the urologist. The accuracy of clinical staging in this matter is poor, and thus other methods are required. CT seemed to be a valuable addition in this regard. The overall primary staging accuracy ranges from 40 % to 92 % (mean 74 %) [2, 4, 6–9, 12, 25, 29–45]. However, pelvic MRI appears to be superior to CT. Multiplanar imaging allows better visualization of the bladder dome, trigone, and adjacent structures such as the prostate and seminal vesicles. Its excellent resolution and high soft-tissue contrast can even be enhanced by using paramagnetic contrast agents. Several reports have attested to the superiority of this technique for separating the deeply invasive stages and recognition of bowel infiltration [2–16]. The accuracy of MRI for primary tumour staging varies from 73 % to 96 % (mean 85 %). These values are 10–33 % (mean 19 %) higher than those obtained with CT. Recently, staging accuracy has improved when using gadolinium-containing contrast agents [8, 14, 15, 46–50]. The reported accuracy of primary staging, using this contrast agent, varies from 67 % to 89 % (mean 83 %).

Much attention has been paid to the possibility of using MRI to differentiate between superficial (stage T2) and deep invasion of the muscle layer of the bladder wall (stage T3a). With clinical staging, CT and intravesical sonography this distinction cannot be made reliably. Most authors reported that these stages can be differentiated on unenhanced T2-weighted images [2, 7, 9, 12,

13]. More recently Nicolas et al. [8], Tachibana et al. [14] and Sparenberg et al. [48] showed that the extent of invasion in the bladder wall is better delineated on post-contrast T1-weighted images than on unenhanced T2-weighted images. From a clinical point of view, however, separating stage T2 from stage T3a tumours is less important.

For differentiation between muscular invasion (stage T3a) and invasion into the perivesical fat (stage T3b) MRI shows results that are slightly better than [2, 6, 7, 9, 14] or equal to [4, 5, 11, 12, 15] those with CT. However, in most centres patients with both stage T3a and stage early T3b tumours are treated with cystectomy.

Beside difficulties in distinguishing stage T1 from T2 tumours, MRI has other limitations. Although differentiation between late fibrosis and granulation tissue and carcinoma is better with MRI than with CT and ultrasonography, differentiation between tumour and acute oedema or hyperaemia, present during the first weeks after transurethral resection, is difficult [8, 12, 14, 15, 46–49]. Therefore, staging after transurethral resection will be less accurate. In the future this problem may be solved by using ultrafast dynamic sequences. An alternative would be to perform MRI before transurethral resection. However, this strategy results in unnecessary MR examinations in all patients with superficial tumours, which is two thirds of all patients with urinary bladder cancer. If one takes into account the high cost and limited availability of MR time for abdominal imaging, the question should be raised whether this is acceptable for the health care system.

Finally, when MRI is used for primary tumour staging, valuable information about the presence of nodal or pelvic bone marrow metastases is also acquired [16]. This matter and the role of MRI in post-therapeutic follow-up will be discussed in future reviews.

Conclusion

MRI and clinical staging are complementary for primary staging of urinary bladder cancer. In superficial tumours, clinical staging, including transurethral biopsy, is the best technique. For invasive tumours, MRI is superior. In the determination of local tumour growth and the detection of bone marrow infiltration, MRI is more accurate than CT. A limitation of all imaging staging procedures is the recognition of minimal tumour growth in the muscle layer of the bladder wall. However, the role of MRI in imaging bladder tumours is continuing to evolve. The use of endorectal surface coils or phased-array multicoils in combination with intravenous contrast agents, or with T2-weighted fast SE sequences might solve this problem.

Another limitation of MRI, i.e. the difficulty in differentiating between tumour and acute oedema as a result of transurethral resection, can perhaps be solved by using ultrafast dynamic sequences during intravenous gadolinium contrast injection.

In all patients with urinary bladder cancer, staging should ideally start with MRI followed by clinical staging, which includes deep transurethral biopsy. However, this is not advised because of the high costs. Therefore, MRI should be reserved for deeply invasive and superficial poorly differentiated tumours.

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Book review

European Radiology

Willing S.J.: Atlas of Neuroradiology. WB Saunders Company, 1995 $99; 625 pages; 614 figures; 98 tables

There are already several atlases available on the subject of neuroradiology. Some are devoted to the brain and others to the spine. Most concentrate exclusively on computed tomography (CT) and magnetic resonance imaging (MRI).

Therefore, another atlas should have something different in terms of approach. Dr. Willing's atlas is such an example. The atlas includes abundant imaging of the brain, spine and head and neck. All images are of high quality and, apart from CT and MRI, many ultrasonographic and angiographic images are given. An advantage to the reader is that the text and the images on a pathological entity are always found together; this is sometimes confusing in other books. The atlas is divided into 13 chapters, all written by Willing. Each chapter presents a comprehensive review of the neuroimaging findings and contains sufficient accompanying text to the reader. The chapters on tumours, vascular disease and congenital malformations are extensively elaborated. The chapter on vascular disease contains many conventional angiographic images but few MR angiography images. The chapters are particularly well referenced (through 1995). A very complete index is available at the end of the book. There is no chapter devoted to the principles of neuroimaging techniques or to neuroanatomy, but this can certainly be considered a plus, since it can now be assumed that the interested reader is sufficiently acquainted with these matters.

An atlas is not intended as a comprehensive reference textbook but intends to illustrate pathology as much as possible. This atlas is a well written and enjoyable book. This Atlas of Neuroradiology more than achieves the author's goal of covering the commonest neuroradiological entities.

The book is well printed and pleasing to look at. The figures are abundant and of excellent quality. The tables and drawings are very clarifying. The price of $99 is certainly appropriate for this book, which I highly recommend. It should be read by all interested in neuroradiology and is extremely well suited for neuroradiology fellows.

Ph. Demaerel, Leuven