MRI in urinary bladder cancer

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Introduction

In 2014, bladder cancer was the tenth most common cancer in the UK with about 10,100 diagnosed each year.[1] It is the eighth most common cancer in males and 14th in females[1] and is three to four times more common in males.[2] There were 5,369 deaths from bladder cancer in 2014 in the UK with a 10-year survival of 50%.[3] Patients most often present with painless haematuria with other less frequent symptoms including change in bladder habits or symptoms of urinary irritation.[4]

The urinary bladder is extra-peritoneal with the superior surface being covered by peritoneum.[4] There are four layers to the bladder wall; mucosa, submucosa, muscularis and serosa/adventitia.[4] Up to 90% of bladder cancers are transitional cell carcinomas (TCC), 6-8% squamous cell carcinoma (SCC), and rarely adenocarcinoma.[4] Risk factors for TCC include smoking, chemical carcinogens such as aniline dyes, and ionising radiation.[4] Long-term catheterisation, urinary tract calculi, Schistosoma infection and non-functioning bladder are risk factors for SCC.[4]

MRI in staging of bladder cancer

Bladder cancer is staged according to the TNM classification (**table 1**).[4] MRI of the pelvis plays an important role in local staging of bladder cancer.[2,4-5] Its particular benefit over CT is differentiation between non-muscle and muscle invasive disease through better visualisation of soft tissue, improved assessment of intramural tumour invasion and extra-vesical extension.[2,4-5] According to Kim et al, CT has a reported accuracy in overall staging of 23% in tumours ≤pT3a and is unable to reliably discriminate between pTa and pT3a disease.[6,7] The presence or absence of extravesical disease is important in the management of bladder cancer, with a worsening prognosis with extravesical extension and need for possible combination treatment with chemotherapy/radiotherapy.[2,4-5] The Royal College of Radiologists has issued guidance on cross-sectional imaging for bladder cancers.[5] The current protocol at the authors' trust is shown in **table 2**.

T1 and T2-weighted sequences

Axial T1-weighted spin echo (SE) sequences are useful for delineating the luminal portion of the bladder tumour, evaluating perivesical fat planes for extra-vesical extension, bone metastases and pelvic lymphadenopathy.[4] On T1-weighted images urine in the bladder has low signal and the bladder wall has intermediate signal whereas on T2, urine is high signal and bladder wall is low signal (**figures 1-3**).[4] High-resolution fast SE T2-weighted sequence is useful for assessing the detrusor muscle for tumour depth and invasion of the surrounding tissue, with the detrusor muscle appearing as a hypointense line on T2 (**figures 1-3**).[4,8] In muscle invasive disease, this low signal is disrupted and an extra-vesical mass can be visualised in T3b disease.[4,8] Fat suppression using a short tau inversion recovery (STIR) sequence can be used to suppress the perivesical fat, showing the tumour signal to be seen more clearly for assessment of perivesical infiltration, although this is currently not in our protocol. Multiplanar image acquisition in coronal and sagittal reduces partial volume averaging and allows better evaluation of the depth of bladder wall invasion.[4]

Dynamic contrast-enhanced MRI (DCE-MRI)

A normal bladder wall does not enhance avidly on early gadolinium-enhanced images (20 seconds after injection), whereas bladder cancers often enhance more, due to abnormal neovasculisation, and this is useful in estimating angiogenesis.[4,8-9] The bladder tumour, mucosa and submucosa all enhance earlier compared to the muscle layer which enhances later, at approximately 60 seconds.[4,8] This also helps to differentiate the tumour from the lower signal of urine.[4,8] On the delayed post contrast T1-weighted images (>5 minutes), urine is a higher signal and the intra-luminal aspect of the bladder can be clearly seen (**figures 1-3**).[4,8]

Contrast-enhanced MR imaging has an accuracy of 75-92% in differentiating ≤ stage T1 from ≥ stage 2. DCE-MRI has an overall accuracy of 52-93% in determining tumour stage.[4] T1W, T2W and DCE-MRI can identify a ≤ pT1 lesion compared to a ≥ pT2 lesion with a sensitivity, specificity and accuracy of 95-97%, 55-67% and 85%, respectively according to Tekes et al.[6,10]

Diffusion-weighted imaging

Diffusion-weighted imaging (DWI) is a functional imaging technique that relies on random proton diffusion properties within water to generate an image contrast by applying motion gradients, characterised by their b-value.[8,11] Increased cellular density usually appears as high signal on DWI with a reduced apparent diffusion coefficient (ADC) (**figure 3**).[4] DWI has improved differentiation between tumour, muscular layer and submucosa due to different signal intensities.[4] Tumour has a high signal, submucosa low signal and muscle intermediate signal on DWI.[4] Takeuchi et al showed DWI was better for distinguishing between non-muscle invasive bladder cancer and muscle invasive compared to T2W-MRI, with an accuracy of 96% compared to 79%.[6,12]

Lymph node metastases

The most common site of nodal metastasis is obturator nodes, with further nodal metastatic sites including common iliac and aortic nodes (**figure 2**).[4] MR has an accuracy of 64-92% in lymph node staging compared to 70-90% of CT.[4] Both MR and CT cannot identify nodal metastasis <10mm.[4]

Treatment

A multidisciplinary approach is crucial for the management of patients with bladder cancer.[2] Treatment options are broken down into non-muscle invasive and muscle invasive bladder cancer.[2] Non-muscle invasive bladder cancer is categorised into low, intermediate and high risk according to NICE guidelines.[2] For intermediate risk non-invasive bladder cancer, patients have at least six doses of intravesical mitomycin C.[2] High risk non-invasive bladder cancers are often treated with transurethral resection of bladder tumour (TURBT) and intravesical BCG (Bacille Calmette-Guérin) or radical cystectomy.[2] Muscle invasive bladder cancer is treated with radical cystectomy, with five-year survival of 66% for T2 disease and 27% for T4 disease.[2,4] Chemotherapy or radiotherapy is frequently used into conjunction with surgery.[2,4]

Conclusion

MRI plays a key role in the local staging of bladder cancer, with its principle use in differentiating between non-muscle invasive and muscle invasive disease, significantly influencing management options.[2]

References

1, Cancer Research UK. Bladder Cancer. http://www.cancerresearchuk. org/about-cancer/bladder-cancer/about (accessed 16/09/2017).

2, National Institute for Health and Care Excellence (NICE) guideline. (2015) Bladder cancer: Diagnosis and management [NG2]. Available at: https://www.nice.org.uk/guidance/ng2.

3, Cancer Research UK. Bladder Cancer Statistics. http://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/bladder-cancer (accessed 16/09/2017).

4, Verma S, Rajesh A, Prasad S R et al. Urinary bladder cancer: Role of MR imaging. Radiographics 2012;32(2):371-87.

5, Royal College of Radiologists (RCR). (2014) Bladder cancer and other urothelial tumours. Available at: https://www.rcr.ac.uk/system/files/ publication/field_publication_files/BFCR%2814%292_14_Bladder.pdf.

6, Green D A, Durand M, Gumpeni N et al. Role of magnetic resonance imaging in bladder cancer: Current status and emerging techniques. BJU Int 2012;110(10):1463-70.

7, Kim B, Semelka R C, Ascher S M et al. Bladder tumor staging: Comparison of contrast-enhanced CT, T1- and T2-weighted MR imaging, dynamic gadolinium-enhanced imaging, and late gadolinium-enhanced imaging. Radiology 1994;193:239-45.

8, de Haas R J, Steyvers M J, Fütterer J J. Multiparametric MRI of the bladder: Ready for clinical routine? AJR Am J Roentgenol 2014;202(6):1187-95.

9, Afifia A H, Masoud T A, EL-noueama K I et al. Multiparametric-MRI as a comprehensive study in evaluation, characterization & local staging of urinary bladder carcinoma. Egyptian Journal of Radiology and Nuclear Medicine 2017;48:493-507.

10, Tekes A, Kamel I, Imam K et al. Dynamic MRI of bladder cancer: Evaluation of staging accuracy. Am J Roentgenol 2005;184(1):121-27.

11, Hafeez S, Huddart R. Advances in bladder cancer imaging. BMC Med 2013;11:104.

12, Takeuchi M, Sasaki S, Ito M et al. Urinary bladder cancer: Diffusion-weighted MR imaging – accuracy for diagnosing T stage and estimating histologic grade. Radiology 2009;251:112-21.

| T – Primary tumour	
Tx	Primary tumour cannot be assessed due to lack of information
T0	No primary tumour
Ta	Non-invasive papillary carcinoma
Tis	Carcinoma in situ
T1	Tumour invades subepithelial connective tissue
T2	Tumour invades muscle
T2a	Superficial muscle
T2b	Deep muscle
T3	Tumour invades perivesical fat
T3a	Microscopically
T3b	Extravesical tumour is visible macroscopically
T4	Tumour invades prostate gland, vagina, uterus, pelvic wall or abdominal wall
T4a	Invades prostate, uterus or vagina
T4b	Invades pelvic or abdominal wall
N – Lymph nodes	
Nx	Regional nodes cannot be evaluated
N0	No regional lymph nodes
N1	Metastasis in a single lymph node <2cm in size
N2	Metastasis in a single lymph node >2cm but <5cm, or multiple lymph nodes <5cm in size
N3	Metastasis in a lymph node >5cm
M - Metastasis	
Mx	Distant metastasis cannot be assessed
M0	No distant metastasis
M1	Distant metastasis

Table 1
TNM staging of bladder cancer.

| Stage	Individual TNM stages
Stage 0	Ta or Tis, N0, M0
Stage 1	T1, N0, M0
Stage 2	T2(a or b), N0, M0
Stage 3	T3(a or b) or T4a, N0, M0
Stage 4	T4b, any N, any M *or* N1-3, any T, any M

Table 2
Staging groups for bladder cancer.

Sequence	Plane	Additional information
T1-weighted	Axial/coronal	Coronal from sacrum posteriorly to anterior abdominal wall, top of liver to pubic symphysis. Axial from iliac crests to pubic symphysis
T1 VIBE fat saturated dynamic contrast-enhanced	Axial	From iliac crests to pubic symphysis
T2-weighted	Axial oblique/ coronal oblique/ sagittal	Axial oblique – 3mm and angle parallel to bladder. Coronal oblique – 3mm and angle perpendicular to bladder. Sagittal – 3mm slice
Diffusion-weighted imaging with corresponding ADC	Axial	B50/b400/b800

Table 3
The authors' trust's current MRI pelvis protocol for bladder cancer. Patients are scanned with a relatively full bladder.
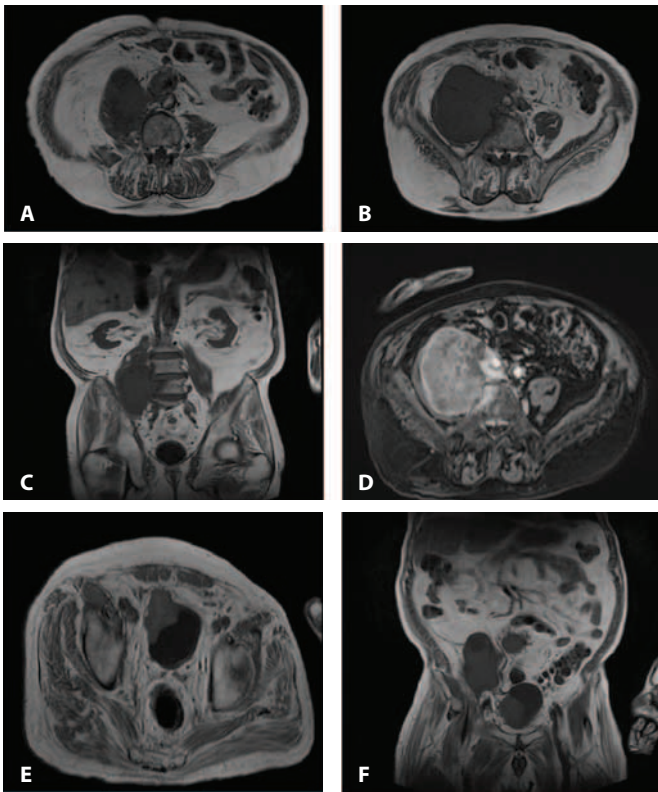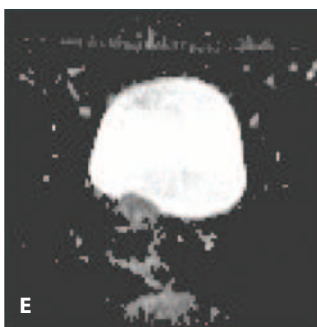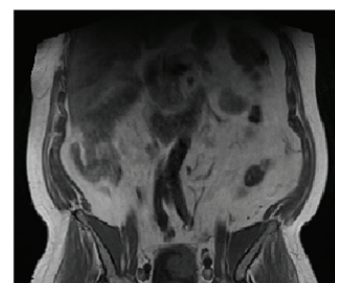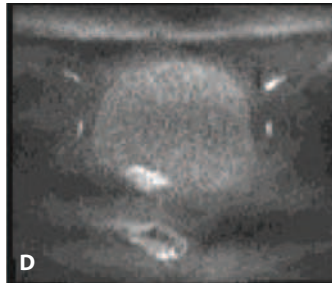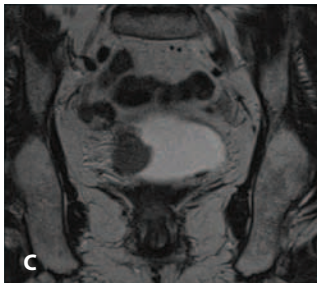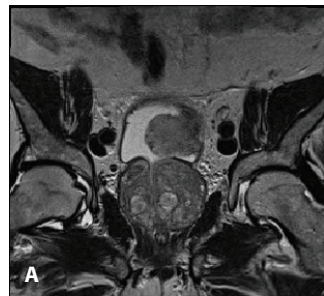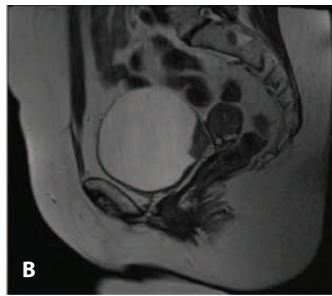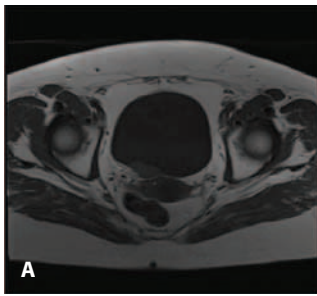
Figure 1
(A-D) T1 axial with (gadovist) and without contrast, coronal MRI pelvis slices. A large, partly necrotic, heterogenous enhancing, nodal metastatic deposit is noted involving the right psoas muscle. It is compressing the right common iliac vein. There is no definite thrombus within the iliac venous system. The mass also extends to reach the right side of the L5 vertebral body suggesting probable infiltration. No obvious extension into the neural foramina. (E-F) Axial T1 with (gadovist) and without contrast, coronal MRI pelvis slices. A solid partly necrotic, heterogenous mass in the anterolateral bladder wall extending from the base to the dome, with extension into the perivesical fat. The staging was T3bN3M1 bladder transitional cell carcinoma.
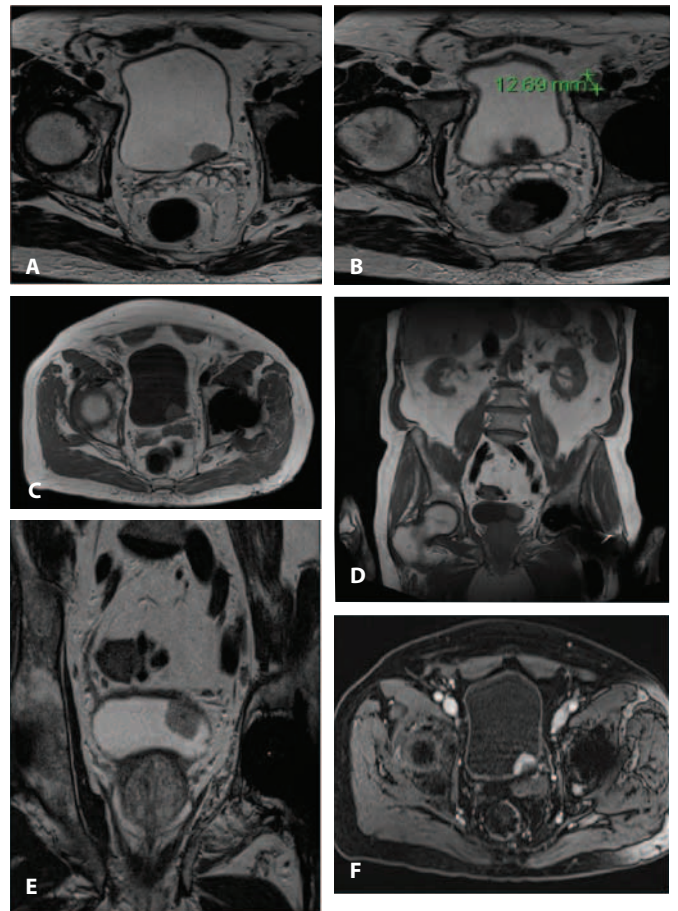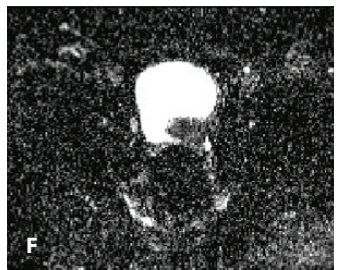

Figure 2
(A-F) Axial T2 and T1, coronal T1 and T2 MRI, T1 with contrast pelvis slices. There is a rounded soft tissue mass centred at/medial to the left ureteric orifice. There is avid homogenous enhancement of this soft tissue mass. There is a pathological left external iliac lymph node. Normal detrusor muscle signal is otherwise preserved. The staging for this tumour was T1N1M0.

Figure 3
(A-E) Axial T1, sagittal and coronal T2, diffusion-weighted imaging (b800) and corresponding ADC. There is intermediate signal mass demonstrating fluid restriction throughout the whole lesion. The staging was T2b/T3aN0Mx.

Figure 4
(A-F) Coronal, axial, sagittal T2. Coronal T1. Diffusion-weighted imaging and corresponding ADC. T3 invasive bladder arising from the left postero-lateral bladder wall. It abuts but does not intrude into the prostate. There is loss of the normal T2 low signal intensity of the muscular layer. There is associated irregularity of the serosal contour, induration and a few small nodules in the adjacent fat. Diffusion restriction and corresponding low ADC value.