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A Comparative Study of Diagnostic Performance of CT and MRI for Abdominal Staging of Paediatric Renal Tumours-A Report from Tertiary Care Centre Hospital

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ABSTRACT

Objective: To compare the diagnostic performance of CT and MRI for local staging of pediatric renal tumours.

Materials and Methods: The study population was derived from our hospital Medical College Kolkata and Hospital. Baseline abdominal imaging performed with both CT and MRI.A retrospective review was done with 50 renal tumour cases selected and planned for nephrectomy over a study period of one year from October 2020 to November 2021. Each case was evaluated for capsular penetration, lymph node metastasis, tumour thrombus, preoperative tumour rupture, and synchronous contralateral lesions. The surgical and pathological findings were the reference gold standard.

Results: The sensitivity of CT and MRI for detecting capsular penetration was 70% and 60%, respectively (P=0.73), while specificity was 84.3% and 84% (P=1.0). The sensitivity of CT and MRI for detecting lymph node metastasis was 80% and 53% (P=0.22), and specificity was 88% and 92% (P=1.0). Synchronous contralateral lesions were identified by CT in 5/12 cases and by MRI in 8/12 cases.

Conclusion: CT and MRI have similar diagnostic performance for detection of lymph node metastasis and capsular penetration. MRI was more accurate in detecting contralateral synchronous lesions; how-ever these were observed in a very a smaller number of cases. Hence either modality can be used for initial loco–regional staging of paediatric renal tumours.

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Introduction

The most common clinical presentation of a paediatric renal malignancy is a palpable abdominal mass, typically requiring sonography, the recommended imaging modality for initial evaluation of a suspected renal mass [1, 2]. However, once a renal mass is documented on sonography, cross-sectional imaging with CT or MRI to further evaluate the abdominal cavity is considered mandatory. Although CT is the most commonly used imaging modality for initial staging of paediatric renal tumours because of its short scan duration and ability to simultaneously evaluate the lungs, MRI has the advantage of lack of ionizing radiation and better soft-tissue contrast. The purpose of this retrospective study was to compare the diagnostic performance of CT and MRI in preoperative loco–regional staging of paediatric renal tumours.

Materials and Methods

The cohort for our retrospective study was derived from the patients referred to our department for suspected renal masses in paediatric patients. Written informed consent was obtained from all subjects prior to enrolment. All children and young adults (<30 years) with a first-time diagnosis of a renal tumour are eligible for this ongoing study. The patients are undergone a contrast-enhanced CT or contrast-enhanced MRI study of the abdomen and pelvis. They are also required to submit operative notes and pathology slides from biopsy or nephrectomy specimens.

As of October 7 2020, a total of 120 people had been selected. The inclusion criteria for this retrospective review were children with renal tumors who had undergone baseline imaging with both CT

and MRI prior to and within 30 days of surgery (partial or complete nephrectomy). No chemotherapy was administered between the first imaging study and surgical evaluation. Baseline imaging with both CT and MRI had been performed in 100 cases. 20 of these 100 had undergone a renal biopsy only at initial evaluation, and 30 had incomplete surgical or pathology data submitted. These 50 cases were excluded from review for lack of an adequate reference standard, resulting in a sample size of 50.

The radiologists were blinded to local radiology reports, all other imaging studies for the patients, and the surgical and pathological findings at the time of the review. All CT scans were read in consecutive order of chronological case, followed by batch reading of the MRIs so as to avoid recall bias from the previously reviewed imaging.

Each case was evaluated for the presence or absence of the following imaging features. Capsular penetration was considered to be present if there was a focal bulge or protrusion in the mass and absent if the margins of the mass were smooth and well-defined (Fig. 1). Retroperitoneal lymph nodes were considered to be involved if they met the criteria of size of ≥1 cm in the short axis [3] (Fig. 2). A discrete filling defect in the renal vein or inferior vena cava in association with distension of the vessel was considered to be a tumour thrombus. If the vessel could not be delineated because of compression by a surrounding mass, venous thrombus was considered to be absent for the purpose of this study [4]. Tumour rupture was considered to be present if there was ascites beyond the culde-sac, extra-capsular retroperitoneal fluid, or fat stranding around the kidney, with ascites being most predictive of rupture contralateral synchronous lesions were defined as non-cystic lesions of any size in the contralateral kidney [5, 6].

The surgical and pathological findings were considered the reference standard for all imaging findings evaluated. Presence or absence of capsular penetration, lymph node involvement, and tumour thrombus was determined at pathology review of the renal mass, surgically sampled lymph nodes, and renal vein or inferior vena cava, respectively. Rupture was evaluated by the central surgical review as positive if the operative note documented the presence of hemorrhagic ascites, peritoneal implants or capsular breach found at the time of laparotomy. If tumour rupture occurred intra-operatively this was not classified as tumour rupture for the purpose of this study.

The sensitivity and specificity of CT and MRI in detecting each criterion of interest (capsular penetration, lymph node involvement, venous extension and preoperative tumour rupture) and 95% confidence intervals (CIs) were calculated by comparing imaging findings with the surgical or pathology review results as the reference standard. The Mc-Nemar two-sided test was used on the CT and MRI paired data for each patient to test the null hypothesis of equality of the sensitivity and specificity of CT and MRI [7, 8]. All analyses were performed using SPSS version 20.

Results

Imaging Technique and Image Evaluation

In the study protocol, all institutions are required to perform abdomen and pelvis imaging with either a contrast- enhanced CT or a contrast-enhanced MRI scan [3]. The guidelines for CT abdomen and pelvis are maximum slice thickness of 5 mm with intravenous bolus timed for the portal venous phase. The guidelines for MR abdomen and pelvis are as follows: slice thickness 5 mm or less, fat-suppressed T2-weighted images in at least two planes, pre-contrast T1-weighted image in at least one plane, and post-contrast T1-weighted images with fat saturation in two planes.

Results

The age range for the study cohort was 31 days to 19.4 years (median 3.9 years, mean 4.9 years). There were 23 girls and 27 boys. All submitted CT scans had been performed with intravenous contrast administration in the portal venous phase with slice thickness of 5 mm or less, and 24/50 subjects had received intraluminal bowel contrast material. In addition, coronal and sagittal reconstructions were available in all cases, and coronal-only reconstructions in 10/50 cases. Regarding MRI, pre-contrast T1-weighted, fat-saturated T2-weighted and post- contrast fat-saturated T1-weighted images with slice thickness of ≤5 mm was available in all cases. Dynamic (multiphase) post-contrast T1-weighted images were available for review in 21/50 cases. Diffusion-weighted images were available in 11/50 cases.

The final histology based on pathology review was as follows: Wilms tumour (n=36), renal cell carcinoma (n=8), cystic nephroma/cystic partially differentiated nephroma (n=2), clear cell sarcoma (n=1), mesoblastic nephroma (n=1), angiomyolipoma (n=1) and metanephric tumour (n=1). The stage distribution was as follows: stage I (n=16), stage II (n= 17), stage III (n=10), stage IV (n=6) and stage V (n=1). This does not include the five renal cell carcinomas, for which the local staging was as follows: T1 (n=1), T2 (n=1), T3 (n=1); N0 (n=3) and Nx (n=2).

The diagnostic performance of CT and MRI, compared to reference standard, is summarized in Tables 1 and 2. The sensitivity of CT and MRI for detecting capsular penetration was 70% and 60% (P=0.73), respectively, while specificity was 84.3% and 84% (P=1.0). Capsular penetration was correctly classified in 68.3% of cases (34/50) by CT and in 64.6% of cases (32/50) by MRI (Figure 1). The sensitivity of CT and MRI for detecting lymph node metastasis was 80% and 53% (P=0.22), respectively, while specificity was 88% and 92% (P=1.0). Lymph node metastasis was accurately classified in 73.2% of cases (37/50) by CT and in 70% of cases (35/50) by MRI (Figure 2). Venous extension was present in only 4/82 cases (3 renal vein, 1 inferior vena cava), and accurately classified by CT in 85.4% (42/50) of cases and by MRI in 89% (44/50) of cases. Preoperative tumour rupture was present in only two cases in our cohort and was accurately classified by CT in 86% (43/50) of cases and by MRI in 91.5% (48/50) of cases.

CT detected five cases with synchronous contralateral tumour or nephrogenic rest while MRI detected eight cases with contralateral tumour or nephrogenic rest. The size of the contralateral synchronous lesions ranged from 0.2 cm to 2.2 cm (mean 1.0 cm). Contralateral lesions were identified by both CT and MRI in 2/12 cases, leaving 8/12 cases in which a contralateral lesion was detected solely on MRI and 5/12 cases in which a contralateral lesion was detected solely on CT (Figure 3).

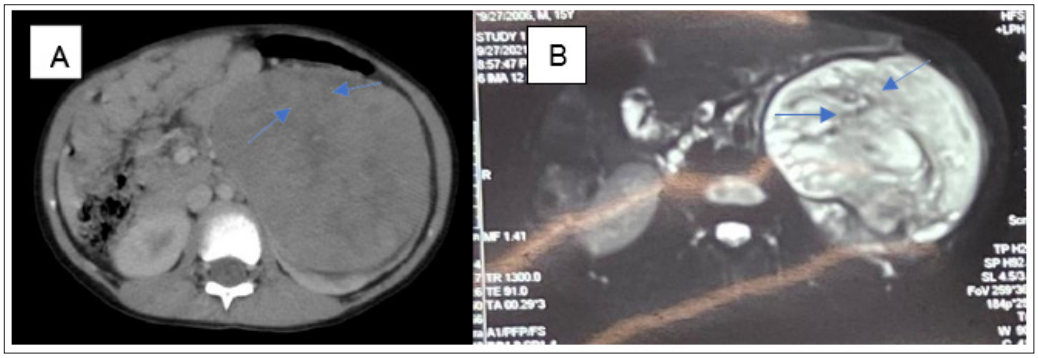

Figure 1: Capsular penetration of Wilms tumour in a 7-year-old boy. Axial CT (A) and MRI (B) images show focal protrusion (arrows) of the renal mass beyond the renal capsule. This was pathologically confirmed to be capsular penetration.

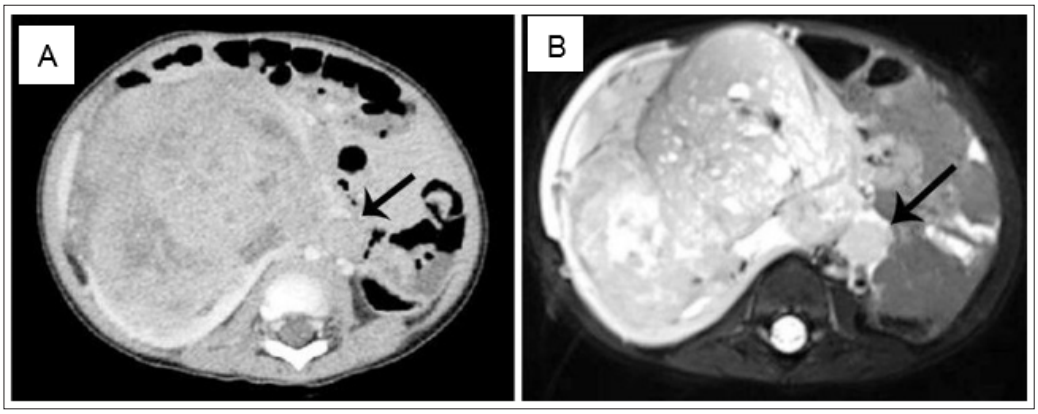

Figure 2: Lymph node metastasis secondary to Wilms tumour in a 4-year-old boy. Axial CT (A) and MRI (B) images show enlarged retroperitoneal lymph node (arrow). Pathology confirmed lymph node metastasis, indicating stage III disease and a need for abdominal radiation.

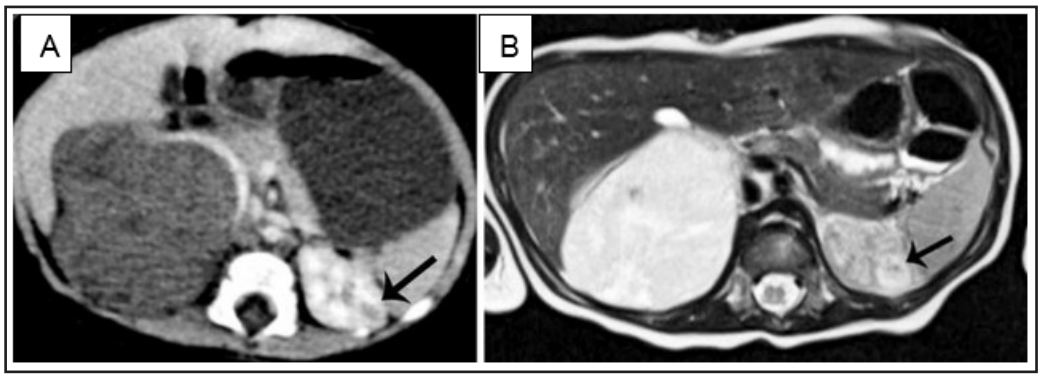

Figure 3: Contralateral synchronous lesion in a 6-month-old girl with recently diagnosed Wilms tumour. Axial CT (A) and T2-weighted MRI (B) images. MRI shows a T2-hyperintense lesion in the superior pole of the left kidney (arrow) which may represent a nephrogenic rest vs. contralateral Wilms tumour. This would upstage the patient to stage V. The lesion is poorly visualized on CT.

Table 1: Cross Tabulation of central pathology or surgical review and CT results. CI= confidence intervals.

	Pathological /Surgical review			
CT result for capsular penetration		Yes	No	Indeterminate
	Penetrated	21	2	6
	Intact	9	8	4
	Total	30	10	10

Sensitivity:21/30=70%, 95% CI: 51.7%,83%.
Specificity:8/10=84.3%, 95% CI: 70.4%,97%.

CT results for lymph node involvement		Positive	Negative	No lymph node
	Positive	12	3	2
	Negative	3	22	8
	Total	15	25	10

Sensitivity:12/15=80%, 95% CI: 49%,92%.
Specificity:22/25=88%, 95% CI: 79%,96%.

CT results for venous extension		IVC	Renal vein	No	Indeterminate
	IVC	1	0	2	0
	Renal vein	0	0	2	0
	No	0	3	32	5
	Total	1	3	36	5
	Sensitivity:1/4=25%, 95% CI: 13%,78%. Specificity:32/36=88%, 95% CI: 86%,98%.				

CT results for tumour rupture		Yes	No	Indeterminate
	Yes	1	9	1
	No	1	36	1
	Total	2	45	2

Sensitivity:1/2=50%, 95% CI: 2.7%,97.3%.
Specificity:8/10=80%, 95% CI: 80%,95.1%.

Table 2: Cross Tabulation of central pathology or surgical review and MRI results. CI= confidence intervals

Pathological /Surgical review

CT result for capsular penetration		Yes	No	Indeterminate
	Penetrated	12	4	0
	Intact	8	21	5
	Total	20	25	5

Sensitivity:12/20=60%, 95% CI: 44%,78%.
Specificity:21/25=84%, 95% CI: 67%,93%.

CT results for lymph node involvement		Positive	Negative	No lymph node
	Positive	8	2	5
	Negative	7	23	5
	Total	15	25	10

Sensitivity:8/15=53%, 95% CI: 28%,76%.
Specificity:23/25=92%, 95% CI: 80%,97.5%.

CT results for venous extension		IVC	Renal vein	No	Indeterminate
	IVC	1	0	0	0
	Renal vein	0	0	1	1
	No	0	3	40	4
	Total	1	3	41	5
	Sensitivity:1/4=25%, 95% CI: 13%,78%. Specificity:40/41=97.5%, 95% CI: 91.6%,99.9%.				

CT results for tumour rupture		Yes	No	Indeterminate
	Yes	1	3	1
	No	1	42	2
	Total	2	45	2

Sensitivity:1/2=50%, 95% CI: 2.7%,97.3%.
Specificity:42/45=93.3%, 95% CI: 88.3%,99%.

Discussion

Baseline staging is one of the most important prognostic criteria for Wilms tumour, the most common paediatric renal malignancy [2, 9]. Even in patients with stage IV disease, local staging is an important guide for appropriate local treatment, and it is a prognostic factor, with increased risk of abdominal recurrence in patients with advanced local disease [3, 7]. Abdominal staging of paediatric renal tumours can be challenging at initial presentation [1, 8]. The large tumour-to-abdominal-cavity size ratio in paediatric renal tumours makes imaging evaluation of normal structures such as the renal capsule, vessels and adjacent organs challenging. Detailed anatomical information obtained with cross-sectional imaging can be critical to guide the treating surgeon in the operative approach.

The treatment protocol is based on the clinical and imaging appearance of the renal tumour, and surgical or pathological evaluation is performed after initial chemotherapy. McDonald et al., [4, 10] recently described the benefits of CT and MRI in staging Wilms tumour. CT evaluation has the advantage of faster scanning with less frequent need for sedation, and allows for simultaneous evaluation of the lungs. MRI provides better soft-tissue contrast and avoids exposure to ionizing radiation. However, MRI in this patient population almost always requires sedation and a longer duration of anesthesia compared to CT. There is increasing evidence to suggest that exposure of the developing brain to anesthetics may cause long-term neurocognitive impairment [6, 11, 12]. Therefore, our study seeks to compare the diagnostic performance of CT versus MRI.

The presence of capsular penetration upstages a Wilms tumour to stage II from stage I. This study shows that CT and MRI have similar diagnostic performance in detection of capsular penetration, with moderate specificity but low sensitivity. This highlights the importance of surgical or pathological staging of Wilms tumour at initial evaluation [5, 9].

The presence of lymph node metastasis and tumour rupture defines stage III disease and indicates need for abdominal radiation therapy and chemotherapeutic intensification for some children. Lymph node involvement has been shown to be an important predictor of 8-year event-free survival and overall survival for favorable-histology Wilms tumour patients with stage III disease [8, 10, 13]. In our study, using a size criterion of ≥1 cm in the short axis, CT had higher sensitivity than MRI for detection of lymph node metastasis, though the difference was not statistically significant [14].

Synchronous bilateral renal lesions can be present in approximately 5% of patients at initial presentation [8]. Presence of a contralateral renal lesion in a child with Wilms tumour can change the stage and initial management of the patient, indicating a role for a renal-sparing approach without up-front surgery. MRI detected more synchronous contralateral lesions than CT in our study. In the two cases in which a synchronous lesion was detected only on CT, the post-contrast MR images were less than optimal because of poor contrast bolus in one case and because of lack of coronal and sagittal sections in another case with failure to show an exophytic lesion at the inferior pole. Superior soft-tissue contrast of MRI compared to CT, even on a non- contrast study, and better characterization of soft tissues from availability of multiple sequences that provide structural and functional information (e.g., diffusion-weighted imaging) likely account for increased sensitivity of MRI for detection of small synchronous lesions. MRI is the preferred imaging modality in children with bilateral Wilms tumour or conditions that predispose to bilateral Wilms tumours; MRI is preferred in these trials because of its lack of ionizing radiation and better soft-tissue contrast. However, because of the small numbers of patients with multiple lesions in this study, no definitive conclusions can be made here. Further evaluation with more subjects, uniform MRI scan parameters, and incorporation of state-of-the-art techniques, such as diffusion-weighted imaging, is needed to determine whether MRI offers a clear advantage.

Our study has limitations. First, in spite of drawing a study sample from a large cohort of patients enrolled in a multi-institutional study that has been open since October 2020, the number of patients that met our eligibility criteria for imaging with both modalities was relatively small. The presence of tumour thrombus in the inferior vena cava, obvious signs of preoperative tumour rupture, or synchronous bilateral tumours can lead the treating oncologist or surgeon to decide on upfront biopsy and pre-nephrectomy chemotherapy, which potentially explains the small number of cases with these findings in our cohort, because all patients with upfront biopsy were excluded from this study for lack of an adequate reference standard [14].

Conclusion

In our study, both CT and MRI had high specificity but relatively low sensitivity in detection of capsular penetration and lymph node metastasis. Though MRI detected more synchronous lesions than CT, no significant difference was demonstrated in this study. Given the similar diagnostic performance of CT and MRI in local evaluation of paediatric renal tumours, we recommend that either modality be used for initial staging based on institutional expertise, need for anaesthesia, and concerns regarding cost, ionizing radiation and side effects of anesthesia. The two modalities can be substituted to avoid repeated exposure to ionizing radiation.

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