Multidetector computed tomography vs magnetic resonance imaging for defining the upper limit of tumour thrombus in renal cell carcinoma: a study and review

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OBJECTIVE

To compare the findings of multidetector computed tomography (CT) with surgical pathology and magnetic resonance imaging (MRI), to determine the accuracy of delineating the superior extent of inferior vena cava (IVC) thrombotic involvement in renal cell cancer (RCC).

PATIENTS AND METHODS

A prospective database was examined of 11 patients (median age 65 years, range 45–77) being assessed for suspected IVC extension of RCC tumour thrombus with both multidetector CT and MRI. All had pathology confirming RCC, and eight of those undergoing surgery had pathological confirmation of tumour thrombus extent. All images were analysed originally, then re-analysed by two independent radiologists, an experienced urologist and a urological trainee unaware of the original reports and other imaging results, with a final determination on tumour thrombus level by consensus.

RESULTS

The multidetector CT results were completely accurate when compared with surgical specimens and were in agreement with MRI on all but one occasion, where MRI determined the renal vein to be clear when it was involved on CT and at surgery, giving MRI an accuracy of seven of eight samples.

CONCLUSIONS

Whilst there were few patients and further studies are needed, multidetector CT was comparable with MRI in determining tumour thrombus level. More importantly, in the eight patients with surgical pathological confirmation, multidetector CT was accurate in all. Ultimately, it may replace MRI as the 'gold standard' for imaging to delineate the upper limit of tumour thrombosis in RCC.

KEYWORDS

renal cell carcinoma, RCC, spiral CT, MRI, venous thrombosis, inferior vena cava, surgery

INTRODUCTION

RCC often invades the renal vein and may extend into the inferior vena cava (IVC) or right atrium [1]. Current staging incorporates such invasion and aids in prognosis. Accurate staging is paramount when assessing patients and planning surgical resection. Of patients undergoing radical nephrectomy for RCC, 4–10% have IVC involvement. The surgical approach and assistance of other specialist surgeons is often crucial the further the tumour thrombus extends [2]. The superior extent of the thrombus determines the operative approach [3,4]. Traditionally, venacavography was the 'gold standard' investigation to delineate thrombus level, with a reported sensitivity of 100% [5–7]. Since the advent of CT and MRI, venacavography is now used rarely. In particular, multiple-plane imaging and accuracy has made MRI the 'gold standard' investigation of RCC with suspected thrombus [8–10].

Nevertheless, CT remains the investigation of choice for most RCCs, as it is often clear that there is no IVC invasion. More than 10 years ago, MRI was compared with CT to delineate IVC involvement, but the quality of CT imaging then was poorer, with reconstructed images unavailable. CT was unable to delineate the exact level of the upper limit of thrombus, the major factor in planning surgery [11,12]. However, with advances in CT technology and multiple-plane reconstructions now available, MRI may not be necessary. In a review of renal imaging, Israel and Bosniak [8] commented that 'with the advent of multidetector CT scanning, it is unclear whether any proposed advantage of MRI still holds true'.

The purpose of the present study was to compare the findings of multidetector CT, providing images in many planes, with surgical pathology and MRI to determine the accuracy of delineating the superior extent of IVC thrombosis involvement in RCC.

PATIENTS AND METHODS

A prospective database of multidetector CT and MRI information was maintained from 2001; additional data were specifically collected on patients with RCC and tumour thrombus, including demographics, surgery, pathology and follow-up. Eleven patients (median age 65 years, range 45–77) were assessed for suspected IVC extension of RCC with both methods (Table 1). Patients were staged according to the 1997 TNM classification; all had pathology confirming RCC, and eight had surgery, with operative and pathological confirmation of thrombus extent. There were no exclusions and ethics committee approval was not required, as MRI is current best practice.

All CT was done on multidetector (-row) machines (Multidetector GE Lightspeed plus, eight-slice, General Electric Medical Systems, Milwaukee, USA). The protocol was identical, with four phases: non-contrast phase images were obtained from the aortic arch to the

symphysis pubis at 2.5 mm intervals; an arterial phase with 100 mL of intravenous non-ionic contrast medium (iohexol), injected at 3 mL/s (timed bolus injection), with scanning starting once the contrast agent was apparent in the aorta (usually 20 s); a delayed phase taken 90 s from the injection with contrast agent, and scanning from the aortic arch to the symphysis pubis; and finally an extra delayed phase, at 10 min after injection with contrast agent, scanning the kidneys and IVC only. From all scans coronal reconstructions of the kidneys and IVC were produced. A thrombus was diagnosed in the IVC when a low-attenuation filling defect was apparent within the lumen [13]. Injection with contrast medium enhanced the thrombus, and when there was incomplete obstruction of the blood flow, the intraluminal enhancement was peripheral and ring-like ('doughnut' appearance). Focal enhancement of the vena caval wall, or infiltration of adjacent soft tissue, indicated vena caval wall invasion, as described previously [12].

For MRI, the same machine was used (GE Echospeed, Software version 9). The protocol consisted of six phases: axial T1 breath-hold; axial T2 breath-hold; coronal T1 breath-hold; dynamic axial T1 with intravenous contrast agent (20 mL of gadolinium); coronal gadolinium venogram; and delayed axial T1 with fat suppression. Three-dimensional reconstructions were used for gadolinium images, with 2.5 mm slices.

RCCs had a varied MRI signal, the most common appearance being a mass with an intensity intermediate between the renal cortex and the medulla on T1-weighted images, and hyperintense on T2-weighted images. A thrombus was diagnosed in the venous system when there was a filling defect and several planes were consulted where necessary. A tumour thrombus was diagnosed when the signal intensity and contrast enhancement matched the primary tumour. For a bland or pure clot thrombus to be diagnosed there had to be no enhancement after giving the contrast agent.

There have been attempts to grade RCC IVC thrombus by superior extent at two, three or four levels [1,14,15]. We chose five levels, distinguishing supraheptic IVC extent from right atrial involvement, and described those at the junction of the renal vein and IVC as 'renal vein only' (Fig. 1) which is more practical from a surgical planning perspective.

All images were analysed originally by two experienced radiologists at the time of scanning, with data recorded. Images were then re-analysed by two independent radiologists unaware of the original reports and other imaging results, with a final determination on tumour thrombus level by consensus. An experienced urologist and urological trainee, also unaware of the reports, assessed the CT scans and recorded their superior level of tumour thrombus. Two pathologists reported all pathology specimens, and the operative level of the thrombus was confirmed by two surgeons before recording, using the levels of thrombus defined.

TABLE 1 Results comparing the superior extent of tumour thrombus in the renal vein and IVC on multidetector CT, MRI and surgery

Age, years/sex	CT Level	MRI Level	Surgery	Stage	Grade	Type
69/F	RV	RV	RV	T3a	2	Clear
64/M	RV	Nil	RV	T3b	2	Clear
65/M	RV	RV	RV	T3b	3	Clear
45/F	INFRA	INFRA	INFRA	T3b	High	Sarcomatoid
58/M	INFRA	INFRA	INFRA	T3a	2	Clear
69/M	INTRA	INTRA	INFRA	T3a	2	Clear
47/M	INTRA	INTRA	INTRA	T3b	3	Clear
73/F	INTRA	INTRA	INTRA	T3b	4	Clear
65/M	SUPRA	SUPRA	Nil	T3c	2	Clear
51/F	RV	RV	Nil	T4	High	RCC (metastasis)
77/M	INTRA	INTRA	Nil	T4	High	RCC (metastasis)

RV, renal vein; INFRA, infrahepatic vena cava; INTRA, intrahepatic vena cava; SUPRA, suprahepatic vena cava.

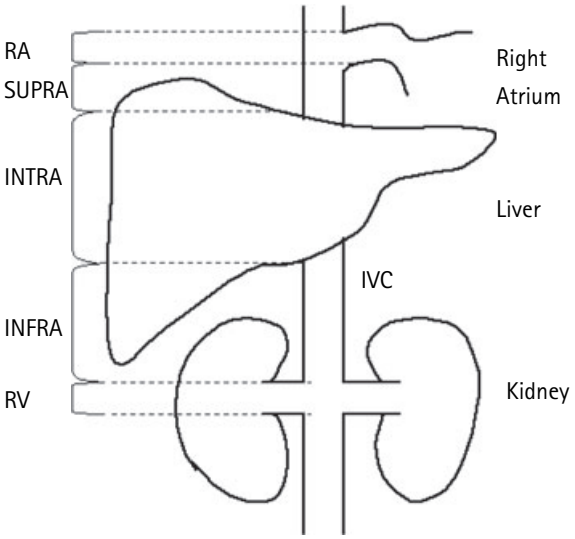
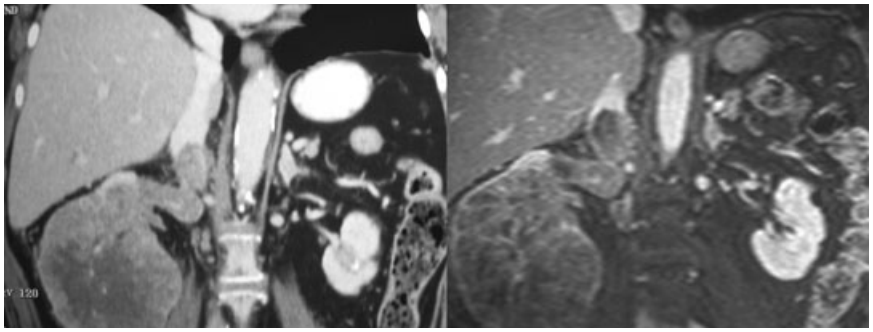


FIG. 1.
Diagram depicting the delineation of the upper limit of tumour thrombus extension in RCC as used in the study. RV, renal vein; INFRA, infrahepatic vena cava; INTRA, intrahepatic vena cava; SUPRA, suprahepatic vena cava; RA, right atrium.

RESULTS

Overall, CT accurately delineated the tumour thrombus level in the IVC in all eight patients, compared to MRI which was correct in seven of the eight (Table 1). The CT results for thrombus level matched those of MRI (Fig. 2) on all but one occasion where MRI determined the renal vein to be clear when it was involved on CT and at surgery. This was a difficult case, as tumour was encasing the vein (noted on MRI) as well as being in the

FIG. 2. Comparison of CT (left) and MRI (right) in the same patient, showing that with coronal reconstruction using multidetector CT, the resultant images are almost identical to those generated by MRI.



lumen, making interpretation difficult. Of the remaining seven patients having surgery, there was concordance of opinion as to thrombus level on MRI and CT. One patient was upstaged from T3a to T4 because of disease extension, not detected on either CT or MRI, for tumour extension beyond Gerota's fascia, but the thrombus level remained unchanged. Only tumour thrombi were diagnosed on MRI.

Three patients had no surgical intervention but CT and MRI were in agreement as to tumour thrombus level in the IVC. Two patients had significant widespread metastatic disease and were considered inappropriate for nephrectomy and immunotherapy. Finally, one patient refused surgery who had previously had a nephrectomy for T1 disease; he was undergoing tumour surveillance when at 18 months after surgery he developed a tumour vein thrombus with extension into the suprahepatic vena cava.

When the opinion of the experienced urologist was compared with that of the radiologists for CT, the delineation of thrombus level was identical on all occasions. There was no discordance between the original reported level of thrombus on CT or MRI and that made by independent radiologists through a consensus.

DISCUSSION

The 5-year survival rate for RCC when completely resecting an IVC tumour thrombus in patients with no metastases is 30–69% and does not depend on the level of thrombus, but on stage [3,16]. During a right radical nephrectomy with no thrombus, the renal vein is normally ligated near its junction with the IVC, whilst on the left it is ligated where it crosses the aorta. If tumour thrombus extends to these margins of the veins, there is a danger of ligating across the thrombus and dislodging it during surgery into the right atrium or beyond [7]. Thrombus in the IVC necessitates extensive mobilization of the involved region to gain control, aiming to remove the thrombus intact [3]. If thrombus extends beyond the diaphragm, cardiopulmonary or venous bypass is often necessary to allow control above the thrombus. RCC on the right side is more likely to extend into the IVC because of the shorter vein, and because the left renal vein crosses the pulsatile aorta [17].

Thus, successfully removing a tumour thrombus remains a technical intraoperative challenge and requires careful preoperative management [3]. In several studies [2,9,10,14,18–20] MRI was as accurate as venacavography in delineating thrombus level. It has the advantages of being noninvasive, delivers no radiation to the patient and gives information in any of the three orthogonal anatomical planes, making it the 'gold standard' [8–10].

MRI has previously had advantages over conventional (single-detector) CT, including those noted for venacavography, in that it can delineate the exact level of thrombus extension, which is critical to surgical planning [4]. Furthermore, MRI can detect the patency of major vessels with no contrast agent if necessary, as the signal from the blood flowing through vessels is much lower than that from the tumour thrombus [21]. MRI may also sometimes delineate bland thrombus from tumour thrombus [9,10]. Finally, in the past, only axial images were available with CT, making image reconstruction difficult, whilst MRI could provide multiplanar images [2]. Attempts at combining CT with ultrasonography improved the sensitivity for tumour thrombus extent, but remained much less sensitive than MRI [22].

The CT level of RCC thrombus and pathological specimens has been compared using conventional CT, with an accuracy of 95% on axial scanning alone [1], but few other studies have reached such precision (Table 2) [11,12,19,23,24]. Studies have also assessed MRI and CT in parallel, but not directly against each other, with MRI having a greater accuracy (complete) at diagnosing the superior extent of thrombus compared to CT (76%) [2,7]. MRI has also been correlated with CT for overall staging accuracy (74–88% MRI vs 67–100% CT), but the superior extent of thrombus involvement has not been specifically highlighted [13,21]. To date, only five studies have directly compared conventional CT to MRI in delineating the thrombus level of extension into the IVC in RCC (Table 2) and these were undertaken >10 years ago in fewer than 50 patients [11,12,19,23,24].

Overall, studies directly comparing MRI with CT found MRI to be completely accurate for the superior extent of tumour thrombus, whereas CT had a mean diagnostic accuracy of only 65% (Table 2). Of more concern for CT was that it completely missed tumour thrombus in four patients in three of the studies [11,12,24]. These CT images were only axial, and they would not compare to current multiplanar imaging. Other reasons for the inaccuracy of CT include incorrect timing and an insufficient amount of intravenous contrast agent in the IVC. These areas have been improved, with better software and high-powered contrast bolus injectors. In support of this, a recent study comparing multidetector CT and MRI for overall RCC staging had similar accuracy with both methods, but tumour thrombus extension into the IVC was not specifically assessed [15].

Although in general MRI is completely accurate in delineating the level of tumour thrombus in the vena cava in RCC, some inaccuracies were reported. In two cases the extent of tumour thrombus was underestimated at the level of the hepatic veins [25,26]. In three other studies the use of preoperative MRI in a total of 57 patients was

90–96% accurate at determining thrombus level, which was similar to the present accuracy [21,27]. In the study with 10 patients, only six from eight venacavography scans were accurate; clearly, no imaging method is always completely accurate, and even 'gold standards' of imaging may be incorrect.

MRI technology has also developed with time; previously, MRI using spin-echo sequences was unable to overcome flow-related intraluminal signals from thrombus and external compression of the vena cava, creating artefacts that made assessing the signal difficult [18]. Also, respiratory and cardiac motion artefacts compromised the delineation of tumour thrombus extent and may explain the cases discussed above. To overcome these issues, gradient-recalled echo sequences were introduced for MRI of vascular structures, including tumour thrombus in RCC, with success [26]. Furthermore, MR image acquisition has become faster, providing more images in a single breath-hold, reducing movement artefact. Further developments will result in even greater imaging capabilities of MRI, but access and cost remain strong impediments to its widespread use.

Other imaging methods have been investigated to delineate tumour thrombus, e.g. ultrasonography and transoesophageal echocardiography. Ultrasonography is not appropriate, as many studies are technically indeterminate because they rely on operator and patient characteristics [7]. There are limited data for transoesophageal echocardiography but no study has shown that it adds any diagnostic advantage, and it may only have a small role during surgery in patients having a cardiopulmonary bypass [28].

Multidetector CT allows faster data acquisition than single-detector CT, with no loss of image quality because of short gantry rotation intervals combined with multiple detectors at each level, providing increased coverage [29]. This, along with short interscan delays, allows image acquisitions in multiple phases of renal parenchymal enhancement and contrast agent excretion in the collecting system after giving one bolus of intravenous contrast agent [30]. Another advantage of CT is improved spatial resolution, providing high-quality three-dimensional datasets of the renal vessels, comparable with angiography and conventional urography [31]. The benefits outlined above also pose significant challenges, including selecting the optimal imaging sequences, controlling radiation exposure to the patient, and efficiently managing the increased data.

TABLE 2 A summary of studies directly comparing CT with MRI and surgery to ascertain the accuracy of delineating the superior extent of RCC tumour thrombus. Studies apart from the present used conventional CT

			Level of thrombus				
Study	N patients	Method	Correct	Understaged	Missed	Accuracy, n/N	Surgery
Present	11	CT	11	0	0	11/11	8
		MRI	10	1	0	10/11	
[23]	8	CT	5	1	2	5/8	8*
		MRI	8	0	0	8/8	
[11]	5	CT	0	4	1	4/5	0†
		MRI	5	0	0	5/5	
[24]	5	CT	3	1	1	3/5	5
		MRI	5	0	0	5/5	
[12]	16	CT	11	3	2	11/16	16
		MRI	16	0	0	16/16	
[19]	15	CT	5	10	0	5/15	15
		MRI	15	0	0	15/15	

**two patients had thrombus extent confirmed at autopsy; †Extent of thrombus not specified, but all patients had surgery or biopsy to confirm RCC.*

Currently, MRI will remain the 'gold standard' for delineating the level and extent of tumour thrombus in the IVC in the staging of patients with RCC. While our experience is limited, multidetector CT was accurate when compared with the surgical specimens and is probably at least the equivalent of, if not better than, MRI in determining thrombus level. Whilst encouraged by these early results, the accuracy of multidetector CT in defining tumour thrombus in RCC must await further analysis from other centres, and so we will continue to use both methods until we are satisfied that it is equal to or better than MRI. Finally, with CT developing rapidly, the challenge as clinicians will be to evaluate new standards of imaging, so that patients have the simplest, most cost-effective and accurate staging technique available to them.

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CONFLICT OF INTEREST

None declared.

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Abbreviations: **IVC**, inferior vena cava.