Cardiovascular magnetic resonance imaging in assessment of intracaval and intracardiac extension of renal cell carcinoma

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Objectives: About 1 in 5 patients with renal cell carcinoma have intravascular tumoral extension at presentation. Level of tumoral extension within inferior vena cava determines surgical approach, with higher extension requiring cardiopulmonary bypass. Tumoral invasion of inferior vena caval wall is associated with poor prognosis. We evaluated accuracy of magnetic resonance imaging (MRI) in assessing level of intravascular extension of renal cell carcinoma and predicting vessel wall invasion.

Methods: MRIs and surgical database were reviewed from January 1999 to December 2008. Sixty-four patients with suspected intravascular extension of renal cell carcinoma underwent MRI. Forty-one underwent curative or palliative surgery at our institution and were included in final analysis. MRI scans were reviewed to determine intravascular extension and tumoral adherence to the vessel wall, as assessed by circumferential flow around the intravascular tumor and its mobility during different phases of cardiac cycle. MRI findings were correlated with surgical findings to assess accuracy.

Results: There was 87.8% agreement ($P < .001$; $\kappa = 0.82$) between MRI and surgical findings regarding level of intravascular extension of tumor. MRI was highly sensitive and specific (93%) in assessing supradiaphragmatic extension (negative predictive value, 96%). Depending on sign used, sensitivities and negative predictive values in assessing tumoral adherence to vessel wall ranged from 86% to 95% and 81% to 91%, respectively.

Conclusions: MRI is highly accurate in staging intravascular and intracardiac extension, aiding in accurate preoperative surgical planning. MRI may help determine prognosis of renal cell carcinoma by accurately assessing tumoral adherence to the vessel wall. (J Thorac Cardiovasc Surg 2012;144:845-51)

Renal cell carcinoma (RCC) accounts for 3% to 4% of cancers in the United States,[1] and its worldwide incidence and mortality are increasing at 2% to 3% per decade.[2] At presentation, venous extension is reported to occur in 20% of patients. The inferior vena cava (IVC) is involved in as many as 15% of all patients with RCC, and right atrial involvement is seen in approximately 1% of cases.[3-6]

Surgical management is preferred, because RCC is uniformly resistant to chemotherapy and not sensitive enough to radiotherapy.[7-9] Intravascular tumoral extension is not associated with an adverse prognosis, provided a complete resection is possible.[6,10] Extension into the IVC, however, is associated with a poorer survival outcome than is extension into the renal vein.[11] The level of tumoral extension within the IVC determines the surgical approach used, with supradiaphragmatic extension requiring cardiopulmonary bypass (CPB) with or without deep hypothermic circulatory arrest.[12,13] It is thus vital to determine the level of intravascular tumoral extension preoperatively. This not only facilitates surgical planning but also allows appropriate involvement of cardiac surgical teams.

Significant difference in prognosis exists between patients with tumoral invasion of the IVC wall and those with free-floating tumor in the IVC.[14,15] Hatcher and colleagues[14,16] reported the 5-year survivals in the 2 groups to be 25% and 69%, respectively. Direct tumoral invasion of IVC wall, into surrounding soft tissue, can be determined by multidetector computed tomography (MDCT) or magnetic resonance imaging (MRI; Figure 1).[17,18] Recognition of vessel wall invasion at early stages, when tumor is adherent to the vessel wall, can be difficult to assess by any imaging modality.

In this study, we looked at the accuracy of cardiovascular MRI in assessing the level of intravascular tumoral extension of RCC and the ability of MRI to predict vessel wall invasion.

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Abbreviations and Acronyms

CPB = cardiopulmonary bypass
IVC = inferior vena cava
MDCT = multidetector computed tomography
MRI = magnetic resonance imaging
NPV = negative predictive value
RCC = renal cell carcinoma

MATERIALS AND METHODS

Patients

Cardiovascular MRIs and the surgical database of a single tertiary cardiothoracic referral center (Royal Brompton and Harefield Foundation Trust) were reviewed between January 1999 and December 2008. All patients who underwent MRI for assessment of known RCC with suspected vascular extension were included in the study. Demographic data, intraoperative findings, and pathology reports were collated. Patients who underwent curative or palliative surgery at our institution were included in the final analysis. Patient consent was not deemed to be necessary by the local research and ethics committee.

MRI Scan Protocols

During the period of study, all the scans were performed in 1 of our 3 1.5-T systems (2 Avanto and 1 Sonata; Siemens Medical Systems, Erlangen, Germany). Standard scan protocol included (Table 1) the following: half-Fourier acquisition single-shot turbo spin echo and cinematic steady-state free precession sequences of the heart in standard cardiac planes (2-, 3-, and 4-chamber and short-axis views) to establish cardiac anatomy and function. Half-Fourier acquisition single-shot turbo spin echo and single-shot steady-state free precession images of the abdomen and pelvis (axial and coronal planes) were acquired to assess anatomy and extent of local and vascular tumoral invasion. A stack of cinematic steady-state free precession images covering the IVC was acquired in 2 planes to assess tumoral invasion of the vessel wall. Gadolinium-enhanced renal angiography in arterial and venous phases was used to detect level of vascular invasion and wall invasion. Toward the latter half of the study, volumetric interpolated breath-hold examination sequence of the abdomen was performed after angiography (Figure 2).

MRI Data Analysis

MRI images were reviewed, independent of the surgical findings, by 2 authors (V.R. and F.A.) with 5 or more years of experience in cardiovascular MRI. Consensus opinion was used for statistical analysis. Specific analysis was made regarding the level of intravascular tumoral extension by stratifying patients into 4 groups according to the level of intravascular extension per the classification proposed by Neves and Zincke[19] (Figure 3): involvement of the renal vein (level I), involvement of the infrahepatic IVC (level II), involvement of the intrahepatic IVC (level III), and supradiaphragmatic extension (level IV). To assess tumoral adherence to the vessel wall, 2 specific MRI signs were analyzed. First sign looked at circumferential blood flow around the intravascular tumor component on true fast imaging with steady-state precession and postcontrast images (Figure 4). Second sign looked at the mobility of the intravascular extension on cinematic images during different phases of the cardiac cycle. Tumor was considered to be adherent to the vessel wall if there was no circumferential flow around it, if it was not mobile within the vessel, or both.

Statistical Analysis

Statistical analysis was performed with Stata software (version 10; StataCorp LP, College Station, Tex). MRI staging of intravascular extension was compared with intraoperative staging to assess agreement by means of κ statistics. The accuracy of MRI in predicting the level of intravascular extension was calculated by assessing sensitivity and specificity values for individual stages, with the surgical findings considered the criterion standard. The MRI findings of circumferential flow and tumoral mobility were specifically analyzed against the intraoperative finding of tumoral adherence to the vessel wall. The sensitivity and specificity of MRI in predicting the need for CPB (levels III and IV) were also assessed.

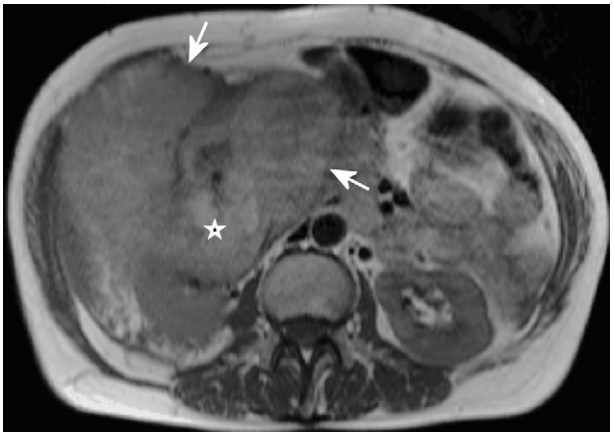

FIGURE 1. Half-Fourier acquisition single-shot turbo spin echo axial image of upper abdomen showing right renal cell carcinoma *(star)* with extensive peritoneal soft tissue extension *(arrows)*.

RESULTS

Study Population

A total of 64 patients with RCC underwent MRI as part of the staging process during the period of study. There were 34 men and 30 women with a median age of 62 years, (range, 24–83 years). Forty-three patients had right kidney tumors, 19 had left-sided tumors, and 2 patients had bilateral RCC. MRI scan was generally well tolerated by patients, with only a couple of incidents in which suboptimal images were obtained because patients were unable to breath hold. On average, the scan duration was less than an hour, and delayed myocardial enhancement imaging after gadolinium contrast was performed in patients with known or suspected coronary artery disease.

Surgical Management

Of the 64 patients, 10 were not suitable candidates for radical or palliative surgery in view of their comorbidities or metastatic spread of the disease. These patients were referred to the oncologists or a palliative care team and were excluded from this analysis. Twelve patients were referred back to their primary hospitals for further management and were excluded from the analysis because operative details were not available. One patient underwent exploratory laparotomy and was excluded from this analysis. In total, 41 patients who underwent curative or palliative surgery at our institution were included for statistical analysis. Average time lag between the MRI