Respiratory dynamic magnetic resonance imaging for determining aortic invasion of thoracic neoplasms

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Objective: An accurate radiological method for evaluating the presence or extent of aortic invasion by thoracic cancer is essential in the preoperative setting. The aim of this study was to assess whether respiratory dynamic (RD) magnetic resonance imaging (MRI) more accurately detects aortic invasion of mediastinal tumors and lung cancer compared with conventional MRI or computed tomography (CT).

Methods: Twenty-six patients (19 male, 7 female; mean age, 63.08 $\pm$ 12.05 years) with inconclusive evidence of aortic invasion on chest CT underwent MRI (conventional and RD MRI using a balanced fast field echo sequence with a 1.5 T unit). The presence of aortic invasion was determined by fixation of the aorta and lack of synchronous motion during respiration on RD MRI. The results of CT and MRI were compared with the pathology results. The sensitivity, specificity, and accuracy of CT, conventional MRI, and conventional MRI with RD MRI were compared.

Results: Of 26 patients, 5 patients had invasion of the aorta. The sensitivity for determining aortic invasion was 100% using CT alone, conventional MRI alone, and conventional MRI with RD MRI. The specificity and accuracy for conventional MRI with RD MRI were significantly higher (71.4% and 76.9%, respectively) than for CT (28.5% and 42.3%, $P < .05$) or conventional MRI alone (33.3% and 46.1%, $P < .05$).

Conclusions: RD MRI may improve the diagnostic accuracy of MRI by predicting aortic invasion use in preoperative staging. (J Thorac Cardiovasc Surg 2014;148:644-50)

Video clip is available online.

GTS

A malignant thoracic tumor that invades the aorta carries a poor prognosis with terrible long-term outcomes. Accordingly, most authorities consider invasion of the great vessels, including the aorta, as a contraindication to surgery.[1] The value of surgical treatment of thoracic tumors with limited local invasion of the thoracic aorta has been described in a few reports.[2,3] An accurate radiological method to evaluate the presence or extent of aortic invasion by thoracic cancer is essential in the preoperative setting.

Currently, computed tomography (CT) is widely used in the preoperative staging of thoracic cancer to evaluate for invasion of the aorta; however, the accuracy and sensitivity of this technique is limited, especially given there are no reliable criteria for aortic wall invasion.[4] Neither the amount of contact (<3 cm and/or 90° circumference) nor the presence of a mass effect on adjacent structures is a reliable sign of invasion or unresectability.[5-8] Therefore, CT imaging studies often fail to differentiate between contact and tumor invasion.

Magnetic resonance imaging (MRI) is another sophisticated modality used to evaluate great vessel invasion in thoracic cancer. Conventional MRI provides better detection of intervening fat planes between a mass and adjacent structures with better contrast resolution than conventional CT, which supplies more information about local invasion of a thoracic neoplasm into musculoskeletal and neurovascular structures.[9] MRI has the same limitations as CT with a slight, but not significant, increase in accuracy.[7,8,10]

A previous study addressed the use of cine MRI to evaluate the invasion of lung cancer into moving structures, such as the chest wall or cardiovascular structures.[11] However, evaluation of major structures with minimal to no motion such as the distal aortic arch, descending thoracic aorta, superior vena cava, and pulmonary veins is limited on cine MRI.[11,12] Respiratory dynamic (RD) MRI during breathing is a useful imaging technique with a high diagnostic accuracy for chest wall invasion by lung cancer.[13,14] Because of the independent motion between the chest wall and lungs during breathing, RD MRI helps to assess chest wall invasion by lung cancer.

Because the lung is a dynamic organ, we hypothesized that the aorta and lungs also move independently during breathing. Therefore, dynamic imaging during respiration may provide additional information beyond static images

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Abbreviations and Acronyms

AUC = area under the curve
CI = confidence interval
CT = computed tomography
MDCT = multidetector computed tomography
MRI = magnetic resonance imaging
RD = respiratory dynamic

alone in the diagnosis of tumor invasion into the aorta. The aim of this study was to assess whether RD MRI more accurately determines aortic wall invasion by mediastinal tumors and lung cancer compared with conventional MRI or CT.

MATERIALS AND METHODS

Patient Selection

The Institutional Review Board of our institution approved this retrospective study. All patients provided written informed consent for CT and MRI after the procedures had been fully explained to them. From June 2008 to July 2012, 90 patients with mediastinal or lung masses and chest CT suspicious for cardiovascular invasion underwent chest MRI before surgery. Of these 90, 37 had lung masses abutting the aorta on axial images of the chest on MRI. Eleven patients were excluded from this study based on the following exclusion criteria: (1) multiple lung metastases or other distant metastases (n = 7); (2) lack of pathology results (n = 3); and (3) failure to provide informed consent (n = 1). Twenty-six patients were included for analysis.

Two radiologists independently reviewed chest CT images to evaluate for aortic invasion. Differences in assessment were resolved by consensus. The study population consisted of 19 men and 7 women aged from 43 to 81 years (mean age, 63.08 ± 12.05 years). Baseline clinical characteristics, including systemic hypertension, pulmonary tuberculosis, diabetes mellitus, and smoking status were determined by analysis of medical records and routine laboratory data.

CT Technique

CT scans were performed with a 16-channel multidetector CT (MDCT; Somatom Sensation 16; Siemens, Forchheim, Germany) or 64-channel MDCT (Sensation 64, Siemens). Patients were placed in a supine position, injected with contrast material, and asked to hold their breath. During this single breath-hold, scanning was performed using the helical technique. A total of 80-120 mL of iopamidol (300 mg of iodine/mL; Radisense, Taejoon, Pharm, Seoul, Korea) was administered intravenously to all patients at a rate of 3-4 mL/s using a power injector (Envision CT; Medrad, Warrendale, Pa). To obtain thin-section CT images, we used the following parameters: 120 kVp, 200 effective mAs, 0.5 s gantry rotation, 0.75 mm collimation, and a 0.5 mm interval. Image data were reconstructed with a thickness of 1.0 mm and an increment of 1.0 mm using a standard algorithm. The scan area ranged from the lung apices to the middle portion of both kidneys. All CT images were retrieved on a picture archiving and communication system (Centricity; GE Medical Systems, Milwaukee, Wis) to allow free manipulation of the images for evaluation of lesions.

MRI Technique

Conventional MRI images were obtained with a 1.5 T unit (Achieva; Philips Healthcare, Best, The Netherlands). We obtained the following sequences: T1-weighted axial images using a three-dimensional (3D) gradient echo sequence with and without fat suppression (THRIVE; repetition time 3 milliseconds, echo time 1 millisecond, flip angle 10°, field of view 40 cm, matrix 256 × 256, and slice thickness 5 mm), and postcontrast T1-weighted axial images using a 3D gradient echo sequence with fat suppression (THRIVE).

RD MRI sequential images were acquired using a balanced fast field echo sequence during deep respiration (repetition time 2.3 milliseconds, echo time 1.1 milliseconds, flip angle 50°, field of view 38 cm, matrix 128 × 128, and slice thickness 10 mm). For evaluation of tumor mobility, the suspected invasion site between the mass and adjacent aorta was identified for each patient; perpendicular to this site, 1 to 5 slices either in the coronal or sagittal plane were obtained. Therefore, 80 to 100 sequential images were obtained during deep respiration, in either the coronal or sagittal planes, depending on the location of the tumor.

Imaging Analysis

Two radiologists independently reviewed the images from CT, conventional MRI alone, and conventional MRI in combination with RD MRI. Differences in assessment were resolved by consensus. MRI scans were initially assessed without RD MRI, followed by a second review 1 week later that combined conventional MRI and RD MRI in the same session.

The criteria for aortic invasion of a thoracic mass on CT and conventional MRI were as follows: (1) obliteration of intervening mediastinal fat between the thoracic mass and the aorta; (2) irregular indentation of the aortic wall by the mass; (3) assessment of the degree of contact between the thoracic mass and surrounding adjacent aorta (ie, greater than 90° or greater than 3 cm on axial images); and (4) the presence of an obtuse angle between the mass and the aorta. CT and conventional MRI findings were classified as either negative or positive for aortic invasion. Only 1 positive criterion was necessary for the tumor to be classified as invading the aorta.

To evaluate direct invasion of a thoracic mass into the adjacent aortic wall by RD MRI, we analyzed the dynamic relationship between the tumor and the aorta in cine-loop mode. RD MRI was considered negative for aortic invasion when the tumor moved along the aorta freely, in synchrony with breathing. Results were positive for aortic invasion when the tumor was fixed to the aorta with lack of synchronous motion during respiration.

If both conventional MRI and RD MRI were positive, imaging was considered to be positive for aortic invasion. If RD MRI was negative, the results was considered to be negative. The CT and MRI results were compared with the pathology results.

Statistical Analysis

Using the pathology report as the reference standard, we calculated the sensitivity, specificity, accuracy, positive predictive value, negative predictive value, and area under the curve (AUC) to compare the accuracy of each imaging modality for diagnosing aortic invasion by mediastinal tumors or lung cancer. Using a generalized estimating equation and receiver operating characteristic analysis, 95% confidence intervals (CIs) were calculated. Bonferroni correction was used for multiple comparisons. Statistical analyses were performed with SAS software version 9.2 for Windows (SAS Institute Inc, Cary, NC).

RESULTS

The postoperative pathologic diagnoses were as follows: lung cancer in 16 patients (6 adenocarcinoma, 9 squamous cell carcinoma, and 1 pleomorphic carcinoma); thymic carcinoma in 3 patients; mature cystic teratoma in 2 patients; schwannoma in 2 patients; pleomorphic malignant fibrous histiocytoma in 1 patient; metastatic carcinoma in