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 ± 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.

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, Taejeon, 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

TABLE 1. Clinical characteristics of 26 patients

Characteristics	Number of patients (%)
Age, mean $\pm$ 1 SD, y	63.08 $\pm$ 12.05
Male	19 (73)
Hypertension	8 (30)
Old pulmonary tuberculosis	4 (15)
Diabetes mellitus	3 (12)
Smoking	11 (42)
Tumor location	
Mediastinum	8
Upper and middle lobes	9
Lower lobes	9

SD, Standard deviation.

1 patient; and metastatic sarcoma in 1 patient. The clinical characteristics of the 26 patients are summarized in Table 1. On final pathology, 21 patients had no invasion, and 5 had aortic invasion of the thoracic aorta (proximal aorta, $n = 1$; descending aorta, $n = 4$). Of these 5 patients, 2 were diagnosed with squamous cell carcinoma, 1 with adenocarcinoma, 1 with metastatic carcinoma, and 1 with metastatic sarcoma.

Our follow-up records on these 5 patients show that 1 patient with confirmed metastatic carcinoma underwent chemotherapy and radiation therapy after surgery but died 7 months later. Another patient diagnosed with metastatic sarcoma also underwent chemotherapy and radiation therapy after surgery but died 12 months later. A third patient with confirmed metastatic carcinoma had additional radiation therapy but died 3 months later. A fourth patient with a diagnosis of adenocarcinoma died 3 months later without additional treatment. The fifth patient with a diagnosis of squamous cell carcinoma is alive 24 months after surgery involving R2 resection and additional chemotherapy and radiation therapy.

On CT, there were 15 false-positive results (9 in the proximal aorta and 6 in the descending aorta). On conventional MRI, there were 14 false-positive results (7 in the proximal aorta and 7 in the descending aorta).

There were no false-negative results. The overall sensitivity, specificity, and accuracy for determining aortic invasion using CT and conventional MRI alone were 100%, 28.57% (95% CI, 9.25%-47.89%), 42.31% (95% CI, 23.32%-61.3%), respectively, for CT and 100%, 33.33% (95% CI, 13.17%-53.5%), 46.15% (95% CI, 26.99%-65.32%), respectively, for conventional MRI alone (Table 2).

On RD MRI, 15 patients showed free movement of the tumor along the aorta and all patients were confirmed as negative for invasion on final pathology (Figure 1 and Video 1). Eleven patients showed fixation of the tumor to the aorta with invasion confirmed in 5 patients (Figure 2 and Video 2); 6 had false-positive results (5 in the proximal aorta and 1 in the descending aorta). Of the 6 cases, 2 cases were confirmed as benign fibrous adhesions at surgery (1 in the aortic arch and 1 in the descending aorta). There were no false-negative results. The overall sensitivity, specificity, and accuracy for determination of aortic invasion using RD MRI were 100%, 71.43% (95% CI, 52.11%-90.75%), and 76.92% (95% CI, 60.73%-93.12%), respectively (Table 2).

The specificity for detecting aortic invasion using conventional MRI with RD MRI was significantly different from CT (71.43% vs 28.57%; $P = .003$) and conventional MRI alone (71.43% vs 33.33%; $P < .001$).

The diagnostic accuracy of conventional MRI with RD MRI was also significantly different from that of CT (79.62% vs 42.31%; $P = .003$) and conventional MRI alone (79.62% vs 46.15%; $P = .003$).

As shown in Table 2, the AUCs for determining aortic invasion using CT, conventional MRI alone, and conventional MRI with RD MRI were 0.643 (95% CI, 0.544-0.742), 0.667 (95% CI, 0.563-0.77), and 0.857 (95% CI, 0.758-0.956), respectively. The AUC of RD MRI was significantly larger than that of CT or conventional MRI alone ($P = .003$ and $P = .003$, respectively).

For the determination of proximal aortic invasion ($n = 14$), there were 9 false-positive results on CT and 7

TABLE 2. Results of CT, MRI, and RD MRI for the determination of aortic invasion in 26 patients with lung cancer

	CT	MRI	(+) RD MRI*
True-positive	5	5	5
True-negative	6	7	15
False-positive	15	14	6
False-negative	0	0	0
Sensitivity (%)	100	100	100
Specificity, % (95% CI)	28.57 (9.25-47.89)	33.33 (13.17-53.5)	71.43 (52.11-90.75)†,‡
Accuracy, % (95% CI)	42.31 (23.32-61.3)	46.15 (26.99-65.43)	76.92 (60.73-93.12)†,‡
Positive predictive value, % (95% CI)	25 (6.02-43.98)	26.32 (6.52-46.12)	45.45 (16.03-74.88)
Negative predictive value (%)	100	100	100
AUC (95% CI)	0.643 (0.544-0.742)	0.667 (0.563-0.77)	0.857 (0.758-0.956)†,‡

CT, Computed tomography; RD, respiratory dynamic; MRI, magnetic resonance imaging; CI, confidence interval; AUC, area under the curve. *Conventional MRI in combination with RD MRI. †CT versus RD MRI, $P < .05$. ‡MRI versus RD MRI, $P < .05$.

FIGURE 1. A 63-year-old woman with squamous cell carcinoma in the left lower lobe. A, Contrast-enhanced computed tomography images demonstrate a 3.8-cm mass in the left lower lobe abutting the descending thoracic aorta (*arrow*). B, T1-weighted magnetic resonance imaging with fat suppression demonstrates an isodense mass in the left lower lobe without suspicious invasion of the descending aorta (*arrow*). C, Postcontrast T1-weighted magnetic resonance imaging with fat suppression demonstrate a heterogeneously enhancing tumor without suspicious invasion of the descending thoracic aorta (*arrow*).

on conventional MRI; on conventional MRI combined with RD MRI, 5 patients had false-positive results and 8 had

true-negative results (Table 3). Specificity for determining proximal aortic invasion was significantly different between conventional MRI with RD MRI and CT (61.54% vs 30.77%; $P = .048$). However, the difference in diagnostic accuracy between conventional MRI with RD MRI and CT was not significantly different (64.29% vs 35.71%; $P = .054$). The differences in specificity and diagnostic accuracy between conventional MRI with RD MRI and conventional MRI alone were not significantly different (61.54 vs 46.15%; $P = .372$ and 64.29% vs 50%; $P = .381$, respectively).

To determine descending thoracic aortic invasion ($n = 12$), 7 false-positive results were obtained with conventional MRI alone, whereas there was only 1 false-positive result with conventional MRI combined with RD MRI. There were no false-negative results (Table 3). The sensitivity, specificity, and accuracy for determining descending aortic invasion using conventional MRI with RD MRI were 100%, 87.5%, and 91.67%, respectively. Between conventional MRI with RD MRI and CT alone, there was a significant difference in specificity (87.5 vs 25%; $P = .033$) and diagnostic accuracy (91.67% vs 50%; $P = .048$). Between conventional MRI with RD MRI and conventional MRI alone, there was a significant difference in specificity (87.5 vs 12.5%; $P < .001$) and diagnostic accuracy (91.67% vs 41.67%; $P = .003$) for the determination of proximal aortic invasion (Table 3).

DISCUSSION

Our study demonstrates that RD MRI can provide additional information and improve diagnostic accuracy of predicting aortic invasion in the preoperative setting. The addition of RD MRI to conventional MRI helps to reduce false-positive interpretations by conventional MRI, especially in the determination of descending thoracic aortic invasion. Aortic invasion by a thoracic neoplasm is rare; however, the presence of aortic invasion is an important factor in determining clinical outcomes.

In clinical practice, T-staging of lung cancer is largely based on CT imaging.^{15,16} Although CT allows accurate assessment of the anatomic relationship between a tumor and surrounding structures, reliable CT criteria of mediastinal tumor invasion have not been fully defined, especially for aortic invasion. Quantification of the extent of direct contact between a tumor and the aorta on CT imaging has been reported to be helpful in predicting aortic invasion.^{5-8,17} Glazer and colleagues⁵ reported that 4 of 8 lung cancers with greater than 90° contact with the aorta showed aortic invasion at surgery. In contrast, all 11 patients in whom the mass had less than 90° contact with the aorta had no invasion of the aorta. Another study reported that the sensitivity, specificity, and accuracy for diagnosing aortic invasion using CT were 60%, 67%, and

FIGURE 2. A 76-year-old woman with a metastatic sarcoma in the left lower lobe. A, Contrast-enhanced computed tomography images demonstrate a 5.3-cm mass in the left lower lobe with suspicious invasion of the descending thoracic aorta (arrow). B, T1-weighted axial magnetic resonance imaging demonstrates a heterogeneously enhancing tumor

64%, respectively.¹⁷ Therefore, CT may be helpful in predicting the absence of aortic invasion, but cannot reliably predict invasion in patients with lung cancer. We applied the well-known CT mediastinal invasion criteria used to evaluate aortic invasion: obliterated fat line between the mass and the mediastinum; mass contact of 3 cm or more with the mediastinum; more than 90° of contact with the mediastinum; and the presence of an obtuse angle between the mass and the aorta. These findings are known to have high sensitivity and low specificity.⁵ Moreover, we consider the result to be positive when even 1 of the 4 criteria is present. Therefore, the sensitivities of CT and conventional MRI were high and their accuracy and specificity were different from previous studies.¹⁷ The primary purpose of this study was to compare the performance of modalities including only inconclusive cases regarding aortic invasion, so it is inevitable that the diagnostic performance of CT and conventional MRI was different from that in previous studies.^{5,17}

Because of its higher soft-tissue resolution, MRI is superior to chest CT for demonstrating the musculoskeletal anatomy and neurovascular structures of the neck and mediastinum. Although MRI seems to be superior to CT for diagnosing mediastinal vascular invasion, it has the same limitations as CT in distinguishing neoplastic contiguity from subtle tumor extension into the mediastinal structures.^{7,8} Comparative studies have not shown significant differences between CT and MRI in assessing mediastinal invasion.^{8,18,19} One study reported that MRI was significantly more accurate than CT for diagnosing mediastinal invasion, but this result was based on a small number of patients with T4 stage tumors.⁸ In our study, the overall sensitivity, specificity, and accuracy for determining aortic invasion using conventional MRI alone were 100%, 33.33%, and 46.15%, respectively.

When considering surgical treatment of a thoracic mass, including lung cancer, it is important to evaluate direct invasion of adjacent structures such as cardiovascular structures. Several studies have assessed cardiovascular invasion of an intrathoracic mass using cine MRI.^{11,20} However, the minimal motion of cardiovascular structures such as the distal aortic arch, descending thoracic aorta, superior vena cava, and pulmonary veins increases the risk of a false-positive or false-negative diagnosis of cardiovascular invasion of a thoracic mass if the diagnosis depends on the absence of sliding motion on cine MRI. In this respect, cine MRI is limited in its ability to predict aortic invasion by lung cancer.

abutting the descending thoracic aorta (arrow). There was obliteration of the fat plane between the tumor and the adjacent aorta (arrowhead). C, Postcontrast coronal T1-weighted magnetic resonance imaging with fat suppression demonstrates a heterogeneously enhancing tumor (arrow) with suspicious invasion of the descending thoracic aorta (arrowhead).

TABLE 3. Results of CT, MRI, and RD MRI for the determination of aortic invasion according to the location of the tumor

	Proximal aorta (n = 14)			Descending aorta (n = 12)		
	CT	MRI	(+) RD MRI*	CT	MRI	(+) RD MRI*
True-positive	1	1	1	4	4	4
True-negative	4	6	8	2	0	7
False-positive	9	7	5	6	7	1
False-negative	0	0	0	0	0	0
Sensitivity (%)	100	100	100	100	100	100
Specificity, % (95% CI)	30.77 (5.68-55.86)	46.15 (19.05-73.25)	61.54 (35.09-87.98)†	25 (0-55.01)	12.5 (0-35.42)	87.5 (64.58-100)‡,‡
Accuracy (%)	35.71 (10.61-60.81)	50 (23.81-76.19)	64.29 (39.19-89.39)	50 (21.71-78.29)	41.67 (13.77-69.56)	91.67 (76.03-100)‡,‡
Positive predictive value, % (95% CI)	10 (0-28.59)	12.5 (0-35.42)	16.67 (0-46.49)	40 (9.64-70.36)	36.36 (7.94-64.79)	80 (44.94-100)‡
Negative predictive value (%)	100	100	100	100	100	100

CT, Computed tomography; RD, respiratory dynamic; MRI, magnetic resonance imaging; CI, confidence interval. *Conventional MRI in combination with RD MRI. †CT versus RD MRI, *P* < .05. ‡MRI versus RD MRI, *P* < .05.

We hypothesized that the aorta and the lungs move independently during breathing because the lung is a dynamic organ that changes in size and shape during a respiratory cycle. Therefore, using dynamic imaging during respiration, free motion of a tumor can be observed along the aorta. In this study, we evaluated the diagnostic performance of RD MRI for aorta invasion according to tumor location. RD MRI reduced the number false-positive results in the diagnosis of proximal aortic (aortic arch or ascending aorta) invasion, but did not significantly improve the accuracy of diagnosis of proximal aorta invasion. This was likely a result of the limited mobility of the upper lobes during respiration. Therefore, the possibility of false-positive findings should be considered even when using RD MRI when the tumor is located in the ascending aorta or aortic arch. For the determination of descending thoracic aortic invasion, the diagnostic accuracy improved significantly for conventional MRI in combination with RD MRI, compared with conventional MRI or CT alone. When the tumor is located in the lower lobes, the sliding motion between the tumor and the aorta can be more easily evaluated because of the wide range of motion in the lower lobes during respiration.

In our study, there were 2 false-positive results (1 at the descending aorta and 1 at the proximal aorta) with RD MRI that were confirmed as benign fibrous adhesions. Because invasion was determined by analyzing the dynamic relationship between the tumor and the aorta, it was sometimes difficult to distinguish between aortic invasion and benign fibrous adhesions. Thus, the possibility of false-positive findings should be considered even when using RD MRI. But the specificity of RD MRI was significantly higher compared with the other modalities. RD MRI may be useful to confirm the absence of aortic invasion, which will lead to an increase in the number of surgical cases.

Despite the many merits of MRI, the usefulness of chest MRI is somewhat limited and is a less attractive option for thoracic neoplasms because of its inability to produce

images of the lung. Moreover, it has limited coverage because of longer image acquisition times, and requires greater physician supervision to direct imaging and maintain examination quality compared with chest CT scans.^{21,22} Despite these limitations, MRI is the most useful tool to complement chest CT and could be selectively applied for preoperative evaluation. In patients with equivocal findings of aortic invasion on static CT scan or MRI, for example, RD MRI may provide conclusive evidence of aortic invasion, thus, we believe that RD MRI is indicated in these cases. RD MRI is a simple noninvasive examination that may improve the detection of aortic invasion by lung cancer through the recognition of restricted tumor movement along the wall of the aorta during deep breathing.

The main limitations of our study were the small size of the study population and the inclusion of various classes of mediastinal and lung cancers, which limits the generalizability of these findings.

CONCLUSIONS

RD MRI can improve diagnostic accuracy by predicting aortic invasion during preoperative staging and can provide additional information not revealed by conventional CT or MRI. Combining RD MRI with conventional MRI helps to avoid the false-positive interpretations seen with conventional MRI, especially for determining descending thoracic aortic invasion. RD MRI improves the specificity and diagnostic accuracy of conventional CT or MRI in the prediction of aortic invasion of thoracic neoplasms. This is especially true in patients with equivocal results from a conventional CT scan or MRI in the presence of a thoracic mass abutting the aortic wall surface without obvious aortic wall invasion.

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