Magnetic resonance and computed tomography evaluation of tracheobronchial lesions prior to laser photoresection[1]

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Magnetic resonance (MR) and computed tomography (CT) images prior to endoscopic laser photoresection for obstructing lesions of the airways were compared in 24 patients. In 33% of the cases, MR was considered superior to CT in defining the relationship of the vessels to the tracheobronchial tree and the location and extent of the airway lesion. In 50% MR and CT were equal. In 17% MR was not diagnostic, mainly because of motion degradation of the images. Transverse MR imaging can define tumor relationship to vessels. Coronal imaging allows visualization of the trachea and mainstem bronchi, and surface coil technology allows imaging with improved resolution of the proximal trachea. MR, when available, is an appropriate first imaging modality for evaluating the relationships of the tracheobronchial tree and vasculature prior to laser photoresection. If MR is not readily available, or if cardiac arrhythmia or patient motion precludes MR imaging, then contrast-enhanced CT evaluation would be the modality of choice.

Index terms: Bronchial neoplasms • Laser coagulation • Nuclear magnetic resonance

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Until recently, the treatment of tracheobronchial lesions causing central airway obstruction has been limited to surgery, radiotherapy, chemotherapy, and occasionally cryotherapy. With the development of laser technology, which may be used with a flexible bronchoscope, direct ablation of endobronchial and tracheal lesions is now possible.[1–4]

Of the different medical laser systems, only the Nd-YAG (neodymium-yttrium aluminum garnet) laser combines a

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Table. Results of MR vs. CT imaging in 24 patients

Case/Age/Sex/Figure	Diagnosis	Preoperative Bronchoscopic Findings	MR Findings	MR Grading*	Comments
I/61/M	Squamous carcinoma	90% occlusion, right BI	Marked narrowing of BI by soft-tissue mass. Consolidation of RLL.	+	No contrast material used on CT because of elevated creatinine level. RPA better defined on MR.
II/65/F	Adenocarcinoma	50% occlusion, lower trachea, with complete occlusion RMSB	Large mediastinal soft-tissue mass. Moderate narrowing of distal trachea. RMSB bronchus occluded.	−	RPA and LPA not well defined on MR.
III/63/M	Large-cell carcinoma	85–90% occlusion of trachea, 2–3 cm above carina	Marked narrowing of distal trachea by posterior soft-tissue mass. Large RUL mass.	°	Anatomy well delineated by both MR and CT.
IV/58/M	Squamous carcinoma	80% occlusion, RSMB, narrowed BI, total occlusion RUL bronchus	Marked narrowing RMSB. Region of RUL bronchus involved with soft-tissue mass. Mediastinal soft-tissue mass present.	°	Both MR and CT showed extrinsic compression of RPA.
V/63/M	Benign stricture	85% occlusion of trachea just above carina	Focal, marked irregularity and narrowing of trachea without soft-tissue mass.	°	Calcification present on CT, not seen on MR. Stricture seen on MR and CT.
VI/67/M	Squamous carcinoma	95% occlusion, LMSB	Marked narrowing LMSB. Associated with soft-tissue mass. Left lung collapse and small left effusion.	°	LPA relationship to bronchus not adequately seen on either CT or MR.
VII/75/M/6	Squamous carcinoma	70% occlusion, BI	RLL, RML volume loss. Mediastinal involvement by tumor. Marked narrowing of BI.	+	RPA better defined by MR.
VIII/31/M	Metastatic epitheloid carcinoma	99% occlusion LMSB by tumor, also extrinsic compression, LMSB	Distal LMSB occluded. Consolidation of LLL with bulging of major fissure.	+	Areas of calcification in mass seen on CT. Course of LPA defined by MR but not CT.
IX/69/M	Squamous carcinoma	95% occlusion, trachea	Moderate, marked narrowing of trachea at level of C6–7.	−	Motion degradation of MR images.
X/57/M/1	Malignant fibrous histiocytoma	Total occlusion LUL bronchus, 80% occlusion LLL bronchus	Moderate narrowing LMSB. Consolidation of LUL. Extrinsic compression of LPA.	+	LPA better visualized on MR.
XI/76/F/3	Small-cell carcinoma	99% occlusion, LMSB 80% occlusion, RMSB	Massive mediastinal lymphadenopathy. LMSB occluded. Marked narrowing RMSB.	+	Bronchial narrowing better defined by MR in coronal plane.
XII/53/M/2	Thyroid carcinoma metastatic to trachea	90% occlusion, trachea	Soft-tissue mass anterior to trachea with intraluminal extension at level of sternal notch.	+	Extent of tumor and vessels in neck better seen on MR (surface coil).
XIII/45/F/4	Squamous carcinoma	85% occlusion, LMSB	Marked narrowing LMSB, associated with soft-tissue mass. Subcarinal adenopathy. LLL collapse.	°	Bronchial narrowing and vascular anatomy equally well seen on MR and CT.

Table—continued

Case/Age/Sex/Figure	Diagnosis	Preoperative Bronchoscopic Findings	MR Findings	MR Grading*	Comments
XIV/61/M	Squamous carcinoma	Total occlusion, LMSB	Large mediastinal mass obliterating LMSB. Left lung collapse and small left effusion.	∘	Similar findings on CT and MR.
XV/64/M	Benign polyps	2 polyps at carina causing 80% occlusion orifice of LMSB, diffuse narrowing of LMSB	Moderate narrowed and irregular LMSB. No mediastinal soft-tissue mass.	+	Prior left upper lobectomy. Course of LMSB and LPA better demonstrated by MR.
XVI/63/M	Squamous carcinoma	95% obstruction, RMSB and lower trachea	Soft-tissue mass involving distal trachea. Marked narrowing proximal RMSB. Previous left pneumonectomy.	∘	Tracheal tumor relationship to aorta seen equally well.
XVII/54/M	Large-cell carcinoma	95% occlusion, RMSB	Large mediastinal soft-tissue mass. RMSB occluded. Consolidation of superior segment RLL.	∘	RPA course equally well seen on MR and CT.
XVIII/73/M	Squamous carcinoma	90% occlusion, RMSB	Marked narrowing RMSB. Mediastinal soft-tissue mass. Mass extending into RUL.	∘	Tumor involvement of right trachea and RMSB well demonstrated.
XIX/61/M/5	Metastatic squamous-cell carcinoma of the neck	99% occlusion, LMSB	Total occlusion proximal LMSB. Left lung collapse. Small left effusion.	∘	Left lung collapse, pleural effusion and LPA course equally well demonstrated.
XX/77/M	Squamous-cell carcinoma	60% obstruction, subglottis	Uninterpretable due to motion degradation.	−	
XXI/65/F	Large-cell carcinoma	99% occlusion, RMSB	Occlusion of RMSB. Large mediastinal mass with anterior displacement of RPA.	−	Motion degradation of MR images.
XXII/75/M	Small-cell carcinoma	99% occlusion, BI	Mediastinal adenopathy. Right hilar mass with occlusion of BI. RUL bronchus moderately narrowed.	+	Course of RPA better defined by MR.
XXIII/83/M	Undifferentiated carcinoma	55% occlusion, trachea, 2 cm below cords with circumferential narrowing of lower trachea	Moderate narrowing and irregularity of trachea with mediastinal soft-tissue mass.	∘	Tracheal narrowing seen on sagittal and coronal MR.
XXIV/69/F	Squamous carcinoma	99% occlusion, RMSB	Mediastinal soft-tissue mass. Right lung collapse. RMSB occluded.	∘	Right lung collapse, relation of LA, RPA to tumor mass equally well demonstrated.

LMSB = Left mainstem bronchus
RMSB = Right mainstem bronchus
LLL = Left lower lobe
LPA = Left pulmonary artery
RPA = Right pulmonary artery
LUL = Left upper lobe

LA = Left atrium
BI = Bronchus intermedius
RUL = Right upper lobe
RLL = Right lower lobe
RML = Right middle lobe

* Grading scale:
− = CT more diagnostic than MR
∘ = CT and MR equally diagnostic
+ = MR more diagnostic than CT

A

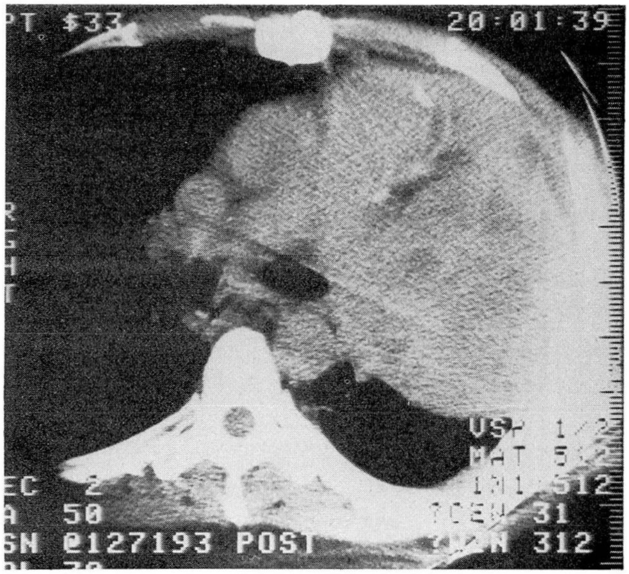
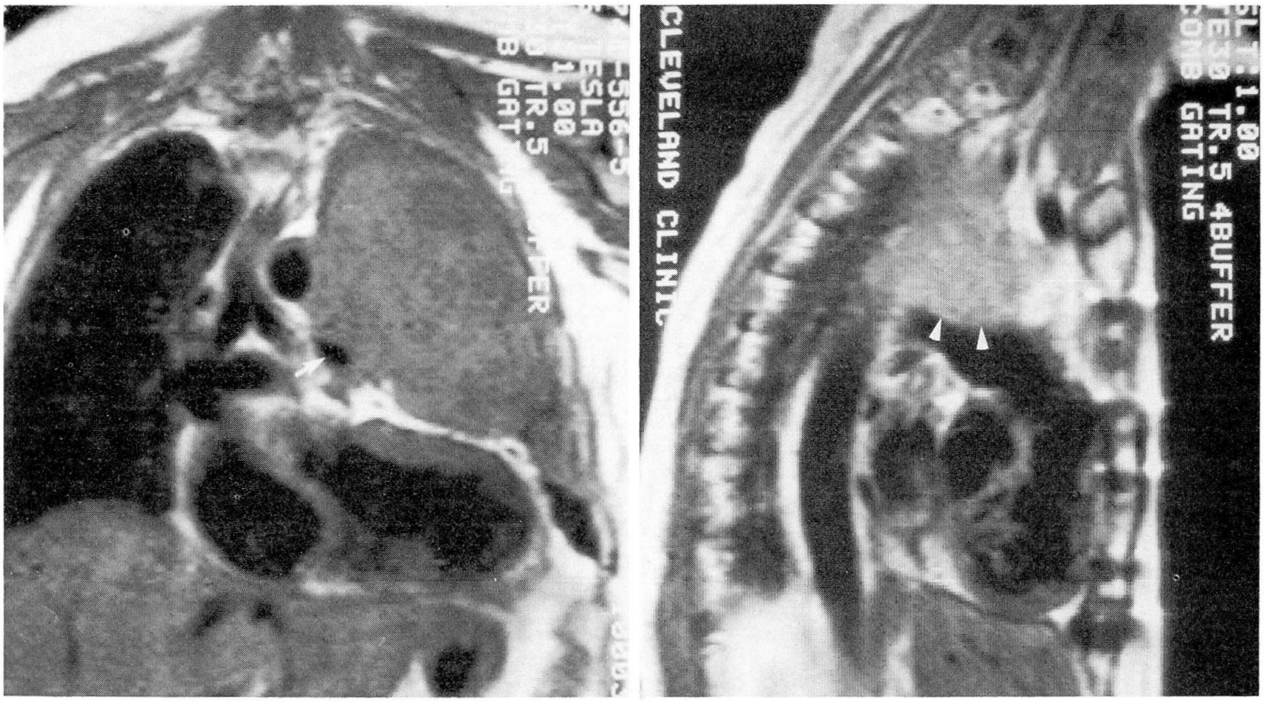


Fig. 1. Malignant fibrous histiocytoma.

A. CT scan. The course of the left pulmonary artery cannot be separated from the adjacent mass and collapse.

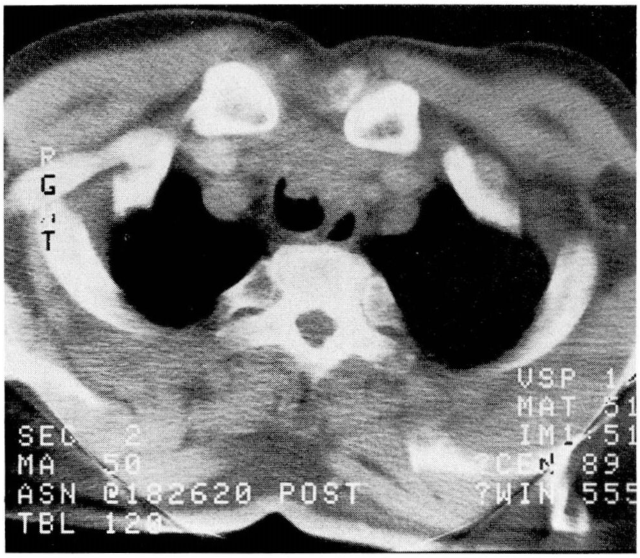
B and **C.** Coronal (**B**) and sagittal (**C**) MR images, TE 30 msec, TR 500 msec. Left pulmonary artery (arrow, **B**) is narrowed by the extrinsic compression of the tumor mass superiorly (arrowheads, **C**).

B,C



suitable wavelength in the near-infrared (1064 nm) and appropriate tissue-ablating properties (because its wavelength is poorly absorbed by hemoglobin), allowing photoresection with either rigid or flexible bronchoscopes. While large series of patients have been operated upon without complications, laser photoresection does have potential risks. The juxtaposition of the tumor to the major vessels and possible penetration of vessel wall by tumor increases the risk of vessel perforation by the laser and subsequent catastrophic bleeding. This has been reported by almost every physician using the Nd-YAG laser.[5]

Computed tomography (CT) has been used successfully in the preoperative evaluation of the mediastinum and airways, and CT anatomy of the mediastinum, bronchi, and hili is well known.[6–9] Magnetic resonance (MR) is also capable of accurately defining mediastinal anatomy and provides better definition of the vasculature than CT, due to greater inherent contrast between flowing blood and soft tissue.[10–13]



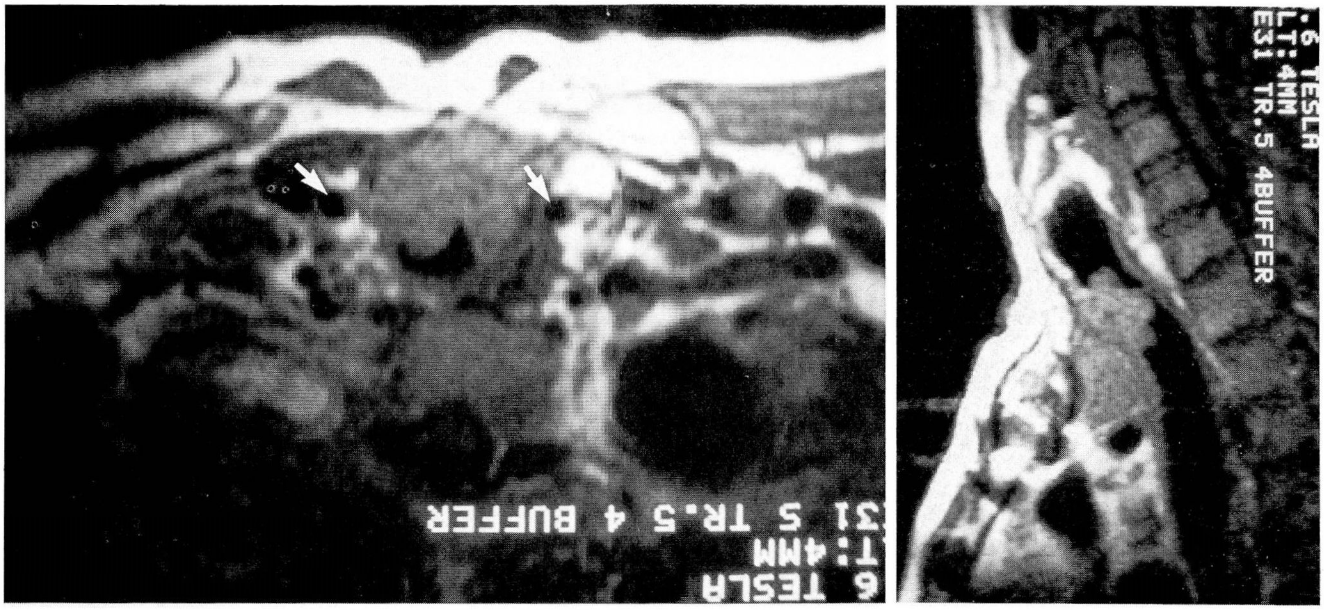
A

Fig. 2. Metastatic thyroid carcinoma.

A. The CT scan shows an exophytic mass involving the anterior wall of the trachea with extension into the soft tissues anteriorly.

B. Transverse MR image, TE 30 msec, TR 500 msec. The mass involving the anterior trachea is demonstrated, as well as the adjacent vasculature (arrows).

C. Sagittal MR image, TE 30 msec, TR 500 msec. The length of the metastatic lesion and its anterior extension is apparent.



B,C

To provide the surgeon with a precise map of the vascular anatomy surrounding the tracheobronchial lesions in order to minimize complications such as vascular perforation, we have compared the utility of MR and CT in 24 patients undergoing laser photoresection for obstructive lesions of the central airways.

Materials and methods

Twenty-two patients with malignant obstruction of a major airway and two patients with benign strictures were examined with MR and CT prior to laser resection. Treatment was given with an Nd-YAG laser system with the monofilament fiber inserted in an Olympus BF-1TR bronchoscope. A xenon aiming light allowed accurate positioning of the invisible laser radiation. Power delivered during the operations varied between 358 and 10,361 joules (1 joule = 1 watt-second). General anesthesia was induced by pretreatment with pancuronium or curare, followed by intravenous sodium pentothal, and maintained after endotracheal intubation with enflurane 0.5–3% in O_2 or room air.

All MR images were obtained with a 0.6-tesla superconducting magnet with a 100-cm bore. Images were acquired using a spin-echo technique with phase-encoding gradient pulses. Coronal and transverse images were obtained in all patients. Sagittal images were obtained if time

A,B

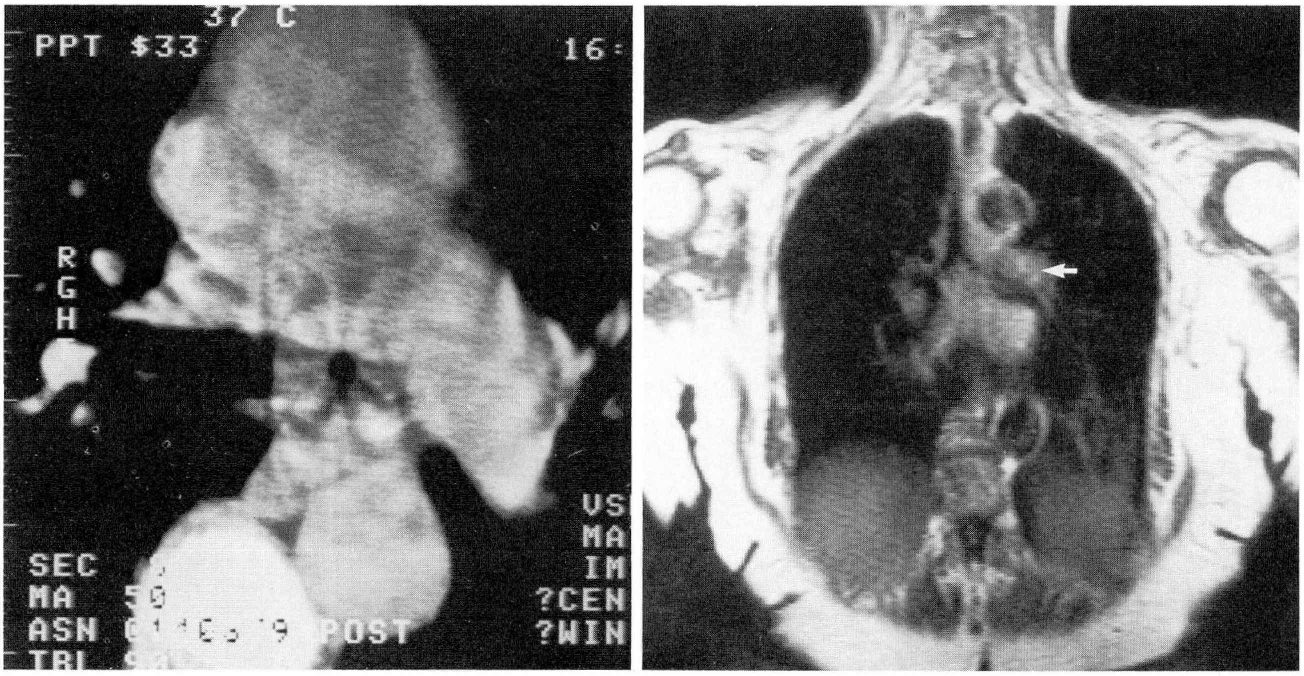


Fig. 3. Small-cell carcinoma.
A. Narrowed left mainstem bronchus demonstrated by CT.
B. Coronal MR image, TE 30 msec, TR 500 msec. Carina and proximal mainstem bronchi are well seen. Note signal arising from left pulmonary artery (arrow) due to cardiac gating.

permitted. A multiple-section method utilizing a body coil was used in the first 13 patients, where 11 contiguous sections of 1 cm thickness were obtained with a TR of 0.5 seconds. In the remaining patients, section thickness was 0.5 to 0.75 cm. In one patient, section thickness was 4 mm utilizing the body coil. A TE of 30 msec was generally used. The majority of images were obtained with two or four signal averages. Combined cardiac and respiratory gating was used in 13 patients. An additional two patients had only cardiac gating, and nine examinations were not gated. In one patient, a surface coil receiver was used, allowing 11 contiguous sections with a 4-mm section thickness and a TR of 0.5 seconds. Electronic axial rotation of the coronal plane was routinely used in an attempt to image the trachea and its bifurcation in one image. This method has been previously described.[14] Reconstruction was by a two-dimensional Fourier method.

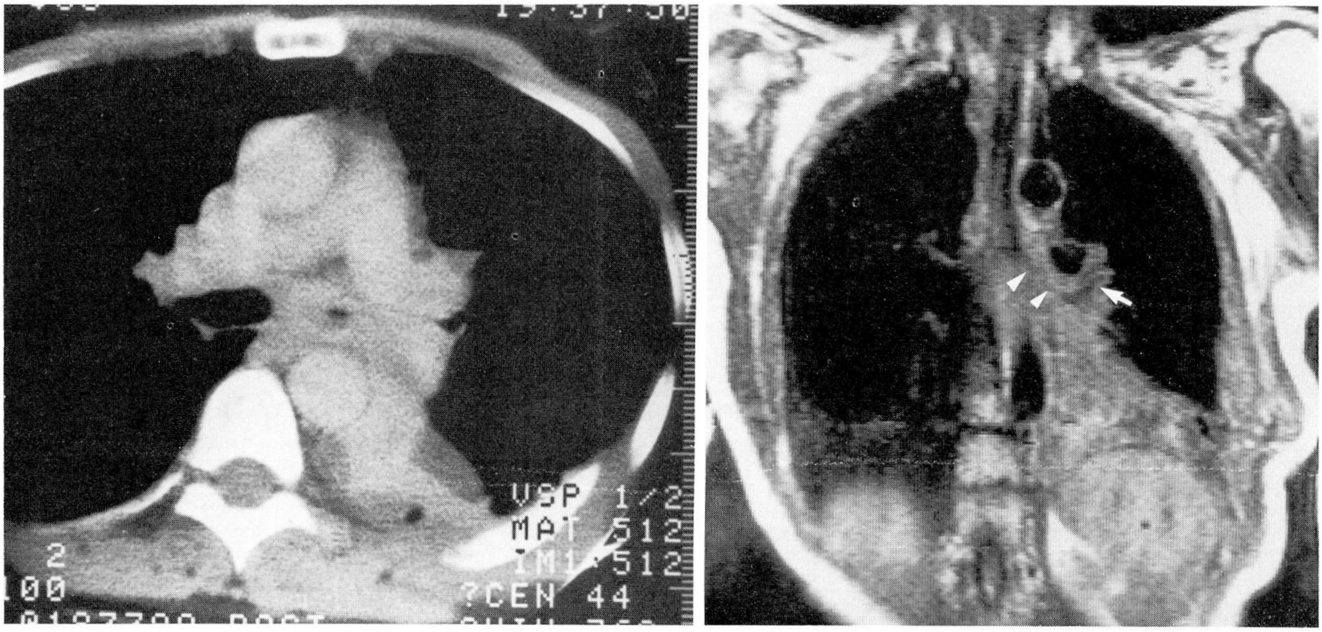
Twenty-three of 24 CT scans were obtained with a Technicare model 2060 using a 2-second scan time. CT scans had contiguous 1-cm or 0.5-cm collimation. Twenty-three of 24 CT scans were obtained after bolus infusions of 50 ml contrast material followed by infusions of 100 ml of contrast material. One CT scan was obtained without contrast enhancement due to the patient's poor renal function.

The MR and CT images were evaluated independently by two of us (JSR, PBO).

Results

In eight cases (33%), MR was considered better than CT in defining vascular anatomy and bronchial obstruction. In 12 of 24 cases (50%), MR was equally diagnostic with CT. In four cases (17%), MR did not give diagnostic studies. The results are summarized in the *Table*.

In six cases, MR was considered superior to CT due to better delineation of the course of the left or right pulmonary arteries in relationship to the tracheobronchial tree. *Figure 1* shows a case of metastatic malignant fibrous histiocytoma that was occluding the left upper and left lower lobe bronchi. The exact course of the left pulmonary artery is not apparent on the CT examination. The MR study shows that the left pulmonary artery is extrinsically compressed along its superior and lateral aspects by tumor. The medial aspect of the left pulmonary artery kept its normal relationship to the left upper lobe bronchus.



A,B

Fig. 4. Squamous carcinoma.
A. CT shows narrowing of the left mainstem bronchus, left lower lobe collapse, and a small pleural effusion.
B. Coronal MR image, TE 30 msec, TR 500 msec. The encasement of the left mainstem bronchus (arrowheads), and left upper lobe bronchus (arrow) by tumor mass is well demonstrated.

In a case of carcinoma of the thyroid metastatic to the trachea, the positions of the vessels in the neck were more apparent by MR than CT, using a surface coil receiver (*Fig. 2*). Also, the length of partial tracheal obstruction produced by the tumor was easily demonstrated in the sagittal plane. Another advantage of MR is the ability to visualize tracheal and bronchial narrowing using coronal and sagittal planes. In two patients MR was considered superior to CT because of improved visualization of location of the site and extent of bronchial narrowing. A small-cell carcinoma nearly producing obstruction of the right and left mainstem bronchi is shown in *Figure 3*. The subcarinal adenopathy and narrowed left mainstem bronchus are quite apparent on the CT study, but the extent of bronchial narrowing is not well demonstrated. On the coronal MR image, the length of narrowing of the left mainstem bronchus is easily demonstrated, surrounded by tumor.

In 12 cases MR and CT were equally diagnostic in defining the positions of the mediastinal vessels, location of bronchial narrowing, and associated soft-tissue masses. *Figure 4* is an example of a case of squamous-cell carcinoma where both CT and MR yielded similar information. The collapsed left lower lobe, associated pleural effusion, and mediastinal involvement by squamous carcinoma are apparent by both imaging modalities.

While similar information may be obtained by transverse MR and CT images, no integration of adjacent sections by the viewer is necessary with coronal or sagittal MR images. If sagittal images are obtained, then the angulation of the trachea with respect to the coronal plane may be determined. Electronically rotating the coronal plane, corrected for this angle, permits imaging of the trachea and mainstem bronchi on one or two sections. *Figure 5* shows a case of head/neck squamous-cell carcinoma metastatic to the left mainstem bronchus. The coronal MR image allows visualization of the carina and the narrowed bronchial lumen on one image.

In four cases, the MR studies were not diagnostic. Patient motion or cardiac arrhythmia degraded image quality in three patients. In the other, the images were obtained early in the series and the gap between image sections did not allow adequate visualization of the pulmonary artery segments (Patient II). None of the CT images were adversely affected by motion artifact.

One postoperative death occurred in this group. Patient VII hemorrhaged two days follow-

A,B

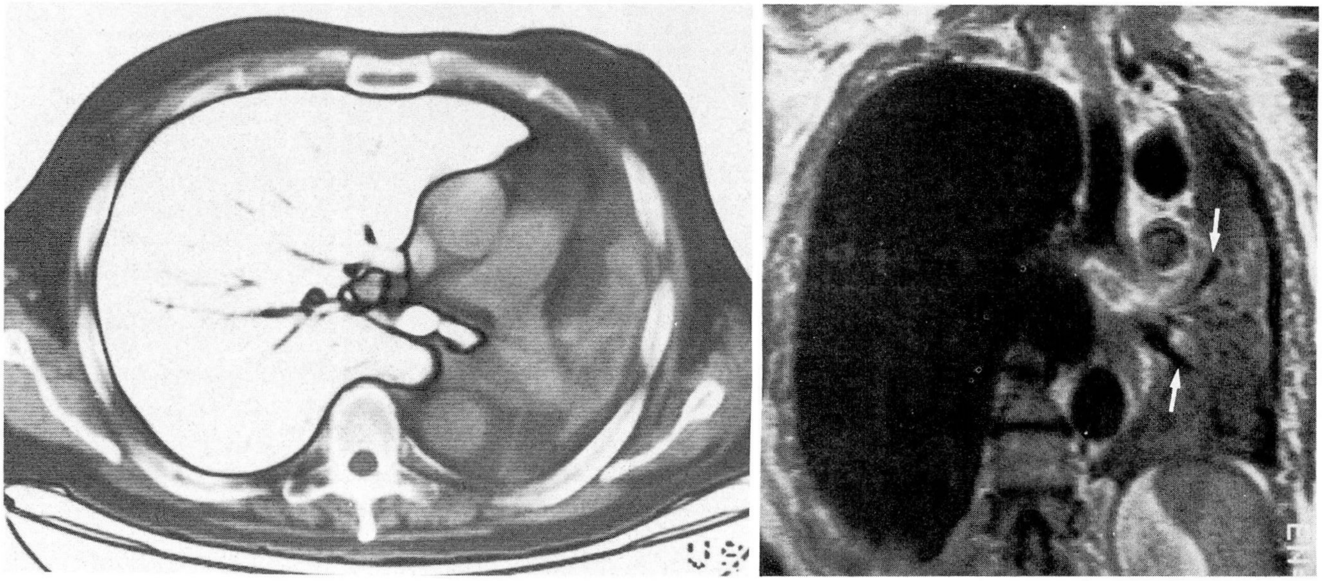


Fig. 5. Squamous carcinoma metastatic from the neck.
A. CT shows a narrowed left mainstem bronchus, left lung collapse, and pleural effusion.
B. Coronal MR image, TE 30 msec, TR 500 msec. The narrowed proximal left mainstem bronchus and distal trachea are clearly seen, along with left lung collapse, effusion, and air bronchograms (arrows).

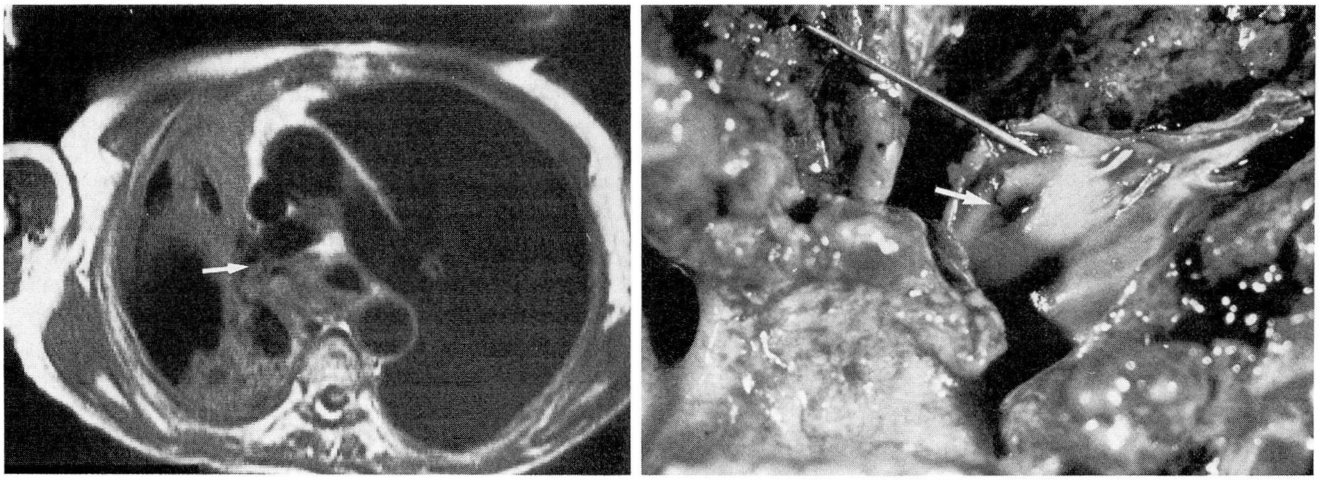
ing laser surgery. At autopsy, there was tumor invasion of the right pulmonary artery, which eventually perforated. In retrospect, the MR image showed subtle irregularity of the posterior right pulmonary artery, representing tumor involvement (*Fig. 6*).

Discussion

Anatomic correlation of the major vessels and the tracheobronchial tree is critical in laser photoresection, since penetration of a major vessel may result in exsanguination. Additionally, the length of airway impingement is valuable information, since this often cannot be determined bronchoscopically if the bronchoscope is larger than the diameter of the compromised lumen.

A major advantage of MR vs. CT for preoperative evaluation lies in the inherent contrast on MR images between rapidly flowing blood and tumor or consolidation. This allows precise localization of the adjacent vasculature and determination of its relationship to the tumor and the central airways, irrespective of anatomic distortion caused by neoplasm or previous treatment. MR is especially useful in imaging the right and left pulmonary arteries when there is associated collapse, which is a frequent sequela of bronchial obstruction. Transverse and sagittal imaging best define the positions of the vessels with respect to the operative site. Sagittal images also provide a cross-section image of the mainstem bronchi, and a long-axis image of the left pulmonary artery. Coronal images optimally demonstrate the relation of the left pulmonary artery to the left upper lobe bronchus and distal trachea. We found coronal imaging most useful in imaging the tracheobronchial lesions, providing valuable information on the degree and extent of luminal compromise. A good example of this application is Patient XII, in whom length of obstruction could not be visually determined, since he did not tolerate the initial bronchoscopy. The length of obstruction was easily demonstrated by sagittal MR.

The disadvantages of MR include long imaging time (approximately 50 minutes), inability to visualize calcium, and image degradation by cardiac and respiratory motion. In general, partially or totally obstructing tracheobronchial lesions are more difficult to image by MR than CT because of an increased amount of motion artifact. These patients are dyspneic, may have a large amount of secretions, and not infrequently are bothered by a persistent cough. The addition of cardiac and respiratory gating for MR, however, did significantly improve image quality. There were four patients in this group where calcium was visualized on CT, but not on MR. In none of the patients did the visualization of calcium by CT change the approach to the surgery.



A,B

Fig. 6. Squamous carcinoma, eroded into right pulmonary artery.

A. Transverse MR image, TE 30 msec, TR 500 msec. There is irregularity of the posterior wall of the right pulmonary artery, representing tumor invasion (arrow).

B. Photograph of right pulmonary artery shows the site of perforation (arrow).

This study is limited by the CT enhancement technique used, namely 50 ml bolus followed by 100 ml drip infusion vs. rapid bolus dynamic scanning at preselected levels. The latter technique would undoubtedly have improved CT results relative to MR. Nevertheless, MR remains an easily performed examination capable of providing excellent vasculature-tumor discrimination without contrast enhancement and its associated (albeit small) risks.

CT has previously been found to be more useful than conventional linear tomography prior to laser photoresection for lesions of the distal trachea, carina, and proximal bronchi.[15] CT's main advantage over linear tomography is the ability to differentiate vasculature from tumor in the resection area. We think that MR, where it is readily available, is an appropriate first imaging modality for evaluating the relationships of the tracheobronchial tree and vasculature prior to laser photoresection. Transverse MR imaging can define tumor relationship to vessels. Coronal imaging shows the trachea and mainstem bronchi, and surface coil technology allows imaging of the proximal trachea. If MR is not readily available, or if cardiac arrhythmia or patient motion preclude diagnostic MR imaging, then contrast-enhanced CT evaluation would be the modality of choice. Further studies are warranted to define the exact roles of MR and CT, as MR software and physiologic gating and CT dynamic scanning improve.

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Commentary

Herbert P. Wiedemann, M. D., Department of Pulmonary Disease, The Cleveland Clinic Foundation, comments: Endoscopic laser photoresection is an important new technique in the management of selected patients with central tracheobronchial obstruction. Laser therapy is most frequently used for the palliation of airway occlusion resulting from bronchogenic or metastatic carcinoma, although benign lesions are occasionally treated as well.

Not all airway obstructions are amenable to laser photoresection. The ideal lesion for such therapy is an exophytic endobronchial mass that compromises the lumen of an otherwise normal airway. In contrast, laser photoresection may not be efficacious when the airway is narrowed due to submucosal infiltration or compressed due to an extrinsic mass. Inspection of the tracheobronchial tree via flexible bronchoscopy is usually sufficient to evaluate whether laser photoresection is warranted.

As outlined by Ross and colleagues, computed tomography and magnetic resonance imaging may provide important ancillary information in patients being considered for endobronchial laser therapy. In order to minimize serious complications during photoresection, it is important to have prior knowledge regarding two anatomic considerations: the location of large central blood vessels that may lie in close approximation to the lesion, and the extent and direction of the airway lesions in those instances where the lumen is so narrow that the distal anatomy of the lesion cannot be visualized with the bronchoscope.

The authors think that magnetic resonance is generally superior to computed tomography for this purpose, since magnetic resonance produced better delineation of vascular structures and provided images in many planes, including the sagittal, coronal, and transverse. However, magnetic resonance images were more often nondiagnostic, largely due to motion artifact. This might be expected to be a frequent problem in dyspneic patients with critical degrees of upper airway compromise.

This study does not show that pre-laser imaging techniques reduce complications (there is no control group), nor does it conclusively demonstrate the advantage of one technqiue over the other. Only one serious complication of laser therapy occurred (death by exsanguination); neither computed tomography nor magnetic resonance showed the tumor invasion of the right pulmonary artery that was subsequently demonstrated at autopsy. The retrospective analysis of the magnetic resonance image showed "subtle irregularity of the posterior right pulmonary artery."

Although definitive conclusions are therefore not possible, the authors do provide a cogent and balanced discussion of the relative advantages of computed tomography and magnetic resonance in the evaluation of intrathoracic pathology in general and obstructing airway lesions in particular. Their comments and recommendations are of interest to physicians who use laser therapy, as well as to all others who evaluate diseases of the thorax.