Magnetic Resonance Angiography of the Central Chest Veins*
A New Gold Standard?

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Purpose: The systemic chest veins may be difficult to show comprehensively by contrast venography, especially if there is limited venous access or contraindications to intravenous contrast. As an alternative, can magnetic resonance angiography (MRA) reliably detect occluded chest veins and predict suitable sites for central venous access?

Patients and methods: Eighty-four patients were examined using breath-hold time-of-flight MRA and three-dimensional image reconstruction. Thirty-three were evaluated to identify possible central venous access. Fifty-seven patients were examined to diagnose and stage central venous occlusion.

Results: The associated diagnoses were malignancy 46, parenteral nutrition 21, hemodialysis 6, chemotherapy 4, and other long-term venous access 7. Of the 28 patients in whom MRA predicted a patent site for central venous access, satisfactory access was achieved. In two patients, cannulation of veins shown to be occluded on MRA was attempted unsuccessfully. Correlation with contrast venography was available in 17. There was agreement with MRA concerning the level of occluded veins in all cases. Contrast venography did not show all patent veins, including some accessed during surgical line placement.

Conclusion: Compared with surgical line placement or contrast venography, MRA of the systemic chest veins is accurate. Patent and occluded chest veins are reliably defined, including potential sites for central line placement, in a way that is not possible with other techniques. MRA may be the new "gold standard" for defining systemic venous anatomy in the chest.

(Ches 1995; 107:1053-57)

Thrombosis of the systemic chest veins is an important cause of morbidity in patients with malignancy, hematologic disease, or long-term indwelling catheters. Various clinical consequences may follow, including restricted venous access, acute superior vena cava (SVC) obstruction, and failure of existing central venous access, which may require cessation of essential therapy.

The increasing use of central venous catheters, for patient monitoring, hyperalimentation, and administering chemotherapeutic agents, has led to a great increase in the prevalence of acute and chronic central venous thrombosis. This is especially important in patients with nonmalignant disease who may have a long life expectancy and require repeated or permanent central venous access. Although central venous occlusion is often clinically apparent, diagnostic imaging is required to clarify the site and severity of venous obstruction and to detect patent veins that are suitable for cannulation.

Contrast venography is widely accepted as the imaging method of choice for evaluating the chest veins. Alternatively, contrast-enhanced computed tomography (CT) may provide useful information on vessel patency and collateral vessels. Both techniques require injection of contrast media, which may be contraindicated and may jeopardize already limited venous access, due to the thrombogenic effects of contrast agents. In some patients, venipuncture is impossible due to edema or phlebitis. Duplex ultrasound of the neck and arm veins is useful, but overlying bone and lung hamper examination of deeper veins.

There is a requirement for an imaging technique that shows the central chest veins without needing venous access, which has an unrestricted field of view (FOV), is unaffected by flow direction, and can provide information on flow direction. Although conventional magnetic resonance imaging can provide some of this information, it too has limitations. In

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FLASH=fast-low-angle-shot; FOV=field of view; MIP=maximum-intensity projection; MR=magnetic resonance; MRA=magnetic resonance angiography; SVC=superior vena cava; TE=echo time; 3-D=three-dimensional; TR=repetition time

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a previous, more limited study,7 we showed that magnetic resonance angiography (MRA) was accurate in the detection of central thoracic venous occlusion. The purpose of the current study was to further evaluate the use of MRA for diagnosing central thoracic venous occlusion and predicting suitable sites for central venous access.

METHODS

Magnetic resonance angiography was performed using sequential, two-dimensional, time-of-flight MRA.7-9 This was a flow-compensated, fast-low-angle-shot (FLASH) optimized for use on a 1.0-T superconducting magnet (Siemens Magnetom SP, Siemens Medical Systems, Iselin, NJ). The imaging parameters were as follows: repetition time (TR), 50 ms; echo time (TE), 10 ms; flip angle, 30°; one signal acquired. A short TE of 10 ms was chosen to enhance fat-water phase cancellation effects. As venous flow in the chest has relatively low velocity and has limited pulsatility, it was not necessary to use ECG gating or k-space segmentation. Selective venographic images were obtained by placing a selective presaturation pulse (Fig 1) through the heart10,11 to suppress aortic, cardiac, and arterial flow signal. No cardiac gating maneuvers were used.

Coronal, axial, and sagittal acquisitions were obtained routinely during suspended respiration, with a breath-hold period per section of 8 to 10 s. Using time-of-flight MRA, artifactual signal loss may occur if flow is close to being in the imaging plane due to repeated exposure of spins in flowing blood to imaging pulses.12 Therefore, when imaging complex three-dimensional (3D) anatomy, as with the chest veins, multiplanar imaging should be performed to ensure that at least one imaging plane produces maximum through plane signal. This prolongs total imaging time but if normal venous anatomy is shown by the initial coronal imaging, then further images are not required. The FOV was adjusted from 350 to 450 mm, depending on patient size. Sequential single sections, 5-mm thick, were overlapped by 1 mm and were processed using a commercially available maximum-intensity-projection (MIP) algorithm to generate 3-D projectional venograms. Typically each study was completed in 30 min, but if normal venous anatomy is demonstrated on the initial coronal images, total imaging time can be reduced to less than 10 min.

METHODS OF ANALYSIS

All MR venograms were reported blind of other imaging (usually contrast venography). Both the 3-D projectional venograms and the individual two-dimensional images were reviewed. Patency was represented by high signal in the anatomic position of a major vein on at least the individual two-dimensional images in an appropriate imaging plane. Artifactual signal suppression can occur using the MIP algorithm if vessels with high and low signals are close to each other; therefore, a definitive diagnosis of occlusion was made from the two-dimensional images. Occlusion was represented by absence of flow signal on all images, including at least one set of images in a plane near perpendicular to the expected direction of flow. Signal loss may occur artifactual because of in-plane signal saturation if the imaging plane is parallel or nearly parallel to the plane of flow in the vessel.

The reports of each study, read by one of us (G.G.H., J.P.F., H.E.L.), represented the prospective evaluation, blind to other studies. Attempted cannulation was always performed after MRA and the precannulation MR was therefore blind to these findings in all cases. All cases, in which there was a noncontrast venography, were then reread blind (by G.G.H. or J.P.F.) to determine the extent of the demonstration of normal and abnormal veins by each technique.

RESULTS

Between January 1990 and April 1994, 84 patients were examined by MRA on 102 occasions, to assess patency of the central systemic chest veins. There were 52 women and 32 men with a mean age of 51.2

![Figure 1](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21712/ on 06/27/2017)
years (range, 21 to 84 years). Associated pathologic conditions are detailed in Table 1.

Correlative imaging was available in 30 patients and the results of attempted surgical line placement (aiming for vessels predicted to be patent by MRA) were available in 30 patients. Five patients had correlative imaging and surgical line placement. There was correlation between MRA and surgery or alternative imaging in 55 patients. The methods used for correlative imaging and the number of patients examined by each method are given in Table 2.

The MRA findings are summarized in Table 3. There were no known errors of MRA diagnosis as determined by correlation with other imaging methods or surgical line placement (55 patients). Occasionally spin-echo magnetic resonance imaging was also used (Fig 2) for further evaluation of an associated tumor mass, but this type of imaging was not evaluated further in this study.

Although difficult to quantify, MRA showed the full extent of collateral pathways more than any alternative method (Fig 3). More importantly, potential alternative sites for venous cannulation were seen by MRA than the alternatives. Contrast venography seldom showed or indicated patency of internal or external jugular veins.

Acceptance of the MRA technique is confirmed by the large number of examinations that were performed as the sole imaging technique (n=72). During 1993, no correlative imaging was performed to check the accuracy of an MRA examination of the central systemic chest veins. Subsequently, contrast venography has been used only as an adjunct to thrombolysis in patients who have had an MRA.

**DISCUSSION**

This study confirms that two-dimensional time-of-flight MRA is an extremely accurate technique for evaluating the systemic chest veins and diagnosing central venous occlusion. Correlation between conventional contrast venography and MRA was excellent, as we reported previously in a smaller patient population. As a result of its much wider FOV, MRA enables more comprehensive evaluation of central venous anatomy than is possible with contrast venography. The use of arterial presaturation and 3-D im-

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**Table 1—Indications for Chest MR Venography**

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<tr>
<th>Indication</th>
<th>No. (%)</th>
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<tr>
<td>Tumor</td>
<td>46 (55)</td>
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<tr>
<td>Short-bowel syndrome/hyperalimentation</td>
<td>21 (25)</td>
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<tr>
<td>Chronic renal failure/hemodialysis fistulas</td>
<td>6 (7)</td>
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<tr>
<td>Drug administration</td>
<td>4 (5)</td>
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<tr>
<td>Others</td>
<td>7 (8)</td>
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**Table 2—Correlation With Imaging or Surgical Outcome**

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<tr>
<th>Method</th>
<th>No. (%) Total</th>
<th>MRA Agrees</th>
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<tr>
<td>Angiography</td>
<td>18 (18)</td>
<td>18/18</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>5 (5)</td>
<td>5/5</td>
</tr>
<tr>
<td>CT</td>
<td>6 (6)</td>
<td>6/6</td>
</tr>
<tr>
<td>Nuclear</td>
<td>1 (1)</td>
<td>1/1</td>
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<tr>
<td>Surgical line placement</td>
<td>30 (30)</td>
<td>30/30*</td>
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*Includes two unsuccessful attempts at cannulation of veins predicted to be occluded by MRA.

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**Figure 2**. Top, Coronal spin echo image shows tumor invasion (→) around the aortic arch and invading the SVC. Venous anatomy cannot be easily assessed from a single image. Bottom, Projection angiogram (MIP, coronal perspective) shows tumor invading SVC (→) and left brachiocephalic vein (†). Note the better definition of vascular anatomy but poorer soft-tissue contrast.
age reconstruction improves the clarity with which abnormal anatomy is presented and separates arterial from venous structures. The safety and reproducibility of the MRA technique also make this especially useful for repeated examination in patients who require frequent central venous cannulation and in whom possible access sites are limited.

Although conventional venography is widely accepted as the reference standard for imaging the central chest veins, several factors limit its usefulness in patients with central venous disease. Injection of contrast usually only opacifies veins between the injection site and the heart. Therefore, injection into an arm vein usually will not show occlusion of a contralateral arm or ipsilateral neck vein. The wide FOV of MRA allows full assessment of patency of all the central chest veins and, if none are seen, can also examine the abdominal veins to detect alternative suitable sites for venous cannulation.

Duplex Doppler ultrasound is an alternative non-invasive technique that may be useful for evaluation of neck and subclavian veins. Accurate duplex ultrasound, however, requires substantial technical skill, and its restricted FOV limits its use for evaluating more central veins.6,7

In patients with malignant or debilitating disease, it is often essential to establish central venous access for delivery of chemotherapeutic agents, systemic antibiotic therapy, creation of surgical arteriovenous shunts, or control of fluid and electrolyte balance. Attempted cannulation of central veins may result in mediastinal hemorrhage and pneumothorax, especially when they are occluded. In sick patients with a history of central venous cannulation or central venous thrombosis, it is desirable to know which vessels are patent before puncture.

MRA is an accurate, noninvasive technique for evaluating central systemic veins. The full extent of patent and occluded chest veins is reliably defined, including potential sites for central line placement, in a way that is not possible with any other modalities. Additionally, MR venography can be effective when the administration of contrast agents is contraindicated or impossible.

To facilitate the use of this technique on non-Siemens’s equipment, we include a list of eponyms used by other manufacturers to describe MR angiography sequences that are similar to FLASH. 1 Other gradient-echo MRA sequences may be suitable for use in this application. Other manufacturers may have similar sequences, but data on their use in chest MR venography are not available. The manufacturers and eponyms are as follows: Elscint, SHORT; General Electric, SPGR; Hitachi, GFE; Philips, CE-FEE-T1; Picker, RF-FAST, T1-FAST; and Shimadzu, STAGE.

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<th>Table 3—MRA Findings</th>
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<tr>
<td>Normal systemic chest veins</td>
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<tr>
<td>Unilateral venous occlusion</td>
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<tr>
<td>Bilateral venous occlusion</td>
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<tr>
<td>Occlusion superior vena cava only</td>
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Figure 3. Top, Coronal projectional angiogram (MIP) showing complete obstruction of subclavian, brachiocephalic, and internal jugular veins. Systemic venous return is retrograde via the azygous vein (*). Bottom, Subtracted contrast venogram, showing multiple superficial collateral veins (*), fails to demonstrate the azygous vein and does not provide any information regarding patency of the jugular veins. This is shown to be occluded in Fig 3, top.

REFERENCES


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