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# Routine MR Imaging of the Internal Carotid Artery Siphon: Angiographic Correlation with Cervical Carotid Lesions

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This study correlates the appearance of the cavernous segment of the carotid artery on MR images with the presence of significant stenosis or occlusion of the cervical carotid artery as seen on angiograms in 100 patients who had brain MR imaging and arteriography within a 1-week period. Four patients demonstrated isointense signal within the carotid artery's cavernous segment; two of these findings correlated with complete carotid occlusion as seen angiographically, while partial compromise was seen angiographically in the other two. Four other patients had variable signal intensity and irregularity of the luminal outline in the carotid siphon, correlating with angiographic evidence of atheromatous disease in three patients and of dissection in one patient. The demonstration of normal signal void within a normal-appearing cavernous segment of the internal carotid artery in the remaining 92 patients correlated with absence of significant stenosis within the cervical segment in 86 patients. In the remaining six, significant disease of the internal carotid artery was found.

Isointensity within the intracranial carotid artery can indicate either complete occlusion or very slow flow. Therefore, angiography is still necessary to completely exclude potentially treatable disease that produces very slow flow leading to isointensity. The presence of normal flow void in the intracranial segment does not exclude significant compromise of the cervical segment of the carotid artery.

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MR imaging offers a major advance in evaluating cerebral ischemia. One examination combines superior sensitivity for the detection of cerebral infarction [1-6], with the ability to depict the vital vascular supply routes. Flow phenomena inherent to the MR methodology offer potential not only for anatomic depiction of blood vessel morphology and its compromise but for frank flow quantification as well [7-11].

Several recent reports [12-14] suggested that routine MR brain scans can depict the intracranial carotid sufficiently well to make reliable statements regarding the status of the subcranial carotid artery. Our own anecdotal experience has been less favorable. This retrospective review of MR and angiographic correlative studies was undertaken to more rigorously assess this observation.

## Materials and Methods

We reviewed the medical records of all patients who had carotid arteriograms over the 3-year period from January 1986 to January 1989. One hundred consecutive patients who had MR brain imaging performed within 1 week of arteriography that included views of at least one of the cervical carotid segments were selected for review.

The patients were 14 to 86 years old. The arteriographic studies were all intraarterial, using either digital subtraction or conventional film-screen and subtraction techniques.

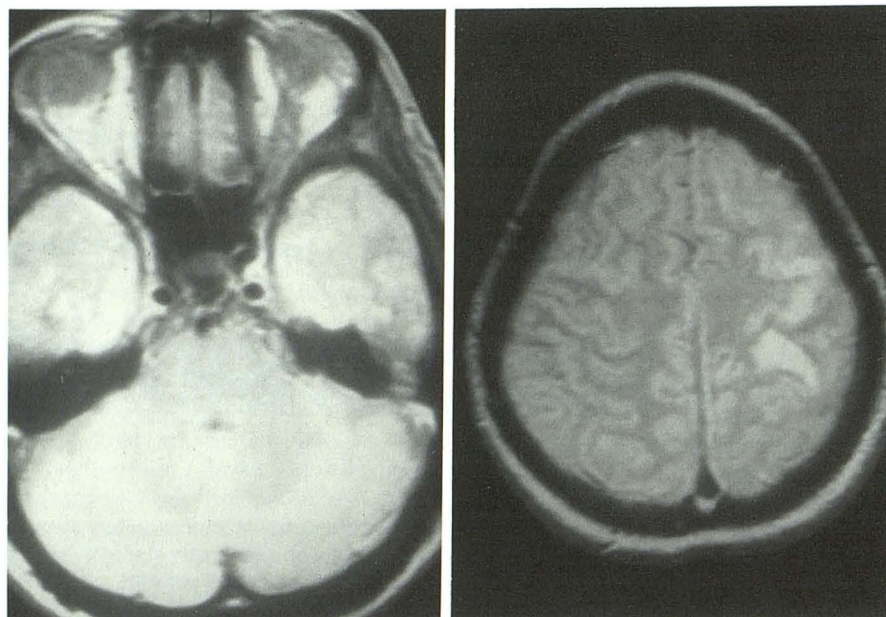
The MR studies were done either with a 0.5-T (Picker International, Highland Heights, OH) or, in 78 of the 100 patients, a 1.5-T (General Electric, Milwaukee, WI) system. Short TR/TE sagittal, long TR dual-echo axial sequences were performed in all patients. The short TR/TE

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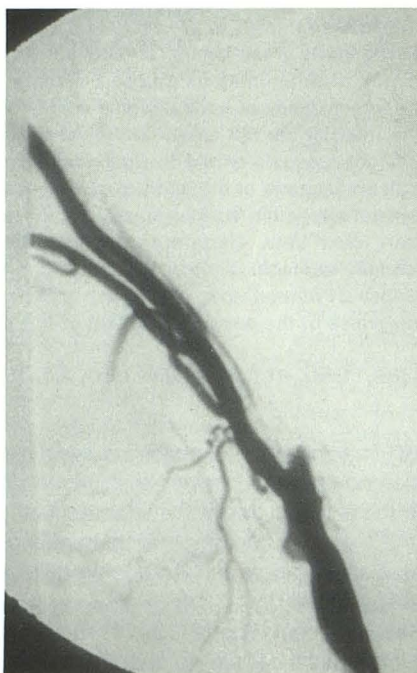




A



B



C



Fig. 1.—64-year-old woman with acute onset of right arm weakness, resolved over 4 days.

A, MR scan at level of cavernous carotid arteries (*left*) and over the convexity (*right*) shows normal flow void in both carotid arteries as well as gyral high signal intensity over left parietal convexity consistent with acute ischemia.

B, Left common carotid artery injection on same day shows a severely stenotic internal carotid artery in its proximal segment.

C, Angiograms obtained 4 weeks later show progression to complete occlusion of the stenosis, despite systemic anticoagulant treatment. Common carotid injection with intracranial filming documents prominent retrograde ophthalmic route to fill the siphon, as well as subcranial carotid in retrograde fashion (emergency surgery reestablished patency of the vessel).

parameters were 600–800/24–30, and the long TR/TE parameters were 2000–2800/80, with a first echo obtained at 24–30 as well. Slice thickness was 10 mm at 0.5 T and 5 mm with a 2-mm gap at 1.5 T. The acquisition matrix was either  $256 \times 256$  or  $128 \times 256$ ,

and the field of view varied from 20 to 24 cm. First-order gradient moment nulling (flow compensation) was used with the long TR sequences done at 1.5 T (it was not used on the 0.5-T system). A caudally placed saturation pulse (15 ml below the volume of excita-



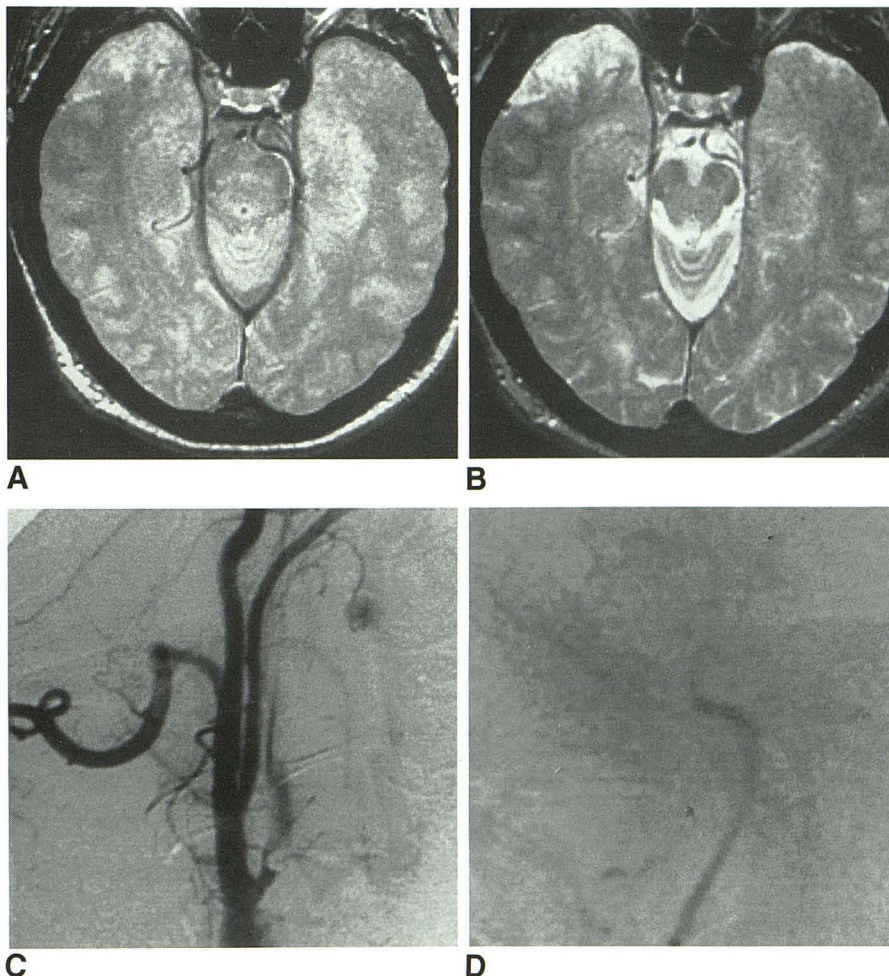
**Fig. 2.**—67-year-old man with sudden onset of left lower extremity weakness and right temporal and basal ganglia infarction documented on MR scan.

**A,** MR image, 2800/30, at level of cavernous carotid arteries shows isointense signal from right internal carotid artery.

**B,** MR image, 2800/70, shows persistent isointensity of signal within right carotid artery.

**C,** Right common carotid artery injection in neck 1 day after MR shows almost complete occlusion of right internal carotid artery with contrast material slowly ascending.

**D,** Right common carotid artery injection, cranial view. The contrast material ascends to level of cavernous carotid at 11 sec. Surgical endarterectomy with backflow obtained documented patency from circle of Willis down to right common carotid artery.



tion) was used to minimize any effects of in-flow phenomena. This was used only with the short TR/TE sequences at 1.5 T. These are the typical instrument parameters employed for routine brain MR studies at our facility. For specific evaluation of flow within vessels, other options might be utilized, but the purpose here was to assess the value of routine brain sequences for the observations discussed.

The MR images were analyzed for presence of normal signal void in the intracranial carotid segment to the level of the clinoid. Specifically, the segments perpendicular to the axial plane of section were particularly scrutinized (the immediate precavernous and subclinoid segments). This avoided the partial volume effect inherent to the cavernous or petrous segments. These regions of the siphon appeared well within the excitation volume, avoiding the time-of-flight, and slice in-flow phenomena. Although evaluation of the findings of the "partial flow void" of Heinz et al. [13] within the petrous segment was attempted, partial volume phenomena in several patients with normal carotid arteries simulated a central high-velocity channel with higher signal edges, and this attempt was abandoned.

Both echoes were evaluated for second-echo rephasing. None of our cases showed a true rephasing effect, presumably due to several factors including the asymmetric echoes used, turbulent flow (when present), nonrefocusable phase shifts, and other fortuitous reasons. The arteriographic evaluation of significant stenosis was judged by measuring the narrowest diameter of the vessel on subtracted views and comparing it with the normal caliber of the vessel just distal to the lesion.

## Results

Ninety-two of the 100 patients showed a normal-appearing subclinoid carotid lumen bilaterally with normal signal void within. The corresponding cervical carotid artery segments were free of significant stenosis in 86 of these 92 patients. However, despite the normal intracranial appearance of the intracranial carotid on MR, six patients demonstrated significant compromise of the cervical portion on arteriography. Stenoses of 66%, 85%, and 90% were found in three different patients. The last of these (Fig. 1) progressed to a complete occlusion in the neck (despite Coumadin therapy), but maintained the patency of the cavernous segment with a prominent retrograde pathway through the ophthalmic artery.

Fibromuscular disease of the high cervical carotid artery was found in two other patients with normal MR appearance of the intracranial carotid—both patients having had a history of transient ischemic attack. The sixth patient, a 29-year-old woman with dissection at the C3 level narrowing the carotid to approximately 75%, had a normal MR appearance of the cavernous segment but an abnormal cervical carotid finding on angiography. The cervical carotid artery was studied with MR (owing to a high index of suspicion) and showed beading and intramural clot.



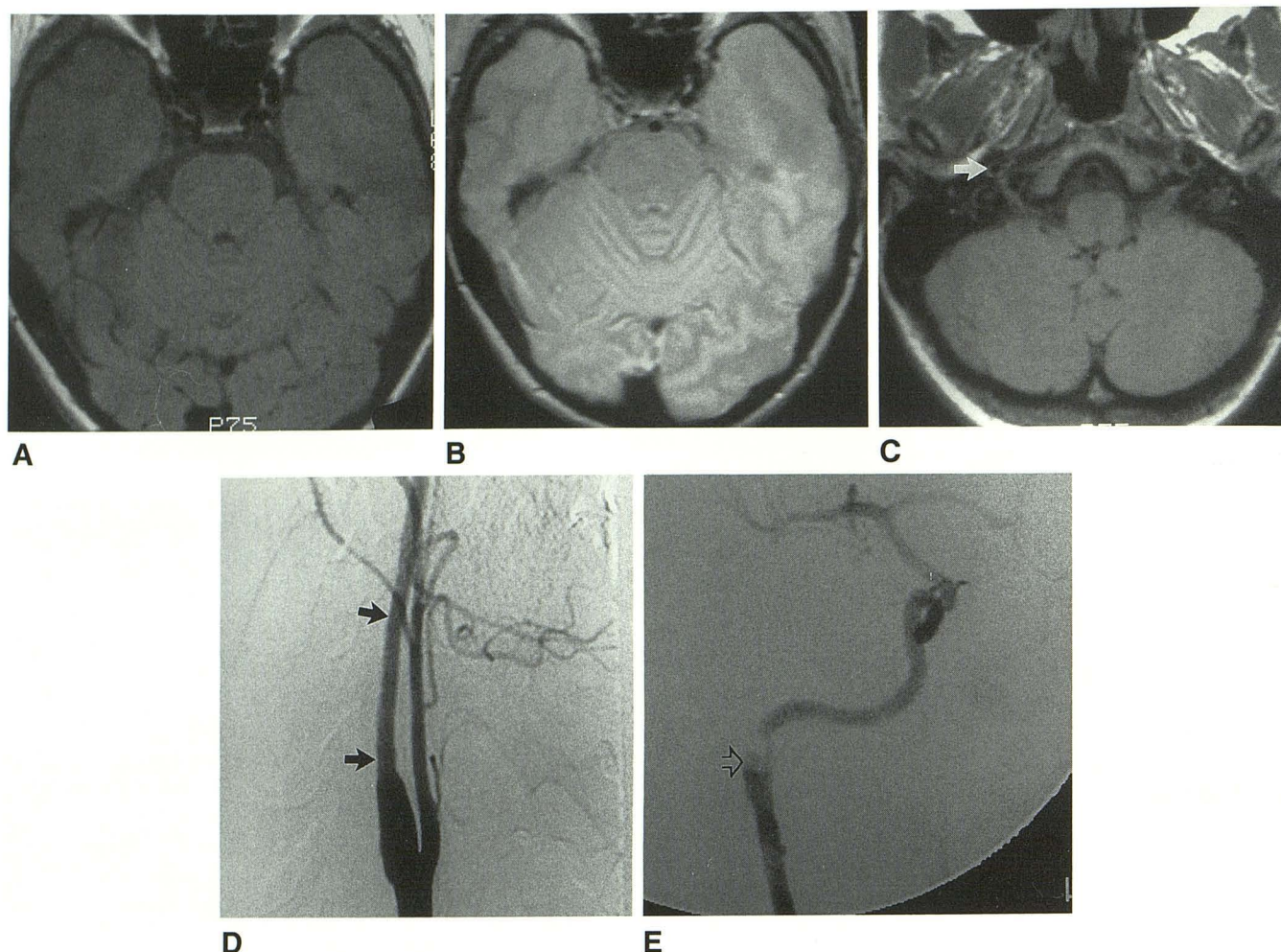


Fig. 3.—33-year-old woman with transient left-sided weakness, resolved over 8 hr.

A, MR image, 600/20, shows signal void within an irregular, narrowed cavernous carotid artery.

B, Long TR image, 2800/30, again shows asymmetry of cavernous carotid arteries with irregular, narrowed right cavernous carotid artery lumen containing signal void.

C, Lower image, 600/30, at proximal intrapetrous carotid canal level shows a relatively narrow right petrous carotid artery (arrow) surrounded by a collar of high signal.

D and E, Angiographic views of neck and cranial portions of internal carotid artery, respectively, reveal generalized narrowing of internal carotid artery (arrows in D) beginning just above the bulb in the neck and extending to the subpetrous portion, where a pseudoaneurysm (open arrowhead in E) is seen with a more severe narrowing just distally, findings typical of dissection.

Isointense signal in the subclinoid intracranial portion of the internal carotid was present on all MR sequences in four patients. This finding was indicative of severe compromise of flow, but not necessarily complete occlusion, which was seen in two of the four patients. The third patients had a string sign. The internal carotid artery was almost occluded at its origin, but a string of contrast material proceeded cephalad, arriving at the siphon in 11 sec (Fig. 2). Surgical endarterectomy in the neck revealed a very severe stenosis, but back-flow down from the circle of Willis verified vessel patency. The patient's fluctuating ischemic deficit resolved after surgery, despite presence of temporal lobe and caudate infarcts on the presurgical MR scan.

The fourth patient was evaluated for sudden, transient dysarthria and chest pain. Right radial pulse was absent on examination. MR showed isointensity within the carotid canal on the left and small gyral infarcts were seen in the distribution on the left middle cerebral artery. MR and arch aortography revealed ascending root aortic dissection, with extension into the left common carotid, which filled very slowly from the false lumen. Surgical repair of the aorta was uneventful.

A fifth patient, a young woman with sudden severe right-sided headache (Fig. 3), showed signal void within a narrowed irregular siphon. Lower sections suggested blood in the walls of the right carotid artery's petrous portion; its dissection was verified by angiography the next day.



Three other patients had irregular, narrowed siphon segments. Signal intensity within the lumen was inhomogeneous, with a portion of the lumen suggesting rephasing on the second echo. Angiography showed atheromatous involvement of the cavernous segment in all three patients.

## Discussion

This retrospective review provides additional evidence as to the usefulness of routine MR brain imaging of the cervicocranial vessels, but certain caveats are reiterated. The finding of isointense signal within the subclinoid carotid on several routine sequences (both echoes of a long TR sequence and the short echo of a short TR sequence) indicates severe compromise of the cervical carotid, but not necessarily complete occlusion as others have recently suggested [12, 14]. Carotid angiography still must be performed, when the clinical indications exist, to differentiate complete occlusion from potentially remedial processes that produce very slow flow. It remains to be seen if specialized pulse sequences such as the gradient-recalled fast scans for flow [15–18], the use of phase-display imaging [18–20], or even angiographic MR imaging [21–23] can truly separate very slow flow (as seen in our patient with the string sign) from complete occlusion. This distinction is vital for appropriate patient management, and currently remains the province of arteriography.

The finding of normal subclinoid carotid morphology and signal void on MR imaging is reassuring, but should not be completely relied upon to exclude significant stenoses, as shown in three of our cases, or other important lesions of the cervicocranial vasculature in symptomatic patients. Flow void on MR within the vessel lumen is one of many flow-related phenomena well described in previous reports [7, 16]. Time-of-flight high-velocity signal loss, turbulence, and intravoxel dephasing of moving spins all contribute to signal void in rapidly flowing channels. Theoretically, a calcified embolus (say from a calcified aortic valve) or clot with predominant deoxyhemoglobin content could simulate focal flow void. Appearance of signal in such channels may be due to partial volume effects (especially when the lumen is parallel to the plane of section), end-slice in-flow phenomenon, pseudogating, second-echo rephasing, and, of course, very slow flow or partial or complete occlusion. Use of flow-compensation gradient-moment nulling can also produce an artifactual signal in slowly flowing vessels, depending on their orientation. The many vagaries of flow-signal interpretation have been well summarized [24].

These various flow phenomena can be a source of confusion, and care must be taken in over-interpreting vascular signal or its absence. Even in the extreme cases of normal flow void and complete fill-in with isointense signal on several routine sequences, the assumptions regarding proximal nor-

mal patency or occlusion must still be verified with angiography for complete accuracy. Further evaluation of flow-specific techniques is needed.

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