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MR Angiography**

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*AJNR Am J Neuroradiol* 2006, 27 (4) 850-852

<http://www.ajnr.org/content/27/4/850>

This information is current as  
of April 16, 2024.

# Feathering: Vertebral Artery Pseudostenosis with Elliptical Centric Contrast-Enhanced MR Angiography

## TECHNICAL NOTE

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**SUMMARY:** Elliptical centric contrast-enhanced MR angiography of the cervical vasculature is a well-established technique that in many practices has replaced conventional angiography for several clinical indications, including atherosclerotic disease and dissections. Occasionally blurring or loss of signal intensity occurs in the vertebral arteries, especially in young patients with rapid circulation times. This ringing artifact, which we termed “feathering,” results from rapidly changing signal intensity in small vascular structures during the sampling of the center of *k*-space.

Elliptical centric contrast-enhanced (CE) MR angiography is a well-established technique that in many practices has replaced conventional digital subtraction angiography for the preoperative evaluation of carotid occlusive disease and cervical arterial dissection.<sup>1</sup> A commonly recognized artifact resulting in loss of signal intensity in the vessel is the presence of surgical clips following endarterectomy.<sup>2</sup> The resulting magnetic field distortion may result in signal intensity loss in both the carotid and vertebral arteries. Another cause of signal intensity loss is the radio-frequency shielding of the vessel lumen by metallic stents.<sup>3</sup> Yet another signal intensity loss mechanism is the premature initiation (ie, triggering) of the 3D examination before the contrast agent has arrived in the vessel of interest.<sup>4</sup> Occasionally, there is poor segmental visualization or pseudostenosis of a vertebral artery, which most frequently involves imaging small vertebral arteries, while CE MR angiography of the cervical vessels is performed. This artifact, which we have termed “feathering,” can be easily recognized with review of coronal and axial reformatted source images and should not be confused with occlusive disease.

### Technique

In a head and neck neurovascular coil or dedicated volume neck coil, a coronal 2D phase-contrast scout sequence is performed to identify the location of the petrous carotid arteries.<sup>5</sup> The 2D time-of-flight (TOF) sequence with 100 sections is obtained from the level of the petrous carotid arteries inferiorly as a screening examination and to center the CE sequence. The 2D TOF uses derated gradients so that a 60%–70% carotid stenosis results in a signal intensity void.<sup>6</sup> The minimum TE of the derated pulse sequence is 8.7 milliseconds, with the following imaging parameters: TR = 28 milliseconds; 256 × 128 matrix; ± 16k Hz receive bandwidth; 60° flip angle; 1.8–2.2-mm-thick sections overlapped so that the center-to-center section spacing is 1.5–1.8 mm; one signal intensity average; and “traveling” spatial presaturation applied superiorly.

The CE elliptical centric spoiled gradient-recalled-echo acquisition is performed by using a 22 × 15.4 cm field of view coronal slab with a 6.2-cm thickness; 48 sections 1.4 mm thick; TE of 1.4; TR of 6.6 milliseconds; flip angle of 45° and a matrix of 256 × 224; 1 excitation; and a 51-second scan time.<sup>7</sup> Recon-

struction uses zero filling in all 3 directions to double the number of sections with a resulting 0.7-mm section overlap and to provide a 512 × 512 display matrix. A bolus of 20–25 mL of gadolinium is injected at 3 mL/s followed by 20 mL of saline at 2 mL/s. Fluoroscopic triggering or test bolus timing is used to determine the time of maximal enhancement of the arteries. If a timing sequence is used, 2 mL of gadolinium is then injected at 3 mL/s followed by 20 mL of saline at 2 mL/s.

### Discussion

Elliptical centric CE MR angiography has proved to be a robust and reliable method to image the carotid and vertebral arteries and is widely used for routine clinical care.<sup>2</sup> With attention to optimizing spatial resolution, the elliptical centric technique can be an accurate clinical tool. For instance, Wilinek et al<sup>8</sup> recently reported a sensitivity of 100% and specificity of 99.3% for stenotic occlusive disease of the supra-aortic arteries. By using 2D TOF as a scout sequence, the smallest imaging volume to obtain the highest spatial resolution can be consistently placed to reproducibly include the entire course of the vertebral arteries and the carotids from their origins (or proximal portions in tall individuals) to the carotid siphons. In addition, the 2D TOF sequence with derated gradient performance serves as a screen for the presence of a high-grade stenosis. The presence of a signal intensity void indicates a stenosis of ≥70%.<sup>6</sup>

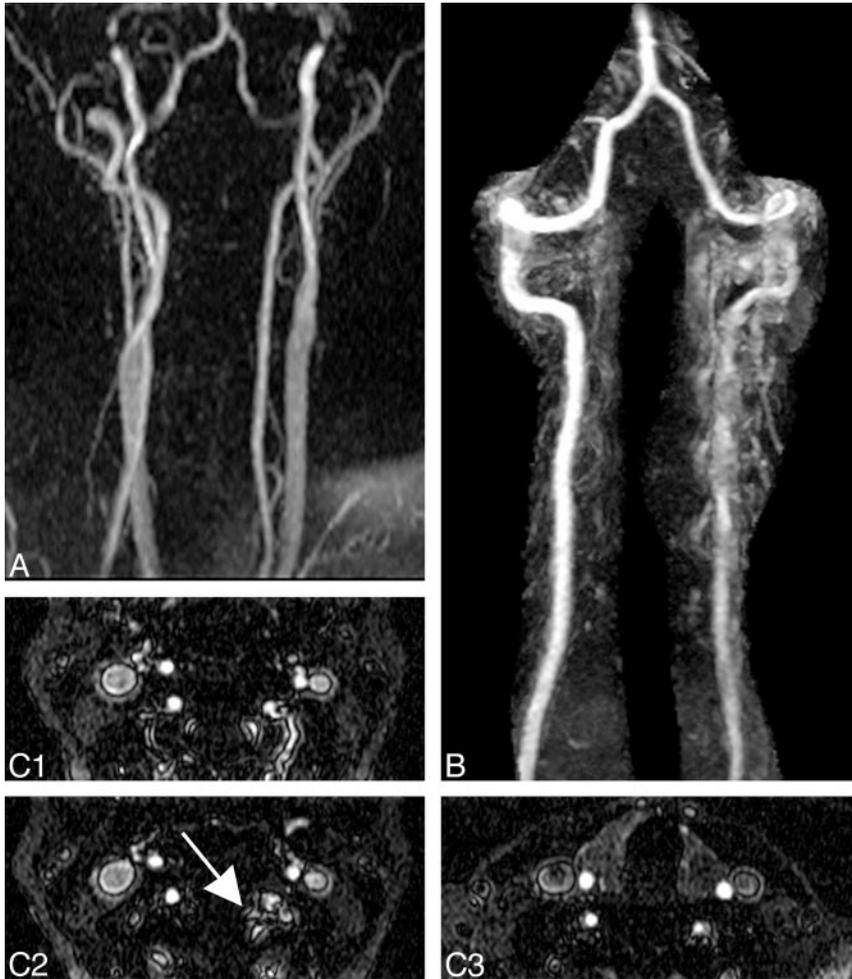
Contrast-enhanced MR angiography of the cervical vasculature occasionally results in segmental blurring or signal intensity loss within the vertebral arteries, especially in the upper neck. Review of source images, especially axially reformatted images, will demonstrate a characteristic pattern of multiple rings or targets. These patterns of alternating high and low signal intensity result in an interference pattern that reinforces and cancels the signal intensity within the vertebral arteries. The degree of distortion is increased as the number of opacified vessels increase and when the vertebral arteries are small in caliber (Fig 1). The 2D TOF sequence serves as an excellent problem solver in difficult cases. When patients do not move, the 2D TOF sequence can confirm the normal nature of the questionable vertebral artery.

The vessels that cause the distortion are likely small muscular arteries that opacify at the same time as the jugular vein. The distortion associated with these small vessels is similar to the target pattern seen with the jugular veins. Therefore, contrast arrives in the both the small vessels and jugular vein at

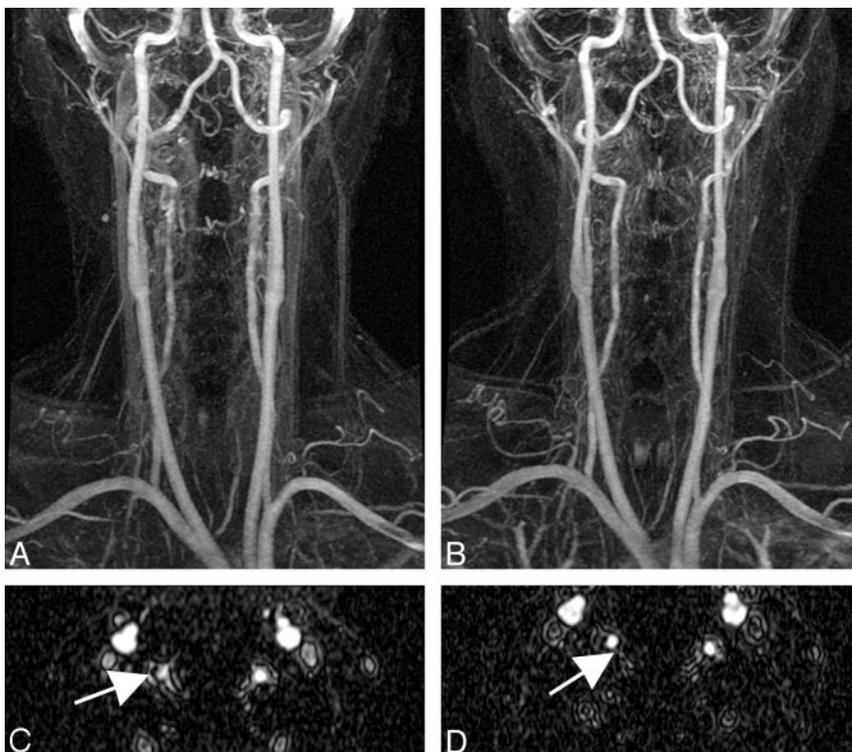
Received June 6, 2005; accepted after revision November 30.

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**Fig 1.** A 46-year-old man with neck pain following trauma referred for MR angiography to exclude a dissection. 2D TOF demonstrates a widely patent left vertebral artery (A). MIP subvolume of the posterior circulation (B) shows an irregular possibly stenotic midleft vertebral artery that was initially felt to represent a dissection. Review of axial reformatted source images shows multiple small ring-shaped areas of signal intensity corresponding to small cervical vessels (arrow, C). The interference pattern created by these target patterns distorts the left vertebral artery resulting in ill-defined borders when compared with the right vertebral artery.



**Fig 2.** A 52-year-old woman with persistent neck pain. CE elliptical centric MR angiogram shows irregularity of both midvertebral arteries, right greater than left (A). Follow-up MR angiogram 1 year later with an earlier trigger time reduces the feathering artifact (B). Review of source images shows that the multiple interference patterns on the first examination (arrow, C) are less evident with the earlier triggering on the second examination (arrow, D). As a result the vertebral arteries are more clearly delineated on the second examination.

nearly the same point of  $k$ -space sampling. We believe that this ringing artifact results from the modulation of  $k$ -space signal intensity in small vascular structures over the course of the bolus arrival and filling of the vessel.

Experience has shown that this artifact occurs most frequently in younger patients or patients who have a rapid circulation times determined with test injections. The feathering artifact can be reduced by using an earlier trigger time in patients with faster circulation times (Fig 2). In our practice, we typically reduce by 1 second the CE MR angiographic trigger time in patients found to have a circulation time of  $\leq 15$  seconds. With this small change in practice, it is possible to reduce or eliminate the feathering or pseudostenosis artifact that occasionally occurs with elliptical centric CE MR angiography.

#### **Acknowledgment**

This work was supported by National Institutes of Health grant EB00212.

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