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# Apparent Vascular Occlusion on Cranial TOF MRA with Peripheral Presaturation Technique

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**Objective:** Improvement in the visibility and accurate representation of intracranial vessels may be achieved on cranial time-of-flight (TOF) MR angiography (MRA) when the signal intensity of orbital and superficial fat is suppressed. This may be accomplished by placement of spatial radiofrequency presaturation bands along the periphery of the head. The objective of this study was to evaluate the potential for this peripheral presaturation technique to result in a spurious appearance of vascular occlusion.
**Materials and Methods:** Three-dimensional TOF MRA of the head was performed in three patients. Flow-compensated spoiled gradient echo images were acquired in the transaxial plane, using the peripheral presaturation technique. The MRA acquisitions were then subsequently repeated in each patient following retraction of the peripheral presaturation bands. A phantom study was also performed to assess the slice profile of the presaturation bands.
**Results:** There was absence of flow-related enhancement, indicating apparent vascular occlusion, involving one carotid siphon in each patient on initial MRA images. Following lateral retraction and/or removal of presaturation bands, the carotid siphons were documented to be patent, with normal caliber and flow-related enhancement demonstrated. Image analysis and phantom experiments indicate this vascular pseudoocclusion is due to proximity of the lateral presaturation band to the lateral aspect of the petrous segment of the internal carotid artery. In this location, there is inadvertent saturation of flowing spins due to imperfections in the presaturation band slice profile.
**Conclusion:** The use of peripheral presaturation bands for cranial TOF MRA is useful for improving vascular depiction. However, patent vessels may occasionally demonstrate an absent signal intensity, suggesting occlusion when this technique is used. Awareness of this diagnostic pitfall is important so that serious misdiagnosis does not occur.
**Index Terms:** Magnetic resonance imaging—Magnetic resonance angiography (MRA)—Artifacts—Magnetic resonance imaging, techniques.

Magnetic resonance angiography (MRA) has demonstrated considerable potential for the noninvasive evaluation of the intracranial circulation. While several MRA techniques are available, the three-dimensional (3D) time-of-flight (TOF) method has been found particularly useful for screening the intracranial arterial vasculature for cerebrovascular disease (1). This method offers the ability to achieve very thin contiguous sections with adequate signal-to-noise ratio and reduced TE, which also contributes to signal-to-noise ratio, and minimizes intravascular signal loss due to intravoxel phase dispersion.

One of the primary objectives for TOF MRA using the maximum intensity projection (MIP) postprocessing algorithm is to maximize the signal intensity of flowing spins relative to that of background stationary soft tissues. The presence of high signal intensity relating to stationary tissues can degrade image quality and can also lead to inaccurate representation of vascular structures on MRA projection images (2) (Fig. 1).

Optimization of flow-related enhancement can be achieved through selection of appropriate imaging

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1a,c

1b,d

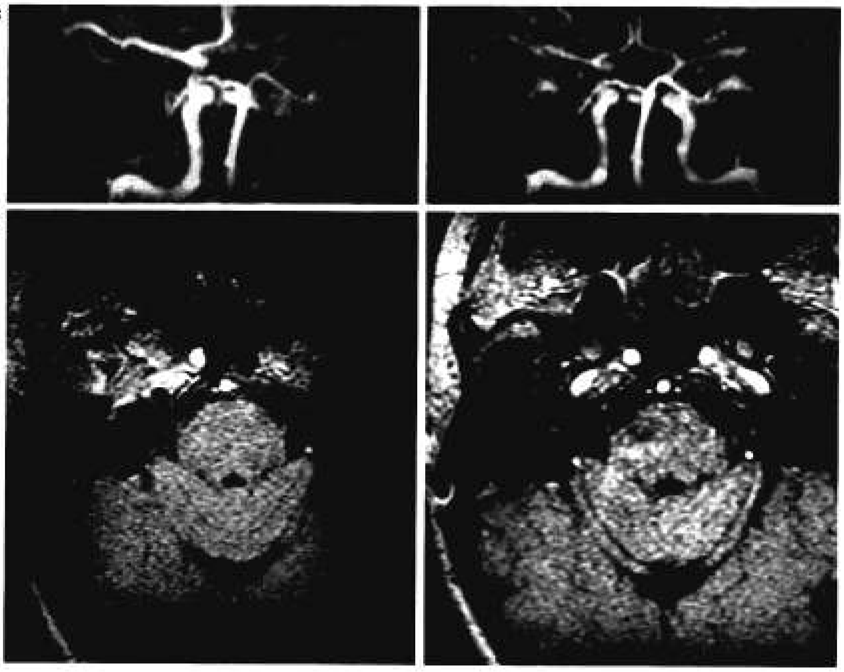


**FIG. 1.** Initial 3D TOF MRA coronal projection image acquired using peripheral presaturation method **(a)** demonstrates absence of flow-related enhancement within the left carotid siphon. The left middle cerebral artery is also poorly visualized, and there is subtle generalized decreased signal intensity on the left as compared with the right side of the image. An axial partition image from this data set **(b)** confirms these findings. The position of the peripheral presaturation bands can be determined on this image, and the left lateral presaturation band is located in a more medial position than is the right-sided band. While the left presaturation band does not approach the cavernous segment of the left internal carotid artery, it does approach the lateral aspect of the petrous segment of this vessel. Spillover of presaturation effects medial to the site of the presaturation band prescription is evident as a moderate reduction in soft tissue signal intensity, with this effect extending into the territory of the petrous segment of the internal carotid artery. Coronal projection **(c)** and axial partition **(d)** images acquired following complete retraction of the presaturation bands demonstrate full recovery of flow-related enhancement within the left carotid siphon, allowing for verification of carotid siphon patency.

parameters (TR, TE, flip angle), the use of gradient moment nulling, orientation of data acquisition perpendicular to the primary direction of blood flow, and use of a relatively small acquisition volume (3–5).

The use of a short TE, which is important for preserving intravascular signal, leads to increased T1 weighting, resulting in relative increased signal intensity from fat. A number of options are available for reducing the signal intensity of fat and other stationary soft tissues on MRA acquisitions. These include 180° inverting prepulses, chemical shift selective radiofrequency saturation of the lipid peak (fat saturation), opposed phase imaging, and magnetization transfer contrast. Definition of a projection based upon a subvolume of the original data set (i.e., targeted MIP) can be used to exclude fat and other high signal intensity tissues from the image, and the phase contrast technique can be used to generate MRA images with highly effective background tissue suppression (6).

While each of the above methods can be used effectively to suppress the signal intensity of fat, these methods are not universally available on all systems. Moreover, many of these methods require additional time for image acquisition and/or postprocessing. The peripheral presaturation method is a simple technique for suppressing the signal intensity of fat on cranial MRA images that is available on all systems and does not incur any time penalty. This method involves placement of spatial radiofrequency presaturation bands along the periphery of the head in anterior, posterior, right, and left positions. These presaturation bands are prescribed so as to overlap fat within the orbits and superficial scalp, while avoiding central vascular structures. We have recently encountered several patients in whom use of this method resulted in a spurious appearance of carotid artery occlusion.

## MATERIALS AND METHODS

Three patients (two men, one woman; 66–84 years) underwent 3D TOF MRA examinations for suspected cerebrovascular disease. Imaging was performed on a 1.5 T system (Signa; GE Medical Systems, Milwaukee, WI, U.S.A.), using a circularly polarized head coil. A flow-compensated 3D radiofrequency spoiled gradient echo sequence (spoiled gradient recalled acquisition in the steady state) was used with the following imaging parameters: TR 48 ms, TE 5 ms, flip angle 25°, and one data excitation. Sixty-four partitions of 1.2 mm thickness were acquired in the axial plane. The field of view was 15–20 cm, and a 128 (phase) × 256 (frequency) matrix was prescribed. These images were submitted to an MIP software algorithm for generation of 18 projection images that were displayed in the coronal plane at 10° increments. Image analysis included these projection images, in addition to the entire set of transaxial partitions, and additional whole-volume or subvolume projection images in other planes as indicated.

Imaging was performed using the peripheral presaturation method to suppress signal intensity of extracranial fat. Spatial presaturation bands (7) of 80 mm thickness were positioned so as to overlap the orbits (anterior band) and fat within the superficial scalp (posterior and right/left lateral bands) as determined on an initial series of localizer images. Subsequent images were later acquired in each patient with the lateral presaturation bands retracted to a more lateral location and/or removed. Repeat examinations were performed at the time of the initial examination or on the following day in all patients.

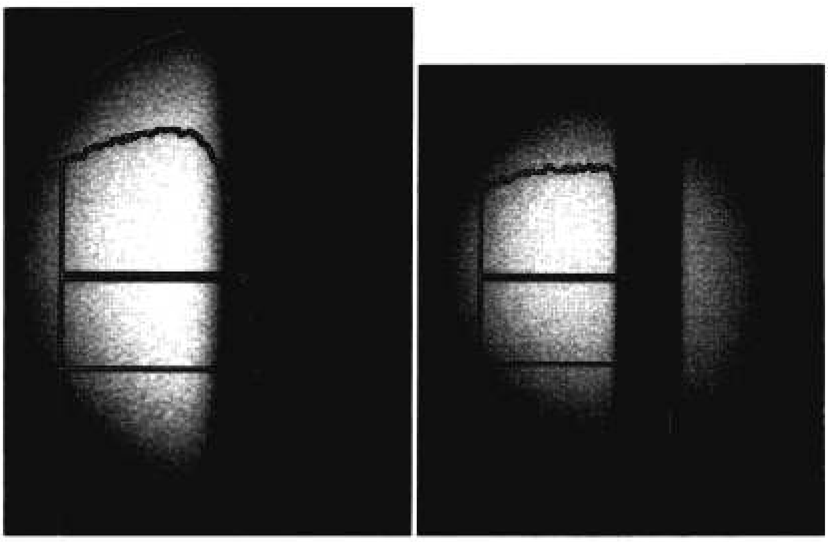
The slice profile of the presaturation bands was analyzed using a round phantom filled with paramagnetic solution. The phantom was imaged in the head coil, using TR of 300 ms, TE of 11 ms, and two excitations. Imaging was performed following prescription of 80 and 20 mm thick presaturation bands with their leading edge at the center of the phantom. A plot of signal intensity across the phantom was used to evaluate presaturation band slice profile.

## RESULTS

Initial 3D TOF MRA projection images demonstrated absence of flow-related enhancement within a single carotid artery siphon in all patients, suggestive of occlusion of this structure (Fig. 1). The lack of signal intensity was present throughout the petrous, cavernous, as well as supraclinoid segments of the affected carotid artery. Relative decreased signal intensity was also present within the middle cerebral artery ipsilateral to the side of apparent carotid artery occlusion. In addition, subtle decreased signal intensity was evident throughout the soft tissues on the same side of the patient's head. Evaluation of individual transaxial partitions confirmed an absence of flow-related enhancement within the affected carotid siphon, as well as the other findings described. The position of the peripheral presaturation bands could be determined on the partition images. In each patient, the partition images revealed asymmetric positioning of the lateral presaturation bands, with the band on the side of suspected carotid occlusion located in a more medial position than the contralateral band (Fig. 1). In none of the patients did the presaturation band intersect or approach the cavernous segment of the internal carotid artery. However, analysis of partitions acquired near the skull base demonstrated that the lateral presaturation band was located in close proximity to the lateral aspect of the petrous segment of the affected internal carotid artery. While the prescribed location of the saturation band did not overlap this segment of the vessel, there was apparent "spillover" of saturation effects from the intended site of saturation into the adjacent soft tissues. This was evident as a gradual extension of reduced soft tissue signal intensity medial to the prescribed location of the presaturation band. These saturation effects extended into the territory of the petrous segment of the internal carotid artery, leading to apparent saturation of flowing spins (Fig. 1).

Repeat examination performed following lateral retraction and/or removal of lateral presaturation bands demonstrated patency and normal caliber of the carotid artery siphon bilaterally in all patients (Fig. 1). Normal and symmetric flow-related enhancement was evident throughout all portions of the intracranial vasculature.

Phantom experiments indicated that use of an 80 mm thick presaturation band was associated with considerable unintended saturation of tissue located medial to the prescribed saturation region (Fig. 2). Marked improvement in the slice profile was achieved upon reducing the thickness of the presat-



2a,b

**FIG. 2.** Image of phantom acquired following prescription of 80 mm wide presaturation band at position of vertical line **(a).** There has been spillover of presaturation medial to the intended location of the presaturation band, as demonstrated by visibly reduced signal intensity. The plot of signal intensity across the image demonstrates a sloped appearance, indicating the poorly defined slice profile of the presaturation band. With reduction of presaturation band thickness to 20 mm **(b),** there is marked improvement in slice profile with essentially no inadvertent presaturation of tissue outside the prescribed location of the presaturation band.

uration band to 20 mm, with no apparent saturation effects located outside the site of presaturation band prescription.

## DISCUSSION

Our findings indicate that use of the peripheral presaturation method may result in apparent occlusion of the carotid siphon due to inadvertent saturation of flowing spins. This may occur for several reasons. First, spatial presaturation pulses have an imperfect slice profile. Consequently, spillover of radiofrequency presaturation from its intended location occurs and can suppress signal intensity of adjacent tissues. The profile of presaturation bands can be improved by reducing their thickness. Therefore, 20 mm presaturation bands have a more accurate slice profile than do 80 mm bands. In the presence of gradient nonuniformity, the position of the presaturation bands may not be limited to their intended location. In this situation, geometric distortion of anatomic structures may also be observed. Movement of the patient's head between acquisition of the initial image used for prescription of peripheral presaturation bands and subsequent MRA acquisition, or during MRA acquisition, may also lead to saturation of flowing spins. This is because movement of the head may bring vascular structures into the territory occupied by the presaturation bands, resulting in saturation of flowing spins. Finally, unintended saturation of flowing spins may occur as the peripheral presaturation bands approach or intersect proximal portions of the vessel that are located in a relatively lateral position. For example, the petrous segment of the internal carotid artery is located in a substantially more lateral location than are the cavernous and supraclinoid segments of this vessel. Therefore, although analysis of partition images may demonstrate that presaturation bands are of sufficient distance lateral to the latter vascular segments, flow within these segments may have been saturated in a more proximal location. The edges of the presaturation band are defined by the head coil excitation profile, rather than by the prescribed field of view.

In this series, saturation of carotid siphon flow appeared to have been attributable to two of these factors. First, whereas the presaturation bands were sufficiently peripheral to avoid the carotid siphons, they approached the most lateral aspect of the petrous segments of the internal carotid arteries. Second, a relatively wide presaturation band thickness of 80 mm was utilized, accentuating slice profile inaccuracies and resulting in inadvertent presaturation of tissues (including the carotid arteries) located medial to the intended margin of the presaturation pulses. The combination of these factors resulted in saturation of flowing spins within the petrous segment of the internal carotid artery, which led to the appearance of occlusion within this segment as well as in more distal segments of this vessel.

When MRA images acquired using the peripheral presaturation method demonstrate apparent occlusion of a carotid siphon, several clues should be sought to determine whether these findings could be artifactual. In the presence of vascular pseudoocclusion due to peripheral presaturation, inspection of axial partition and projection images may demonstrate reduced signal intensity throughout the soft tissues (e.g., brain parenchyma) on the side of apparent occlusion. In addition, apparent occlusion of the other vascular structures (e.g., middle cerebral artery) on this side may be evident. Axial partition and projection images will reveal asymmetry of the presaturation bands, with the band on the side of suspected occlusion located in a relatively more medial position. Partition images acquired near the skull base may demonstrate that the presaturation band on the side of suspected occlusion is located in close proximity to the lateral aspect of the petrous segment of the internal carotid artery. Finally, correlation with SE images that may be acquired as part of a parenchymal brain examination will demonstrate a flow void within the carotid siphon, indicative of vascular patency. Each of these signs should alert the reader to the possibility that the suspected occlusion may be artifactual and attributable to peripheral presaturation pulses.

When vascular pseudoocclusion related to peripheral presaturation is suspected, the 3D TOF MRA acquisition can be repeated with prescription of the presaturation bands in a more lateral position. The thickness of the lateral presaturation bands should also be reduced so as to improve their slice profile. Alternatively, the use of lateral presaturation bands may be eliminated, and a region of interest limited to the vessel(s) of interest can be defined for generation of "targeted MIP" images, on which extracranial fat will be excluded.

In conclusion, use of the peripheral presaturation technique for performing 3D TOF MRA may result in spurious depiction of vascular occlusion. This phenomenon is attributable to proximity of lateral presaturation bands to the petrous segment of the internal carotid arteries, with inadvertent saturation of flowing spins in this segment occurring due to imperfections in presaturation band slice profiles. This pitfall can be avoided through awareness of its potential existence and by evaluation for ancillary signs as described herein.

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