Canon

MR / White Paper

Scan Time Reduction with Fast 3D for Non-Contrast TOF and Time-SLIP Magnetic Resonance Angiography of Carotid Arteries

Won C Bae, PhD
Vadim Malis, PhD
Mitsue Miyazaki, PhD
Department of Radiology, UCSD School of Medicine
University of California, San Diego, CA

Introduction

Carotid artery stenosis (CAS) is a frequent disease seen in general practice. It is one of the most common causes of acute ischemic stroke, accounting for around 20% of occurrences.[1] Thus, it is critical to diagnose, prevent, and treat it early. In general, the combination of non-contrast MRA and plaque imaging like black blood is utilized for the diagnosis of CAS.

Non-contrast MR angiography (MRA) using Time-of-Flight (TOF) or Time-Spatial Labeling Inversion (Time-SLIP) are some of the most popular methods for CAS assessment, although contrast-enhanced MRA may also be used. All techniques offer high sensitivity and specificity values of 80% or greater.[2,3] However, the main challenge with the non-contrast MRA techniques is the long scan time.[4,5]

Scanning time can be reduced by various acceleration techniques. Fast 3D is an acceleration technique that reduces k-space sampling. This is especially useful for volume-based sequences that take time to acquire due to extra phase encoding steps. Fast 3D has two methods called "Wheel" and "Multiple". Wheel is a Fast 3D technique for acquiring the k-space in a deformed wheel pattern in the PE-SE plane, in which the Fast 3D factor represents the k-space filling ratio. Multiple is another Fast 3D technique for acquiring more than one SE k-space line (1.5 or 2) continuously in a single shot. Both methods can be combined with asymmetric or partial Fourier imaging, where only a certain percentage of k-space defined by the fill factor is obtained and the rest is estimated, further reducing the amount of k-space data acquired.

In this study, we compared the depiction of carotid artery using 3D time-of-flight (TOF) and flow-in 3D balanced steady-state free precession (bSSFP) with time spatial labeling inversion pulse (Time-SLIP, with and without using Fast 3D acceleration. Additionally, we determined the effects of using Fast 3D in terms of image quality, signal-to-noise ratio (SNR), and contrast-to-noise ratio (CNR).

Materials and Methods

This human subject study was approved by the institutional review board and written informed consents were obtained.

Human Subjects: Seven healthy subjects were scanned on a clinical 3T scanner (Vantage Galan 3T, Canon Medical Systems, Japan) after signing an IRB- approved consent form.

MR Acquisitions: Images were acquired using an Atlas Head and Neck SPEEDER coil for the carotid arteries. The scanning protocol for the carotid artery consisted of the following series: (i) 3D TOF and (ii) 3D TOF Fast 3D both with 11 slabs covering the aortic arch to middle cerebral arteries without gating; (iii) 3D bSSFP and (iv) 3D bSSFP Fast 3D; scanned with PPG gating and Time-SLIP tag pulse (TI=1200ms) applied to the carotid artery region in the coronal orientation. Acquisition windows of Fast 3D are extended due to the filling of ky-kz k-space trajectory, which can cause blurring around the aortic arch. To address this, we have increased the parallel imaging reduction factor (SPEEDER) to reduce the acquisition window. Detailed acquisition parameters are shown in Table 1. As seen from Table 1, Fast 3D allows the scan time reduction of 33% for TOF and 50% for Time-SLIP sequences.

Data Analysis: For quantitative assessment, an image slice showing the largest cross-section of an artery was chosen. Regions of interest were placed in the artery, nearby muscle, and background to determine the mean and standard deviation (SD) of the signal intensity (SI). SNR of the artery was

	Carotid TOF		Carotid Time-SLIP	
	w/o Fast 3D	w Fast 3D	w/o Fast 3D	w Fast 3D
TR [ms]	10	10	4	4
TE [ms]	3.4	3.4	2	2
FA [deg]	18	18	120	120
FOV [mm^2]	200x200	200x200	320x320	320x320
voxel [mm^3]	0.4x0.4x0.8	0.4x0.4x0.8	0.63x0.63x0.8	0.63x0.63x0.8
SPEEDER	3	3	2.8	2.8
Scan Time [min:sec]	5:30	3:40	3:53	1:57

Table 1: Scanning parameters. Use of Fast 3D enabled 33% to 50% time savings.

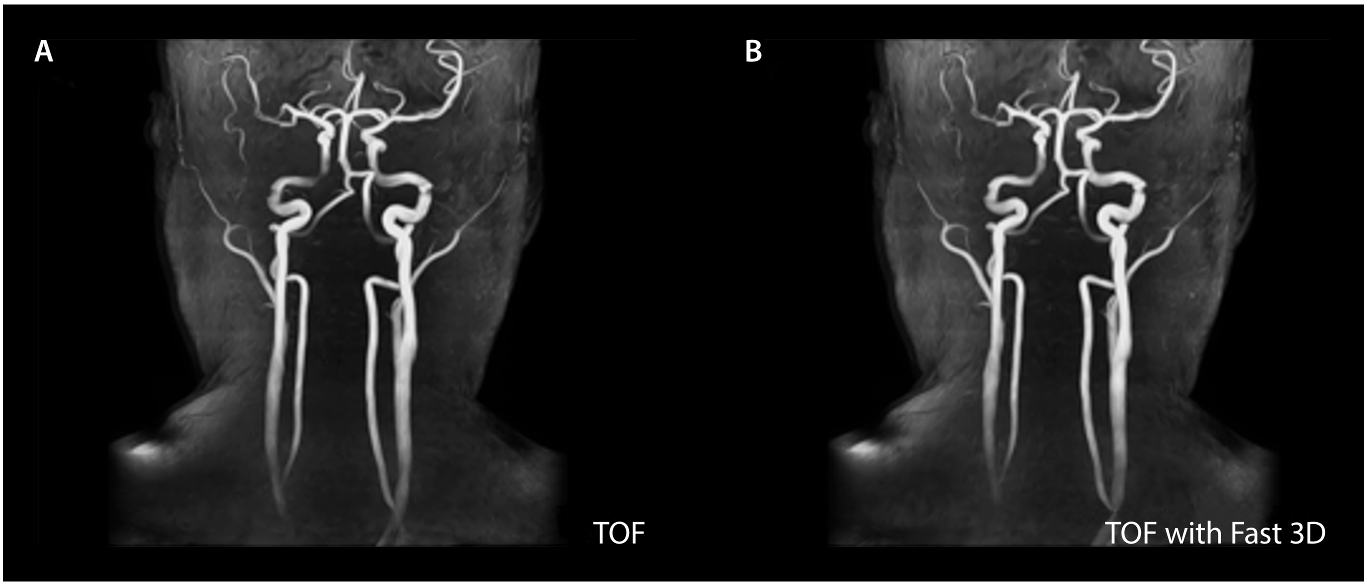

Figure 1: Coronal MIP of Time-of-Flight MRA of the carotid artery without (A) and with (B) Fast 3D acceleration.

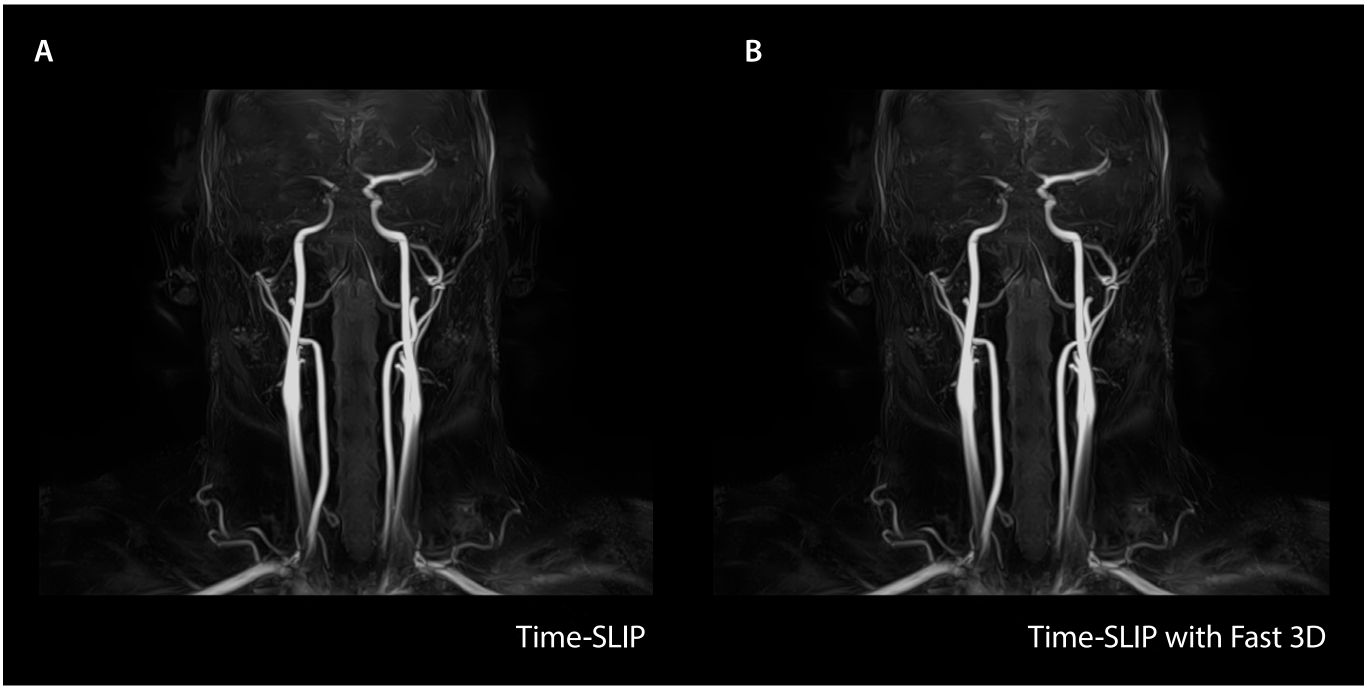

Figure 2: Coronal MIP of the flow-in Time-SLIP 3D bSSFP MRA of carotid artery without (A) and with (B) Fast 3D acceleration.

determined as the mean SI of the artery divided by the SD of SI of the background. Similarly, CNR of the artery was determined as the difference in SI between the artery and the muscle, divided by the SD of the background.

For qualitative assessment, simple maximum intensity projection (MIP) images were reconstructed for all the series for side-by-side comparison. Additionally, for a technical demonstration, we further improved MIP images using a Hessian-based Frangi filter, as well as manual removal of spinal cord for Time-SLIP images.

Results

Figure 1 shows MIP in the coronal orientation of TOF MRA of the carotid artery without (A) and with (B) Fast 3D acceleration. The arteries are well-depicted with Fast 3D sequence without compromising the image quality. Note in Table 1, a 33% scan time reduction in TOF Fast 3D for 11-slab acquisition from the neck to middle cerebral arteries from 5:30 to 3:40 minutes.

Figure 2 shows the MIP in coronal orientation of the flow-in Time-SLIP 3D bSSFP MRA of the carotid artery without (A) and with (B) Fast 3D acceleration. Similar to TOF, the arteries are well-depicted in both sequences without a sacrifice in image quality. In this application, scan time reduction with Fast 3D is approximately 50%.

Figure 3 demonstrates the utility of the Frangi filtering and spinal cord removal on carotid Time-SLIP images obtained without (A) and with (B) Fast 3D. In both cases, the image processing delineated carotid arteries while completely suppressing the background signal.

Table 2 shows the mean SNR and CNR values for the arteries. No marked differences in the values without or with Fast 3D can be seen.

Summary

Both images of 3D TOF and Time-SLIP bSSFP with Fast 3D show comparable image quality compared to those without Fast 3D yet achieving substantial scan time reductions. SNR and CNR were maintained as well. Additional image processing can further aid in isolating arteries from background signal for improved evaluation.

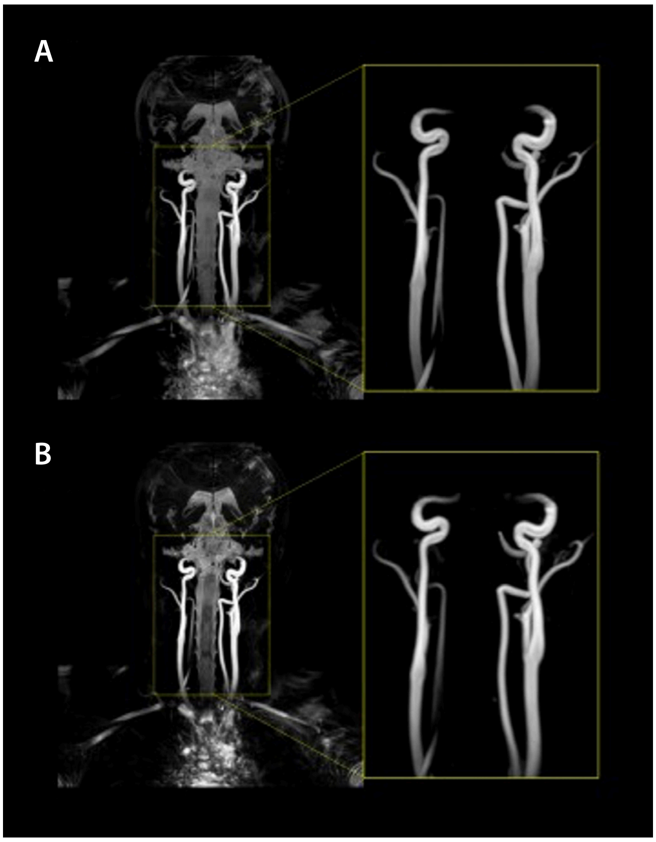

Figure 3: Coronal MIP of the flow-in Time-SLIP 3D bSSFP of carotid artery without (A) and with (B) Fast 3D acceleration. Inserts demonstrate visual improvements using the Frangi filter and removal of the spinal cord.

	SNR	CNR
Carotid TOF	132	14.9
+ Fast 3D	128	13.1
Carotid Time-SLIP	253	12.8
+ Fast 3D	207	12.1

Table 2: Signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) of the blood signal in the imaged arteries show no discernable difference with the use of Fast 3D.

References

1. Rockman CB, Garg K. Contemporary Treatment of the Asymptomatic Carotid Patient. Surg Clin North Am 2023; 103:629-44.
2. Choi CG, Lee DH, Lee JH, et al. Detection of intracranial atherosclerotic steno-occlusive disease with 3D time-of-flight magnetic resonance angiography with sensitivity encoding at 3T. AJNR Am J Neuroradiol 2007; 28:439-46.
3. DeMarco JK, Huston J, 3rd, Bernstein MA. Evaluation of classic 2D time-of-flight MR angiography in the depiction of severe carotid stenosis. AJR Am J Roentgenol 2004; 183:787-93.
4. Parienty I, Rostoker G, Jouniaux F, Piotin M, Admiraal-Behloul F, Miyazaki M. Noncontrast time-spatial labeling inversion pulse 3D MR angiography with regulated breathing versus digital subtraction angiography in patients with chronic kidney disease for evaluation of renal-artery stenosis. Radiology 259:592-601, 2011.
5. Takahashi J, Ohmoto-Sekine Y, Yoshida T, Miyazaki M. Comparison of axial and coronal acquisitions by non-contrast-enhanced renal 3D MR angiography using flow-in time-spatial labeling inversion pulse. Magnetic Resonance Materials in Physics, Biology and Medicine, MAGMA 2020;33:95-102.

CANON MEDICAL SYSTEMS USA, INC.

https://us.medical.canon

2441 Michelle Drive, Tustin, CA 92780 | 800.421.1968

MRWP14513US