Intracranial Arterial Wall Imaging using 3D High Isotropic-Resolution Black Blood MRI at 3.0 T

Y. Qiao[1], D. A. Steinman[2], Q. Qin[1], M. Etesami[1], M. Schär[1,3], B. C. Astor[1], and B. A. Wasserman[1]
[1]The Johns Hopkins Hospital, Baltimore, MD, United States, [2]University of Toronto, Toronto, ON, Canada, [3]Philips Healthcare, Cleveland, OH, United States

INTRODUCTION: The presence of intracranial vascular disease is highly predictive of stroke. However, disease prevalence may be underestimated due to the lack of an appropriate diagnostic tool to depict the intracranial vessel wall [1]. Black blood MRI (BBMRI) has emerged as an effective method to identify pathological features of extracranial vessels [2]. Recently, it has been extended to evaluate intracranial vessels using 2D sequences [3], which are prone to partial volume artifacts amplified by the inherent curving course of intracranial vessels [4]. A newly proposed 3D technique, Volumetric ISotropic TSE Acquisition (VISTA, Philips), employs variable-flip-angle refocusing pulses to achieve a higher signal-to-noise ratio (SNR) efficiency and stronger black-blood effects compared with conventional TSE sequences [5,6]. Our aim was to develop an isotropic high-resolution sequence to evaluate intracranial vessels at 3.0T.

METHODS: Thirteen healthy volunteers and 4 patients with intracranial stenosis were imaged on a 3T MRI scanner (Philips Healthcare) using an eight-channel head coil. 3D VISTA images were acquired in a coronal plane with the following parameters: TR/TE, 2000ms/38ms; Turbo factor, 60 including 4 startup echoes; sense factor, 2; number of averages, 1; FOV, 200x166x45 mm^3; acquired voxel size, 0.5x0.5x0.5mm^3; and scan time,~ 7.5 minutes. A variable-flip-angle refocusing pulse train was used, with α_{min} of 50°and α_{max} of 120°. ECG-gated 2D-TSE images (TR/Turbo factor/TE: 2 heart beats/10/9ms) were acquired at standard locations for comparison: a) basilar artery; b) M1 segment of the middle cerebral artery (MCA); c) horizontal petrous segment of the internal carotid artery (ICA). Two sets of 2D images were acquired with resolutions of 0.25 x 0.25 x 2mm^3 and 0.5 x 0.5 x2 mm^3.

For signal comparison (i.e., SNR_{wall}, wall-lumen contrast-to-noise-ratio ($CNR_{wall-lumen}$)), the reconstructed 0.5mm-thick VISTA images (0.5x0.5x0.5mm^3) were matched with the 2D TSE images (0.25x0.25x2mm^3), having identical voxel sizes. For morphologic comparison, the reconstructed 2mm-thick VISTA images (0.5x0.5x2mm^3) were matched with the 2D images (0.5x0.5x2mm^3), having the same in-plane resolution and slice thickness, to test whether they provided comparable lumen area (LA), wall area (WA) and mean wall thickness (MWT) measurements. Agreement between MRI measurements obtained from 2D and 3D techniques was assessed using intraclass correlation coefficients (ICC).

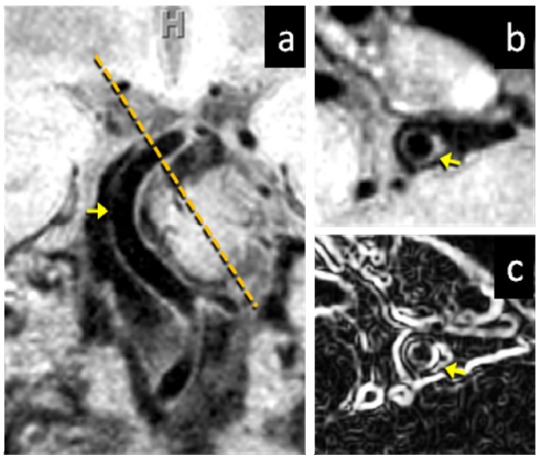

Figure 1. 3D VISTA images (0.5mm-isotropic) of a basilar artery in an 82 year old healthy volunteer. Long-axis view of the basilar artery (a) to orient short axis view (b, reconstructed at line shown in a). A gradient image (c) is generated using Sobel operator to guide contour placement [7]. Basilar artery, arrows.

RESULTS: In healthy volunteers, 3D VISTA images revealed excellent flow suppression and depiction of intracranial vessel walls (Figure 1). Compared with 2D-TSE measurements, 3D-VISTA provided 58% improvement in SNR_{wall} (6.34±1.84 vs. 10.01±2.45, p<0.01) and 74% improvement in $CNR_{wall-lumen}$ (3.70±1.20 vs. 6.45±1.84, *P*<0.01), respectively. LA, WA and MWT from 3D and 2D techniques highly correlated (ICCs of 0.96, 0.95 and 0.96, respectively, Table 1). Improved plaque and lumen delineation was observed in 4 patients using 3D VISTA compared to the 2D technique.

Table 1. Morphologic measurements from 3D VISTA and 2D TSE images

	2D TSE (0.5x0.5x2 mm^3)			3D VISTA-r (0.5x0.5x2 mm^3)		
	MCA	**Basilar**	**Petrous ICA**	**MCA**	**Basilar**	**Petrous ICA**
LA (mm^2)	7.6±2.4	7.3±2.4	18.9±0.4	8.0±2.7	7.7±2.4	18.2±0.4
WA mm^2)	6.5±1.4	7.15±1.88	16.1±0.1	6.4±1.6	7.2±1.9	16.6±0.1
MWT(mm)	0.57±0.07	0.65±0.08	0.97±0.16	0.58±0.06	0.65±0.07	0.96±0.14

P not significant for paired (2D TSE-3D VISTA) measurements.
VISTA-r, reconstructed 2mm-thick VISTA images

DISCUSSION: In this study, we introduce a new MRI method for isotropic high-resolution imaging of intracranial arterial walls at 3T without the anticipated difficulties of suboptimal flow suppression or substantial partial volume averaging effects. This acquisition can cover a large volume of intracranial vessels in a clinically-acceptable scan time (7-8 minutes) to provide highly reliable measurements of vessel wall size. In particular, the superior SNR efficiency afforded by the variable-flip-angle refocusing pulses, along with the inherent ability to reconstruct this isotropic imaging volume in any plane, enable better vessel wall visualization compared to 2D TSE black blood sequences employed for intracranial arterial imaging.

CONCLUSION: 3D-VISTA provides SNR-efficient, highly reliable measurements of intracranial vessels at high isotropic-resolution, enabling broad coverage in a clinically-acceptable time.

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