Comparison of CBF Augmentation with Diamox Challenge Using Arterial Spin Labeling and Xenon CT in Moyamoya Disease

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INTRODUCTION

Cerebral blood flow (CBF) response to a vasodilatory challenge, such as provided by CO2 modulation or acetazolamide (Diamox) administration, provides a better assessment of hemodynamic compromise because cerebral autoregulation can maintain the baseline CBF via chronic vasodilation. Arterial spin labeling (ASL) is a noninvasive technique for measuring CBF and may be ideal for such cerebrovascular challenges because it does not require ionizing radiation or multiple contrast agent injections, and in principle provides a quantitative measurement. In this study, we evaluated the performance of different ASL methods to measure CBF augmentation in Moyamoya disease patients, using xenon CT (xeCT) as a reference standard.
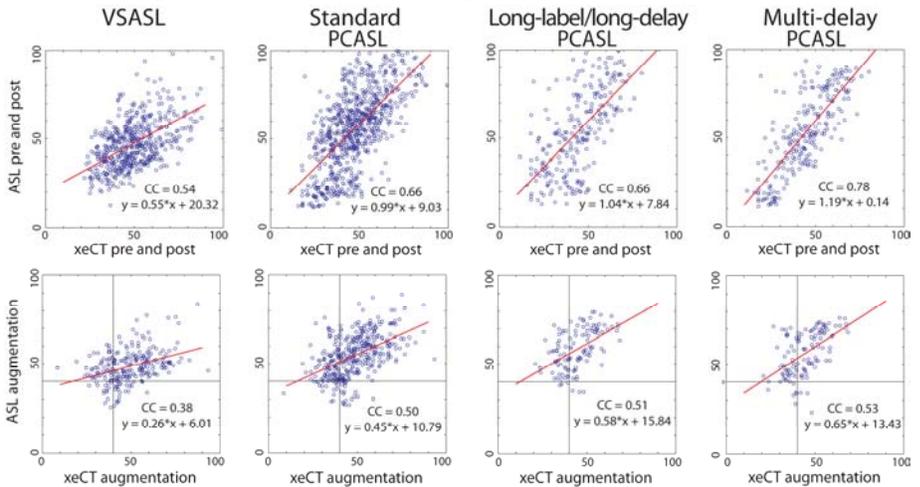
METHODS

Subjects: Sixteen Moyamoya-disease patients (age 43±10 yrs, 12 F) were consecutively recruited during preoperative assessment for possible bypass surgery. Each patient provided informed consent and underwent MRI and xeCT imaging. All ASL and xeCT imaging was performed twice, at baseline and 15 min after injection of 1 g of IV acetazolamide (ACZ), a potent vasodilator.

MRI: All imaging was performed at 3T (GE MR750). We evaluated four different ASL methods: 1) velocity-selective ASL (VS-ASL) [1], 2) standard pseudocontinuous ASL (PCASL) [2], 3) long-label/long-delay PCASL, and 4) multi-delay PCASL[3,4]. Eleven patients received VS-ASL and standard PCASL imaging, and 5 patients received the 3 different PCASL sequences. VS-ASL was performed using a 2 cm/s cut-off velocity and 2D single-shot spiral spin-echo imaging with in-plane resolution = 3.4×3.4 mm^2, FOV 22 cm, and 10 slices with slice thickness/gap 6/2 mm. All 3 PCASL sequences had fast-spin-echo 3D stack-of-spiral readout. Standard PCASL and long-label/long-delay PCASL had the same spatial resolution ($3.8 \times 3.8 \times 4$ mm^3), and FOV ($24 \times 24 \times 14.4$ cm^3), but different labeling duration (LD) and post-labeling delay (PLD); 1.5/2 s for standard PCASL and 3/3 s for long-label/long-delay PCASL. Multi-delay PCASL had an LD of 2 s and 5 different PLD's (0.7, 1.3, 1.9, 2.5, 3 s) and lower spatial resolution ($6 \times 6 \times 5$ mm^3). Scan times were 5:30, 4:38, 6:59, and 3:36 min for VS-ASL, standard PCASL, long-label/long-delay PCASL, and multi-delay PCASL, respectively. Structural imaging was performed using IR-prepped 3D SPGR.

xeCT: Imaging was performed with a GE 8-detector scanner with 4 contiguous 10-mm slices[5].

Image Analysis: All ASL and xeCT images were co-registered to T1-weighted images, and ASL images were re-sliced to match the xeCT. Six peripheral cortical segments corresponding to the left/right anterior, middle, and posterior cerebral artery territories were defined for each slice. For each segment, mean pre- and post-ACZ CBF was calculated. CBF augmentation was defined as their difference. We chose difference rather then ratio because we found that the ratio was more sensitive to noise.


Figure 1. Scatter plots of CBF measurements and CBF augmentation acquired using four different ASL methods and xenon CT (unit in ml/100 g/min).

RESULTS AND DISCUSSION

Fig 1 contains scatter plots and correlation coefficients of the different ASL methods and xeCT. Multi-delay PCASL achieved the highest correlation with xeCT in CBF measurement. However, for measuring CBF augmentation, all 3 PCASL methods showed similar correlation, while VS-ASL had lower correlation than any of the PCASL methods. While this latter finding may be related to lower SNR or different readout strategy, we conclude that, if given the choice, multi-delay PCASL would be the preferred technique for measuring reserve in patients with cerebrovascular disease. Our results support the previous finding of high correlation between multi-delay ASL and SPECT for CBF reserve measurement[6].

REFERENCES [1] Wong *et al*, MRM 55: 1334, 2006. [2] Dai *et al*, MRM 60: 1488, 2008. [3] Dai *et al*, MRM 67: 1252, 2012. [4] Wang *et al*, Neuroimage 3: 1, 2013. [5] Zaharchuk *et al*, JMRI 30: 743, 2009. [6] Uchihashi *et al*, AJNR 32: 1545, 2011.
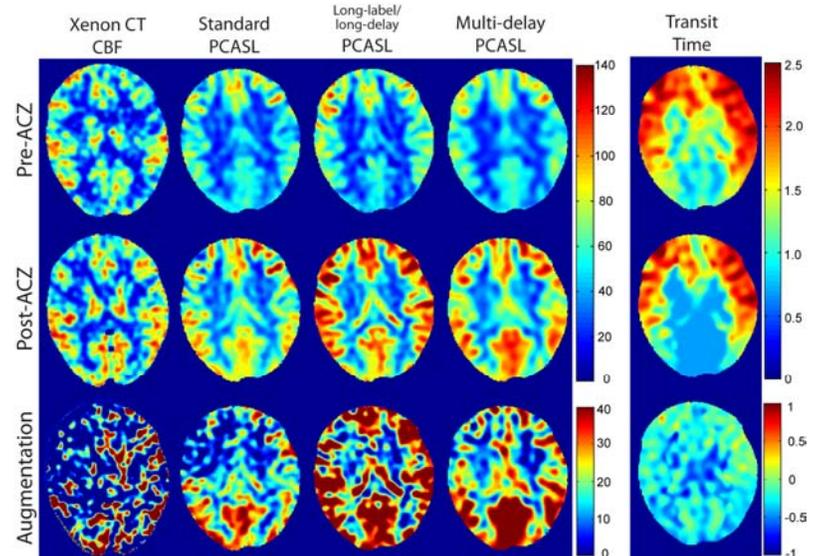
Figure 2. Images from one representative patient. CBF in unit of ml/100 g/min and transit time in sec.