Effect of flip angle on volume flow measurement with non-triggered phase-contrast MR

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Purpose: To investigate the effect of flip angle with a range from 4 to 90° on in vivo measurement. Specifically, blood flow in the internal carotid arteries and basilar artery were measured with both cine, that is, retrospectively gated, and non-triggered phase-contrast MR. Blood volume flow rates obtained with cine phase-contrast MR studies were adopted as gold standard.

Materials and Methods: This study consisted of two parts. In the first part, flip angles of 4, 15, 60 and 90° were used for the non-triggered phase-contrast measurements in 40 normal volunteers, and 8, 15 and 30° in the second part in 54 normal volunteers. MR examinations were performed on a 1.5-T Imager (Signa, General Electric). MR examination consisted of three-dimensional (3D) time-of-flight MR angiography and two-dimensional (2D) phase-contrast MR imaging. After obtaining 3D time-of-flight MR angiography images, cine phase-contrast MR images were obtained and non-triggered phase-contrast MR imaging with different flip angles followed immediately at the identical scan plane. Parameters of 2D cine phase-contrast imaging were: [TR= 24 msec, TE= 6.6-7.2 msec, matrix = 256x256, FOV= 120 mm, slice thickness= 5 mm, number of cardiac phases= 16, flip angle = 30°, phase encoding direction = anterior to posterior, number of signal averagings= 1]. Encoding velocity of the cine phase-contrast imaging was set at 100 cm/sec. If aliasing was detected, imaging was repeated at an encoding velocity of 150 cm/sec. After absence of aliasing was confirmed with cine phase-contrast imaging, 2D non-triggered phase-contrast imaging was performed at an identical encoding velocity. The parameters of 2D non-triggered phase-contrast imaging were: [TR= 24 msec, TE= 6.6-7.2 msec, matrix= 256x256, FOV= 120 mm, slice thickness= 5 mm, phase encoding direction = anterior to posterior, number of signal averagings = 4]. By using previously obtained 3D MR angiogram as a guide, the scan plane for 2D phase-contrast imaging was planned as perpendicularly as possible to the precavernous internal carotid arteries and the middle or distal portion of the basilar artery. During this planning, the angle between the scanning plane of the 2D phase-contrast image and the arteries was measured. If the angle was greater than 30° from the perpendicular, a new scanning plane of the phase-contrast image was used. Since we wanted to use identical lumen for cine and non-triggered phase contrast, subjects who moved more than 0.5mm or rotated more than 0.5 degree during phase-contrast MR imaging were excluded.

Lumen boundaries were semi-automatically determined by pulsatility-based segmentation using cine phase-contrast MR imaging (1). Identical lumen boundaries were used for non-triggered phase-contrast imaging. Signal-to-noise ratio and contrast-to-noise ratio were measured in magnitude images obtained with non-triggered phase-contrast acquisition.

Results: The ratios of volume flow rates obtained with non-triggered phase-contrast imaging to that obtained with cine phase-contrast imaging were 0.80 +/- 0.17 (mean +/- standard deviation), 0.91 +/- 0.12, 1.02 +/- 0.13, 1.11 +/- 0.14 for flip angle of 4, 15, 60, and 90 degrees respectively. They were 0.87 +/- 0.12, 0.92 +/- 0.10, 0.98 +/- 0.12 for flip angles of 8,15, and 30 degrees respectively. The ratio significantly increases with an increase in the flip angle. The mean ratios lie within a relatively narrow range of +/- 15 % with a wide range of flip angles of 8 to 90°. As the flip angle increases, ghost artifacts become prominent and signal-to-noise and contrast-to-noise ratios increase but saturate at flip angles over 60 degrees.

Conclusions: Flip angles between 8 and 60° are most appropriate for non-triggered phase-contrast MR measurements in the internal carotid and the basilar artery.

References:

1. Alperin N, Lee SH. PUBS: pulsatility-based segmentation of lumens conducting non-steady flow. Magn Reson Med. 2003;49:934-44.