Improving flow characterization in SNAP with k-space acquisition reordering

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Purpose:

Simultaneous Non-contrast Angiography and intraPlaque hemorrhage (SNAP) imaging was proposed as a technique for joint MRA and high risk atherosclerotic plaque feature (intraplaque hemorrhage, or IPH) detection[1]. Since its initial proposition for carotid artery imaging, it has been adopted in a number of vascular beds including intracranial, aorta, coronary and peripheral arteries. In its daily implementation, however, the performance of SNAP MRA can be impacted by hardware limitations. For carotid artery imaging, to achieve ideal MRA, an inversion coverage of 60cm is desired but is not possible using the body coil on by most scanners due to short transmission coil size. As a result, flow artifacts can be occasionally observed on the carotid SNAP MRA images in the proximal carotids. To address this issue, a new SNAP acquisition scheme is proposed to improve the MRA performance by optimizing k-space acquisition ordering so that flow artifacts can be minimized.

Methods:

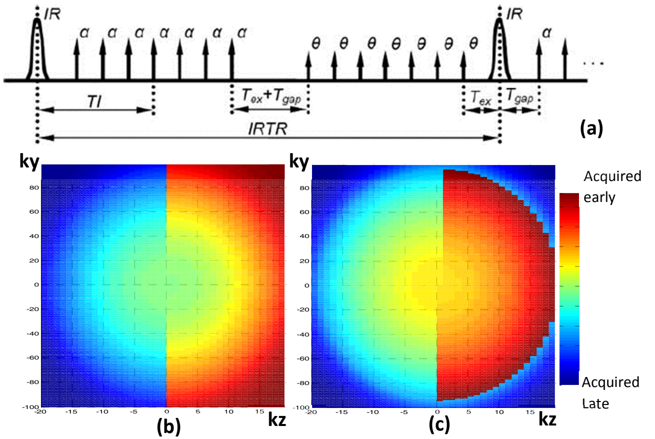


Fig. 1 The SNAP sequence (a) and its k-space order comparison between original (b) and new (c) schemes. The new SNAP acquisition scheme allows for the more flexible placement of k-space center in each acquisition shot. The less important portion of k-space (corners) were collectively acquired at the end of each shot so the center the k-space can be acquired with less flow artifacts.

<u>k-space reordering:</u> SNAP is a 3D sequence, so the k-space ordering is performed on the ky-kz plane. To maintain the high contrast among blood/tissue/IPH in the SNAP images, the inversion time between two inversion pulses (IRTR) should be maintained. On the other hand, to mitigate the flow artifacts caused by short transmit coil size, the inversion time (TI) of the image acquisition should be shortened. The linear k-space filling option does not allow shortening TI without changing IRTR.

An asymmetrical filling scheme is proposed – in this scheme, a TI time can be flexibly selected without impacting the IRTR duration. As shown in a sample k-space radial filling scheme (Fig.1b&c), instead of using a strict linear profile, the new scheme fills the k-space in two steps: 1) it preferably fills the center region (with customizable size/radius) in the first half of IRTR when flow artifacts are less likely to present; 2) it then fills the rest of the k-space (corners in Fig.1c) in the order of its distance to the k-space center.

<u>Optimization:</u> With the new flexibility in filling k-space, the inversion time needs to be re-optimized to balance between the IPH contrast and robust flow excitation. With a goal of reducing TI while maintaining the existing IPH/lumen contrast, the previously utilized parameter optimization approach is used. The optimized TI was then used for the following comparison.

<u>MR Scan and Data Analysis:</u> With IRB approval and consenting, twelve subjects with diagnosed carotid artery disease were recruited to evaluate the flow suppression performance of new SNAP, as compared to the original SNAP protocol. All scans were conducted in a whole body 3T scanner (Philips Achieva, R3.2.1, the Netherlands). SNAP parameters were the same as reported before; new SNAP parameters were also the same except the optimized TI. Standard contrast enhanced MRA was also acquired as a reference. After the images were acquired, SNAP MRA images were generated. Both SNAP and CE MRA images were then reformatted to axial slices for lumen size comparisons. Images with flow artifacts were noted during independent review and Bland-Altman plots were used to evaluate agreement between methods.

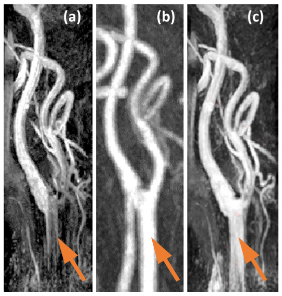
Results:

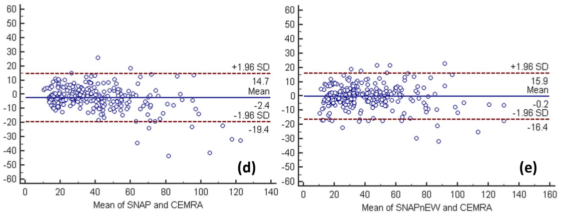
<u>Sequence Optimization:</u> The new k-space acquisition scheme was programmed with flexible TI selection in the UI interface. A TI of 360ms was found to provide the highest IPH/lumen contrast. This TI was then selected as the inversion time in the following scans.

<u>SNAP vs. new SNAP Comparison</u> A total of 446 slices of 24 arteries were quantified and measured using all three sequences. The new SNAP sequence was found to be more robust against flow artifacts, compared to the original SNAP sequence (Fig.2a&c). Significantly fewer subjects had flow artifacts using the new SNAP sequence (SNAP/new SNAP/CEMRA: 27.5/12.7/9.9%), comparable to CEMRA images.

In the Bland-Altman plots, although SNAP was found to agree well with CEMRA, a small bias of 2.4mm^2 area difference remains (Fig. 2d, Mean area: 38.0mm^2); in new SNAP, the bias is much smaller at 0.2mm^2 (Fig.2e, Mean area: 40.1mm^2).

Fig. 2 SNAP and new SNAP clinical comparison Comparisons among SNAP (a), CEMRA (b) and new SNAP (c). An obvious flow improvement was achieved on the new SNAP image, as pointed by the arrows. The BA plot comparison (SNAP (d) & new SNAP (e)) showed much smaller bias (0.2mm^2 vs. 2.4mm^2) on new SNAP images, when using CEMRA as the reference.





Conclusions:

By optimizing the k-space acquisition ordering in SNAP, more robust flow characterization can be achieved as the center of the k-space was acquired before the artifact arises. New SNAP was also found to provide nearly identical measurements when compared to CEMRA.

References: 1. Wang J et al. MRM 2013; 69:337-45.