The potential problems associated with carotid motion in carotid artery imaging

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Aim:

To measure bulk respiratory and swallowing motion affecting carotid artery imaging and to investigate optimal head support for carotid work.

Background:

Recent advances in carotid artery wall imaging have seen a transition from 2D to more efficient 3D imaging[1]. However, a disadvantage of 3D scans is their longer time to complete the acquisition, making them more susceptible to motion artefacts, particularly swallowing[2] and bulk head motion during the long acquisition time. Whilst, in still the more commonly used 2D sequences, these motion artefacts may also affect reliability and registration. Respiratory movement artefact is controversial[3], but in a study using real-time transaxial cines[4], its detrimental effect on carotid wall imaging has been demonstrated. However, during quiet supine respiration, physiological breathing is predominantly diaphragmatic resulting in the greatest carotid movement in the head-foot direction. We used a novel high-temporal resolution interleaved approach to study carotid artery movement in all directions, over the typical 3D scan duration, for a true representation of the potential problem for 3D imaging.

Methods:

19 healthy volunteers were scanned at 1.5T (Siemens Magnetom Avanto) with phased array carotid coils (Machnet). They had high-resolution bSSFP scans of the right carotid artery in the oblique-sagittal plane centered about the bifurcation and in the transverse plane to measure movement in the Head-Foot, Antero-Posterior and Left-Right directions. Each volunteer was scanned twice: with a vac-lok™ fixation pillow (CIVCO Medical Solutions), followed by a standard Siemens foam head support. Subjects were all asked "to lie still and relax" during scans.

Parameters: For 500 cardiac cycles, ECG-triggered diastolic oblique-sagittal and transverse single-shot bSSFP images were alternately acquired (one image/cardiac cycle) with pixel size 0.6x0.6x6mm, flip angle 70°, TR 395ms, TE 1.6ms. The vessel motion was measured by image post-processing using 2D-correlation to track an ROI with MATLAB® (The MathWorks) (figure 1). For this, image pixels were 2D-interpolated to 0.31x0.31mm.

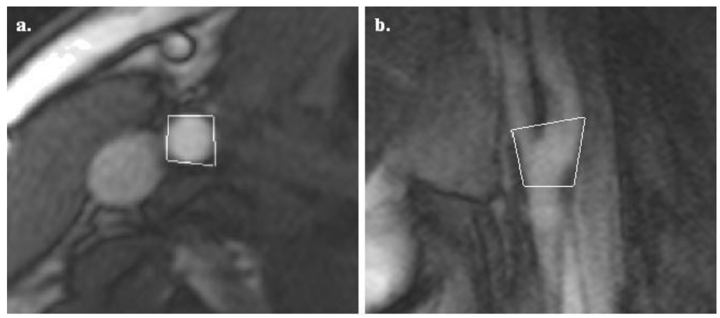

Figure 1a. Regions of interest are drawn around the common carotid artery in the transverse plane and 1b. in the oblique-sagittal plane allowing for ROI automatic tracking using MATLAB after image acquisition.

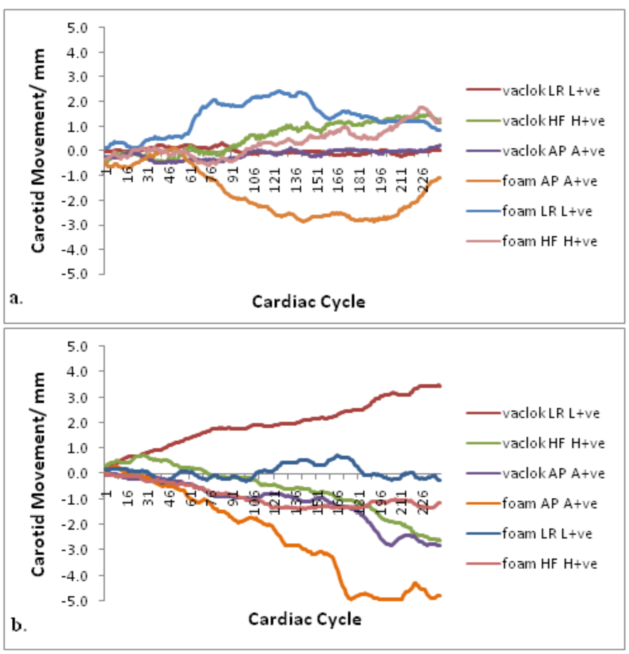

Figure 2. depicts the different type of "drift" pattern in the three perpendicular directions with both types of head support in 2 individuals. In figure 2a. the carotid "drift" seen in this subject appears to increase as the scan progresses but then seems to decrease towards the end. This could be due to increasing somnolence during the scan but becoming more alert towards the end. Whereas, in figure 2b. the carotid "drift" in this volunteer is away from baseline until the end of the scan. Here, the phenomenon can be explained by increased muscle tension at the start; individuals are generally tense and anxious prior to the scan but once the scan has commenced, they begin to relax and consequently muscle tension decreases resulting in the observed "drift".

Results and Discussion:

Involuntary "drift": In 30/38 scans, there was "drift" of the carotid artery compared to the baseline reference image with no clear pattern. The mean "drift" in the 3 directions are AP 3.6mm (range 0.3-5.0mm), LR 3.2mm (range 0.3-4.3mm) and HF 2.3mm (range 0.3-3.1mm). Figure 2 illustrates the "drift" seen in all three directions with both types of head support from 2 individuals. We observed no obvious bulk head motion during scans with either pillow.

Respiratory motion of the carotids: The amount of movement during quiet respiration was measured from the difference between smoothed and unsmoothed traces excluding swallowing events. The largest respiratory movement was in the HF direction 1.4mm (peak-peak) with substantially less movement in the LR 0.9mm (peak-peak) and AP 0.5mm (peak-peak). The data was transformed to a log normal distribution and ANOVA testing was done. There was no relationship between the different types of pillow and the direction of carotid movement. There was a significant difference between the directions, $p<0.001$. The geometric means (95% CI) of the 3 directions are: HF 1.22 (1.06, 1.41), LR 0.69 (0.59, 0.81) and AP 0.48 (0.40, 0.57).

Swallowing motion of the carotids: During a swallow event, there was variable movement of carotid artery in all 3 directions. To measure swallowing motion, the position measurements were compared between smoothed and unsmoothed motion traces. We found that the average carotid movement in the HF direction was greater than LR and AP, 3.5mm (range 1.6-6.2mm), 2.8mm (range 0.9-6.2mm) and 1.7mm (range 0.6-5.1mm), respectively.

Although there was no statistical difference, $p=0.87$, in head motion between the different head supports, individuals reported that the vac-lok™ pillow was more comfortable and offered greater neck support.

Conclusions:

We have shown that respiratory motion previously regarded as insignificant may be large enough to contribute to blurring and ghosting of 3D carotid images. Involuntary head motion even in motivated volunteers during 3D imaging times is clearly an issue for 3D imaging reliability, as is swallowing motion in some subjects. These motion artefacts can corrupt the entire 3D sequence and affect wall imaging and plaque characterisation.

References:

[1]Fayad ZA. Circ Res. 2001;89(4):305-16. [2]Chan CF JMRI in press. [3]Aoki S. AJNR 2000;21:381–385. [4]Boussel L. JMRI 2006;23:413–415.