Is a Velocity Encoding of 5 cm/sec Sufficient to Quantify Brain Motion?

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INTRODUCTION

Brain motion during cardiac cycles presents an interesting challenge for physiologists. It has been demonstrated by using phase contrast MRI (1) and DENSE (2). It is linked to the oscillatory motion of the cerebro-spinal fluid (CSF) but not demonstrated to be a cause or a consequence of it (3). Quantifying brain motion can be used to analyze the stiffness parameters of the brain or "elastography" (4). CSF flow quantification is a routine procedure: certain brain pathologies, such as hydrocephalus, lead to changes in CSF flow patterns. It is still unclear which brain pathologies or if brain atrophy can be assessed by quantification of brain motion. Five cm/sec is a common value of velocity encoding to measure CSF flow. Our hypothesis was to validate quantification of brain motion with this encoding value to enable larger studies of populations scanned for CSF flow.

MATERIAL AND METHOD

Seventeen volunteers (10 men, 7 women, age 33.2 Std. Dev. 12.5 yrs) were scanned at the levels of both thalami and the brain stem with a Signa 3T HDx (GE Healthcare, Waukesha, WI). A 2D phase contrast sequence was used with a velocity encoding of 5 cm/sec and the following parameters: TR 16.4 – 19.0 ms, TE 7.7 – 9.0 ms, pixel size 0.7 mm, slice thickness 5 mm. Slices were done parallel to the anterior and posterior commissures line. A peripheral gating was used for phase contrast series.

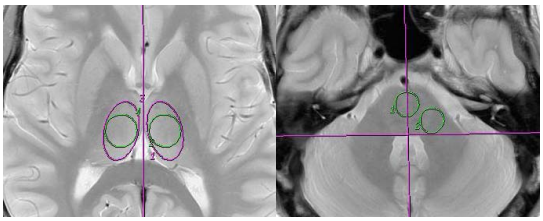

Figure 1: ROI definition

Four Regions of Interest (ROIs) were drawn on a Proton Density scan acquired at the same levels as the phase contrast series (see Fig. 1). For left and right thalami: an ellipse was drawn to encompass the left thalamus; the symmetrical ROI for the right thalamus was computed using the inter-hemispheric symmetry axis. Measurements were performed in a circular ROI in the center of the ellipse. In the brain stem, a sagittal axis and a frontal axis aligned with the floor of the fourth ventricle were drawn. A first circle ROI was positioned on the sagittal axis on the central part of the pons, avoiding any large CSF flow effects. A second lateral ROI was positioned tangentially to the frontal axis, on the left middle cerebellar peduncle, avoiding any flow artifacts or large CSF flow effects. ROIs in the brain stem had an area of 100 mm^2.

Quantification of motion using phase contrast imaging presents an issue at low speed because of a constant offset of the static tissue. To correct for this, we made an assumption that tissue would return to its initial position after a cardiac cycle. Quantification of motion relies on the integration of speed along time, to which an average position during cycle is added as an initial tissue position.

RESULTS

After correction for offset explained above, brain tissue speeds in absolute values were measured to be between 0.0002 and 0.17 cm/sec in thalami ROIs; and between 0.0014 and 0.48 cm/sec in brain stem ROIs. Measurements of motion in left and right thalami were found to be in agreement with previous literature. Average displacement of the left and right thalami, pons and left middle cerebellar peduncle ROIs are displayed in table 1. In our population, no statistical difference was found between men and women at the level of the thalamus, but a small difference was found for brain stem and lateral cerebellum ROIs. Age difference between the 2 groups was 5 years more for the men. Brain motion was reduced when cardiac frequency increased. There is also a small decrease of motion with age in the thalami, not seen in the pons or in the left middle cerebellar peduncle.

	L. Tha.	R. Tha.	Pons	L. MCP
Average	0.20	0.19	0.40	0.34
Std. Dev.	0.07	0.06	0.16	0.13

Table 1: Left (L.), Right (R.)Thalamus, Pons and Left (L.) Middle Cerebellar Peduncle (MCP) motion in mm

Brain motion in the thalami was found to be highly reproducible across our population, as shown on the average curve and 95% confidence interval (see Fig. 2). There was more variability at the level of the brain stem.

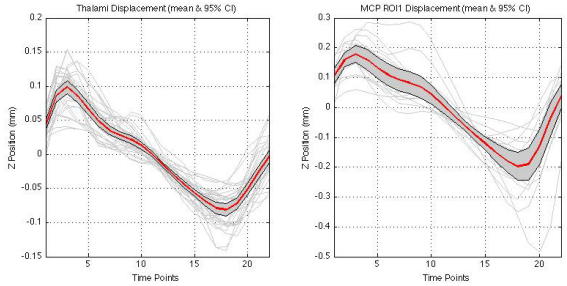

Figure 2: Thalami and brain stem motion (average: red, 95 % confidence intervals: gray)

DISCUSSION

In this study, we limited to the Z component of motion (along the cranio-caudal direction) which is an order of magnitude larger than the X and Y component (1,2). We acquired 2D slices: a 3D approach of brain motion would allow a better analysis at the expense of in-plane resolution. Finally, an ECG can be used for better triggering.

Despite these limitations, this study allows us to analyze populations with known pathologies such as hydrocephalus, or simply to observe aging of the brain. Brain motion is usually considered an effect of cardiac cycles, as it is linked to the oscillation of CSF flow. Shorter diastolic time in higher cardiac frequencies could lead to a reduction of brain motion. Reduction of brain motion with aging in the thalami could contradict observed atrophy with aging: even though there is more space for motion, motion is not increased. This could be explained by an increase in the volume of CSF circulating around the brain compared to CSF in the central ventricular system. As a result, the brain would not have to adapt as much to blood flowing through cardiac cycles. Lastly, brain compliance is likely to be affected with pathologies or aging, which in turn could affect motion.

REFERENCES

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