Brain Stem Motion in Acqueductal Stenosis Hydrocephalus

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INTRODUCTION

The brain shows a pulsatile motion synchronously to the heartbeat[1,2]. At the level of the brain stem, this motion is primarily in the cranio-caudal direction[3]. The dynamics in the cranium could be altered in certain brain disorders such as hydrocephalus, syringomyelia, Chiari malformation, traumatic brain injury or focal diseases. In non-communicating hydrocephalus, brain pulsatility may be affected by the change in the pattern of CSF flow. Our study aims at evaluating the changes in pattern or amplitude of brain stem motion linked to non-communicating hydrocephalus.

MATERIALS AND METHODS

21 healthy volunteers and 15 patients were scanned at the level of the brain stem using 3T (Signa HDxt, GE Healthcare, Milwaukee, WI) and phase-contrast MRI sequences. Scanning was approved by the local review board. The velocity encoding parameter (V_{enc}) was 5 cm/sec. Another phase contrast sequence was added to the protocol to quantify blood flow into the basilar artery, with a V_{enc} of 80 cm/sec. A peripheral gating was used. Regions of Interest (ROIs), of an approximate area of 100 mm^2, were drawn in the central part of the pons. Care was taken to avoid any large CSF cavity, CSF or venous flow effects. To correct for constant offset of the static tissue, we hypothesized that tissue would return to its initial position after a cardiac cycle. Quantification of motion relied on the integration of speed along time. A time shift algorithm was used to align brain stem motion waveforms between subjects. Using basilar artery flow waveforms, a systolic phase was defined as the phase of maximum flow velocity, and was used as a reference to realign all subjects' data in time.

RESULTS

The volunteer population was not statistically different in age or in heart rate from the patient population. The amplitude of brain stem motion did not exhibit strongly correlated changes, only a trend to increase (resp. decrease) with increasing age (resp. heart rate). Results (mean +/- standard deviation) are summarized on Table. Brain stem motion amplitude in the volunteer population was larger in men than in women ($p = 0.018$). Brain stem motion amplitude in the patient population was significantly lower than in the volunteer population ($p = 0.009$).

	Volunteers	Patients
	0.41 +/- 0.13 mm (n = 21)	0.31 +/- 0.09 mm (n = 15)
Male	0.47 +/- 0.14 mm (n = 12)	0.32 +/- 0.10 mm (n = 13)
Female	0.34 +/- 0.08 mm (n = 9)	0.27 mm (0.21 – 0.34) (n = 2)

Table: comparison of brain stem motion amplitude between volunteers and patients.

Motion pattern of the brain stem over patients was different to the motion pattern of the brain stem over volunteers. All brain stem motion waveforms demonstrated the same pattern of the brain stem being 'pushed' towards the subject's feet when arterial blood flows in. The peak brain stem displacement, corresponding to the systolic basilar artery phase, was slightly delayed in the patient population with respect to volunteers, on average by 67 ms (see Fig.). An attenuation of the brain stem motion amplitude was seen in the patient population average with respect to the volunteer population average.

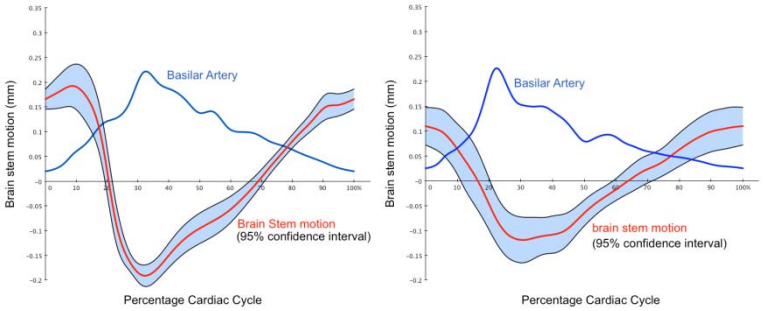

Figure: Brain stem motion waveforms in populations of volunteers (left) and patients (right). Scale on the left hand side corresponds to the displacement of tissue in mm (positive values towards head). Blood flow patterns in basilar arteries are superimposed for comparison.

DISCUSSION

Our study demonstrates an impact from a pathology affecting the oscillating CSF flow on brain stem motion. Using a velocity encoding parameter of 5 cm/s, motion over a cardiac cycle can be measured routinely. When there is no communication between the third and the fourth ventricle, a reduction in CSF flow and an increased pressure are usually observed. Compression of tissue could lead to changes in its properties: a compressed tissue may be less compliant, so it may move with more difficulty than the same tissue at baseline. Delay and dampening in brain stem motion could be also be due to an increased resistance for CSF to flow through the central brain cavities, and an easier path to flow through the peripheral spaces.

The difference in the amplitude of brain stem motion between the male and female volunteer populations was not previously reported. It could be linked to the size of posterior fossa, which may be genetically larger in men than in women[4]. The same origin may be the reason for a larger prevalence of Chiari I and II in females.

There are some limitations to this study: we limited to the Z component of motion (along the cranio-caudal direction) and 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.

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