ORAL PRESENTATIONS

Measuring respiratory and cardiac influences on blood and cerebrospinal fluid flow with real-time MRI

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Background

A link between various pathological conditions and blood and cerebrospinal fluid (CSF) flow alterations has been suggested by numerous studies.[1] The blood and CSF dynamics are influenced by many factors, such as posture,[2] heart beating, and thoracic pressure changes during respiration.[2,3] The blood/CSF flow rate can be estimated using phase-contrast (PC) – magnetic resonance imaging (MRI). However, the clinical cardiac-gated cine PC-MRI requires several heartbeats to form the time-resolved flow images covering the entire cardiac cycle, not allowing to assess beat-by-beat variability differences and respiratory-driven flow changes. To overcome these limitations, we recently used a real-time (RT)-PC prototype for the study of blood and CSF flow rate modulations, showing low-frequency oscillations (Mayer waves)[4]. With the same MRI technique, in the current study we focused on assessing the cardiac and respiratory modulations on the blood and CSF flow rates, and the effects of different respiration modes.

Methods

Thirty healthy volunteers (21 females, median age=26 years old, age range= 19-57 years old) were examined with a 3 T scanner. RT-PC sequences (Figure 1) allowed for a quantification of the flow rates of internal carotid arteries (ICAs), internal jugular veins (IJVs), and CSF at the first cervical level. The superior sagittal sinus (SSS) was also studied in 16 subjects.[5] The flow rates were estimated with a temporal resolution of 58.5 ms for the blood, and 94 ms for the CSF. Each RT-PC lasted 60 seconds and was repeated three times: while the subject breathed with free (F) breathing, at a constant rate with a normal (PN) or forced (PD) strength. The systolic, diastolic and average flow rates and their power spectral densities were computed. High and very-high frequency peaks were identified on the spectra. Frequencies associated to the identified peaks were compared to the respiratory and cardiac frequencies estimated by a thoracic belt and a pulse oximeter. The area under the spectra, normalized by the flow rate variance, was computed in the respiratory and cardiac frequency ranges (0.5

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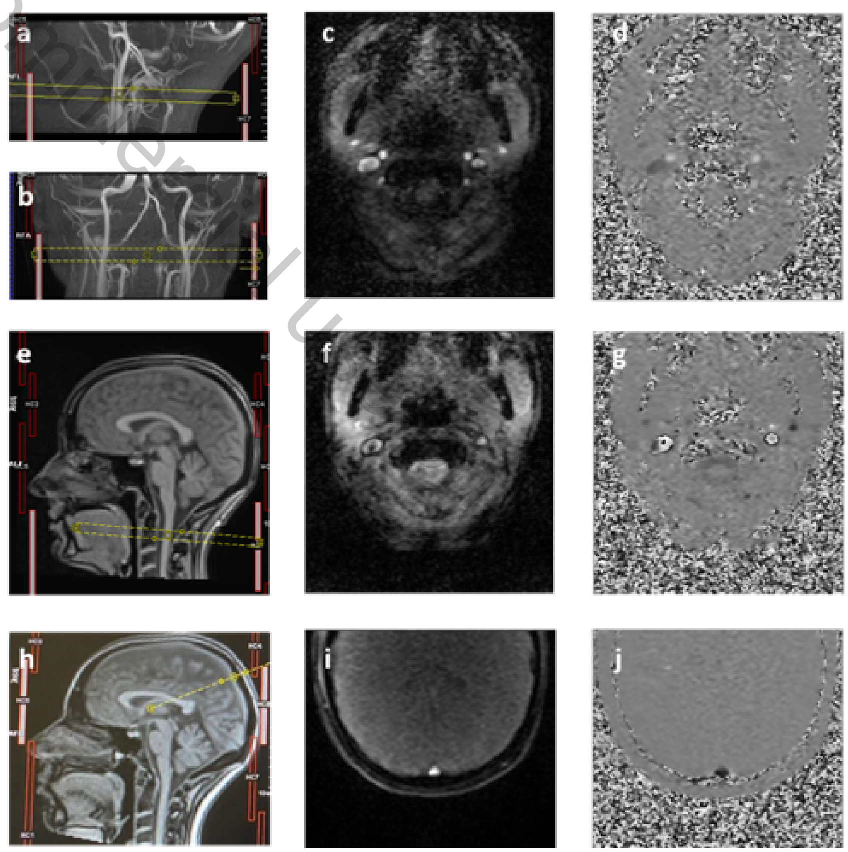

Figure 1. Positioning of real-time (RT) phase-contrast (PC) sequences. RT-PC slice perpendicular to neck vessels was positioned on sagittal (a) and coronal (b) time of flight maximum intensity projections for estimating the flow of the internal carotid arteries (ICAs) and internal jugular veins (IJVs). Corresponding RT-PC magnitude (c) and phase (d) images. RT-PC slice perpendicular to the spine (e) at the cervical level for the cerebrospinal fluid flow estimation. Corresponding RT-PC magnitude (f) and phase (g) images. RT-PC positioning perpendicular to the superior sagittal sinus (h), and obtained magnitude (i) and phase (j) images.

Hz-wide ranges, centered on the cardiac or breathing frequency peaks, respectively).

Results

The frequencies associated with the spectral peaks were not significantly different compared to the respiratory and cardiac frequencies, for all regions and breathing modes. The average blood flow rate and the diastolic CSF peak progressively decreased from F to PN to PD breathing, the flow rate variance remained stable, and only the ICAs cross-sectional area decreased. The respiratory modulation increased with PD breathing compared with F and PN, while the cardiac modulations were less predominant for all the structures of interest.

Conclusions

Using the RT-PC sequence we showed that the blood and CSF flow rates were modulated at the respiratory and cardiac frequencies. The observed reduced blood flow rate during forced breathing in the arteries and consequently in the extra and intracranial veins are suggestive of compensatory vasoconstriction in response to decreased CO2 blood concentration. Breathing modulation of flow rates was observed both in the extracranial and intracranial compartments, and it was greater during forced breathing than free breathing, due to the greater thoracic pump effect on the flow rates.

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