CSF Flow in the Aqueduct and skull base as a Function of Heart Rate

M. Forjaz Secca[1,2], J. Duarte[2,3], J. Ferreira[1], A. Goulão[2,3], P. Vilela[3]

[1]Cefitec, Dep. of Physics, Univ. Nova de Lisboa, Caparica, Portugal, [2]Ressonância Magnética de Caselas, Lisboa, Portugal, [3]S. Neurorradiologia, H. Garcia D'Orta, Almada, Portugal

Abstract

Most of the studies that quantify CSF flow do it at the level of the Aqueduct measuring two different quantities: Stroke Volume[1] and Flow Rate[2]. It has been shown that both these quantities vary with Heart Rate[3]. To further understand the dynamics of CSF flow we obtained measurements of Stroke Volume and Flow Rate both at the level of the Aqueduct and at the level of the skull base as a function of the heart rate (HR) within the same person. In both the Aqueduct and the skull base we observed a bigger decrease in the SV than in the FR, as expected, but for each quantity the variations for the Aqueduct and skull base were similar.

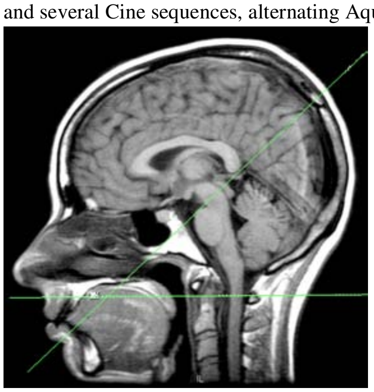
Introduction

The quantitative study of the CSF flow at the level of the aqueduct of Sylvius has been used for some pathologies, in particular NPH. Two different parameters have been used: the Stroke Volume (SV) and the Flow Rate (FR), with Nitz et al.[1] suggesting normal values below 42 µl, for the SV, and Luetmer et al.[2] suggesting normal values below 18 ml/min, for the FR. It has been shown that both these quantities vary with HR[3] and that SV has a bigger variation. To add further light onto the dynamics of the CSF flow we measured the flow both at the Aqueduct and at the skull base as the Heart Rate of several volunteers was varied.

Methods

All MRI images were obtained on a 1.5T system using a Cine Vascular 2D PC sequence with an S/I flow direction, a VENC of 15 cm/s and a sequential acquisition with Flow Comp. We used a Flip Angle=20°, TE=7.9 ms, TR= 40.0 ms, BW=16.0 Hz, 1 NEX, Sl.Th.=5.0 mm, FOV=24 ×18 cm and a 512x512 matrix. The acquisition was performed with peripheral Cardiac Gating with 32 cardiac phases per cycle. For the Aqueduct the acquisition was obtained on one oblique axial localization perpendicular to its mid section, and for the skull base, in order to avoid turbulence of CSF flow in the cisterna magna, an axial plane that intersects the posterior arch of the atlas was used, Fig. 1. All the post-processing and calculations were performed using the Flow software on a GE Advantage Windows 3.1 workstation.

Our preliminary results were obtained on three healthy young volunteers, always following the same procedure: two Cine sequences were acquired at their rest heart rate (HR), then they left the machine and went for a ten minute run to increase their HR; after the run they went directly back to the machine while their HR was high, and several Cine sequences, alternating Aqueduct and skull base measurements, were obtained as their HR lowered.



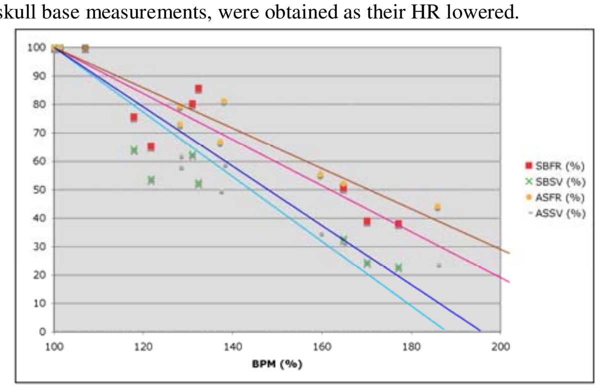


Figure 1: Localization of the axial planes for the Aqueduct and the skull base

Figure 2: Graph of percentage Aqueduct Stroke Volume (ASSV) and Flow Rate (ASFR) and skull base Stroke Volume (SBSV) and Flow Rate (SBFR) versus BPM in terms of percentage of the initial values.

Results

To show the variations of SV and FR we plotted SV and FR as a function of Beats Per Minute (BPM), but, since our concern was variations, we plotted the percentage decrease of SV and FR versus a percentage BPM, considering the rest HR as the 100%, for both locations for the different subjects. In this way we could combine the data from the different subjects onto a single graph, Fig. 2. The values of SV for both locations decreased to as low as 23% of the initial rest values while the values of FR never went below 38% of the rest values. We observed that the variations of FR for both locations was very similar, and that the same was true for SV.

Discussion

The flow of CSF is a consequence of the varying intracranial pressure produced by the variations in arterial blood pressure between systole and diastole. Cerebral blood perfusion (ml/minute) remains more or less constant under all circumstances, therefore, as the HR increases, the amount of blood reaching the brain per heart beat should decrease. A decrease in the CSF SV was observed, as expected, but a decrease in the FR was also observed, even though slightly less, and this happened for both locations. This is possibly due to compliance of the brain tissue and deserves a more in depth study to further understand the dynamics of the CSF flow.

This also shows that when measuring the FR and SV it is important to check how the HR is in comparison to the rest state, otherwise we could be measuring low values that seem normal but in reality are low because the HR is higher than normal, for either pathological or emotional reasons.

References

1. Nitz, W.R., et al. Radiology, 1992. **183**:395-405.
2. Luetmer, P. H., et al. Neurosurgery, 2002. **50**(30):534-543.
3. Secca, M.F. et al. 13th Meeting of the ISMRM 2005, 1742.