Variation of CSF Flow in the Aqueduct as a Function of Heart Rate

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Abstract

The quantification of CSF flow has been used to assess abnormality of flow at the level of the Aqueduct measuring two different quantities: Stroke Volume and Flow Rate. To clarify their relative validity we measured the variation of both quantities as the heart rate changed within the same person. We observed a bigger variation in the Stroke Volume than in the Flow Rate, which gives us some insight into the physiology of CSF flow and suggests that the Flow Rate is a better parameter.

Introduction

In the quantitative MR radiological study of some pathologies, in particular Normal Pressure Hidrocephalus, the CSF flow at the level of the aqueduct of Sylvius has been evaluated. Of the different parameters possible to measure two 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 Stroke Volume (SV), and Luetmer et al.[2] suggesting normal values below 18 ml/min, for the Flow Rate (FR). We have shown previously[3] that these two criteria lead to contradictory diagnosis for a large number of cases. To further clarify the relative validity of these two quantities we acquired MR Cine data as the Heart Rate of several volunteers was varied.

Methods

All MRI images were obtained on a 1.5T Signa CV/i-NV/i (GE) using a Cine Vascular 2D PC (Phase Contrast) 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 of 20˚, a TE of 7.9 ms, a TR of 40.0 ms, a BW of 16.0 Hz, 1 NEX, a Slice Thickness of 5.0 mm, a FOV of 24 ×18 cm and a 512x512 matrix (with a pixel size of 0.47 mm). The acquisition was performed with peripheral Cardiac Gating with 32 cardiac phases per cycle to obtain better time resolution. The acquisition was obtained on one oblique axial localization perpendicular to the mid section of the Aqueduct. 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: a first Cine sequence was 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 were obtained as their HR lowered.

Results

To show the influence of HR in CFS flow we plotted SV and FR as a function of Beats Per Minute (BPM). However, since we were concerned with variations, we plotted the percentage decrease of SV and FR versus BPM, Fig.1, for the different subjects. The values of SV decreased to as low as 29% of the initial rest values while the values of FR never went below 43% of the rest values. To combine the data from the different subjects we converted the absolute HR to a relative HR, considering the rest HR as the 100%, and plotted percentage SV and FR versus percentage BPM, Fig. 2, becoming clear that the SV always reduced to lower percentage values than the FR. It is important to note that within the same subject both values reduce to less than half the original rest values as the heart rate increases.

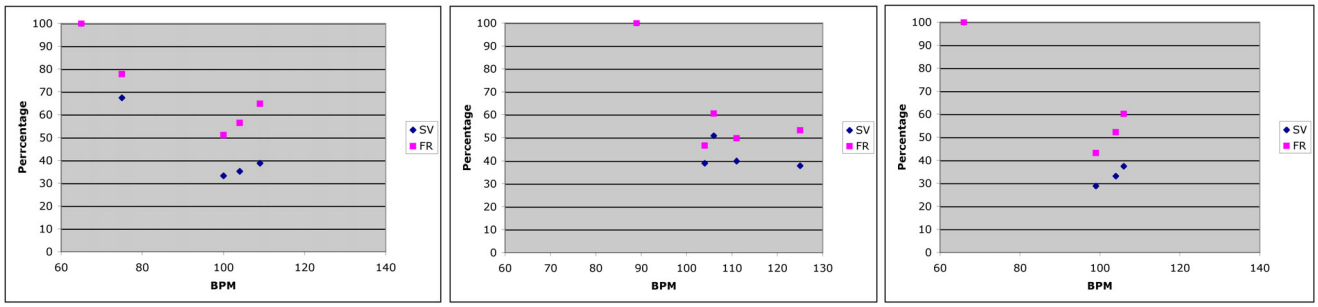

Figure 1: Graphs of the percentage Stroke Volume (SV) and Flow Rate (FR) versus Beats Per Minute (BPM) for the different subjects.

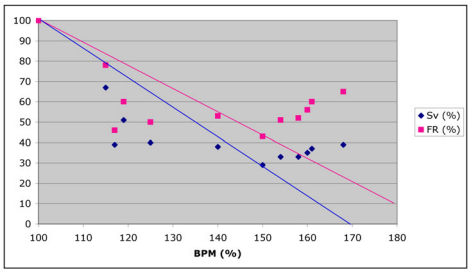

Figure 2: Graphs of percentage Stroke Volume (SV) and Flow Rate (FR) versus BPM in terms of percentage of the initial value.

Discussion

The CSF flows in the Aqueduct as a consequence of the varying intracranial pressure produced by the variations in arterial blood pressure between systole and diastole. Since the cerebral blood perfusion (ml/minute) remains more or less constant under all circumstances, as the HR increases the amount of blood reaching the brain per heart beat should decrease. This should produce a decrease in the CSF SV, as observed. We also observed that, percentage wise, the FR reduced less than the SV as the HR increased, leading us to conclude that the Flow Rate (ml/min) is a better parameter to assess abnormality of flow since it is less sensitive to the cardiac frequency.

References

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