Comparison of Stroke Volume with Flow Rate in the Measurement of CSF Flow in the Aqueduct

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Abstract

Different studies on the quantification of CSF flow at the level of the Aqueduct suggest different quantities to assess abnormality of flow: Stroke Volume and Flow Rate. In this study we compared the results of these two quantities for over 200 patients and considered physiological data to conclude that the Flow Rate should be a better parameter to assess abnormality. We also obtained some correlation between these parameters and the cross sectional area of the Aqueduct.

Introduction

The measurement of CSF flow at the level of the aqueduct of Sylvius has been recently used in the quantitative MR radiological study of some pathologies, in particular Normal Pressure Hidrocephalus. However, in the literature, two different studies suggest two different quantification approaches: Nitz et al.[1] suggest the use of the Stroke Volume (SV), specifying normal values below 42 µl; and Luetmer et al.[2] suggest the use of the Flow Rate (FR), specifying normal values below 18 ml/min. These two criteria can lead to distinctively different results for the same patients, therefore it is important to assess their validity and decide which parameter will be more physiologically sound. With this aim we studied the different results obtained simultaneously for a group of patients and complemented them with physiological knowledge to aid the decision.

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 comparative analysis of the two methods of quantification was based on studies performed over the past three years on 235 patients with several pathologies, but mainly with a suspicion of Normal Pressure Hydrocephalus. However, it should be noted that the results presented do not take into account the pathologies, but concentrate just on the physiological parameters.

Discussion

The flow of CSF in the Aqueduct is a consequence of the varying intracranial pressure due to the variations in arterial blood pressure between systole and diastole. We know from physiological data that the blood flow rate (ml/minute) to the brain changes very little throughout our awake period, this means that when the heart rate increases the blood stroke volume to the brain should decrease in order to maintain the overall blood flow rate. This seems to indicate that FR should be a better parameter. To further support this assumption we plotted our data as SV versus FR for each patient, Fig. 1, noticing that all the values are limited by two straight lines and that for each Flow Rate there is wide range of Stroke Volumes, which increases with increasing Flow Rate. Using the SV criteria the number of abnormal cases is much higher than with the FR criteria, and there is an area in the graph for which values are abnormal for SV but not for FR. And from the clinical data the abnormal values should be a smaller portion of the total.

We also studied the variation of both SV and FR with respect to Aqueduct area, Fig. 2, showing that all our results fall in a triangle, which means that for each Aqueduct area there is a physiological maximum for both SV and FR. This requires further study to properly understand the biophysics behind the phenomenon.

Based on the physiological data and the results we obtained it seems more correct to use Flow Rate (in ml/min), instead of Stroke Volume (in µl) to quantify CSF flow in the Aqueduct.

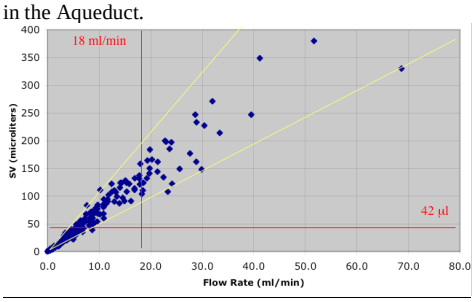

Figure 1: Graph of Stroke Volume versus Flow Rate with two lines (yellow) limiting all the points and two lines (red) separating normal from abnormal according to the two different criteria: 42 µl for SV and 18 ml/min for FR.

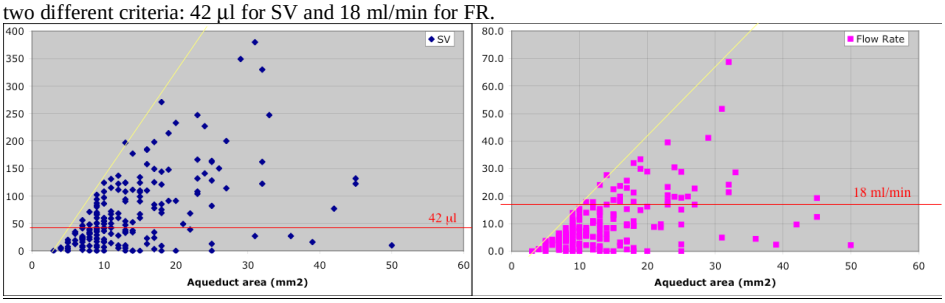

Figure 2: Graphs of Stroke Volume (SV) and Flow Rate (FR) versus Aqueduct area.

References

1. Nitz, W.R., et al. Radiology, 1992. **183**:395-405.
2. Luetmer, P. H., et al. Neurosurgery, 2002. **50**(30):534-543.