

Importance of Cardiac Rhythm in the assessment of Flow Rate and Stroke Volume in CSF flow

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Introduction: It has been quite common in the study of NPH (Normal Pressure Hydrocephalus) to measure flow in the Aqueduct through Stroke Volume (abnormality above 42 microliters)¹ and Flow Rate (abnormality above 18 ml/min)². These two parameters are both easily calculated from the same original data and can produce contradictory results. Their observed variation with cardiac rhythm makes us question its present use, being extremely important to study them from a different perspective, taking into account the cardiac rhythm of the patients with a reference to their rest rhythm. For that, we analyzed the data from our total group of patients correlating it to their cardiac rhythm and performed a study of the variation of both parameters with heart rate on a group of volunteers.

Subjects and Methods: Images were obtained on a 1.5T GE Signa using a Cine Vascular 2D PC sequence with an S/I flow direction (VENC=15 cm/s, 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) and post-processed on a GE Advantage workstation. Data was acquired with peripheral Cardiac Gating (32 cardiac phases/cycle) and obtained on one oblique axial localization perpendicular to the mid section of the Aqueduct.

So far we have measured CSF flow in 731 patients, acquiring both Stroke Volume and Flow Rate values at the Aqueduct. However for this study we only considered the data for our 457 patients aged over 60, which had a suspicion of NPH.

For our 12 healthy volunteers we measured Stroke Volume (SV) and Flow Rate (FR) at the Aqueduct, acquiring first a Cine sequence at rest HR, and then asking the person to run for ten minutes to increase HR, and returning to the machine to obtain three extra sequences as HR lowered.

Results: From a simple statistical analysis of comparison of the two parameters for our 457 cases we found that 34% of them were considered normal by both criteria (SV below 42 microliters and FR below 18 ml/min), 66% were considered abnormal by the SV criteria only (SV above 42 microliters), 48 % were considered normal by the FR criteria and abnormal by the SV criteria, (SV above 42 microliters and FR below 18 ml/min) and 18 % were considered abnormal by both criteria (SV above 42 microliters and FR above 18 ml/min). This means that the SV criteria considers abnormality in more than three times the cases the FR criteria does!

When we grouped the patients by heart rate at the time of the exam the study comparing the two parameters taking into account the cardiac rhythm showed surprising results, with the slope of SV versus FR decreasing as the heart rate increased (see arrow in Fig. 1). This shows that SV decreases faster than FR as the heart rate increases.

Analyzing variation of both parameters with heart rate in the 12 volunteers we found out that FR never decreases below 32% of the original values as the heart rate increased, obviously not changing as much as SV, which can decrease to as low as 19% of the original heart rate nearly doubles. (Fig. 2) A line steeper than the 45° line indicates that the Stroke Volume varies faster than the Flow Rate with values getting lower as the heart rate increases (see line with arrow in Fig. 2).

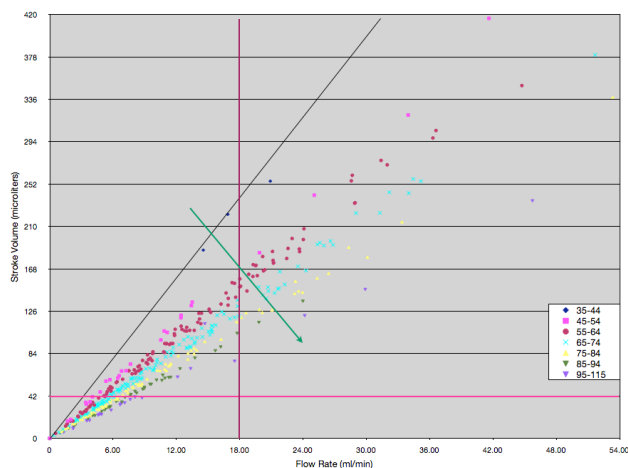


Figure 1

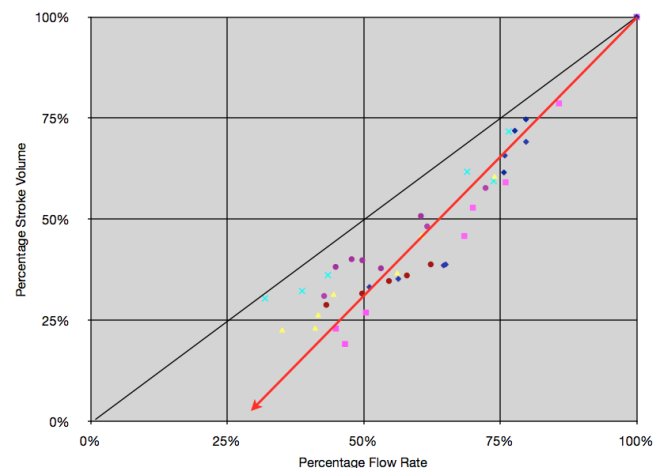


Figure 2

Figure 1 – Graph of SV versus FR separated by cardiac rhythm (Arrow indicates direction of increasing cardiac rhythm).

Figure 2 – Graph of percentage variations of SV versus FR (Arrow indicates direction of increasing cardiac rhythm).

Conclusion: Both Flow Rate and Stroke Volume decrease a lot with the increase in cardiac rhythm, being possible for a transient tachycardia to bring the values temporarily below the established pathology limits. We suggest that the measurements be always accompanied by a recording and measurement of the cardiac rhythm and a reference be made to the basal cardiac rhythm of the patient. We also observed that SV varies more rapidly with increasing cardiac rhythm than FR, suggesting FR to be a more reliable parameter.

References

1. Nitz WR, et al. Radiology [1992] 183:395-405.
2. Luetmer PH, et al. Neurosurgery [2002] 50(30):534-543.