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Influence of the MR field strength on the PC quantitative analysis of cerebrospinal fluid flow within the aqueduct

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Purpose: To study the influence of magnetic field strength on the parameters related to the motion of cerebrospinal fluid (CSF) flow by Phase Contrast (PC) MR within the aqueduct of Sylvius: stroke volume, mean flow, maximum diastolic and systolic velocities, maximum diastolic and systolic flows and CSF production rate.

Subjects and Methods: Several PC measurements were obtained from the same subject and at the same time but at different days in a 1,5 T and a 3,0 T MR machine. Globally, 34 quantitative PC analysis were carried out: 23 in a 1,5 T (Gyroscan Intera) and 11 in a 3,0 T (Intera Achieva) magnet. MR examinations were obtained with a PC sequence (FOV=140mm, 5 mm slice thickness, Venc=15 cm/s, TR=18 ms, TE=10 ms and 27 frames per cardiac cycle). The ANOVA test was used to evaluate the influence of field strength on the different measurements. Null hypotheses were verified using a 2-sided test. P-values smaller than 0.05 were considered significant.

Results: All the parameters that characterize CSF flow were slightly higher under a 3,0 T than at 1,5 T. However, from all these parameters, only the stroke volume and the maximum systolic velocity showed statistical differences (see Table 1).

Discussion: Magnetic field strength is a factor to consider when quantifying CSF flow PC parameters. The normality range of the different parameters for every magnetic field strength should be obtained to improve the quantitative analysis interpretation of the CSF.

Reference: Magn Reson Imaging. 1993; 11(4):549-55.

Parameters		N	Mean (SD)	F	p
Stroke volume (µl/cycle)	1,5 T	23	32,20 (5,30)	6,98	0,013
	3,0 T	11	37,09 (4,44)		
Maximum systolic velocity (cm/s)	1,5 T	23	27,00 (5,85)	13,40	0,001
	3,0 T	11	34,14 (3,87)		
Maximum diastolic velocity (cm/s)	1,5 T	23	26,52 (3,46)	4,00	0,054
	3,0 T	11	28,93 (2,87)		
Mean flow (ml/min)	1,5 T	23	2,45 (0,30)	3,95	0,055
	3,0 T	11	2,68 (0,31)		
Maximum systolic flow (ml/min)	1,5 T	23	4,04 (0,77)	2,25	0,143
	3,0 T	11	4,41 (0,33)		
Maximum diastolic flow (ml/min)	1,5 T	23	3,97 (0,41)	2,66	0,112
	3,0 T	11	3,74 (0,28)		
CSF production (ml/min)	1,5 T	23	0,75 (0,76)	0,18	0,667
	3,0 T	11	0,64 (0,42)		

Table 1: *Influence of the magnetic field strength on the quantitative analysis of the parameters that characterize the cerebrospinal fluid flow.*

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Dependence on heart rate of CSF flow in the aqueduct and skull base

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Introduction: The flow of CSF at the Aqueduct has been used[1,2] to assess abnormality, but no relevance is given to variations of the heart rate, although some correlation between the heart cycle and the CSF cycle has been studied[3]. We have measured Stroke Volume (SV) and Flow Rate (FR) at the Aqueduct (AS) and at the skull base (SB) as a function of the heart rate (HR) within the same person and observed how the CSF flow pattern varies with HR.

Subjects and Methods: All flow images were obtained on a 1.5T GE Signa CV/i-NV/i using a Cine Vascular 2D PC sequence (VENC=15 cm/s) and post-processed with a GE Flow software. The acquisition was performed with peripheral Cardiac Gating (32 cardiac phases per cycle) and obtained on one oblique axial localization perpendicular to the mid section of the Aqueduct, and on an axial plane intersecting the posterior arch of the atlas at the skull base, Fig. 1.

Figure 1: Localization of the axial planes for AS and SB.

For our preliminary results we studied 3 healthy volunteers, first acquiring a Cine sequence at rest HR, then asking the person to go for a ten minute run to increase HR, and return to the machine to obtain three extra sequences as HR lowered.

Results: Plotting the cardiac phase at which peak systole and diastole CSF flow occurs shows the time delay between the cardiac trigger and the CFS flow peaks, Fig. 2.

Fig. 2: Graph of systole and diastole phase peaks versus Beats Per Minute (BPM) in terms of percentage of the initial value.

Plotting the phase difference between diastole and systole peak phases shows the change in CSF flow pattern, Fig. 3.

Fig. 3: Graphs of phase difference versus in terms of percentage BPM.

Discussion: As the HR increases both the systolic and the diastolic phase peaks come earlier showing less delay from the cardiac cycle, but the decrease in the SB delay is more pronounced. We observed that both in the skull base and the Aqueduct the phase differences shorten as the HR increases. This distinct delay between the CSF flow at SB and AS can help us understand the dynamics of CSF flow within skull.

References: 1. Nitz WR, et al. Radiology [1992] **183**:395-405; 2. Luetmer PH, et al. Neurosurgery [2002] **50**(30):534-543; 3. Baledent O, et al. Invest Radiol. 2004 Jan;39(1):45-55.