CSF dynamic in a population of children with intracranial CSF increase

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Target Audience: Pediatric neuroradiology

Purpose: The intracranial cerebrospinal fluid (CSF) volume increase is frequently seen in the ventricles or in the subarachnoid spaces of newborn and children patients. In number of cases, morphological images can't conclude if it is a passive or active dilatation. Phase contrast MRI (PC-MRI) is the only tool able to measure CSF oscillations in vivo during the cardiac cycle. Some teams[1, 2, 3] have already studied PC-MRI flow in children to investigate CSF dynamic in pathology. However, none of these studies until 2013 has studied quantitatively CSF oscillations during cardiac cycle. Recently, PC-MRI study[4] has shown that CSF oscillations increase with growth, but keeping a similar ratio between the CSF oscillation in the aqueduct and the spinal canal. The aim of this work was to see if the CSF hydrodynamic can bring complementary information to study CSF volume increase in pediatric populations.

Methods: Forty three patients, children aged 5 days to 111 months, with an intracranial CSF volume increase (ventricular or/and subarachnoid spaces) were included. They underwent a morphological MRI and a PC-MRI study to quantify CSF oscillations. Kinetic phase contrast sequences were carried out on a 3T MRI Signa HDx GE Healthcare. The parameters used were: a matrix (in mm^2) 384 * 256 for the aqueduct and 256 * 256 for CSF cervical; a flip angle of 30 °; slice thickness 5 mm; a repetition time of 10 to 18 ms; an echo time of 4 to 8.5 ms; a field of view of 140 mm * 98 mm; 32 frames per cardiac cycle. The synchronization was performed by a plethysmograph. The antenna used were: HDxKNEE for newborns less than one month; HDxHEAD for child less than 10 kg and HDx BRAIN for child over 15 kg. From a sagittal T1-weighted sequence, acquisition plane for phase contrast sequences have been placed: one perpendicular to the aqueduct, the other perpendicular to the cervical plane (Figure 1). Encoding speed was 10 cm / second. A CSF volume index ($CSF_{Repartition}$) was calculated, equal to ventricular area divided by the intracranial subarachnoid spaces area. These areas were automatically segmented using MIPAV software (Figure 2). A CSF dynamic index ($CSF_{Dynamic}$) was calculated, equal to the CSF stroke volume in the aqueduct divided by the stroke volume at the cervical level in the spine. A $CSF_{Dynamic}$ lower than 20% was considered as normal[4].

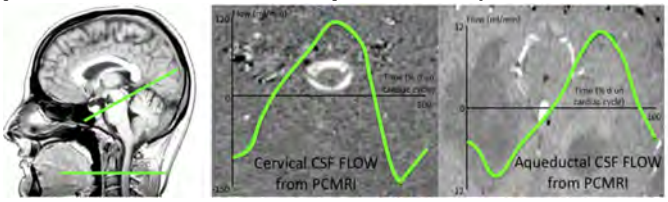

Figure 1. *Dynamic analysis by phase contrast MRI*

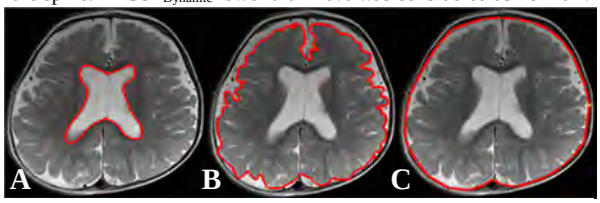

Figure 2. *Morphological analysis: A: area of the ventricles; B: area of the brain; C: area of the skull*

Results: The entire population was divided in 3 subgroups (Figure 3). The first group with 23 patients presented only ventricular dilatation: $CSF_{Dynamic}$= 20 ± 25; $CSF_{Repartition}$: 120 ± 151. There was no correlation between $CSF_{Dynamic}$ and $CSF_{Repartition}$. The second group with 16 patients presented both dilatations (ventricular and subarachnoid spaces): $CSF_{Dynamic}$= 18 ± 17; $CSF_{Repartition}$= 1.67 ± 0.81; There was positive correlation between $CSF_{Dynamic}$ and $CSF_{Repartition}$. And the last group with 4 patients presented only a subarachnoid spaces dilatation: $CSF_{Dynamic}$= 11 ± 6; $CSF_{Repartition}$= 0.65 ± 0.19. Results were different in each subgroups probably linked to different pathophysiological origins.

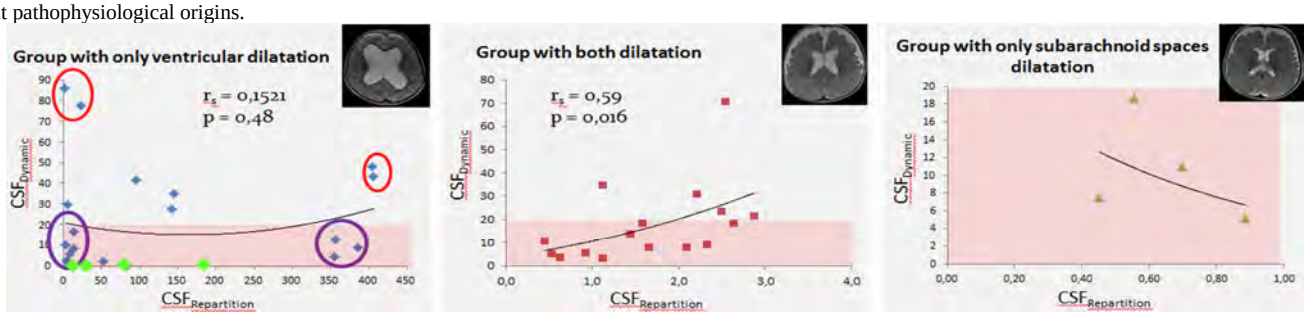

Figure 3. *Link between $CFS_{Repartition}$ and $CSF_{Dynamic}$ per subgroup. Pink area represents patients with normal CSF dynamic. Four patients had aqueductal stenosis which were not detected by morphological imaging (◆).*

Discussion: In the global population and in the first group with only ventricular dilatation, there was no significant correlation between $CSF_{Dynamic}$ and $CSF_{Repartition}$. Some of children had normal $CSF_{Dynamic}$. Normal $CSF_{Dynamic}$ could be associated with small or high $CSF_{Repartition}$. In the group with ventricular dilatation, some children presented an abnormal CSF volume dilatation, but among them, some of children had a normal $CSF_{Dynamic}$. Contrariwise, in the group with both dilatations, relationship was underlined between the CSF flow and the size of the CSF compartments. This interesting correlation shows that an increase of the ventricular compartment in front of the subarachnoid spaces size is correlated with an increase of CSF oscillations through the aqueduct. That could help to understand ventricular dilatation's mechanism in children. We notice that children of this group were very young. We know that at this period, the fontanels are not completely closed. Finally, in the group with only dilatation of subarachnoid spaces, the four children had normal $CSF_{Dynamic}$. The dilatation of subarachnoid spaces in children is often described as a benign diagnosis.

Conclusion: In pediatric population, the absence of correlation between the dynamic of the CSF and its volume in the global population shows that the CSF oscillations are not only the result of the size of the ventricles or the subarachnoid spaces. The CSF oscillations bring complementary information concerning the active aspect of the CSF. Further studies are needed with a larger population and long-term follow-up to evaluate the pertinence of these new morphological parameters.

References: **1.** Bateman GA and al. The measurement of CSF flow through the aqueduct in normal and hydrocephalic children: from where does it come, to where does it go? Child's Nervous System. 2012; 28(1): 55- 63. **2.** Mbonane SS and al. Interpretation and value of MR CSF flow studies for pediatric neurosurgery. South African Journal of Radiology. 2013; 17(1). **3**. Quencer RM. Intracranial CSF flow in pediatric hydrocephalus: evaluation with cine-MR imaging. American journal of Neuroradiology. 1992; 13(2): 601-8. **4.** Capel C and al. Insight into Cerebrospinal Fluid and Cerebral Blood Flows in Infants and Young Children. Journal of child neurology. 2013.