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Editorial

Magnetic resonance angiography in the evaluation of infants with hydrocephalus: a new standard?

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As part of the Dutch Hydrocephalus and Ischemia Research project, Leliefeld and colleagues have conducted a prospective study in which they attempted to use quantitative MR angiography to measure cerebral blood flow (CBF) in infants with progressive hydrocephalus. Furthermore, they aimed to explore the relationship between CBF and intracranial pressure (ICP) before and after cerebrospinal fluid (CSF) diversion.

As the authors point out, clinical signs alone may be inadequate for defining the optimal time point for intervention in infants with hydrocephalus. Moreover, with suture closure in infants, ICP does not always correlate with ventricular size or with clinical signs or symptoms. Hence, an overall goal of this study was to determine whether CBF, as determined by quantitative MR angiography, could provide additional objective data that may guide the treatment of infants with hydrocephalus.

Fifteen patients with progressive hydrocephalus (age range 1 day–7 months) were included. All patients underwent intracranial pressure monitoring with either anterior fontanel pressure (AFP) measurement or intraventricular measurement, quantitative MR angiography, and mean arterial blood pressure measurement before and after CSF diversion procedures. To correct for age-dependent increases in CBF, brain volume was also determined using MR imaging. Although mean arterial blood pressure did not change before and after CSF diversion procedures, ICP decreased significantly (from a mean of 19.1 to 6.7 cm H_2O), and CBF increased significantly (from a mean of 25.7 to 50.1 ml/100 cm^3 brain/min) following CSF diversion (a shunt in 12 patients and a third ventriculostomy in 3 patients).

Several aspects of this study merit further discussion. First, the method for measurement of ICP requires clarification. Intracranial pressure was measured by assessing the AFP by using the Rotterdam Teletransducer (and subsequently applying an established correction factor as AFP values are typically slightly higher than ICP values). This technique has been previously validated and demonstrates excellent correlation with intraventricular pressure. If the fontanel was closed or too small for measurement, ICP was measured directly from the ventricle. All measurements were obtained with patients asleep without sedation except for 4 patients who underwent intraventricular ICP measurement while in a state of general anesthesia on the day of the postoperative MR imaging. There were no significant differences noted between these pressure measurements. One concern regarding the way in which these measurements were obtained is whether anesthesia or failure to control for CO_2 levels influenced the results. However, consecutive measurements were obtained under similar conditions and, as mentioned, measurements obtained after induction of general anesthesia were compared with those obtained while the child was asleep without sedation. Taken together, the methods used appear reasonable and the authors have, at least in part, attempted to minimize the influence of these variables. It is worth noting that 8 of the 15 patients in the authors' series had ICP values of 15 cm H_2O or less, a number that is often considered normal, whereas 3 of these patients had ICP values of 10 cm H_2O. Despite these potentially normal ICP values, when treated with shunts the patients in question exhibited significant decreases in ICP, with concomitant increases in CBF. This could perhaps signify that while the ICP values appeared to be within normal limits, they may have actually been suboptimal for those particular patients. Although there was a wide range of preoperative ICP values, shunt treatment had a profound effect across all starting points, and resulted in changes after CSF diversion that are striking and believable.

A second critical aspect of this study that warrants discussion concerns the methods used for assessing CBF. Is phase-contrast MR angiography an appropriate tool for measurement of CBF in this context? The authors clearly outline the technique used for the study in the text of the manuscript. Furthermore, they provide an extensive bibliography of prior work validating this method for measuring CBF and they correct for the physiological increase in CBF with increasing age. It appears that this method is indeed appropriate for measuring CBF in this context. Similar to their findings regarding ICP values, the marked improvement in CBF following CSF diversion is plausible.

The authors state that CBF improves to normal levels following CSF diversion. Historical control data are used to support this assertion. The technique used for establishing normal baseline CBF, however, is important for historical control data to be appropriate for inclusion. The authors provide references where CBF is measured using various techniques including the ^{15}O steady-state inhalation technique,[3] SPECT using ^{133}Xe,[2] and most importantly using a

noninvasive MR imaging technique with arterial spin labeling.[1] The CBF measurements following CSF diversion procedures did indeed appear to fall within the normal limits found using all 3 of these methods.

Enhancement of understanding of the pathophysiology of hydrocephalus has historically been ushered in by advances in technology. One of the earliest examples is illustrated by Papenheimer's perfusion method, which helped establish the rates of CSF production and absorption. This was made possible by the introduction of radioactive tracers in the 1950s.[4] The present study demonstrates the feasibility of quantitative measurement of CBF by using MR angiography in infants with hydrocephalus. The authors have also defined the relationship of ICP with CBF before and after CSF diversion in a prospective fashion. Furthermore, they have also elucidated the fact that abnormal CBF can be seen despite seemingly normal ICP values, perhaps bolstering the argument for using MR angiography in cases in which the ICP monitoring is equivocal. In doing so, the authors have provided an important contribution and have provided impetus for further investigation. For example, the authors allude to the fact that the observed increase in CBF following CSF diversion may not only be due to a decrease in ICP, but also to a reduction in cerebrovascular resistance. These relationships may be explored in future studies in which MR angiography will be an important technique applied in the study. Whether MR angiography becomes a standard objective tool used in the assessment of infants afflicted with hydrocephalus remains to be seen. We certainly look forward to future contributions from this group and others that will help to optimize the evaluation and treatment of infants with hydrocephalus.

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Response

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We thank Dr. Dumont and colleagues for their interest in our work on noninvasive detection methods for hydrocephalus in general and their useful comments regarding this paper in particular.

We accept their comments regarding our ICP and CBF measurements. Furthermore, we agree that infants with hydrocephalus may benefit from CSF drainage when ICP is relatively normal. This means that normal ICP in infants with signs and symptoms of (progressive) hydrocephalus should not be an exclusion criterion for CSF drainage. We know that "normal" ICP eventually can cause brain damage. Therefore, treatment decisions for these infants should be made on an individual basis.

The fact that we have found decreased CBF in infants with hydrocephalus (even in infants with seemingly normal ICP) provides us with a rationale for further investigation in this field. We are investigating the consequences of the decreased CBF and the increased ICP for the brain parenchyma. In this context the Dutch Hydrocephalus and Ischemia Research group will, in the near future, report on diffusion-weighted imaging studies in infants with hydrocephalus. *(DOI: 10.3171/PED/2008/2/9/161)*