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Initial brain CT scan and shunting outcomes in children with hydrocephalus

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Abstract

Background Hydrocephalus is one of the most common clinical conditions affecting the central nervous system, with a congenital hydrocephalus incidence of 3-4 per 1000 births. Incidence of acquired types of hydrocephalus is unknown. Brain computerised tomography (CT) scan can be used to assess the size of ventricles and other structures. Shunting has long been performed to alleviate hydrocephalus. Shunting has dramatically changed the outlook of children with hydrocephalus, with many of them having normal life expectancies and attaining normal intelligence.

Objective To determine the outcomes of shunting in children with hydrocephalus based on initial brain CT scan.

Methods We performed a cross-sectional study in Dr. Kariadi Hospital. Initial brain CT scan data were collected from the medical records of children admitted to the Neurosurgery Ward for ventriculoperitoneal (VP) shunt surgery from January 2009 to December 2010. We studied the brain CT scan findings before VP shunt surgery and the outcomes of the children after VP shunt surgery. Radiological findings were determined by a radiologist responsible at that time.

Results This study consisted of 30 subjects, 19 boys and 11 girls. Initial brain CT scans to assess disease severity revealed the following conditions: lateral ventricle dilatation in 7 subjects, lateral and third ventricle dilatation in 16 subjects, and lateral, third and fourth ventricle dilatation in 7 subjects. After VP shunt surgery, 3 subjects in the lateral, third and fourth ventricle dilatation category died. They were grouped according to their condition. Group 1 consisted of subjects with only lateral ventricle dilatation and subjects with lateral and third ventricle dilatation (23 subjects), while group 2 consisted of subjects with lateral, third and fourth ventricle dilatation (7 subjects). More survivors were found in group 1 than those in group 2.

Conclusion Less severe initial brain CT scan findings are associated with better shunting outcomes children with hydrocephalus. **[Paediatr Indones. 2013;53:200-3.]**

Keywords: *hydrocephalus, brain CT scan, shunting, ventricle dilatation*

Hydrocephalus is a condition in which excess fluid accumulates in the brain. It is often referred to as "water on the brain," with the "water" actually being cerebrospinal fluid (CSF), the clear fluid surrounding the brain and spinal cord.[1] Pathophysiologically, hydrocephalus is regarded as an imbalance in the formation and absorption of CSF to a sufficient magnitude thereby producing accumulation of fluid leading to elevated intracranial pressure.[2,3]

The incidence of congenital hydrocephalus is 3-4 per 1,000 live births, however, the incidence of acquired hydrocephalus is not known due to the variety of disorders that may cause it. About 100,000 shunts are implanted each year in developed countries, but little information is available for other countries.[4] Hydrocephalus is most often treated with the surgical placement of a shunt system. This system diverts the flow of CSF from a site within the central nervous system (CNS) to another area of the body where it can be absorbed as part of the circulatory process. In untreated, death may occur by tonsillar herniation

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secondary to raised intracranial pressure (ICP) with compression of the brain stem and subsequent respiratory arrest.[4]

Brain CT scan can be used to assess the size of ventricles and other structures. Brain CT scan criteria for acute hydrocephalus include clearly visible, greater than 2 mm-sized temporal horns bilaterally. In the absence of hydrocephalus, the temporal horns should be barely visible. In hydrocephalus, the ratio of the largest width of the frontal horns to the maximal biparietal diameter (i.e., Evans ratio) is greater than 30%. Transependymal exudate is translated from images as periventricular hypoattenuation on CT. Ballooning of the frontal horns in lateral ventricles and third ventricle (i.e., "mickey mouse" ventricles) may indicate aqueductal obstruction.[5]

This study was conducted to determine the shunting outcomes of children with hydrocephalus based on their initial brain CT scans.

Methods

We conducted a cross-sectional study from January 2009 to December 2010. Initial brain CT scan data were collected from medical records. Children with hydrocephalus who were admitted to the Neurosurgery Ward of Dr. Kariadi Hospital for VP shunt surgery were recruited for this study. We included children with congenital hydrocephalus, under 5 years of age, and who had undergone brain CT scan as part of the diagnostic workup. We excluded children who had previous shunting or those with multiple congenital anomalies.

We reviewed the initial brain CT scan findings taken prior to shunting surgery and compared them to the outcomes in the children after surgery. Radiologic expertise was provided by radiologists who were responsible at that time. Data was analyzed by percentage and Chi-square test.

Results

During the study period, we found 30 children with hydrocephalus, consisting 11 females and 19 males, aged 0 days to 60 months. Basic characteristics of the subjects are shown in **Table 1**.

Table 1. Basic characteristics of subjects

Characteristics	n=30
Gender, n	
Male	19
Female	11
Age, n	
<12 months	27
12-60 months	3

Table 2 shows that from 30 children with hydrocephalus, there were 7 with lateral ventricle dilatation, 16 with lateral and third ventricle dilatation, and 4 with lateral, third and fourth ventricle dilatation. Three subjects with lateral, third and fourth ventricles dilatation died.

We divided the subjects into two groups, with group 1 consisting of subjects with lateral ventricle dilatation alone and subjects with lateral and third ventricle dilatation (23 subjects), and group 2 consisting of subjects with lateral, third and fourth ventricle dilatation, as shown in **Figure 1** (7 subjects). Chi-square analysis revealed that group 1 had significantly better outcomes than that of group 2 ($P<0.001$), as shown in **Table 3**.

Table 2. Initial brain CT scan findings and outcomes

Brain CT scan findings	Survived	Died
Lateral ventricle dilatation	7	0
Lateral and third ventricle dilatation	16	0
Lateral,third and fouth ventricle dilatation	4	3

Table 3. Relationship between brain CT scan findings and shunting outcomes

Brain CT scan findings	Survived	Died	P value
Group 1	23	0	P < 0.001
Group 2	4	3	

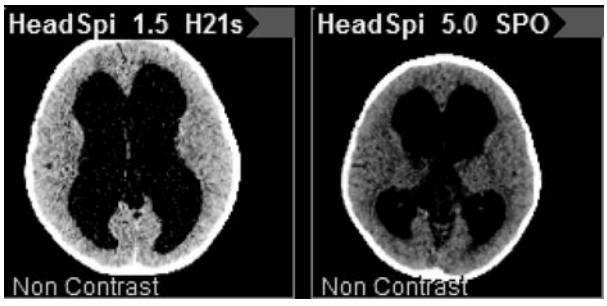

Figure 1. Brain CT scan shows dilatation of lateral, third, and fourth ventricles in a child with hydrocephalus

Discussion

Hydrocephalus was first defined by Vesalius in 1761 and the first shunt was put in by Mickuliez in 1893.[2] Khattak *et al*. reported that of 50 subjects with congenital hydrocephalus, there were 24 males (48%) and 26 females (52%). Their subjects ranged in age from 9 days to 13 months, with 42 subjects under the age of 6 months (84%) and 8 subjects above 6 months.[6] In our study, there were 19 males and 11 females, with 27 subjects (90%) under 12 months of age. Similarly, a study by Myrianthopoulos *et al*. reported that the majority of hydrocephalus patients were infants under one year of age (76%). In addition, they reported that congenital aquaductal stenosis accounts for about 10% of all hydrocephalus cases in children.[7]

Hydrocephalus can be classified on the basis of etiology, CSF pressure, morphology, obstruction status, or active/arrested status. From a surgical point of view, the site of CSF obstruction and ventricular size are important. Signs and symptoms of increased intra cranial pressure (ICP) must be relieved and the patient condition stabilized. There are unique clinical features of hydrocephalus associated with specific etiologies.[8] These features can help elucidate the natural history of the specific hydrocephalic syndrome, which children to shunt, and predict problems and outcomes to families. Most causes of childhood hydrocephalus are due to impaired CSF absorption. Cerebrospinal fluid absorption, however, is usually still possible in most cases of hydrocephalus through either normal CSF absorptive pathways or alternate CSF absorptive pathways.[9] This is particularly evident in instances of arrested hydrocephalus, where ventricular enlargement stabilizes due to these alternate pathways.[10] Laurence *et al*. noted that in up to 45% of children with hydrocephalus, progressive ventricular enlargement will eventually arrest. This is at the cost, however, of high morbidity and mortality. A better way to look at the phenomenon of arrested hydrocephalus is to consider it to be "compensated" hydrocephalus. However, many factors can upset this balance, such as fever or infection, leading to sudden decompensation of the hydrocephalus and elevated ICP. Close follow-up, therefore, is needed in cases with suspected shunt-independent, "compensated" hydrocephalus.[10]

All case outcomes in the Khattak *et al*. study were excellent and no mortality occurred. They attempted to correlate clinical radiological findings with outcomes in surgically-treated hydrocephalus. Eighteen children (72%) in the congenital hydrocephalus group were aged less than 6 months. The children were brought to the hospital when their symptoms were obvious. In that study, a large head was noticed at birth, along with a progressive increase in head size in 16% of cases; 92% of them had symptoms of hydrocephalus within 6 months after birth.[6] In our study, a diagnosis of hydrocephalus was made by brain CT scan findings according to ventricle dilatation. All subjects in our study had ventricle dilatation and the communicating type of hydrocephalus. Ventriculoperitoneal shunting was performed in all 30 subjects. Three children died, all of whom had lateral, third and fourth ventricle dilatation.

Although shunt-related mortality is reportedly uncommon, a review by O'Brien *et al*. reported that most shunt-related mortalities were due to shunt malfunction, shunt infection, and pulmonary emboli, while most non-shunt-related mortalities were due to pneumonia, urinary tract infections, coagulopathies, and meningitis. A recent retrospective analysis found that the overall mortality in pediatric patients with non-neoplastic hydrocephalus at 1, 5, and 10 years post-shunt insertion was 4.5%, 8.9%, and 12.4%, respectively. Multivariate analysis revealed a statistically significant association between all deaths and a history of shunt infection.[11] In our study, we did not confirm the etiology of mortality in the 3 subjects who died, as we were looking for a possible relationship between the initial brain CT scan and shunting outcome in children with hydrocephalus. All death cases occurred only in subjects with more severe brain CT scan images, while better shunting outcomes happened to subjects with less severe brain CT scan images ($P<0.001$).

Neuroimaging is typically obtained to help identify patients with post-shunt hydrocephalus. Imaging usually includes a shunt series (SS) and CT scan of the head. Shunt series is a set of plain radiographs of the entire course of the shunt tubing (e.g., skull, chest and abdominal radiographs). Possible causes of shunt malfunction, such as tube disconnection, fracture, calcification or migration of the tip from the intended end point may be identified

on the SS. If shunt malfunction is present, an expected finding on CT scan of the head is absolute or relative ventriculomegaly. Currently, there is little evidence to support the use of this neuroimaging to identify children with shunt malfunction, as diagnostic neuroimaging has a low sensitivity for shunt malfunction. Neurosurgical consultation should be sought if shunt malfunction is clinically suspected, despite normal neuroimaging.[12]

Limitations of our study include its retrospective methodology and the small of sample size, which potentially limits the generalizability of our results. We did not perform SS imaging after surgery to evaluate possible complications. In addition, due to the retrospective study design, we had limitations in obtaining secondary data. Also, a Kappa test for assessing inter-rater agreement between radiologists was not done.

In conclusion, less severe initial brain CT scan findings are associated with better survivals in children with hydrocephalus.

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