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Clinical Study

Timing of endoscopic third ventriculostomy in pediatric patients with congenital obstructive hydrocephalus: assessment of neurodevelopmental outcome and short-term operative success rate

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ABSTRACT

The purpose of this study was to determine the impact of early (⩽6 months old), midterm (6–12 months old) and late (>12 months old) endoscopic third ventriculostomy (ETV) on the operative success rate and postoperative neurodevelopmental outcome of children with congenital obstructive hydrocephalus. We divided 63 children into three groups according to whether they underwent early, midterm or late ETV. Their preoperative developmental quotient (DQ) was assessed using the Gesell developmental diagnosis schedule (GDDS). Three and 6 months after the initial procedure, GDDS was used to obtain postoperative DQ from two assessments (blinded and non-blinded). Meanwhile, two observers studied the operative success rate of initial ETV. There were no substantial differences between blinded and non-blinded assessments. The success rate of early ETV was only 20.8%. By contrast, this rate was 55% and 73.7% for midterm and late ETV, respectively. Before operation, we observed severe developmental abnormalities in all children (DQ score < 40). However, children in midterm and late ETV groups achieved improvement after the operation, which was particularly remarkable in late ETV group. Six months after the first surgery, 16 (84.2%) children in the late ETV group, nine (45%) in the midterm ETV group and four (16.7%) in the early ETV group had moderate developmental disability. Nevertheless, overall prognosis for the three groups was not optimistic. There were no children with mild neurodevelopmental disability or normal function. Our data confirmed that age is a determinant for ETV effectiveness and overall prognosis.

1. Introduction

After Jason Mixters performed an endoscopic third ventriculostomy (ETV) for the first time in 1923, the procedure became an option for treating occlusive hydrocephalus of various origins. During the past decades, it has been widely used on pediatric patients with aqueduct stenosis in many centers because of its advantage of providing a natural route for cerebrospinal fluid (CSF) flow within the range of indications. The long-term success rate has been reported to be as high as 80% [1–4], however, according to some reports on ETV, children younger than 6 months have a lower success rate of 12.5% [6]. Furthermore, several studies have indicated that age at the time of ETV is the most important independent risk factor for surgical effectiveness and long-term functional outcome [5]. More recent evidence from a larger, multicenter series supported the finding that age was the main determinant for outcome in younger children, particularly neonates [20,24,25]. Due to the high failure and complication rates of ETV, severe neurodevelopmental sequelae and poor quality of life of these children, ETV has been preformed on a highly selective basis. Therefore, determining suitable candidates for ETV was difficult, but important [7].

Little is known about long term outcome in pediatric patients with hydrocephalus, particularly neurodevelopmental outcomes and health-related quality of life. The effectiveness of ETV should not merely be measured by morbidity rate. In this study, we investigated the success of ETV and the postoperative neurodevelopmental outcome of 63 consecutive children who underwent initial ETV at different ages for the treatment of congenital obstructive hydrocephalus.

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2. Materials and methods

2.1. Patients

A total of 459 pediatric patients enrolled between January 2010 and January 2014 underwent primary ETV for the treatment of congenital obstructive hydrocephalus (aqueduct stenosis) and 63 fulfilled the highly selective inclusion criteria. The exclusion criteria were previous history of supra- or infratentorial tumor, myelomeningocele, intracranial infection, intracranial cyst, intraventricular hemorrhage, Chiari malformation, Dandy–Walker syndrome, trauma, or bone marrow or blood diseases. Children with suspected or known congenital cerebral dysplasia, congenital disorders (genetic disorders and chromosomal abnormality), or endoscopic aqueductoplasty were also excluded.

Preoperative MRI (3.0-T Philips; Philips Healthcare, Andover, MA, USA) and CT scans (64-slice Lightspeed VCL; GE Healthcare, Little Chalfont, Buckinghamshire, UK) were performed for each child. Frontal-occipital horn ratio was calculated and the width of the third ventricle was measured in millimeters by axial CT scan. Phase contrast cine-MRI confirmed the diagnosis of congenital aqueduct stenosis. All imaging data were obtained from the picture archiving and communicating system (PACS) of the Medical Imaging Center at our hospital.

All children were categorized into three groups depending on whether they underwent early (n = 24), midterm (n = 20) or late (n = 19) ETV. Data including age, sex, birth weight, gestational age at delivery, age at ETV and head circumference were collected from medical records. For individuals under the care of other departments, information was collected from these units.

2.2. Definitions

ETV failure was clinically defined as children in whom clinical symptoms of hydrocephalus (progressive head enlargement, bulging anterior fontanelle) did not regress and as children who required additional neurosurgical treatment for hydrocephalus. Radiologically, enlargement of the ventricles on MRI/CT scan or no CSF flowing through the third ventriculostoma on magnetic resonance (MR) ventriculography was also regarded as failure in ETV.

Patients who refused repeat ETV treatment after initial ETV failure or who had repeated ETV failure underwent ventriculoperitoneal shunt (VPS) placement.

For the developmental quotient (DQ) score, we defined DQ = 40 as a cutoff. Children with DQ < 40 were diagnosed as having severe neurodevelopmental disabilities [26] (normal developmental status: DQ > 75; mild developmental disability: $55 \leqslant DQ \leqslant 75$; moderate developmental disability: $40 \leqslant DQ \leqslant 54$; severe developmental disability: $25 \leqslant DQ \leqslant 39$).

2.3. Follow-up data and assessment of neurodevelopmental performance

A total of 63 patients participated in a formal follow-up at 3 and 6 months after the initial procedure. Follow-up imaging was primarily performed by non-enhanced MRI and CT scans. In addition, MR ventriculography was used if these methods could not confirm whether ETV was effective. A certified radiologist analyzed images. Neurodevelopmental outcomes (DQ) of individuals were evaluated by two well-trained occupational child psychological assistants (one blinded and one non-blinded) using the Gesell developmental diagnosis schedule (GDDS). The purpose of GDDS [27] is to examine childhood general developmental progress and delay, the presence of balance, motor functions, and other findings over a wide range of development factors (under 6 years of age). It is an individualized face to face test administered by experienced psychologists to assess development in the following five areas: gross motor, fine motor, linguistic, adaptive and personal-social functions. GDDS provided us with quantitatively comparable index scores corresponding to each tested domain. DQ was obtained by dividing the estimated developmental age (DA) by chronological age and then multiplying the quotient by 100 [26]. The test took approximately 2 hours. All assessed scores were recorded using GDDS pediatric intelligence development evaluation software (Cheng Xiang Electronic Information Company, Guangzhou, China).

2.4. Statistical analyses

All data were analyzed with the commercially available statistical software package SPSS (version 16.0; IBM Corporation, Armonk, NY, USA). Variables were described using the mean ± standard deviation or median and range. Proportions were compared using chi-squared and Fisher's exact test and were presented as percentages. Continuous variables were compared using the analysis of variance. When analyzing pre- and postoperative GDDS scores of the three groups in relation to time and groups, we used repeated measurement multifactor analysis of variance. To examine the independent effect of age at the time of initial ETV on the operative success rate and neurodevelopmental outcome, we used multivariate logistic regression. p values <0.05 were considered statistically significant.

3. Results

ETV was initially performed in 63 children who were diagnosed for the first time with obstructive hydrocephalus due to congenital aqueduct stenosis. The children were under 18 months of age (median 7.8 months; range: 3.3–18) with no previous history of neurosurgical interventions (external ventricular drainage or VPS). All selected children were categorized into three groups according to whether they underwent early (age $\leqslant$ 6 months), midterm (6 < age $\leqslant$ 12 months) or late (age > 12 months) ETV. In addition, the children participated in regular follow-up 3 and 6 months after the procedure (Fig. 1).

Table 1 shows the perinatal characteristics and clinical profiles of the 63 children. We compared the three groups with each other using analysis of variance. There were no significant differences among the three groups in all perinatal factors and radiological features ($p > 0.05$). The only significant difference between the groups was patient age at the time of primary ETV ($p < 0.05$), which corresponds to the group classifications.

Table 2 shows the effectiveness of ETV and postoperative complications. The disease was clinically and radiologically controlled in only five children (20.8%) in the early ETV group at 6 months following the procedure, compared with 14 children (73.7%) in the late ETV group. In addition, 11 children (55%) underwent effective ETV in the midterm ETV group. There was statistical significance of the difference in initial ETV success rate among the three groups ($p < 0.05$).

Kaplan–Meier survival analysis for time to initial ETV failure in each group is shown in Figure 2. The most delayed failure in our series was 158 days after ETV. Assessment using the Kaplan–Meier method also showed that if ETV failures occurred, most of them declared themselves during the first 3 months after surgery.

Table 3 shows severe developmental disability in all children (DQ score < 40) preoperatively. However, children in the midterm and late ETV groups achieved improvement after the operation, which was particularly remarkable in the late ETV group. Six months after the first surgery, 16 children (84.2%) in the late, nine