

First experiences with an adjustable gravitational valve in childhood hydrocephalus

Clinical article

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Object. The goal of this report was to describe the authors' initial experiences with an adjustable gravity-assisted valve (GAV) called the ProGAV in treating childhood hydrocephalus.

Methods. The ProGAV was implanted in 53 children (29 boys and 24 girls, median age 7.3 years) with hydrocephalus of various origins. The ProGAV consists of a differential-pressure unit with adjustable opening pressures and a gravitational unit with a fixed opening pressure.

Results. The mean follow-up period was 15.2 months (range 6–44 months). The authors did not observe any valve-related complications. Four infections (7.5%) occurred, warranting the removal of the shunt. In 19 children, the opening pressure was changed at least once during the follow-up period, for underdrainage in 10, overdrainage in 8, and shunt weaning in 1, with substantial clinical improvement in 18 children. Overall, good clinical results were obtained in 47 (88.7%) of the 53 valve placements.

Conclusions. With an overall success rate of 88.7%, the first experiences with the ProGAV in childhood hydrocephalus are promising and justify its further use in the pediatric population. (DOI: 10.3171/2008.11.PEDS08154)

KEY WORDS • adjustable valve • children • gravitational valve • hydrocephalus • overdrainage

CEREBROSPINAL fluid overdrainage is a well-known problem in shunt-treated hydrocephalus in adults and in children. In adults, overdrainage mainly results in subdural hematoma and hygroma formation, whereas slit ventricles with repetitive ventricular catheter obstructions, slit ventricle syndrome, and craniostenosis are found in children.¹¹ Differential-pressure valves with adjustable opening pressures and gravitational valves with fixed opening pressures had been developed to overcome complications related to overdrainage.^{6,7,15} These developments reduced the sequelae of overdrainage substantially. The subdural hematoma rate dropped from 15.4% with a fixed DP valve to 9.7% with an adjustable DP valve, and to 1.6% with a gravitational valve.^{5,8,16} For childhood hydrocephalus in observational, uncontrolled studies, both

adjustable DP and gravitational valves were reported to improve shunt survival, which might be considered as a surrogate parameter of a lower rate of overdrainage-related shunt failure.^{3,12} Very recently, an adjustable GAV has been introduced, which has been used only in adult hydrocephalus so far.⁹ Therefore, we feel encouraged to report our first experiences with an adjustable GAV in childhood hydrocephalus.

Methods

The adjustable GAV (Miethke ProGAV Programmable Shunt System; Aesculap, Inc.) consists of an adjustable DP unit and a gravitational unit. The DP unit allows selection of opening pressures between 0 and 20 cm H₂O prior to shunt placement and, if required, transcutaneous readjustment. The gravitational unit has an opening pressure of 15, 20, 25, or 30 cm H₂O, which cannot be changed after the operation.

Abbreviations used in this paper: CSF = cerebrospinal fluid; DP = differential pressure; FOHR = frontooccipital horn ratio; GAV = gravity-assisted valve.

TABLE 1: Demographic data in 53 hydrocephalic children undergoing implantation of an adjustable GAV

Characteristic	Value
total no.	53
sex (M/F)	29/24
median age (yrs)	7.3
range	0.1–17
cause of hydrocephalus	
hemorrhage	15
tumor & aqueductal stenosis	10
infection	5
myelomeningocele	5
congenital cyst formation	5
Chiari malformation	4
other	5
unknown	4
previous ops for hydrocephalus	31

The ProGAV was used in 68 children. The study population consisted of 53 children, in whom the follow-up was at least 6 months. The valve was placed in the retroauricular region in strict vertical position, ensuring correct function of the gravitational unit and allowing easy readjustments by the firm bone underlying the adjustable unit. Skin incisions were made in a curved manner and subcutaneous pockets were prepared to position the adjustment unit away from the incision site. The age of the 53 children ranged from 0.1 to 17 years (median 7.3 years). There were 29 boys and 24 girls. The hydrocephalus was caused by intraventricular hemorrhage ($n = 15$), tumor and aqueductal stenosis ($n = 10$), infection ($n = 5$), myelomeningocele ($n = 5$), congenital cyst formation ($n = 5$), and Chiari malformation ($n = 4$). Rare causes of hydrocephalus were Dandy-Walker malformation, anencephaly, porencephaly, encephalocele, and vein of Galen malformation (1 each). In the remaining 4 children, the origin of the hydrocephalus remained unknown (Table 1).

Thirty-one children had already undergone at least one previous shunt operation. In 3 children, endoscopic procedures for polycystic hydrocephalus directly preceded ProGAV placement.¹⁴ In 2 children, shunt therapy was performed after failed endoscopic third ventriculostomy. The initial opening pressure of the adjustable unit of the ProGAV was set to 16, 7, and 4 cm H₂O in 1 child each; to 14 and 6 cm H₂O in 2 children each; to 11, 9, and 3 cm

H₂O in 3 children each; to 8 cm H₂O in 5 children; to 12 cm H₂O in 6 children; to 5 cm H₂O in 12 children; and to 10 cm H₂O in 15 children. (In 1 child the initial opening pressure was inadvertently set to 15 cm H₂O and then adjusted to 3 cm H₂O.) The selection of the initial opening pressure of the DP unit depended on the clinical history, the imaging appearance of the hydrocephalus, and the individual neurosurgeon's decision. In cases of shunt revision, the selected opening pressure corresponded to that of the explanted valve. In children with a dystrophic thin cortical mantle, an opening pressure of 10 cm H₂O and higher was set to prevent hygroma formation. In the remaining children the neurosurgeon's preference guided the selection of the initial opening pressure, with two different philosophies being identifiable: either an initially low opening pressure between 3 and 7 cm H₂O was chosen, with the prospect of increasing the opening pressure in cases of overdrainage (V.R., H.L.), or an initially high opening pressure of at least 9 cm H₂O was selected for primary avoidance of overdrainage complications (E.J.H., U.W.T.). For the opening pressure of the gravity unit, either 20 (45 patients), 25 (7 patients), or 35 cm H₂O (1 patient) was selected, depending on the age and the height of the child, with higher opening pressures in older and taller children.

In all children who underwent readjustment of the initial opening pressure, the FOHR at the time of placement of the ProGAV and the FOHR immediately prior to readjustment of the opening pressure were calculated. No routine imaging was performed after readjustment, which did not allow calculation of the postadjustment FOHR (Table 2). Outcome was rated as good if shunt placement alleviated the symptoms of hydrocephalus without being accompanied by clinical signs of overdrainage. For the follow-up period, the survival of the valve and the surgery-free shunt survival were determined.

Results

The mean follow-up period was 15.2 months (range 6–44 months). We did not observe any valve-related complication, but 4 infections (7.5%) occurred, making shunt removal necessary. In 1 child, shunt infection developed weeks after shunt placement due to head trauma resulting in rupture of the frontal wound and CSF leakage. Overall, 26 opening-pressure changes were performed in 19 (35.8%) of the 53 patients. The opening pressure was increased by 1 cm H₂O (to 12 cm H₂O) in 7 children with symptoms of overdrainage. Those symptoms were eliminated in 6 children and improved in 1; however, this child

TABLE 2: Reasons for readjustment of the initial opening pressure of the valve in 19 children with hydrocephalus

Adjustment	No. of Patients	FOHR*		Reason for Readjustment
		At Valve Placement	Prior to Readjustment	
↑	7	0.38 ± 0.05	0.36 ± 0.06	clinical sx of overdrainage
↓	10	0.43 ± 0.11	0.46 ± 0.1	clinical sx of underdrainage
↑	1	0.39	0.44	shunt weaning
↑	1	0.34	0.32	slit ventricle

* Values are expressed as the mean ± SD.

later required implantation of a gravitational unit with a higher opening pressure. The opening pressure was increased in 1 child with asymptomatic slit ventricles and in 1 child for shunt weaning. Seven children did not improve substantially after shunt placement, and 1 developed subcutaneous CSF accumulation. By decreasing the opening pressure by 1 cm H₂O (to 6 cm H₂O), the assumed underdrainage was successfully treated in 6 children. In the remaining 2 children, underdrainage was not related to selection of an inadequate initial opening pressure, but instead to an improperly placed ventricular catheter and to proximal catheter occlusion. Two additional patients had symptoms of occlusion and were scheduled for surgery, without adjusting the valve beforehand. All of the latter children improved after proximal shunt revision, and in 2 of the patients readjustment of the valve was performed, to a higher opening pressure (by 2 cm H₂O). The FOHR before placement of the ProGAV and that before adjustment are given in Table 2. Children who reported overdrainage symptoms already had smaller ventricles at the time of ProGAV placement and prior to readjustment than did children with symptoms of underdrainage.

Overall, good clinical results ultimately were obtained in 47 (88.7%) of the 53 implanted valves (Fig. 1). Unsatisfactory results were related to shunt infection (4 cases), to mild overdrainage symptoms despite maximum opening pressure (1), and to death (1) during embolization of a vein of Galen malformation after successful hydrocephalus management (a nonshunt-related event). In addition to these 6 valve-related operations, 7 reoperations became necessary (2 for malpositioned ventricular catheters, 2 for obstructed ventricular catheters, and 3 for revisions of peripheral catheters), with these 13 cases accounting for a surgery-free shunt survival in 75.5%.

Discussion

Placement of a ventriculoperitoneal shunt is still the treatment of choice in the management of nonocclusive childhood hydrocephalus. Complications after shunt placement are frequent. Whereas shunt infection and malplacement are surgery-related complications, headache in upright position, slit ventricles with repetitive ventricular catheter obstructions, slit ventricle syndrome, and cranio-stenosis are regarded to be valve-related. All but the gravitational and the so-called flow-regulating valves are prone to the siphoning effect, with excessive CSF drainage in the upright position.¹ The flow-regulating valve was reported to prevent overdrainage in children. In the European Orbis Sigma II valve survey, overdrainage was seen only in 0.4% of the 287 children studied. However, the valve obstruction rate was 8.4%, probably due to the device's design.⁴ Encouraging results have been reported with gravitational valves in childhood hydrocephalus: in the study of Eymann and coworkers,³ the rate of overdrainage in 55 children who underwent shunt placement was only 3.6% and the valve obstruction rate was 0%. Cedzich and Wiessner² did not observe any overdrainage complications in a series of 32 children who received shunts. Both studies are in contrast to the study of Meling and coworkers,¹⁰ who observed an overdrainage rate of 9.4% and a valve obstruction rate of 15.6% in 32 children undergoing shunt revision

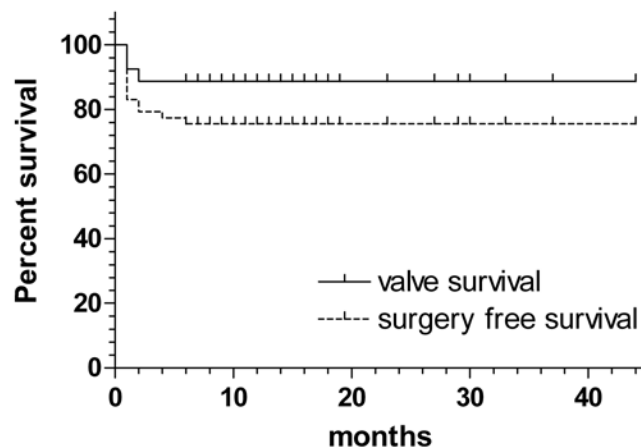


FIG. 1. Kaplan-Meier curves of valve survival and surgery-free shunt survival after a mean follow-up of 15.2 months and a maximum follow-up of 44 months.

with valve exchange. In these 3 studies, the Paedi-GAV, which consists of a posture-dependent gravitational unit and a posture-independent ball-in-cone valve in the same housing, was routinely implanted. The posture-dependent and -independent valves have fixed opening pressures that have to be chosen by the neurosurgeon. For the posture-independent part, Eymann et al. and Meling et al. preferred an opening pressure of 9 cm H₂O, and Cedzich and Wiessner preferred 4 cm H₂O; for the gravitational unit, Eymann et al. selected an opening pressure between 19 and 29 cm H₂O according to the child's height, Cedzich and Wiessner routinely used an opening pressure of 19 cm H₂O, and Meling et al. used an opening pressure of 24 or 29 cm H₂O (29 and 13 patients, respectively). This nonuniform selection of the opening pressures makes it probable that a mismatch of chosen opening pressure and actual hydraulic requirements of the patient might occur. This especially holds true in the pediatric population because the hydraulic requirements in a child change substantially with body growth and the ability to stand and walk. Thus, it is not surprising that Meling et al. reported that in 2 (6.25%) of the 32 children an inadequate selection of the opening pressure made a valve exchange necessary. Therefore, it was a logical step to use the newly developed adjustable gravitational valve (the ProGAV) in children, because it might compensate for some of the well-known overdrainage complications and the problem of inadequate opening pressure selection.

Our first experiences with the adjustable GAV in childhood hydrocephalus are encouraging. A good outcome rate exceeding 90% is high, but the comparatively short follow-up period has to be kept in mind. On the other hand, most shunt failures occur within 1 year after shunt placement. Thus, the critical period for shunt failure was already surpassed in most of the children in the present series, suggesting that the use of the ProGAV increases shunt survival. The readjustment rate of 36.5% is low in comparison with data from adjustable DP valves, with which rates of 53.2 and 76.9% have been reported.^{12,17} Because most readjustments in DP valves are related to overdrainage,¹³ the low readjustment rate with the ProGAV could be interpreted as a parameter of successful avoidance of overdrainage by the gravity unit.

Conclusions

The results obtained in this study justify the further use of the ProGAV in hydrocephalic children. Despite the short follow-up, we believe that the results indicate that the valve design at least is not inferior to that of other valves. However, only a prospective, randomized trial may prove the worth of adjustable and gravitational controlled valves in childhood hydrocephalus. In future comparative shunt trials, the ProGAV should be included.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Manuscript submitted June 23, 2008.

Accepted November 6, 2008.

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