

Neuroendoscopic surgery in children: does age at intervention influence safety and efficacy? A single-center experience

Amy L. Bowes, BSc, MBBS, Josh King-Robson, BSc, BMBS, William J. Dawes, BSc, MRCS, PhD, Greg James, FRCS, PhD, and Kristian Aquilina, FRCS, MD

Department of Paediatric Neurosurgery, Great Ormond Street Hospital for Children, London, United Kingdom

OBJECTIVE The aim of this study was to review the safety of pediatric intraventricular endoscopy across separate age groups and to determine whether intraventricular endoscopy is associated with an increased risk of complications or reduced efficacy in infants younger than 1 year.

METHODS In this retrospective cohort study, 286 pediatric patients younger than 17 years underwent intraventricular endoscopy at Great Ormond Street Hospital between December 2005 and December 2014. The primary diagnosis, procedure, and complications were recorded.

RESULTS Neuroendoscopic surgery was performed in 286 pediatric patients (51 neonates 0–6 months [Group 1]; 37 infants 6–12 months [Group 2]; 75 patients 1–5 years [Group 3]; 54 patients 5–10 years [Group 4]; and 69 patients ≥ 10 years [Group 5]; male/female ratio 173:113). The most common procedures included endoscopic third ventriculostomy (ETV) in 159 patients and endoscopic fenestration of intracranial cysts in 64 patients. A total of 348 consecutive neuroendoscopic procedures were undertaken. Nine different complications were identified, of which postoperative seizures (1.7%), CSF leak (3.1%), CSF infection (2.4%), and intracranial hemorrhage (1.7%) were the most common. Specifically, no significant difference in complication rate (11.9%) or infection rate (2.4%) was observed among age groups ($p = 0.40$ and $p = 0.91$, respectively). In addition, there were no perioperative deaths; 30-day mortality was 1.1%. After neuroendoscopy for CSF diversion ($n = 227$), a significantly higher rate of shunt insertion was observed in the youngest group (Group 1, 63.0%) when compared with older groups (Group 2, 46.4%; Group 3, 26.3%; Group 4, 38.6%; and Group 5, 30.8%; $p = 0.03$). Similarly, for patients who underwent ETV as their initial neuroendoscopic procedure or in combination with additional surgical interventions ($n = 171$), a significantly higher rate of shunt insertion was also observed within young infants (Group 1, 67.9%; Group 2, 47.6%; Group 3, 19.6%; Group 4, 27.3%; and Group 5, 23.3%; $p = 0.003$).

CONCLUSIONS Intraventricular endoscopy is a safe neurosurgical intervention in pediatric patients of all ages, although it might be associated with increased shunt rates after endoscopic surgery, specifically ETV, in younger infants.

<https://thejns.org/doi/abs/10.3171/2017.4.PEDS16488>

KEY WORDS hydrocephalus; intraventricular endoscopy; infants; neuroendoscopy; surgical technique

INTRAVENTRICULAR endoscopy is a firmly established neurosurgical approach in children. Several techniques are used routinely across a wide spectrum of pathologies, including obstructive hydrocephalus,^{2,3,8,12} intracranial cysts,^{5,9,11,14,19,23} and intra- as well as paraventricular tumors.^{1,17,18} However, the rates of success and complications after intraventricular endoscopic surgery are highly variable, which may reflect different prognoses between patients of different ages.^{7,10,16,20}

While numerous studies have successfully reported on the safety of neuroendoscopic techniques in the pediatric

population,^{4,15} neuroendoscopic surgery in infants younger than 1 year poses a particular clinical research challenge.^{6,16} Inconsistencies commonly arise between studies, particularly when defining success rates, selection criteria, or events leading to surgical failure in young infants.⁶ Despite previous overwhelming support for the use of intraventricular endoscopy in young children, the International Infant Hydrocephalus Study has recently concluded that a ventriculoperitoneal shunt may be superior to endoscopic third ventriculostomy (ETV) for hydrocephalus in infants.¹⁶ That study was the first prospective, multicenter

ABBREVIATIONS ETV = endoscopic third ventriculostomy; GOSH = Great Ormond Street Hospital.

SUBMITTED September 7, 2016. **ACCEPTED** April 3, 2017.

INCLUDE WHEN CITING Published online July 28, 2017; DOI: 10.3171/2017.4.PEDS16488.

TABLE 1. Primary procedure

Primary Procedure	Group 1	Group 2	Group 3	Group 4	Group 5
ETV	21	20	46	30	42
Endoscopic fenestration of intracranial cysts	16	12	14	11	11
Endoscopic intracranial washout	3	1	0	0	0
Endoscopic septostomy	5	3	5	4	6
Endoscopic foraminoplasty	2	0	0	0	0
Endoscopic drain insertion or revision	4	1	6	5	4
Endoscopic disconnection of hypothalamic hamartoma	0	0	0	0	1
Tumor resection &/or biopsy	0	0	4	4	5
Total no. of patients	51	37	75	54	69

Age groups are as follows: Group 1, 0–6 months; Group 2, 6–12 months; Group 3, 1–5 years; Group 4, 5–10 years; and Group 5, ≥ 10 years.

study of its kind, strongly suggesting that the role of the child's age in the efficacy of neuroendoscopic procedures is not completely understood.

The principal aim of this study was to review the safety of intraventricular endoscopy across pediatric age groups and to determine whether it is associated with an increased risk of complications or reduced efficacy in infants younger than 1 year.

Methods

In this retrospective cohort study, paper/electronic clinical records and images obtained in 286 pediatric patients younger than 17 years who had undergone intraventricular endoscopy at Great Ormond Street Hospital (GOSH) between December 2005 and December 2014 were reviewed. The study was registered as a clinical audit and service evaluation at GOSH; at our institution, ethics board review is not required for anonymized retrospective audits of this kind. The primary neurosurgical diagnosis, procedure type, and complications were recorded for each patient. CSF infection was defined as a positive finding on CSF

TABLE 2. Primary diagnosis

Primary Diagnosis	Group 1	Group 2	Group 3	Group 4	Group 5
CSF-related disorder	37	27	50	20	29
Intracranial tumor	6	2	24	31	39
Vein of Galen malformation	1	0	0	0	0
Cranial dysraphism	2	1	0	0	0
Other vascular pathology	3	2	0	1	1
Intracranial infection	1	1	0	1	0
Craniosynostosis	0	4	1	0	0
Spinal dysraphism	1	0	0	1	0
Total no. of patients	51	37	75	54	69

TABLE 3. Complications associated with pediatric intraventricular endoscopy

Complication	Group 1	Group 2	Group 3	Group 4	Group 5
Postop seizures	2	2	0	1	0
CSF leak	2	3	0	2	2
CSF infection	0	2	2	2	1
Intracranial hemorrhage	1	1	1	1	1
CN III palsy	0	0	0	1	1
Diabetes insipidus	0	0	0	0	2
Loss of vision	0	0	0	0	1
Hemiplegia	0	0	0	2	0
Venous sinus thrombosis	0	1	0	0	0
Total no. of patients (% risk)	5 (9.8)	9 (24.3)	3 (4.0)	9 (16.7)	8 (11.6)

CN = cranial nerve.

culture. The need for further definitive CSF diversion was defined as the development of clinically significant hydrocephalus. Seven neuroendoscopic procedures were performed in children younger than 1 month; their age was not corrected for gestational age.

All statistical analyses were performed using SigmaPlot software (version 12.0, Systat Software, Inc.). Chi-square analysis was used to compare overall complication rates, CSF infection rates, CSF diversion surgery, and ETV success rates across different age groups (0–6 months [Group 1], 6–12 months [Group 2], 1–5 years [Group 3], 5–10 years [Group 4], and ≥ 10 years [Group 5]).

Results

A total of 286 consecutive pediatric patients, age up to 17 years, underwent intraventricular endoscopy for a number of neurosurgical indications. There were 51 neonates in Group 1, 37 infants in Group 2, 75 patients in Group 3, 54 patients in Group 4, and 69 patients in Group 5; the male/female ratio was 173:113. Specifically, 7 neuroendoscopic procedures were performed in patients younger than 1 month.

The most common procedure was ETV (Group 1, 41.1%; Group 2, 54.1%; Group 3, 61.3%; Group 4, 55.6%; and Group 5, 60.9%), followed by endoscopic fenestration of intracranial cysts (Group 1, 31.4%; Group 2, 32.4%; Group 3, 18.7%; Group 4, 20.4%; and Group 5, 15.9%; Table 1). The majority of primary neuroendoscopic procedures performed in patients 0–12 months old was for the treatment of CSF-related disorders (i.e., hydrocephalus and arachnoid/porencephalic cysts) (Group 1, 72.5%; Group 2, 73.0%; Group 3, 66.7%; Group 4, 37.0%; and Group 5, 42.0%), whereas a higher proportion of neuroendoscopic procedures was performed for the management of intracranial tumors in patients aged 1 year and older (Table 2) (Group 1, 11.8%; Group 2, 5.4%; Group 3, 32.0%; Group 4, 57.4%; and Group 5, 56.5%).

Nine different complications attributable to intraventricular endoscopy were identified (Table 3). The 4 most common complications included CSF leakage (3.1%), CSF infection (2.4%), postoperative seizures (1.7%), and intra-

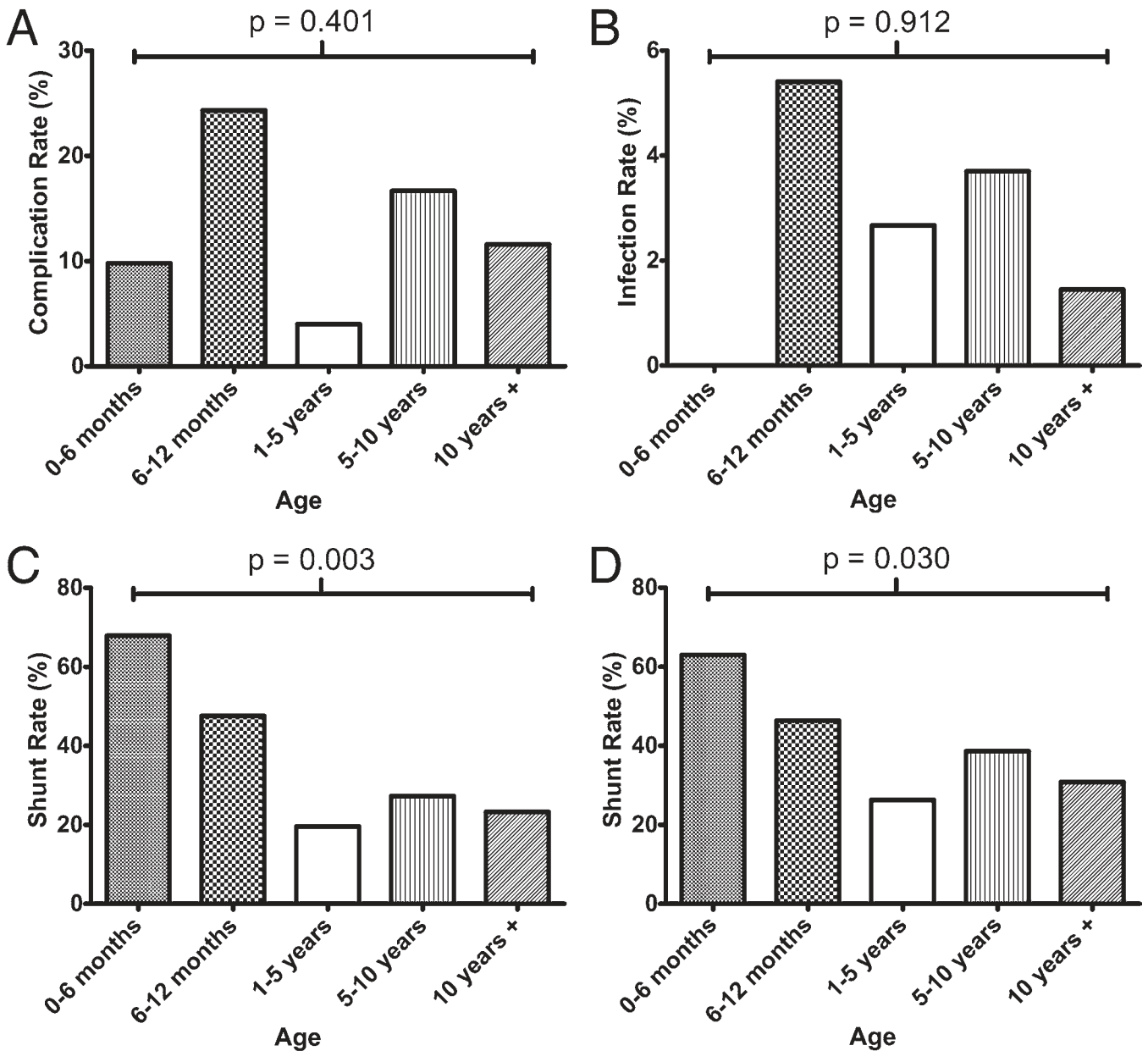


FIG. 1. A and B: Complication (A) and infection (B) rates after neuroendoscopy. No differences in complication ($p = 0.401$) or CSF infection ($p = 0.912$) rates were observed between the different age groups. **C and D:** Shunt rates post-ETV (C) and post-CSF diverting endoscopy (D) were significantly higher in younger infants than those in older pediatric patients ($p = 0.003$ and $p = 0.030$, respectively).

cranial hemorrhage (1.7%). The overall complication rate for all patients was 11.9% (Table 3) (Group 1, 9.8%; Group 2, 24.3%; Group 3, 4.0%; Group 4, 16.7%; and Group 5, 11.6%). There was no significant difference in complication rates between age groups ($p = 0.401$; Fig. 1A). In the current study, the overall infection rate was 2.4% with no CSF infections being reported within the 0- to 6-month cohort (Group 1, 0%; Group 2, 5.4%; Group 3, 2.7%; Group 4, 3.7%; and Group 5, 1.4%). Similarly, there was no significant difference in infection rates between age groups ($p = 0.912$; Fig. 1B).

Of 171 patients who underwent ETV as their initial

neuroendoscopic procedure or in combination with additional surgical interventions, there was a significantly higher rate of subsequent shunt insertions in young infants than in older pediatric patients (Group 1, 67.9%; Group 2, 47.6%; Group 3, 19.6%; Group 4, 27.3%; and Group 5, 23.3%; $p = 0.003$) (Fig. 1C). Similarly, after neuroendoscopic surgery for CSF diversion, including ETV and endoscopic septum pellucidotomy ($n = 227$), a significantly higher rate of shunt insertion was observed in patients in Group 1 (63.0%) compared with older age groups (Group 2, 46.4%; Group 3, 26.3%; Group 4, 38.6%; and Group 5, 30.8%; $p = 0.030$) (Fig. 1D).

Discussion

The primary objective of our study was to evaluate the safety of intraventricular endoscopy in pediatric patients, with a specific aim to determine whether age at intervention influences the efficacy of such procedures and the need for definitive CSF diversion surgery. The ages of our 286 pediatric patients ranged from 7 days to 17 years and the cases included a wide variety of neurosurgical pathologies from obstructive hydrocephalus and intracranial cysts to intracranial tumors and intracranial infections, making this one of the largest reported case series (Table 1). Seven neuroendoscopic procedures were performed in infants younger than 1 month. As hydrocephalus is probably the most common pathology requiring neurosurgical intervention in pediatric patients,^{6,10} it is not surprising that the majority of patients within the current study underwent ETV ($n = 159$) for the management of CSF-related disorders (defined at GOSH as hydrocephalus or nontumor cysts, e.g., arachnoid or porencephalic), closely followed by the biopsy and/or resection of intracranial tumors ($n = 102$) (Table 2). As expected, primary diagnosis varied according to age, with younger infants more likely to require intraventricular surgery for the management of CSF-related disorders, whereas for older pediatric patients, the indication for neuroendoscopy was more commonly tumor related (Table 2).

In this present study, the overall complication rate was 11.9%. The most common complications included postoperative seizures (1.7%), CSF leak (3.1%), CSF infection (2.4%), and intracranial hemorrhage (1.7%) (Table 3). Interestingly, there was no significant difference in the rate of complications between age groups ($p = 0.401$; Fig. 1A), suggesting that intraventricular endoscopy is equally safe in young infants and older children. Although there are several large series documenting the complication rates of ETV,^{3,4,7,8,21} few publications have reviewed pediatric endoscopic procedures as a whole.¹⁰ Despite this, our complication rates are comparable to those in previously published studies.^{7,10} In agreement with our study, a detailed consecutive analysis of 200 neuroendoscopic procedures performed in 177 pediatric patients reported an overall complication rate of 11% with no difference in complication rates between separate age groups (0–6 months, 6–12 months, and ≥ 1 year).¹⁰ Hence, we conclude that intraventricular surgery is safe among the youngest age groups, including those younger than 1 year of age.

In our cohort, the overall CSF infection rate was 2.4%. Specifically, no CSF infections were reported within the 0- to 6-month age group (Group 1), with a similar rate of CSF infections recorded across all other age groups (0% in Group 1, 5.4% in Group 2, 2.7% in Group 3, 3.7% in Group 4, and 1.4% in Group 5). Our results are comparable to those in the published literature, with Elgamal et al. and Furlanetti et al. reporting overall CSF infection rates of 2.0% and 4.0%, respectively.^{7,10} Importantly, there was no significant difference in CSF infection rates between age groups ($p = 0.912$) (Fig. 1B).

Of 171 pediatric patients who underwent ETV as their initial neuroendoscopic procedure or in combination with other neurosurgical procedures, there was a significantly higher rate of subsequent shunt insertion within younger

age groups than for older pediatric patients ($p = 0.003$) (Fig. 1C). In particular, 67.9% of young infants (Group 1) went on to undergo further CSF shunting procedures compared with only 23.3% in children ≥ 10 years. The overall shunt rate post-ETV was 33%. In agreement with our study, Oertel et al. reported a 26% overall shunt rate post-ETV in pediatric patients younger than 18 years.²⁰ Once again, infants within their first 6 months of life more frequently required shunts; however, there was no significant difference between separate age groups (children < 14 years and < 2 years).²⁰ Similarly, in a recent study by Jernigan et al., it was concluded that a higher failure rate might occur after ETV than after shunt placement in infants younger than 1 year with hydrocephalus.¹³ We conclude that ETV failure and the need for further CSF shunting is more likely in young infants. Although the mechanisms behind ETV failure in young infants remain unclear, a likely cause is CSF pathway closure via the formation of new arachnoid membranes or the development of scar tissue.²²

Of interest, disappointing success rates and the need for definitive shunting in young infants are not solely limited to ETV alone. In our study, neuroendoscopic surgery for CSF diversion including ETV and endoscopic septostomy ($n = 227$) was also more likely to be unsuccessful in younger age groups ($p = 0.030$) (Fig. 1D). More specifically, 63.0% of patients in the 0- to 6-month cohort who underwent any CSF-diverting procedure eventually required further shunt insertion surgery compared with only 30.8% within the cohort aged 10 years and older. Therefore, we conclude that patient age plays a vital role in the efficacy of neuroendoscopic surgery for CSF diversion. Despite lower success rates in young infants compared with older children, neuroendoscopy remains a safe and useful option in this group.

As our study aims to compare the complications associated with neuroendoscopic surgery from a relatively small population of patients, we should be cautious in the interpretation of our results. In addition, this is not a randomized study comparing neuroendoscopy to other CSF diversion procedures. In the context of clinical equipoise between ETV and shunting during the study period, our institution favored endoscopic CSF diversion as the first-line procedure in infants with obstructive hydrocephalus; however, the risks and benefits of shunts and ETV were always discussed with parents, and their wishes were always taken into account. Infants who underwent primary shunting were excluded from this study. We are aware that, despite a 9-year study period and a consistent approach, a degree of selection bias may still have been introduced. Further studies should aim to elucidate prognostic factors to adequately guide neurosurgical case selection, as well as combining sample populations from several different neurosurgical centers.

Conclusions

In our cohort of 286 pediatric patients, we report a similar rate of complications, including CSF infections, across separate age groups. We conclude that intraventricular endoscopy is a safe neurosurgical intervention in pediatric patients of all ages. However, the risk of ETV failure and

subsequent shunt insertion post-ETV is higher in infants, specifically those younger than 1 year. In addition, young infants who undergo any CSF-diverting neuroendoscopic surgery may also be prone to experiencing higher failure rates. It is likely that careful case selection and surgical planning is crucial in young infants requiring neuroendoscopy.

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Disclosures

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

Author Contributions

Conception and design: all authors. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Aquilina. Statistical analysis: all authors.

Correspondence

Kristian Aquilina, Department of Paediatric Neurosurgery, Great Ormond Street Hospital for Children, Great Ormond St., London WC1N 3JH, United Kingdom. email: kristian.aquilina@gosh.nhs.uk.