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The interhemispheric approach in children: our experience and review of the literature

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Abstract

Objective The interhemispheric approach (IA) has been extensively described for treating pathologies located at the lateral or third ventricle, pineal region, and periventricular locations. While these anatomical locations are the target of many pediatric pathologies, very few series have analyzed the morbidity and outcome of the IA in children. The aim of this study is to describe our experience using the IA in children, emphasizing the approach-related morbidity.

Methods Twenty-six patients underwent 28 procedures using the IA between the years 2012 and 2016. Data for these patients was retrospectively analyzed. Surgical and approach-related morbidity were collected and analyzed.

Results The mean age of the cohort was 10.1 ± 4.2 years and included 15 females (57.7%). Approach-related morbidity occurred following eight surgeries (28.6%; seven with anterior IA and one with posterior IA), including two pseudomeningoceles (7.1%), three persistent subdural effusions (10.7%), of which two were locally drained and one required subduro-peritoneal shunting, one epidural bleed (3.6%) which resolved spontaneously, and two infections (3.6%) treated with antibiotics. Cerebrospinal fluid leaks, supplementary motor area syndrome, seizures, and subdural hematomas did not occur in any of the patients. None of the approach-related complications led to permanent morbidity or to mortality.

Conclusion The IA for lesions in and around the ventricular system is feasible and associated with a low permanent complication rate. When choosing this approach, the morbidity, although rarely permanent, should be considered.

Keywords Interhemispheric · Surgical approach · Pediatric neurosurgery · Ventricular lesions · Morbidity

Introduction

The interhemispheric approach (IA) is used to access lesions within the ventricular system or its proximity. In addition, it can be used for lesions located at the mesial frontal, pineal, and suprasellar regions, and within the corpus callosum. In children, lesions within the pineal region and the ventricular system and its surrounding areas are relatively frequent, making the IA an important and useful approach in this group of patients. Many studies describe the different interhemispheric approaches and techniques to access the ventricular system and the pineal region [1–4]. Most of these studies emphasize surgical techniques, patient outcome, and the rate of tumor resection. Very few studies focus on the IA approach in pediatric patients [1, 3] and on complications related to the IA itself in children [5]. The aim of this study is to describe our experience using the IA for pediatric patients presenting with various pathologies, focusing on approach-related morbidity.

Methods

The study protocol was approved by the local ethics committee. We included 26 consecutive pediatric patients (under the age of 18 years) who underwent 28 interhemispheric approaches for various intracranial pathologies between the years 2012 and 2016 at the Pediatric Neurosurgery Department in Tel Aviv, Israel. Patient data was retrospectively collected through an

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analysis of medical and radiological records. In addition to patients' demographics, we collected the underlying pathology, surgical data, such as the type of interhemispheric approach (anterior, centered at the coronal suture; vs posterior, centered at the interparietal region), the size of opening of the corpus callosum (CC) in centimeters, which ventricle was approached, whether a septostomy was completed, usage of intraoperative monitoring (IOM) measuring the somatosensory-evoked potentials (SSEP) and transcranial electric motor-evoked potentials (MEP), and the insertion of an EVD intraoperatively (to assist in brain relaxation during the IA). We organized morbidity into two categories: approach-related and non-approach-related morbidity. Approach-related morbidity included infection, subdural effusion, approach-related bleeding (e.g., subdural hematoma, epidural hematoma), pseudomeningocele, cerebro-spinal fluid leaks, approach-related shunting procedures (e.g., ventriculo-peritoneal shunt (VPS) not related to a ventricular-periventricular pathology obstructive CSF pathways, or subduro-peritoneal shunt (SPS)), and supplementary motor area (SMA) syndrome. All other complications were defined as non-approach-related morbidity. These included neurological insults related to the "target" region, obstructed hydrocephalus related to the lesion itself, and local bleeds at the "target" region.

In addition, we analyzed risk factors that might influence the rate of approach-related complications, such as the type of interhemispheric approach (anterior vs posterior), age, gender, insertion of an EVD intraoperatively, opening of the CC, the size of opening of the CC in cm, the approached ventricle, completion of septostomy, and previous IA surgery.

Surgical technique

For the anterior IA After fixating the head in a head clamp, the patient is positioned in a supine position with the head turned horizontally and tilted approximately 45° above the horizontal plane (Figs. 1, 2, and 3). Alternatively, the patient is positioned in a supine position with the head in neutral position tilted 20° above the horizontal plane. Over the years, the later positioning was abandoned in favor of the first. Generally speaking, we opt to use a right-sided approach (and thus the right side will be the dependent one), except for left ventricular or left cerebral lesions for which the left-sided approach will be preferred. Contralateral approaches are selectively used. Care is taken to avoid neck flexion during positioning, to facilitate brain relaxation, and to avoid venous engorgement. After installing neuro-navigation and dressing the patient in orderly fashion, usually a bicoronal incision is done anterior to the coronal suture. Two burr holes are placed on the sagittal sinus and a craniotomy is completed (about 3 cm anterior and 3 cm posterior to the coronal suture, extending about 1 cm to the contralateral side). Mannitol (0.5 g/kg) and mild hyperventilation (ETCO2 at about 30) are supplied. In the context of hydrocephalus, and if the brain seems swollen, an EVD is inserted into the ipsilateral ventricle under ultrasound guidance. Thereafter, a one-sided c-shaped (based on the SSS) opening of the dura is performed. The lowermost hemisphere is allowed to fall away from the midline with the aid of gravity. Under microscopic vision, the brain is gently pulled away from the falx. Small bridging veins can be cauterized and cut; however, large veins should be preserved if possible. We use brain retractors as needed—both for contralateral retraction of the falx and for mild retraction of the ipsilateral brain. Retraction is minimized by CSF drainage from the pericallosal cistern and gravity. Lateralization of the pericallosal arteries and a longitudinal opening of the corpus callosum is performed to gain access into the ventricle.

For the posterior IA After head fixation, the patient is positioned in a prone position. Neck flexion is avoided to reduce venous pressure. After installing neuro-navigation and dressing the patient in orderly fashion, a both-sided centrally placed horseshoe-shaped incision is done. Two burr holes are placed on the sagittal sinus and a both-sided craniotomy is completed overlapping the parietal region. The reason for a symmetric craniotomy is to enable a contralateral approach if there are large draining veins on the planned side (which, as opposed to the frontal region, should be preserved). After opening the dura, the angle connecting between the splenium, the internal cerebral veins, and the tentorium is approached. If necessary, the tentorium is cut parallel to the straight sinus, to improve visibility and access to the pineal region. Retractors are used as needed both on the falx and on the ipsilateral brain.

Statistics

All statistical analyses were done using SPSS (SPSS Statistics Version 21.0 IBM Corp, 2012, New York, USA). Contingency tests were done using Fisher's exact test. For non-parametric tests, the Mann-Whitney U test was used. A p value of < 0.05 was considered significant.

Results

Patient demographics

This series included 26 children (< 18 years of age) who underwent 30 IA. Data was available for 28 surgeries, since in two patients, the first surgery was not done at our institution. The mean age of the cohort was 10.1 years (± 4.2 years, median 9.5 years, range 2–17 years), and included 15 females (57.7%) and 11 males (42.3%). Three patients (11.5%) suffered from neurofibromatosis type I (NF1). One patient (3.8%) suffered from drug-resistant epilepsy of unknown origin and underwent three previous surgical procedures (vagal nerve stimulator implantation, resection of the left temporal

Fig. 1 Positioning of an anterior IA with the patient in a supine position, the head fixated in a head clamp and turned horizontally. A bicoronal incision is marked anterior to the coronal suture after shaving the hair

lobe, and left parieto-occipital cortical resection) before undergoing a corpus callosotomy. Preoperative hydrocephalus was apparent in 15 patients (53.6%) and was treated with a ventriculo-peritoneal (VP) shunt (7 cases), or an ETV (3 cases) before the underlying pathology was addressed. Indication for surgery was oncological in 25 surgeries (89.3%), vascular in 2 (7.1%), and epilepsy in 1 (3.5%). The underlying pathologies/etiologies and their anatomical locations are summarized in Table 1. The distributions of preoperative symptoms are presented in Table 2.

Surgical data

An anterior IA was completed in 22 surgeries (78.6%), and a posterior IA in 6 (21.4%) (Table 3). The ventricles were approached in 25 surgeries: in 11 re, the right lateral ventricle;

Fig. 2 Positioning of an anterior IA with the patient in supine position, the head fixed in a head clamp and turned horizontally and tilted 45° above the horizontal plane. Great care is taken to avoid neck flexion

Fig. 3 Positioning of an anterior IA with the head tilted 45° above the horizontal plane avoid neck flexion. In this specific case, the left side was dependent due to a left sided lesion

in 8 cases, the left lateral ventricle; in 5 cases, the third ventricle; and in one case, both the left and the right ventricles were accessed. In 3 cases, one bifrontal tumor, one parietal tumor, and one pineal lesion, the ventricular system was not accessed. The mean opening length of the corpus callosum, based on postoperative magnetic resonance imaging (MRI) measurements, was 2.3 cm (± 0.7 cm). In 10 cases (35.7%), a septum pellucidotomy was completed. In 22 patients (78.6%), an external ventricular drainage (EVD) was left within the ventricular system; 2 (9.1%) of these patients were converted at a later time point to a VP shunt due to chronic hydrocephalus. In addition, one patient (16.7%) in which an EVD was not inserted after surgery required a later VP-shunt insertion, resulting in an overall rate of postoperative VP-shunt insertion of 10.7% ($n = 3$). Of the intraoperatively inserted EVDs, 7 (31.8%) were inserted, under ultrasound guidance, before dura opening to help brain relaxation. In 7 cases (25.0%) with

eloquent brain region involvement (e.g., thalamus, basal ganglia), intraoperative monitoring was used.

Approach-related morbidity

Eight patients (28.5% of surgeries) suffered approach-related complications; none were permanent. Two patients (7.1%) showed postoperative pseudomeningocele which resolved spontaneously with time, while in one case multiple tapping of the pseudomeningocele was needed. Three patients (10.7% of surgeries) suffered postoperative persistent subdural effusion, leading to burr-hole drainage in two cases, and subduro-peritoneal shunt (SPS) insertion in the third case. An infection occurred in two patients (7.1%). In one case, a superficial wound infection with stenotrophomonas maltophilia resolved after antibiotic treatment. The other

Table 1 Distribution of pathologies and anatomical location

Anatomical location	n (%)	Pathology/etiology	n (%)
Intraventricular	10 (35.7)	Oncological	
Suprasellar	4 (14.3)	Low grade glioma	6 (21.4)
Pineal region	4 (14.3)	Ganglioglioma	1 (3.6)
Basal ganglia/thalamus	4 (14.3)	Pilocytic astrocytoma	5 (17.9)
Hypothalamus	3 (10.7)	Optic pathway glioma	1 (3.6)
Cortical	2 (7.1)	DNET	1 (3.6)
Corpus callosum	1 (3.6)	Ganglioneuroblastoma WHO IV	1 (3.6)
		Glioblastoma multiforme WHO IV	2 (7.1)
		Anaplastic ependymoma	1 (3.6)
		Choroid plexus carcinoma	2 (7.1)
		Pineal lesions	4 (14.3)
		Papillary tumor of pinealis tumor	1 (3.6)
		Pinealoblastoma	1 (3.6)
		Pineocytoma	1 (3.6)
		Pineal parenchymal tumor of intermediate type	1 (3.6)
		Hamartoma	3 (10.7)
		Craniopharyngioma	3 (10.7)
		Vascular	
		Cavernoma	1 (3.6)
		Bleeding	1 (3.6)
		Functional	
		Refractory epilepsy	1 (3.6)

patient developed a ventriculitis/meningitis due to *Klebsiella pneumoniae*, requiring protracted antibiotic treatment. One patient (3.6%) suffered an epidural hematoma, which resolved spontaneously. Subdural hematoma, SMA syndrome, or CSF leaks did not occur in any of the study patients. None of the analyzed risk factors showed an association with approach-related complications.

Non-approach-related morbidity

Bleeding complications occurred following two surgeries (7.1%). One patient suffered a third ventricular bleed leading to hydrocephalus and placement of a VPS, while the other patient showed a small postoperative thalamic bleed treated conservatively. Three patients (10.7% of surgeries) developed chronic hydrocephalus requiring insertion of a VP shunt. In two of these patients, preoperative hydrocephalus was already evident, due to the location of the pathology, while in one patient, a third ventricular bleed occurred, initially treated by EVD, which could not be weaned, leading to the insertion of a VP-shunt. Four patients (14.2% of surgeries) suffered temporary postoperative motor weakness (non-SMA related) which resolved with time, two patients (7.1%) had postoperative visual decline, two patients (7.1%) developed postoperative aphasia, two patients (7.1%) developed Parinaud's syndrome, and one patient (3.6%) had psychomotor deficits which

improved over time. All of these neurological deficits were related to the lesion resection itself and not to the approach. Endocrinological disturbances occurred in two patients (7.1%), who developed postoperative diabetes insipidus treated with desmopressin.

Mean clinical and radiological follow up time was 22.9 months (± 23.4 months). Mean hospitalization time was 16.6 days (± 13.4 days), and there was no mortality.

Discussion

Based on our results, following 28.5% of IA surgeries, there was a transient, approach-related complication. Despite this seemingly high complication rate, all complications were successfully treated, with no permanent morbidity. Thus, this approach is proven feasible in the pediatric population, and is associated with a low permanent complication rate.

Very few studies assessed the complication rate after an IA in the pediatric population [3, 5]; some series analyze both adult and pediatric patients [2, 4, 6–8]. Our study is the first to focus on approach-related complications of the IA in the pediatric population. Aryan et al. showed that 6.2% of the children undergoing an IA show persistent hemiparesis, memory disturbances, or medication refractory seizures after 1 year [5]. Similarly, Patel et al. showed 17 complications in 12

Table 2 Distribution of preoperative symptoms

Symptom[*]	n (%)
Visual disorders	12 (48.9)
Headache	10 (35.7)
Vomiting	7 (25.0)
Seizures	5 (17.6)
Motor deficits	3 (10.7)
Endocrine[α]	3 (10.7)
Cognitive disorder	2 (7.1)
Cranial nerve deficit	2 (7.1)
Impaired consciousness	1 (3.6)
Gait disturbance	1 (3.6)
None	2 (7.1)

[*] 12 patients suffered more than one symptom

[α] 2 patients suffered diabetes insipidus, 1 patient suffered panhypopituitarismus

children undergoing an IA for various pathologies, with complications related to CSF issues the most common [3]. Other complications in their series included postoperative stroke, neuroendocrine complications, seizure, and memory disturbance due to injury of the fornix [3]. However, these studies do not focus solely on approach-related complications and are therefore difficult to compare with our results. In our cohort, CSF-related issues were the most common approach-related complications. None of the patients suffered an approach-related postoperative stroke, SMA syndrome, or CSF leak. All other complications (e.g., neuroendocrine, seizure, hemiparesis) were related to the lesion resection itself or the location of the lesion and not to the interhemispheric approach.

Table 3 Distribution of tumor location by type of interhemispheric approach (anterior vs. posterior)

Approach (n)	Tumor location (n)
Anterior interhemispheric (22)	Intraventricular (10)
	Suprasellar (4)
	Pineal region (1)
	Basal ganglia/thalamus (2)
	Hypothalamus (3)
	Cortical (1)
	Corpus callosum (1)
Posterior interhemispheric (6)	Pineal region (3)
	Thalamus (2)
	Cortical parietal (1)

n number

Davidson and colleagues analyzed the safety and efficacy of the posterior IA approach in the pediatric population for lesions in the pineal region and the posterior fossa [1]. Approach-related complications occurred in 7.1% (two patients with transient homonymous hemianopia). No patient developed a stroke, even though veins were sacrificed in six cases. In our cohort, one out of six patients (16.7%) undergoing a posterior IA developed an approach-related complication, in this case, a superficial wound infection treated successfully with antibiotics. Based on our results, in matters of approach-related complications, the anterior IA and posterior IA do not differ significantly. In our cohort, hemianopsia did not occur in any of the patients undergoing a posterior IA. Of course, while obviously in children hemianopsia can sometimes be difficult to assess.

Studies analyzing the neuropsychological outcome of the IA in adults showed that the transcallosal IA might lead to memory deficits, executive cognitive and behavioral syndrome, and disturbance in interhemispheric transfer of learning [9, 10]. In a study by Mazza, transverse dissection of the callosal fibers led to better neuropsychological outcome than sagittal dissection/retraction of the callosal fibers [9]. In our study, due to its retrospective nature, we could not assess the neuropsychological outcome before and after surgery. Clearly, in children, neuropsychological evaluation can be difficult or even impossible; however, studies analyzing this aspect in children undergoing an IA are warranted.

Brain damage or infarction after an IA, due to venous infarction or retraction of the frontal lobe, has been described [11–13]. In patients undergoing an IA with acute subarachnoid hemorrhage (aSAH), scarifying bridging veins led to a higher rate of infarctions, especially if operated upon before day 11 after aSAH [13]. However, it is difficult to extrapolate data from adults suffering aSAH undergoing IA to our pediatric patient cohort. Kanno et al. described radiologically evident brain damage in 17.8% of patients undergoing an anterior IA, while clinical relevant symptoms were seen in only 3.6% [11]. In, addition, they found that patients without radiologically evident brain damage were on average 10 years younger than those with [11]. In our cohort, none of the patients showed radiologically evident brain damage or stroke, although in some cases, small bridging veins were sacrificed. One explanation might be the fact that our cohort consists of pediatric patients only, and due to their young age, the brain is less easily damaged by retraction and closure of small bridging veins. Data on the number of bridging veins sacrificed during surgery, as well as their location, was not available for our cohort, which is a limitation of our study. However, we do know that in no cases did the surgeons sacrifice veins lying or draining from cortical areas posterior of the coronal suture. In

addition, veins of large caliber were always preserved; only small bridging veins were sacrificed. Whenever possible, brain retraction using a brain retractor was avoided and held to a minimum through opening of the interhemispheric cisterns and draining cerebrospinal fluid from the cisterns.

Regarding the specific methods used for the IA, we have implied several technical nuances which may be of value. For the anterior IA, we position the patient in the lateral decubitus, so that the superior sagittal sinus is horizontal. For lateral ventricular or frontal lesions, the ipsilateral side is placed on the dependent side, and for third ventricular lesions, the right side is kept down. Head is kept above the torso, and neck flexion is avoided, all means of improving venous drainage. Self-retaining retractors are used at minimum, and usually with mild tension. For posterior IA, the patient is placed prone, and rotated slightly to the pathological side. Neck flexion is avoided, and the primary and assistant surgeons face each other, thus both can see in 3D. For all IA, mild hyperventilation is maintained, and mannitol is administered before the craniotomy. In cases with preoperative hydrocephalus, an EVD is placed in the ipsilateral ventricle under US guidance, to assist in brain relaxation. Once the pericallosal cistern is exposed, CSF is drained to assist in relaxation and retraction. All these maneuvers enable minimizing tension on the retracted brain.

This retrospective study was subject to all the limitations of data collection inherent in such studies. The rather small cohort and the lack of a control group of patients with similar lesions undergoing a transcortical approach are additional limits of our study. Lastly, we did not account for cognitive and neuropsychological deficits due to the retrospective nature of the study. However, as previously mentioned, these evaluations in children, especially of very young age, are often difficult or even impossible. The homogenous surgical technique of the IA for all patients, the rather long postoperative follow-up, and the focus on approach-related complications are strengths of this study.

Conclusion

The IA for lesions in and around the ventricular system is feasible, safe, and important in pediatric patients. When choosing this approach, the morbidity, although rarely permanent, should be considered. Further studies analyzing neuropsychological outcomes after IA in the pediatric population and comparing outcome of other surgical approaches to the IA in children are warranted.

Compliance with ethical standards

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