The Costs of Skull Base Surgery in the Pediatric Population

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Abstract

Objectives To determine the costs of endoscopic endonasal surgery (EES) for pediatric skull base lesions.

Methods Retrospective chart review of pediatric patients (ages 1 month to 19 years) treated for skull base lesions with EES from 1999 to 2013. Demographic and operative data were recorded. The cost of care for the surgical day, intensive care unit (ICU), floor, and total overall cost of inpatient stay were acquired from the finance department.

Results A total of 160 pediatric patients undergoing EES for skull base lesions were identified. Of these, 55 patients had complete financial data available. The average total inpatient and surgical costs of care were $34, 056 per patient. Angiofibromas were the most costly: $59,051 per patient. Fibro-osseous lesions had the lowest costs: $10,931 per patient. The average ICU stay was 1.8 days at $4,577 per ICU day. The average acute care stay was 3.4 days at $1,961 per day. Overall length of stay was 4.5 days. Three cerebrospinal fluid leaks (4%) and two cases of meningitis (3%) occurred. One tracheostomy was required (1.5%).

Conclusions EES is a cost-effective model for removal of skull base lesions in the pediatric population. Costs of care vary according to pathology, staged surgeries, length of ICU stay, and need for second operations.

Keywords
- pediatric
- skull base
- costs
- endoscopic

Introduction

Endoscopic endonasal surgery (EES) for skull base lesions has continued to evolve in the past decade to approach more aggressive lesions and to use the techniques in more diverse populations of patients. The pediatric population presents a unique challenge to the skull base surgeon. Pediatric patients can achieve maximal benefits from EES, but they also have various challenges that are not present in the adult population. Small nostrils and nasal cavities, incompletely pneumatized sinus corridors, and limited blood loss due to smaller blood volumes are all limitations that the skull base surgeon must work through. However, the benefits of EES are significant in comparison with open surgical resection of similar skull base lesions. EES prevents any need for brain retraction that can lead to frontal lobe edema, pneumocephalus, and possible neurologic morbidity. Endoscopes and endoscopic instrumentation can provide direct access to the tumors without manipulation of neural or vascular structures. There is also early literature that EES may improve postoperative pain scores in children and decrease hospitalization length of stay.[1]

As EES continues to expand in the pediatric population, we need to more clearly define the costs and benefits to the

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patient and the health care system of this technique. Costs to the patient can include length of operative surgical time, intensive care unit (ICU) stay, blood loss, transfusions, length of overall hospitalization, complication rates, and readmissions to the hospital. All of these factors have an impact not only the patient but also the health care system. The published literature is very sparse in defining these outcomes whether it be open surgical resection or endoscopic resection of skull base lesions in the pediatric population. A 2013 study of outcomes in 23 pediatric patients treated with open surgical resection of skull base tumors found a median length of stay in the hospital of 7 days, a 9% cerebrospinal fluid (CSF) leak rate, and a 9% meningitis incidence.[2] Massimi et al[3] compared 14 pediatric patients who underwent microsurgical transsphenoidal resection of sellar lesions compared with 17 patients who underwent the endoscopic endonasal transsphenoidal approach and found a length of stay change from 5.7 days in the microscopic groups to 4.0 days in the endoscopic endonasal group. Their blood transfusion and pediatric intensive care unit (PICU) admissions rates were also less in the endoscopic group.

The objective of this study was to determine the costs for EES for pediatric skull base lesions. Our hypothesis was that EES is associated with shorter operative times, fewer days in the ICU, and decreased overall length of hospitalization. All of these will lead to significant cost reductions to the patient and the health care delivery system.

Methods

This was a retrospective chart review and financial record data collection from 1999 to 2013 at Children's Hospital of Pittsburgh of UPMC approved by the institutional review board (#PRO13060264). Pediatric patients (ages 1 month to 19 years) were included in the study. All patients who had undergone endoscopic endonasal approaches for surgical resection of primary skull base lesions were reviewed. Pathologic diagnosis, age, gender, length of surgery, complications, repeat admissions, repeat trips to the operating room (OR), recurrence, length of ICU stay, acute care stay, and total hospitalization length were all recorded and entered into an Excel database.

Financial data were acquired from the finance department of the Children's Hospital of Pittsburgh of UPMC. The "cost of care" data were calculated as hospital-only costs related to the patient's stay. These include all services that had contact with the patient: respiratory, radiology, pharmacy, physical therapy/occupational therapy (PT/OT), laboratories, perioperative care, and nursing. Costs of care did not include physician services, preoperative imaging, rehabilitation, or home services provided after hospitalization. Readmission charges were included in the overall costs of total hospitalization. We calculated the cost of care normalized to fiscal year 2014 costing rates to accurately compare data between patients. Charges or reimbursements from the perspective of the U.S. third-party payers were not used.

Results

A total of 160 pediatric patients were identified from 1999 to September 2013. Complete financial data were available on 55 patients who underwent endoscopic endonasal approaches for surgical resection of skull base lesions. Financial data were available from November 2008 to September 2013 due to a new financial reporting system put into place. All data are reported in costs normalized to fiscal year 2014 costing rates. There were 64 admissions for the 55 patients. Overall, 34 males and 21 females were treated.

Craniopharyngiomas were the most common diagnosis treated. ►**Table 1** lists the diagnoses of all patients treated. The average length of surgery for surgical resection was 3 hours and 56 minutes. Removal of packing averaged 26 minutes, and repair of CSF leak averaged 1 hour and 25 minutes.

There were 66 tumor resections, 13 trips to the OR for packing removal, and 4 CSF leak repairs in the OR. Seven patients underwent staged resections of their tumors. The average OR costs for resection were $13,114, packing removal cost $ 4,109, and CSF leak repair cost $6,326. Full surgical day average costs were $15,905 per resection, $4,850 per packing removal, and $8,416 per CSF leak repair.

The average length of postoperative stay in the ICU was 1.8 days. The average number of days in acute care floor after surgery was 3.8 days with an average length of stay after surgery of 4.5 days. The average daily cost of ICU stay was $4,577, and acute care was $1,961 per day. The average total cost of inpatient stay including surgery was $34,056 per patient.

We evaluated the cost based on pathologic diagnosis (►**Table 2**). Juvenile nasopharyngeal angiofibromas (JNAs) required the longest time for resection (5.12 hours) and were the most expensive lesion to treat ($28,886 per OR day). Fibro-osseous lesions had the shortest operative time at

Table 1 Pathologic diagnosis of tumors resected

Diagnosis	No. of patients
Craniopharyngioma	11
Clival chordoma	7
Encephalocele/meningocele/CSF leak	7
JNA	6
Juvenile ossifying fibroma	3
Pituitary adenoma	3
Dermoid	3
Sarcoma	3
Rathke cleft cyst	2
Fibro-osseous lesion	2
Epidermoid cyst	1
Teratoma	1
Other	5

Abbreviations: CSF, cerebrospinal fluid; JNA, juvenile nasopharyngeal angiofibroma.

Table 2 Costs and length of stay per tumor diagnosis

Diagnosis	Time in OR, h	OR costs	Full surgical day costs	Days in ICU	Average daily cost	Days in acute care	Average daily cost	Total postoperative stay, d
Craniopharyngioma	4.24	$11,799	$14,932	1	$4,689	2.89	$2,312	3.89
Clival chordoma	4.38	$13,854	$15,993	1.3	$4,689	3.92	$2,081	5
Encephalocele/ meningocele/ CSF leak	2.96	$12,864	$14,292	0.29	$3,238	1.57	$1,783	1.86
JNA	5.12	$23,564	$28,886	0.6	$5,733	2.7	$1,898	3.3
Fibro-osseous lesions	2.2	$7,735	$9,379	0	0	0.86	$1,533	0.86

Abbreviations: CSF, cerebrospinal fluid; d, days; h, hours; ICU, intensive care unit; JNA, juvenile nasopharyngeal angiofibroma; OR, operating room.

2.2 hours and $9,379 per surgical day in costs. The length of stay also varied based on tumor diagnosis Clival chordomas had the longest length of stay with 1.3 average days in the ICU and a total hospitalization time of 5 days. Patients with fibro-osseous lesions typically stayed in the hospital < 1 day postoperatively. JNAs were the most expensive tumor to treat overall with an average total hospitalization cost of $59,915 (►**Table 3**).

There were few complications. Three patients (4%) had postoperative CSF leaks that required surgical repair. There were two episodes of meningitis (3%) and one lost airway that required a tracheostomy. Four patients were readmitted for postoperative complication management. There were no deaths within the perioperative time period. Six tumors did recur: two craniopharyngiomas, two clival chordomas, one dermoid tumor, and one sarcoid tumor.

Discussion

Pediatric skull base surgery is an evolving surgical discipline that has seen significant changes and advancements within the past 15 years. As the use of endoscopic endonasal techniques continues to advance, the pediatric population has benefited from the application of these techniques and technologies to manage their smaller and more complex anatomy.[4] Our study sought to define the costs of EES in the pediatric population to determine if it was a cost-effective model for the patient and the health care system.

The average length of stay for our series was 4.5 days with 1.8 days in the ICU. A 2011 study comparing the microscopic approach versus the endoscopic approach to pediatric sellar lesions found a similar decrease in the length of stay and ICU days.[3] The average length of stay was 5.7 days for microscopic resections versus 4.0 days for endoscopic. They also saw a decrease in ICU admissions from 100% to 35%. They reported a CSF leak rate of 11% (2 of 17) in their treatment of sellar lesions.

Table 3 Total hospitalization cost by tumor diagnosis

Diagnosis	Total hospitalization costs
Craniopharyngioma	$46,149
Clival chordoma	$32,699
Encephalocele/ meningocele/CSF leak	$13,803
JNA	$59,915
Fibro-osseous lesions	$10,931

Abbreviations: CSF, cerebrospinal fluid; JNA, juvenile nasopharyngeal angiofibroma.

Traditional open craniofacial and skull base approaches have been fraught with high levels of immediate postoperative complication rates and long-term sequelae. Teo et al[5] treated 26 pediatric patients with skull base lesions and had a 57% immediate postoperative complication rate. Brockmeyer et al reported their experience with 55 pediatric skull base lesions and found an 11% long-term permanent neurologic morbidity rate.[6] The need for radical resection of these lesions has been called into question in recent years due to the previously reported immediate and long-term morbidities associated with attempts at complete surgical resections. Transfacial, Le Fort I osteotomy, and zygomatic osteotomy approaches can lead to asymmetric facial growth and loss of tooth buds as reported in previous studies.[7,8] Avoidance of these approach techniques by using endoscopic endonasal approaches can have a significant long-term impact on pediatric patients as they continue to grow and develop.

The management of JNA is an excellent example of how the development of new endoscopic techniques has caused a significant shift in how most JNAs are now treated. In a retrospective review of 72 patients by Cloutier et al,[9] they found a significant change in their surgical practice when comparing JNAs treated from 2000 to 2005 compared with 2005 to 2010. They saw a shift of 45% of cases using an endoscopic approach in the early group as compared with 82.9% in the later group. They also had a significant decrease in postoperative hospitalization from 9.74 days in the early group to 6.76 days in the more recent treatment arm. They suggested that the endoscopic approach could be used in all cases but pointed out three areas that may pose challenges for the endoscopic route if the goal is to completely remove all of the disease. These include massive extension to the middle cranial fossa, ICA encasement, or encasement of the optic nerve. They also noted improvement in blood loss by avoiding large open incisions with an average of 600 mL for the endoscopic resections. With the shift toward endoscopic

resection, a new endoscopic staging system was introduced to help account for the route of intracranial extension and to adequately stage the vascularity of the tumor to assist with surgical planning and intraoperative management.[10] Both of these studies showcase the shifting paradigm of surgical management of these skull base tumors.

The costs of treating pediatric patients are not limited to the time they spent in the OR for their tumor removal. ICU days costs, PT and OT, respiratory therapy, and overall days spent in the hospital can lead to significant hospitalization fees. By decreasing the length of time spent in the OR, ICU, and on the floor we can improve patient outcomes and help benefit the overall system. Pediatric patients often have a more difficult time tolerating packing removal and repeat surveillance nasal endoscopy. What is typically performed in the office in the adult population may require a trip to the OR in young patients (typically age $\leq$ 6 years). In our series, 13 of the 55 patients (24%) required a trip to the OR for packing removal. With an average cost of $ 4,109 per trip, this can significantly add to the overall cost for the patient. However, the controlled setting allows an excellent debridement and surveillance to evaluate for any possibility of CSF leak. We also had four patients who were readmitted for management of complications, which again contributes to rising costs.

We found that tumor pathology did lead to significant differences in the overall cost of care for the patient. As a tertiary referral regional children's hospital, we are often treating more complex tumors. However, the higher caseload has allowed the team of surgeons, anesthesiologists, nurses, and ICU doctors to become facile in the treatment and care of these special patients.[11,12] JNAs were the most expensive tumors to treat due to their longer operative resection times, increased need for transfusions, and closer postoperative monitoring for hemodynamic stability. Fibro-osseous lesions and encephaloceles required shorter operative times and with length of stays $<$ 1 day postoperatively. These pathologies tend to be favorable for endoscopic resection due to their midline locations and lack of significant vascularity.

The limitations of our study include that it is a single institution's experience. We have a high-volume adult skull base practice, and the adult team joins the pediatric team to perform the surgical resections. This allows the most experienced surgeons to treat the most difficult tumors, but it also combines the expertise of the pediatric neurosurgeons and otolaryngologists in planning and caring for the special needs of pediatric patients. There is a paucity of data in the published literature for the cost of open resections of pediatric skull base lesions. This made it impossible to compare costs directly between the open and endoscopic surgical groups. There were not enough internal control open resection cases from our institution to perform a meaningful direct comparison.

Conclusions

EES in the pediatric population is a cost-effective model for removal of skull base lesions with low rates of complications, recurrence, and readmissions.

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