Hospitalization Cost Model of Pediatric Surgical Treatment of Chiari Type 1 Malformation

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Objectives To develop a cost model for hospitalization costs of surgery among children with Chiari malformation type 1 (CM-1) and to examine risk factors for increased costs.

Study design Data were extracted from the US National Healthcare Cost and Utilization Project 2009 Kids' Inpatient Database. The study cohort was comprised of patients aged 0-20 years who underwent CM-1 surgery. Patient charges were converted to costs by cost-to-charge ratios. Simple and multivariable generalized linear models were used to construct cost models and to determine factors associated with increased hospital costs of CM-1 surgery.

Results A total of 1075 patients were included. Median age was 11 years (IQR 5-16 years). Payers included public (32.9%) and private (61.5%) insurers. Median wage-adjusted cost and length-of-stay for CM-1 surgery were US $13 598 (IQR $10 475-$18 266) and 3 days (IQR 3-4 days). Higher costs were found at freestanding children's hospitals: average incremental-increased cost (AIIC) was US $5155 (95% CI $2067-$8749). Factors most associated with increased hospitalization costs were patients with device-dependent complex chronic conditions (AIIC $20 617, 95% CI $13 721-$29 026) and medical complications (AIIC $13 632, 95% CI $7163-$21 845). Neurologic and neuromuscular, metabolic, gastrointestinal, and other congenital genetic defect complex chronic conditions were also associated with higher hospital costs.

Conclusions This study examined cost drivers for surgery for CM-1; the results may serve as a starting point in informing the development of financial risk models, such as bundled payments or prospective payment systems for these procedures. Beyond financial implications, the study identified specific risk factors associated with increased costs. *(J Pediatr 2016;179:204-10).*

Chiari malformation type 1 (CM-1) is a common entity managed in pediatric neurosurgery, and surgical treatment of this disease presents a significant outlay of healthcare expenditures.[1] Unadjusted cost estimates are between $7000 and $30 000 for a single hospitalization.[2,3] As payers continue to develop reimbursement models for the bundling of payments, it is becoming increasingly important to define the costs of elective surgical procedures such as that for CM-1.

In recent years, the concept of the "bundled payment," which transitions away from the fee-for-service model, has gained significant traction. Medicare and private insurance plans have begun using this model for reimbursement, as seen in the Centers for Medicare and Medicaid Services (CMS) Diagnosis-Related Groups and Medicare Severity-Diagnosis-Related Groups.[4-6] Furthermore, CMS employs risk-adjusted models and hierarchical coexisting conditions models to adjust Medicare reimbursement.[7] A newly developed scheme of bundled payments named CMS bundled payment for care improvement (BPCI) was proposed in 2009 and initiated in 2010.[8] The BPCI aggressively links payments for the multiple services that beneficiaries receive during an episode of care. The purpose is to drive toward a higher quality of care while containing costs. Particularly for surgical hospitalizations, several models proposed by BPCI motivate providers to contain costs with their own risk. Model I is similar to current payments with a discount applied by CMS. Model II defines the payment for the episode of care as a bundle of hospital costs and 90 days of postoperative care. Model IV proposes bundling hospital costs and postoperative readmission costs into 1 payment. Finally, Model III focuses only on postacute care.

As costs of pediatric surgical admissions are rising each year,[9] cost containment reimbursement policies, such as prospective payment systems or bundled payments, may be considered in the future. At present, there have been no large-scale studies evaluating the costs for pediatric CM-1 surgery. Risk factors associated with increased hospital costs and how risk factors may affect risk adjustment for payment models have not been explored. Patients who have surgery for CM-1 may also have other congenital anomalies, syndromes,

API	Application programming interface	FTEs	Full-time equivalents
APR-DRGs	All patient refined diagnosis-related groups	GLMs	Generalized linear models
BPCI	Bundled payment for care improvement	ICD-9-CM	*International Classification of Disease, Ninth Revision, Clinical Modification*
CCC	Complex chronic conditions	KID	Kids' Inpatient Database
CCR	Cost-to-charge ratio	LOS	Length of stay
CM-1	Chiari malformation type 1	LPN	Licensed practical nurse
CMS	Centers for Medicare and Medicaid Services	RN	Registered nurse

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or medical conditions. Our study evaluates hospitalization cost of CM-1 surgery as a first step in approaching cost estimates for BPCI model I, which is similar to a prospective payment system. The purpose of this study is to identify cost drivers of hospitalization and develop a hospitalization cost model for the surgical treatment of pediatric CM-1.

Methods

Data were extracted from the Kids' Inpatient Database (KID), one of a family of administrative databases developed by the Healthcare Cost and Utilization Project, sponsored by the Agency for Healthcare Research and Quality (Rockville, Maryland). Hospitalization discharge data included patient demographics, admission type and source, diagnostic and procedural *International Classification of Disease, Ninth Revision, Clinical Modification* (ICD-9-CM) codes, length of stay (LOS), disposition, and payer data. The number of participating states was 44 in 2009, with data from 4100 hospitals. The KID contains information from 2-3 million pediatric discharges, weighted to represent 6.5-7.5 million national discharges. The basic unit of analysis is a patient discharge, rather than an individual patient. The KID records were poststratified by US region, urban or rural location, hospital teaching status, ownership, and bed size, with the addition of a stratum for freestanding children's hospitals.[10] This study received exempt status from the Institutional Review Board of the Baylor College of Medicine as analysis of this deidentified data constitutes nonhuman subjects research.

Pediatric patients (aged 0-20 years) with CM-1 surgery in the 2009 KID database were selected using an algorithm recently validated to identify accurately patients undergoing Chiari surgery. The database was queried for all patients with a primary ICD-9-CM diagnosis code of 348.4 and procedure codes consistent with CM-1 decompression, 01.24 for cranial decompression or 03.09 spinal decompression or laminectomy.[11] Patient records missing age, missing cost-to-charge ratio at their treatment hospital, missing number of registered nurse (RN) full-time equivalents (FTEs) per 1000 adjusted inpatient days, or associated with Chiari type 2 malformation (741.0), were excluded (**Figure 1**; available at www.jpeds.com).

Cost Estimation

The KID provides 2 types of cost-to-charge ratios. Patient charges were converted to costs by either hospital-specific application programming interface (API) cost-to-charge ratio (CCR) if available, or the group-weighted average CCR in the minority who were missing API CCR values.[12] Moreover, hospitalization costs were adjusted by the area wage index to adjust for price factors in a geographic area compared with the national average hospital wage level.[12] We analyzed risk factors associated with a total wage-adjusted cost per inpatient episode of CM-1 surgery.

Patient Demographics and Clinical Characteristics

The following patient demographics and clinical characteristics associated with cost were examined: age (0-4 years, 5-9 years, 10-14 years, or 15-20 years), sex (male or female), insurance status (private, public, and other), race (white, black, Hispanic, Asian, other, and unspecified), complex chronic conditions (CCC), and complications. Prior studies have shown that pediatric CCC groupings better characterized disease severity and healthcare utilization for the pediatric population than Elixhauser's comorbidity index, which was developed for adults.[13,14] This study used updated pediatric CCC version 2 as the risk adjustment for Chiari surgery costs.[15] All complications were identified by ICD-9-CM diagnosis and procedure codes.[16,17] Surgical complications included shunt insertion, revision, or exploration, meningitis, wound infection, dural graft complication, wound disruption, iatrogenic cerebrovascular infarction or hemorrhage, other neurosurgery-specific complication (such as cerebrospinal fluid leak and pseudomeningocele), and bleeding requiring transfusion. Medical complications included pulmonary complication/pneumonia, urinary-renal complication, septicemia, cardiac complication, thrombotic complication, gastrostomy, tracheostomy, pressure ulcer, and catheter-associated infection. In addition to CCC and complications, the impact of 3 disease-specific comorbidities was examined separately: hydrocephalus (331.3, 331.4, and 742.3), syringomyelia (336.0), and scoliosis (737.3X).[14] **Tables I** and **II** (available at www.jpeds.com) list the codes used in the study.[14,15,17] Only 1 of 1075 observations had an in-hospital death. Sensitivity analysis was conducted for hospital transfers. The hospital costs for the 22 transfer patients (2.2% of total cohort) did not differ significantly from the patients who were not transfer patients ($P = .934$).

Hospital Characteristics

Hospital characteristics examined in the study included census region, number of RN FTEs per 1000 adjusted inpatient days, and hospital type, which was categorized into government-owned, nonprofit nonchildren's hospitals, nonprofit freestanding children's hospitals, nonprofit children's units within adult hospitals, investor-owned private hospitals, and unspecified. Teaching status, hospital size, and hospital volume were not included in the analysis because of high collinearity with either hospital type or RN FTEs.

Factor Selection for Cost Model

Several state Medicaid programs, including Texas, Arizona, and Florida, have also adapted prospective payment and pricing systems for reimbursement based on all patient refined diagnosis-related groups (APR-DRGs) recently.[18,19] APR-DRGs include non-Medicare populations, such as pediatric patients with adjusted severity of illness.[5,20] This study included data elements used by APR-DRGs, principal diagnosis, secondary diagnosis, procedures, age, and sex to construct the cost models. In addition, consideration of geographic variation, hospital types, RN FTEs, nonclinical socioeconomic covariates, such as race, insurance status, and income level, were examined for their impact on hospital costs.[21,22] Three disease-specific comorbidities for CM-1 (hydrocephalus, syringomyelia, and scoliosis), CCC, and perioperative complications were also