A Method to Account for Variation in Congenital Heart Surgery Charges

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Background. In response to societal pressure to reduce expenditures and increase quality, we sought to develop a methodology to predict hospital charges related to congenital heart surgery.

Methods. Patients undergoing congenital heart surgery at Boston Children's Hospital in fiscal years 2007 to 2009 comprised the derivation cohort. Clinical data, including Current Procedural Terminology coding of the primary surgical intervention, were collected prospectively and linked to total hospital charges for an episode of care. Surgical charge categories were developed to group surgical procedure types using empiric data and expert consensus. A multivariable model was built using surgical charge categories and additional patient and procedural characteristics to predict the outcome, total hospital charges. A contemporary cohort for fiscal years 2010 to 2012 was used to validate surgical charge categories and the multivariable model.

Results. In the derivation cohort, 2,105 cases met inclusion criteria. One hundred three surgical procedure types were categorized into seven surgical charge categories, yielding a grouper variable with an R^2 explanatory value of 47.3%. Explanatory value increased with consideration of patient age, admission status, and preoperative ventilator dependence ($R^2 = 59.4\%$), as well as weight category, noncardiac abnormality, and genetic syndrome other than trisomy 21 ($R^2 = 61.5\%$). Additional variability in charge was explained when extracorporeal membrane oxygenation utilization and greater than one operating room visit during the episode of care were added ($R^2 = 74.3\%$). The contemporary cohort yielded an R^2 explanatory value of 67.7%.

Conclusions. The combination of clinical data with resource utilization information resulted in a statistically valid predictive model for total hospital charges in congenital heart surgery.

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As outcomes improve in congenital heart surgery (CHS), there is growing interest in the high resource utilization associated with congenital heart disease patients, but previous studies are limited. Congenital heart disease is estimated to account for $6 billion annually in acute care alone [1]. Between 2005 and 2011 Smith and colleagues [2] found a 50% increase in costs and a 66% increase in mean charges among neonates undergoing CHS. In addition, there is significant variability among institutions in the costs and resource utilization for congenital heart disease, with prematurity, noncardiac abnormalities, age, length of stay, and in-hospital complications found to account for increased resource consumption [1, 3–7].

Methods to accurately predict resource utilization for CHS do not currently exist. In the diagnosis related groups system used for determining hospital reimbursement, coding occurs after discharge and depends on all cardiac and noncardiac diagnoses and procedures, including diagnoses that have arisen during the hospitalization. Therefore, by definition it is not a predictive model. The Medicare resource-based relative value scale (RBRVS) for physician payment has limitations in predicting physician work and resource utilization in pediatrics and in accounting for the variability and complexity associated with cardiac catheterization [8, 9]. Risk stratification tools have been developed to evaluate in-hospital mortality and technical performance in CHS through consensus-based approaches and use of empiric data, but no similar risk stratification methods exist to predict resource utilization [10–12].

Given these limitations, our institution formed a multidisciplinary panel to develop a methodology to predict resource utilization for CHS. Using total hospital charges as the outcome, we developed a procedure-based financial grouper based on Current Procedural Terminology (CPT) codes to allow for generalizability in multicenter databases, and thus allow comparisons of charges at a single point in time and longitudinally. We hypothesized that the development of this procedure-based financial grouper including a priori characteristics could serve as a predictive model for patient resource utilization.

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Abbreviations and Acronyms

APR-DRG = all patient refined diagnosis related groups
CHS = congenital heart surgery
CPT = Current Procedural Terminology
ECMO = extracorporeal membrane oxygenation
EOC = episode of care
OR = operating room
RBRVS = resource-based relative value scale
SCC = surgical charge category
SOI = severity of illness
STS-CHSD = Society of Thoracic Surgeons Congenital Heart Surgery Database

Patients and Methods

This study was conducted as a quality improvement project according to the Institutional Review Board guidelines at Boston Children's Hospital.

Database Sources

The Boston Children's Hospital administrative and billing databases include charge data for patients receiving services at the institution. The Department of Cardiovascular Surgery clinical database supports professional billing by collection of primary and secondary CPT codes and includes clinical data used in the Society of Thoracic Surgeons Congenital Heart Surgery Database (STS-CHSD). Total hospital charges for an episode of care (EOC), defined as the time from admission to discharge, was chosen as the outcome variable for analysis. Total hospital charges from the administrative and billing databases were matched to CHS cases in the clinical database by medical record number and date of discharge to abstract patient characteristics. Cases were also linked to an All Patient Refined Diagnosis Related Groups (APR-DRG) version 20.0 value based on *International Classification of Diseases, 9th revision, Clinical Modification* procedure and diagnosis codes assigned in the hospital database.

Cohort

All cases with a CPT code linked to a congenital heart operation in the Department of Cardiovascular Surgery database were considered. Cases were excluded if they contained incomplete data, were patent ductus arteriosus ligations in premature infants, were minor same-day surgeries, or were for noncardiac surgeries during the EOC (eg, a patient whose only cardiac surgery was rescue extracorporeal membrane oxygenation [ECMO]). Fiscal years 2007 to 2009 comprised the derivation cohort. A validation cohort was examined for fiscal years 2010 to 2012.

Predictor Variables

We considered patient and procedural characteristics collected from the Department of Cardiovascular Surgery clinical database as potential predictor variables for total hospital charges. A priori characteristics included age, weight, history of prematurity, previous cardiac surgery, noncardiac abnormality, genetic syndrome, admission status, ventilator before surgery, ventilation at admission, and weekend admission. As an exploratory analysis, ECMO utilization and the number of visits to the operating room (OR) for a cardiac surgery during the EOC, excluding cases of delayed or secondary closure of the sternotomy, were recorded.

Development of Surgical Procedure Types and Surgical Charge Categories

Because CHS includes a wide variety of case types, a surgical procedure type variable was developed based on the primary cardiac surgical procedure's CPT code during the EOC. The multidisciplinary panel stratified selected primary procedures by factors that seemed likely to influence resource intensity and complexity, such as patient age. Total hospital charges for mutually exclusive surgical procedure types were summarized and placed in rank order. The surgical procedure types were then grouped into surgical charge categories (SCCs) according to empiric similarity. After this, expert consensus was used to group surgical procedure types near the threshold of a category or with limited empiric data, such as a small sample size. Different numbers of categories were evaluated to minimize variation within a group and maximize the discrimination between groups until face validity no longer increased.

Statistical Methods and Development of Multivariable Model

Patient and procedural characteristics were summarized by geometric mean and interquartile range charges. Geometric mean charge was chosen to reduce skewed distribution effects. The distribution of cases in each of the four APR-DRG severity of illness (SOI) subclasses was summarized for each SCC. Mean SOI and geometric mean case mix index were calculated for each SCC. The coefficient of determination (R^2) was calculated by univariate and multivariable linear regression models, which were built using stepwise forward regression for the outcome. Starting with SCC, statistically significant ($p < 0.01$) a priori patient and procedural characteristics were considered for inclusion until no further explanatory value could be found. The panel then considered postadmission factors that might explain variability in resource utilization. The performance of the final SCC and multivariable model were assessed in the contemporary validation cohort.

Results

Derivation Cohort

In fiscal years 2007 to 2009, 2,105 CHS admissions qualified for analysis. Charges were summarized according to a priori patient and procedural characteristics and postadmission factors (Table 1). Geometric mean charge was higher for neonates, premature patients, and patients with noncardiac