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Rising Charges and Costs for Pediatric Catheter Ablation

KRISTIN M. BURNS, M.D.^{*,†}, FRANK EVANS, PH.D.^{*}, GAIL D. PEARSON, M.D., Sc.D.^{*,†},
CHARLES I. BERUL, M.D.[†], and JONATHAN R. KALTMAN, M.D.^{*,†}

^{*}National Heart, Lung, and Blood Institute, National Institutes of Health, Bethesda, Maryland, Washington, DC, USA

[†]Children's National Medical Center, Washington, DC, USA

Abstract

Introduction—Catheter ablation has been shown to be effective for pediatric tachyarrhythmias, but the associated charges and costs have not been described in the recent era. Understanding such contemporary trends may identify ways to keep an effective therapy affordable while optimizing clinical outcomes.

Methods—We used the 1997-2009 Kids' Inpatient Databases to examine trends in charges and costs for pediatric catheter ablation and identify determinants of temporal changes.

Results—There were 7,130 discharges for catheter ablation in the sample. Mean age at ablation was 12.1 ± 0.2 years. Patients with congenital heart disease (CHD) made up 10% of the sample. Complications occurred in 8% of discharges. Mean total charges rose 219% above inflation (from $\$23,798 \pm 1,072$ in 1997 to $\$75,831 \pm 2,065$ in 2009). From 2003 to 2009, costs rose 25% (from $\$20,459 \pm 780$ in 2003 to $\$25,628 \pm 992$ in 2009). Charges for ablation increased markedly relative to surgical procedures, but with a similar slope to other catheter-based interventions. Multivariable analysis revealed that year ($P < 0.0001$), payer ($P = 0.0002$), CHD ($P < 0.0001$), valvular heart disease ($P = 0.0004$), cardiomyopathy ($P = 0.0009$), hospital region ($P < 0.0001$), length of stay ($P < 0.0001$), and complications ($P < 0.0001$) predicted increased charges. The same factors also predicted increased costs. Charges and costs varied considerably by region, particularly for high-volume centers ($P < 0.0001$).

Conclusions—Charges and costs for pediatric catheter ablation increased relative to other procedures and significantly outstripped inflation. Further study of complications, length of stay, and regional differences may help control rising costs while maintaining quality of care.

Keywords

catheter ablation; congenital heart defects; epidemiology; health care costs; pediatrics

Address for correspondence: Kristin M. Burns, M.D., Heart Development and Structural Diseases Branch/Division of Cardiovascular Sciences, National Heart, Lung, and Blood Institute/National Institutes of Health, 6701 Rockledge Drive, Room 8107, Bethesda, MD 20892, USA. Fax: 301-480-2858; kristin.burns@nih.gov.

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Introduction

In this era of health care reform, legislators and taxpayers alike are scrutinizing the health care system. Consumers seek assurance that every dollar spent will return value to the patient. Some argue that the benefits of technology justify rising health care costs,¹ whereas others assert that greater spending for health care does not guarantee quality.² Consequently, research increasingly emphasizes determining the cost-effectiveness of expensive medical interventions.³

The field of pediatric cardiology has made great strides over the last several decades in improving outcomes for patients, but the care of children with heart disease remains expensive, complex, and reliant on technology. Resource utilization among patients undergoing surgery for congenital heart disease (CHD) has been explored,^{4–7} but the economic aspects of other facets of pediatric cardiovascular care are less well described.

Catheter ablation for tachyarrhythmias has become standard of care in children with both structurally normal hearts and CHD.^{8,9} In children older than 5 years of age with Wolff–Parkinson–White Syndrome and supraventricular tachycardia (SVT), catheter ablation has been shown in a cost-effectiveness model to have lower cost, morbidity and mortality than medical management and surgery.¹⁰ Similarly, in patients with monthly episodes of SVT, radiofrequency ablation was found to be more effective and less expensive than pharmacologic therapy.¹¹ Although one study found the long-term costs to be similar between patients undergoing ablation and those maintained on medication, quality of life indicators were improved and symptoms were eliminated more completely in patients undergoing catheter ablation.¹² This suggests that catheter ablation may provide more value.

Though compelling, these data are more than 10 years old. In the interim, health care costs have increased significantly, yet temporal trends in costs for pediatric catheter ablation have not been described. Understanding trends in costs for pediatric catheter ablation and their drivers may help to identify ways to keep an effective clinical therapy affordable and available while optimizing clinical outcomes and increasing health care value.

The purpose of this study was to evaluate contemporary trends in costs for pediatric catheter ablation. Although our true interest lies in the cost of pediatric catheter ablation, our data source, the Kids' Inpatient Database (KID), contains information on charges and does not include information on reimbursement. We recognize that charges are complex and do not reflect the true cost of care delivered. Therefore, we examined charges for pediatric catheter ablation from 1997 to 2009 and used cost-to-charge ratios (when available) to derive information on costs from 2003 to 2009. We then used a multivariable model to identify predictors of increased charges and costs for pediatric catheter ablation.

Methods

Data Source and Population

Data were obtained from the KID, an all-payer database of pediatric inpatient care in the United States. Released every 3 years, the KID is a stratified sample of discharges from all

community, nonrehabilitation hospitals in states participating in the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project (HCUP). The KID contains information typically found in a discharge abstract, with safeguards to protect the privacy of hospitals, physicians, and patients. Data in the KID are stratified by geographic region, location/teaching status, bed size category, ownership, and whether the hospital is a freestanding children's hospital. Discharges are also stratified by uncomplicated in-hospital births, complicated in-hospital births, and nonnewborn pediatric discharges. Using the known number of American Hospital Association discharges in a given year, the KID assigns each stratum a weight based on its proportion of the known national discharges. Individual observations (discharges) in the KID are then multiplied by these weights to produce national estimates. For example, each of the 900 ablation observations in the 2009 KID is multiplied by its corresponding weight to produce a national estimate of 1,313 ablation discharges.¹³

Length of stay in the KID is determined by calendar dates. Patients who were admitted and discharged on the same calendar day are reported as having a length of stay of zero days. Patients who were admitted on 1 calendar day and discharged the next day are counted as having a length of stay of 1 day, even if the duration of hospitalization was less than 24 hours. Therefore, same-day admissions are captured in the sample. Hospital type is specified within the KID and is based on information provided by the National Association of Children's Hospitals and Related Institutions.

With the exception of hospital data, all data presented are weighted national estimates, not actual observations. Hospital data reflect only the hospitals within the KID; therefore, it is not weighted for national estimates. Cells based on 10 or fewer observations were suppressed due to the HCUP Data Use Agreement, but we included those values in the analysis.¹⁴

We queried the KID for 1997, 2000, 2003, 2006, and 2009 for discharges involving patients less than 18 years of age with a length of stay less than 365 days and an International Classification of Diseases, Ninth Revision (ICD-9) procedure code for catheter ablation (37.34).¹⁵

Data Elements

Each discharge was examined for the following variables: charges, patient characteristics (age, gender, payer, and underlying diagnoses), hospital qualities (type, region, teaching status, and annual procedure volume), and hospitalization-related outcomes (length of stay, complications, and mortality). For discharges from the 2003, 2006, and 2009 KID, HCUP hospital-specific cost-to-charge ratios were used to convert charges to costs. Cost data were available for 78% of the sample in 2003, 100% of the sample in 2006, and 97% of the sample in 2009.

An associated arrhythmia diagnosis was identified by ICD-9 code for all catheter ablation discharges. Three major categories of arrhythmia diagnosis were prospectively identified: SVT (427.0, 426.7), ventricular tachycardia (VT) (427.1), and atrial fibrillation/flutter (AF/AFL) (427.3). These were identified in a nonhierarchical fashion; that is, patients may have

had more than one diagnosis. Discharges with other arrhythmia diagnoses (e.g., premature atrial contractions, paroxysmal tachycardia, and cardiac arrest; 427.2, 427.6, 426.8, 427.9, 780.2, 427.5) were combined into a single category for univariate analysis. To explore trends in charges for higher complexity cases, nonarrhythmia cardiac diagnoses were also identified and categorized as CHD (745-747), acquired valvular heart disease (394-397, 424), and cardiomyopathy (425, 422, 398.0).

Age was analyzed using a break-point of 4 years based on prior registry data suggesting that age <4 years is an independent risk factor for procedural complications.¹⁶ On the basis of the distribution of the data, a high-volume center was defined as one performing 50 or more ablations in a single year.

Complications were identified based on ICD-9 codes and classified as follows: atrioventricular (AV) block (426.0, 426.1, 426.6, 426.9), cardiac complications (cardiac arrest during a procedure, 997.1, ventricular fibrillation, 427.41, ventricular flutter, 427.42, acute coronary occlusion without myocardial infarction, 411.81, and acute myocardial infarction, 410), and respiratory complications (pulmonary embolism, 415.1, pulmonary collapse, 518.0, pleural effusion, 511.9, iatrogenic pneumothorax, 512.1, and acute respiratory failure, 518.81). Procedural complications were based on AHRQ's Pediatric Quality Indicators, a set of measures used with hospital discharge data to identify iatrogenic events and potentially preventable complications.¹⁷ The Pediatric Quality Indicators considered most relevant to catheter ablation and therefore included in the analysis were: accidental puncture/laceration (E870.6, 998.2), postoperative hemorrhage/hematoma (998.1), thrombosis (453.40), and cardiac catheterization as the cause of a later complication (E879.0).^{15,17} A composite of these complications was used in the univariate and multivariable analyses.

To contrast trends in charges for ablation with other common pediatric catheter-based and surgical procedures, we then queried the KID for discharges and associated charges for procedures such as implantable cardioverter-defibrillator placement, catheter closure of an atrial septal defect, percutaneous balloon valvuloplasty, surgical repair of an atrial septal defect, surgical repair of a ventricular septal defect, tonsillectomy, and laparoscopic appendectomy.

Statistical Analysis

This analysis consisted of 4,027 unweighted discharges (7,130 weighted discharges) over the 5 sample years that met the inclusion criteria and contained information about total charges. Survey analysis methods were used for stratified, 2-stage cluster samples, with hospital as the primary sampling unit. Degrees of freedom were calculated as the number of primary sampling units minus the number of strata within the domain.¹⁸ Descriptive statistics were performed on the sample using sums, percentages and means with standard deviations. Year was treated as a categorical variable. Comparisons of categorical variables between years were made using a Rao–Scott chi-square test on the corresponding contingency table.¹⁹

Mean total charges and costs (when available) with standard errors were calculated for catheter ablation discharges in each available year of the KID. Total charges and costs were

adjusted to 2009 dollars using the Bureau of Labor Statistics consumer price index for medical services for all urban consumers.²⁰

To identify predictors of increased charges for catheter ablation, univariate analysis was performed using the following variables: year, age <4 years, gender, payer, SVT, VT, AF/AFL, other arrhythmia diagnosis, CHD, acquired valvular heart disease, cardiomyopathy, hospital type, region, teaching hospital status, high-volume center status, length of stay, and a composite of complications. Mortality was excluded from univariate analysis due to the low number of observations.

A multivariable model was then used to examine the effects of each variable on charges while controlling for the other variables. Inflation-adjusted total charges were logtransformed and fit to a linear regression multivariable model with categorical independent variables that yielded $P < 0.05$ in the univariate analysis and with length of stay as the single continuous independent variable. A breakpoint was included in the slope for length of stay 14 days. Length of stay data before that breakpoint are presented as increments of 1 day. In addition, interaction terms were included in the multivariable model for high-volume center status by region, a composite of complications by region, and a composite of complications by high-volume center status. The same multivariable model was then applied to available cost data.

To illustrate how charges for a “typical” catheter ablation would be affected by each variable, the difference in charges for each significant variable in the multivariable model was then transformed into a percent change in charges and compared to a reference case. Features of the reference case were selected to reflect a “typical” patient undergoing ablation and included the year 2009, age 4 years, private payer, SVT diagnosis, lack of structural cardiac disease, length of stay 0 days, no complications, not a high volume center, and Northeast Region. The choices of the Northeast Region and 2009 as “typical” were arbitrary.

Calculations were performed with SAS for Windows 9.2 (SAS Institute Inc., Cary, NC, USA).

Results

There were 7,130 discharges for catheter ablation in the sample (Table 1). Mean age at ablation was 12.1 ± 0.2 years; the percentage of patients younger than 4 years of age increased from 4% to 9% over the study period. The majority of patients had private insurance; however, the proportion of Medicaid patients increased from 16% in 1997 to 30% in 2009 ($P = 0.001$). The most common arrhythmia diagnosis was SVT, with smaller proportions of ablations performed for VT and AF/AFL. The percentage of patients with CHD increased from 8% to 14% ($P = 0.07$). Most ablations were performed in teaching hospitals and hospitals described as children’s units in a general hospital. Thirteen hospitals (3%) were classified as high-volume centers.

Length of stay was 0 days for 6% of hospitalizations, 1 day for 67% of hospitalizations, and 2 days or less for 84% of hospitalizations, but there was a broad range in lengths of stay across the sampled years (0-168 days). Complications occurred in 8% of all discharges, and

were most often described as AV block or cardiac in nature. The percent of hospitalizations complicated by AV block was 3% or 4% across all sampled years and did not change significantly over time ($P = 0.55$). Mortality during hospitalization for ablation was rare. (The actual numbers for mortality were suppressed due to the low number of observations in accordance with the HCUP Data Use Agreement.)¹⁴

Over the entire study period, mean total charges for catheter ablation (adjusted to 2009 dollars) increased by 219%, from $\$23,798 \pm 1,072$ in 1997 to $\$75,831 \pm 2,065$ in 2009. This 219% increase is above the 66% increase in the indexed medical care services inflation rate from 1997 to 2009.²⁰ Mean total charges by year for relevant variables are displayed in Table 2.

Between 2003 and 2009, mean total costs for pediatric catheter ablation increased by 25% above inflation (from $\$20,459 \pm 780$ in 2003, to $\$23,125 \pm 719$ in 2006, to $\$25,628 \pm 992$ in 2009). This represents a 25% increase in costs above the 30% increase in the indexed medical care services inflation rate from 2003 to 2009.²⁰ In the same time period from 2003 to 2009, charges increased by 69% above inflation, from $\$44,977 \pm 1,780$ in 2003 to $\$75,831 \pm 2,065$ in 2009.

Significant univariate predictors of hospital charges include: year, age <4 years, payer, SVT, AF/AFL, CHD, acquired valvular heart disease, cardiomyopathy, hospital region, high-volume center status, length of stay, and complications. Gender, race, VT, other arrhythmia diagnosis, hospital type, and teaching hospital status did not reach a P value of <0.05 in univariate analysis of charges.

In the multivariable model (Table 3 and Fig. 1), year ($P < 0.0001$), payer ($P = 0.0002$), CHD ($P < 0.0001$), acquired valvular heart disease ($P = 0.0004$), cardiomyopathy ($P = 0.0009$), hospital region ($P < 0.0001$), length of stay ($P < 0.0001$), and complications ($P < 0.0001$) predicted increased charges for pediatric cardiac ablation. Age <4 years, SVT, AF/AFL, and high-volume center status did not predict increased charges. The overall adjusted R^2 value for the charges model is 0.52. The same variables predicted increased costs in the multivariable model (Table 3).

A significant interaction was identified between hospital region and high-volume center status ($P < 0.0001$) (Table 3). Among high-volume centers, charges and costs varied considerably. High-volume centers in the West and Northeast regions predicted decreased charges, whereas high-volume centers in the South and Northeast regions predicted decreased costs. There were no regional differences in the distribution of diagnoses, annual procedure volume, or lengths of stay to explain the regional variations in charges and costs. No significant interactions were identified between complications and region ($P = 0.35$) or complications and high volume center status ($P = 0.21$).

To explore whether the increase in charges for pediatric catheter ablation is procedure-specific, we plotted the change in inflation-adjusted total charges for various pediatric procedures (Fig. 2). Catheter ablation demonstrates a marked increase in percent change in charges that is comparable to other catheter-based cardiac interventions but more dramatic than surgical pediatric procedures.

Discussion

Our analysis reveals an increase in charges for catheter ablation of more than 200% above inflation between 1997 and 2009, and an increase in costs of 25% above inflation from 2003 to 2009. The multivariable model identified several factors that predict increases in both charges and costs for catheter ablation. Although factors such as diagnosis and year are nonmodifiable, some factors are amenable to improvement and provide opportunities for further research. Understanding and targeting these modifiable predictors will be an important strategy for containing health care costs while maintaining quality of care and clinical outcomes.

Complications are an example of a modifiable predictor of increased charges and costs. Our finding that complications are independently associated with charges is consistent with other studies in pediatric cardiology and pediatrics in general. Using the 2000 KID database, Benevisez *et al.* demonstrated that a congenital heart surgery admission with a complication resulted in higher charges than those without a complication, even after adjusting for patient and hospital factors.²¹ In a study of children admitted to the pediatric intensive care unit with status asthmaticus, Carroll and Zucker found that complications led to longer lengths of stay and a 3-fold increase in hospital charges.²²

AV block and cardiac complications were the most commonly reported complications in our cohort. The rate of AV block was unchanged during the 13 years studied, despite the introduction of cryoablation in the early-to-mid 2000s. Cryoablation is thought to have a better safety profile in patients with septal accessory pathways.²³ The 3-4% rate of AV block in our analysis is higher than the 1.2% incidence in previously reported multicenter data.⁸ This likely reflects ascertainment bias between data obtained from large children's hospitals with robust pediatric electrophysiology programs and administrative data from a cross-section of hospitals nationwide. Such a discrepancy suggests that the field would benefit from a systematic multicenter evaluation among centers with higher and lower complication rates to distinguish high-risk patients, elucidate underlying mechanisms, and identify preventive strategies that may improve outcomes and contain costs.

Length of stay is another modifiable predictor of increased charges and costs. Our cohort showed a progressive increase in charges and costs for each additional hospital day. This is also true for congenital heart surgery admissions,⁶ admission to the pediatric intensive care unit,²⁴ and neonatal intensive care admissions complicated by necrotizing enterocolitis.²⁵ In addition, increased length of stay is associated with economic burden due to increased risk of iatrogenic events²⁶ and lost opportunity costs for caregivers who may be unable to work while a child is hospitalized. Although it is common to suggest that reducing length of stay will reduce charges and costs, the relationship with overall health care costs is complex. Because hospitals have a high proportion of fixed costs, reducing length of stay for individual patients does not affect hospital costs in the short term.²⁷ Future research aimed at understanding this complex relationship could help identify means of moderating increases in charges and costs.

Regional differences in healthcare spending have been described previously both for Medicare patients and those with CHD. Using Medicare claims from 2006, Gottlieb *et al.* showed that regional price adjustment (i.e., differences in payment to account for regional differences in the cost of living) accounts for only a small fraction of the regional variation in costs.²⁸ In their analysis of Medicare spending from 1992 to 2006, Fisher *et al.* found that the decision to use available technology and resources was highly correlated with regional differences in per capita spending. Physicians in higher spending regions were more likely to refer to subspecialists for less complicated diseases or pursue aggressive and expensive care for the elderly and those with end-stage disease.²⁹ They also conclude that higher spending does not always result in increased quality of care.³⁰ Regional differences in resource utilization have also been noted in patients with CHD. Connor found increased numbers of high resource use admissions in 8 of 27 states, whereas 2 states had significantly lower odds of being high resource utilization cases.⁴

In our study, charges and costs varied significantly by region, but the reasons for this regional variation cannot be fully explained by any of the factors in the multivariable model, suggesting that additional factors not examined by our model may also drive these regional variations. Understanding such regional variations may allow for adoption of model strategies to mitigate cost increases nationwide.

Our comparison of various pediatric procedures reveals an increase in charges for catheter ablation of more than 200% above inflation between 1997 and 2009, and a similar increase for other catheter-based cardiac interventions. Several pediatric surgical procedures demonstrate an increase in charges that is also above inflation, but the magnitude of the increase is less than for catheter-based interventions.

Reasons for this remarkable increase in charges for catheter-based interventions relative to surgical procedures cannot be explained by our analysis, although rapidly evolving advancements in the technology and tools used in catheter-based procedures may play a role. For example, cryoablation has been increasingly used as an alternative to radiofrequency ablation in children with septal accessory pathways or AV nodal reentrant tachycardia. The cost of cryoablation catheters far exceeds the cost of radiofrequency ablation catheters. Cryoablation has also been associated with higher rates of recurrence than radiofrequency ablation, potentially necessitating repeat ablation procedures.²³

In addition, high-complexity catheter ablations in patients with CHD have been facilitated in the recent era by the use of advanced, 3-dimensional mapping systems. Triedman demonstrated that use of electroanatomic mapping systems to guide ablation is a positive predictor of chronic success in patients with CHD and intraatrial reentrant tachycardia.³¹ Because the diagnosis of CHD is an important predictor of increased charges and costs in our model, it is reasonable to hypothesize that such expensive technology may be contributing to the temporal increase in charges and costs. Yet, the use of such technology may actually diminish the likelihood of complications in patients with complex anatomy and therefore decrease charges and costs. Systematic assessment of the costs and efficacy of such advanced mapping and ablative systems compared with less technologically intensive

strategies may be valuable in clarifying the cost-benefit balance of technology for pediatric catheter ablation.

Our analysis demonstrates an increase in costs from 2003 to 2009 of 25% above inflation. Although this cost increase is much less dramatic than the 69% increase in charges from 2003 to 2009, it still significantly outstrips inflation. We have alluded to the possible role of technology in the rising charges for catheter ablation. Although advanced mapping systems and cryoablation were both introduced before 2003, their use became more widespread during the time period of this analysis. Therefore, the possible increase in costs due to those innovations may have occurred earlier and is unlikely to be fully responsible for the cost increase observed from 2003 to 2009.

Study Limitations

Administrative databases have the benefit of including large groups of patients and providing a cross-section of national data. For rare diseases, they can be particularly helpful in garnering larger sample sizes than would be available from single or even multiinstitution studies. Yet, administrative databases such as the KID are susceptible to coding errors and are limited by a lack of clinical detail. Such a lack of detail limited our ability to explore more fully certain potential drivers of increased charges and costs, such as regional differences, procedural techniques, and the role of technology. Moreover, data in the KID are limited to one hospitalization. Complications occurring after discharge were thus not captured in our analysis. Readmissions for complications related to catheter ablation could add significantly to already rising charges. Data in the KID are reported in terms of charges, not costs, and do not include information about reimbursement. Charges may not accurately reflect the true cost of services provided. Cost-to-charge ratio files were analyzed for the 2003, 2006, and 2009 KID; however, cost data from 2003 were only available for 78% of the sample, which may limit our ability to draw conclusions about trends in costs for catheter ablation. Although we recognize that the factors that drive charges are complex and that charges are a poor surrogate for costs, we found that costs rose significantly above inflation in a similar fashion to charges, and that the same factors that predicted increased charges for catheter ablation also predicted increased costs. In addition, charges do reflect relative costs of hospitalizations for different diagnoses and provide a means to compare between various diagnoses and procedures.³²

Conclusions

Charges and costs for pediatric catheter ablation increased markedly during the study period relative to other pediatric procedures and significantly outstripped the medical services inflation rate. Understanding modifiable predictors of increased charges, including complications, length of stay, and regional variation, will play an important role in containing rapidly rising costs while maintaining quality of care and clinical outcomes in a climate of limited financial resources.

References

1. Cutler DM, McClellan M. Is technological change in medicine worth it? *Health Aff (Millwood)*. 2001; 20:11–29.
2. Skinner JS, Staiger DO, Fisher ES. Is technological change in medicine always worth it? The case of acute myocardial infarction *Health Aff (Millwood)*. 2006; 25:w34–w47. [PubMed: 16464904]
3. Beller GA. Implications of randomized studies of medical therapy vs revascularization for reducing rising costs of health care. *J Nucl Cardiol*. 2009; 16:483–485. [PubMed: 19562423]
4. Connor JA, Gauvreau K, Jenkins KJ. Factors associated with increased resource utilization for congenital heart disease. *Pediatrics*. 2005; 116:689–695. [PubMed: 16140709]
5. Pasquali SK, Sun J, d'Almada P, Jaquiss RDB, Lodge AJ, Miller N, Kemper AR, Lannon CM, Li JS. Center variation in hospital costs for patients undergoing congenital heart surgery. *Circ Cardiovasc Qual Outcomes*. 2011; 4:306–312. [PubMed: 21505154]
6. Ungerleider RM, Bengur AR, Kessenich AL, Liekweg RJ, Hart EM, Rice BA, Miller CE, Lockwood NW, Knauss SA, Jaggars J, Sanders SP, Greeley WJ. Risk factors for higher cost in congenital heart operations. *Ann Thorac Surg*. 1997; 64:44–49. [PubMed: 9236333]
7. Dean PN, Hillman DG, McHugh KE, Gutgesell HP. Inpatient costs and charges for surgical treatment of hypoplastic left heart syndrome. *Pediatrics*. 2011; 128:e1181–e1186. [PubMed: 21987703]
8. Van Hare GF, Javitz H, Carmelli D, Saul JP, Tanel RE, Fischbach PS, Kanter RJ, Schaffer M, Dunnigan A, Colan S, Serwer G, Participating Members of the Pediatric Electrophysiology Society. Prospective assessment after pediatric cardiac ablation: Demographics, medical profiles, and initial outcomes. *J Cardiovasc Electrophysiol*. 2004; 15:759–770. [PubMed: 15250858]
9. Morwood JG, Triedman JK, Berul CI, Khairy P, Alexander ME, Cecchin F, Walsh EP. Radiofrequency catheter ablation of ventricular tachycardia in children and young adults with congenital heart disease. *Heart Rhythm*. 2004; 1:301–308. [PubMed: 15851174]
10. Garson A Jr, Kanter RJ. Management of the child with Wolff-Parkinson-White syndrome and supraventricular tachycardia: Model for cost effectiveness. *J Cardiovasc Electrophysiol*. 1997; 8:1320–1326. [PubMed: 9395176]
11. Cheng CH, Sanders GD, Hlatky MA, Heidenreich P, McDonald KM, Lee BK, Larson MS, Owens DK. Cost-effectiveness of radiofrequency ablation for supraventricular tachycardia. *Ann Intern Med*. 2000; 133:864–876. [PubMed: 11103056]
12. Bathina MN, Mickelsen S, Brooks C, Jaramillo J, Hepton T, Kusumoto FM. Radiofrequency catheter ablation versus medical therapy for initial treatment of supraventricular tachycardia and its impact on quality of life and healthcare costs. *Am J Cardiol*. 1998; 82:589–593. [PubMed: 9732885]
13. Calculating Kids' Inpatient Database (KID) Variances. Healthcare Cost Utilization Project (HCUP). Rockville, MD: Agency for Healthcare Research and Quality; 2005. Methods Series Report #2005-5 Available at: <http://www.hcup-us.ahrq.gov/db/nation/kid/reports/CalculatingKIDVariances.pdf>. (Accessed October 21, 2010)
14. HCUP Data Use Training. Healthcare Cost and Utilization Project (HCUP). Rockville, MD: Agency for Healthcare Research and Quality; 2009. Available at: http://www.hcup-us.ahrq.gov/tech_assist/dua.jsp. (Accessed June 29, 2011)
15. International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). National Center for Health Statistics; Hyattsville, MD: 2009. Available at: <http://icd9cm.chrisendres.com/> (Accessed October 21, 2010)
16. Friedman RA, Walsh EP, Silka MJ, Calkins H, Stevenson WG, Rhodes LA, Deal BJ, Wolff GS, DeMaso DR, Hanisch, Van Hare GF. NASPE Expert Consensus Conference: Radiofrequency catheter ablation in children with and without congenital heart disease. Report of the writing committee North American Society of Pacing and Electrophysiology. *Pacing Clin Electrophysiol*. 2002; 25:1000–1017. [PubMed: 12137336]
17. AHRQ Quality Indicators. Agency for Healthcare Research Quality. Rockville, MD: p. 2007 Available at: http://www.qualityindicators.ahrq.gov/pdi_overview.htm. Accessed October 21, 2010

18. Korn, EL., Graubard, BI. Analysis of Health Surveys. Wiley Series in Probability and Statistics. xiii ed. Vol. 382. New York, NY: Wiley; 1999. p. 141
19. Rao JNK, Scott AJ. On simple adjustments to chi-square tests with sample survey data. *Ann Stat*. 1987; 15:385–397.
20. Bureau of Labor Statistics. Consumer price index detailed report tables. 2006. Available at: <http://data.bls.gov/cgi-bin/surveymost?cu> (Accessed March 14, 2011)
21. Benavidez OJ, Connor JA, Gauvreau K, Jenkins KJ. The contribution of complications to high resource utilization during congenital heart surgery admissions. *Congenit Heart Dis*. 2007; 2:319–326. [PubMed: 18377447]
22. Carroll CL, Zucker AR. The increased cost of complications in children with status asthmaticus. *Pediatr Pulmonol*. 2007; 42:914–919. [PubMed: 17726707]
23. Bar-Cohen Y, Cecchin F, Alexander ME, Berul CI, Triedman JK, Walsh EP. Cryoablation for accessory pathways located near normal conduction tissues or within the coronary venous system in children and young adults. *Heart Rhythm*. 2006; 3:253–258. [PubMed: 16500293]
24. Chalom R, Raphaely RC, Costarino AT Jr. Hospital costs of pediatric intensive care. *Crit Care Med*. 1999; 27:2079–2085. [PubMed: 10548186]
25. Bisquera JA, Cooper TR, Berseth CL. Impact of necrotizing enterocolitis on length of stay and hospital charges in very low birth weight infants. *Pediatrics*. 2002; 109:423–428. [PubMed: 11875136]
26. Kugelman A, Inbar-Sanado E, Shinwell ES, Makhoul IR, Leshem M, Zangen S, Wattenberg O, Kaplan T, Riskin, Bader D. Iatrogenesis in neonatal intensive care units: Observational and interventional, prospective, multicenter study. *Pediatrics*. 2008; 122:550–555. [PubMed: 18762525]
27. Weeks WB, Resar R. Does reducing length of stay make a business case? *Jt Comm J Qual Patient Saf*. 2008; 34:627–628. [PubMed: 19025082]
28. Gottlieb DJ, Zhou W, Song Y, Andrews KG, Skinner JS, Sutherland JM. Prices don't drive regional medicare spending variations. *Health Aff (Millwood)*. 2010; 29:537–543. [PubMed: 20110290]
29. Fisher ES, Bynum JP, Skinner JS. Slowing the growth of health care costs-lessons from regional variation. *N Engl J Med*. 2009; 360:849–852. [PubMed: 19246356]
30. Fisher, E., Goodman, D., Skinner, J., Bronner, K. A Dartmouth Atlas Project Topic Brief 2009. The Dartmouth Institute for Health Policy and Clinical Practice, Center for Health Policy Research; Hanover, NH: Feb 27. 2009 Health care spending, quality, and outcomes: More isn't always better.
31. Triedman JK, Alexander ME, Love BA, Collins KK, Berul CI, Bevilacqua LM, Walsh EP. Influence of patient factors and ablative technologies on outcomes of radiofrequency ablation of intra-atrial re-entrant tachycardia in patients with congenital heart disease. *J Am Coll Cardiol*. 2002; 39:1827–1835. [PubMed: 12039499]
32. Hospital stays, hospital charges, and in-hospital deaths among infants with selected birth defects—United States. 2003; 56:25–29. *MMWR Morb Mortal Wkly Rep* 2007

Figure 1.

Percent change in charges for significant predictors in the multivariable model. Horizontal bars demonstrate the percent change in charges attributable to each variable over a reference discharge for catheter ablation. Reference discharge features are 2009, age 4 years, private payer, SVT diagnosis, lack of structural cardiac disease, length of stay 0 days, no complications, not a high volume center, and Northeast Region.

Figure 2.

Change in inflation-adjusted total charges for various pediatric procedures over time. Percent change in charges over time for various pediatric surgical and catheter-based procedures are shown. Charges are adjusted to 2009 dollars, so the percent change illustrated represents changes above the indexed inflation rate for medical care services.

TABLE 1

Sample Characteristics by Year

	1997	2000	2003	2006	2009	Total
Discharges for ablation: n	1,463	1,336	1,473	1,545	1,313	7,130
Age						
Years: mean $\pm$ std deviation	12.2 $\pm$ 0.3	12.4 $\pm$ 0.2	12.1 $\pm$ 0.1	12.1 $\pm$ 0.1	11.9 $\pm$ 0.1	
<4 years: n (%)	60 (4)	74 (6)	94 (6)	118 (8)	113 (9)	
10 years: n (%)	420 (29)	368 (28)	442 (30)	442 (29)	418 (32)	
>10 years: n (%)	1,043 (71)	968 (72)	1,031 (70)	1,103 (71)	895 (68)	
Gender: n (%)						
Male	807 (55)	739 (55)	809 (55)	900 (59)	745 (57)	
Female	656 (45)	597 (45)	658 (45)	634 (41)	565 (43)	
Payer: %						
Medicaid	16	15	20	26	30	
Private	76	78	73	66	63	
Self pay	3	2	1	1	1	
Other	5	5	6	7	6	
Arrhythmia Diagnosis: n (%) [†]						
Supraventricular tachycardia	954 (65)	763 (57)	806 (55)	837 (54)	701 (53)	
Ventricular tachycardia	122 (8)	111 (8)	142 (10)	134 (9)	92 (7)	
Atrial fibrillation/flutter	80 (5)	124 (9)	109 (7)	116 (7)	107 (8)	
Cardiac diagnosis: n (%) [†]						
Congenital heart disease	119 (8)	112 (8)	133 (9)	175 (11)	180 (14)	
Valvular heart disease	45 (3)	20 (1)	37 (3)	39 (3)	54 (4)	
Cardiomyopathy	38 (3)	44 (3)	68 (5)	59 (4)	48 (4)	
Hospital region: % of discharges						
Northeast	32	29	37	32	27	
Midwest	19	15	21	19	18	
South	29	30	26	31	40	
West	20	26	16	18	15	
Hospital type: n (%)						

	1997	2000	2003	2006	2009	Total
Not children's hospital	357 (24)	408 (31)	327 (22)	307 (20)	289 (22)	
Children's hospital	366 (25)	322 (24)	486 (33)	466 (30)	255 (19)	
Children's unit	740 (51)	593 (44)	628 (43)	681 (44)	592 (45)	
Missing	0 (0)	12 (1)	32 (2)	90 (6)	178 (14)	
Teaching hospital Discharges: n (%)	1,298 (89)	1,202 (90)	1,297 (89)	1,408 (93)	997 (86)	
Length of stay, days						
Mean $\pm$ std deviation	1.9 $\pm$ 0.2	2 $\pm$ 0.2	2.3 $\pm$ 0.1	2.4 $\pm$ 0.1	3 $\pm$ 0.1	
(Range)	(0-58)	(0-44)	(0-71)	(0-168)	(0-82)	
Complications: n (%)						8%
Atrioventricular block	61 (4)	39 (3)	64 (4)	52 (3)	57 (4)	
Cardiac	53 (4)	29 (2)	38 (3)	39 (3)	49 (4)	
Respiratory	15 (1)	11 (1)	20 (1)	22 (1)	28 (2)	
Procedural	22 (1)	18 (1)	20 (1)	21 (1)	21 (2)	
Mortality: n (%)	— [‡]	— [‡]	— [‡]	— [‡]	— [‡]	— [‡]

[‡] Diagnoses were identified in a nonhierarchical fashion; that is, patients may have more than one diagnosis.

[‡] Cells based on 10 or fewer observations were suppressed due to the HCUP data use agreement.

TABLE 2

Mean Total Charges by Year and by Variable

Variable: \$, mean $\pm$ standard error (adjusted to 2009 dollars)	1997	2000	2003	2006	2009
All	23,798 $\pm$ 1,072	31,954 $\pm$ 1,509	44,977 $\pm$ 1,780	59,446 $\pm$ 1,843	75,831 $\pm$ 2,065
Range of charges	902-416,428	124-371,259	188-847,549	2,193-1,047,132	455-1,025,298
Age					
<4 years	52,108 $\pm$ 7,302	47,447 $\pm$ 5,676	91,450 $\pm$ 8,599	155,642 $\pm$ 10,536	194,404 $\pm$ 13,209
4 years	22,597 $\pm$ 1,278	31,043 $\pm$ 1,580	41,823 $\pm$ 2,144	51,465 $\pm$ 1,859	64,697 $\pm$ 1,604
Payer					
Medicaid	31,117 $\pm$ 4,228	42,433 $\pm$ 4,552	50,284 $\pm$ 2,850	69,404 $\pm$ 3,201	98,232 $\pm$ 4,079
Private	22,124 $\pm$ 1,310	29,950 $\pm$ 1,235	43,730 $\pm$ 1,847	54,892 $\pm$ 1,672	64,487 $\pm$ 2,374
Self pay	22,946 $\pm$ 2,246	35,188 $\pm$ 4,297	66,846 $\pm$ 16,346	55,268 $\pm$ 2,718	— [†]
Other	24,808 $\pm$ 2,336	34,169 $\pm$ 4,227	36,342 $\pm$ 3,091	67,253 $\pm$ 4,751	83,214 $\pm$ 4,017
Other cardiac diagnosis					
Congenital heart disease	47,430 $\pm$ 5,143	65,942 $\pm$ 5,531	85,170 $\pm$ 5,493	122,812 $\pm$ 7,374	166,005 $\pm$ 7,886
Acquired valvular disease	43,053 $\pm$ 9,303	42,142 $\pm$ 2,556	124,371 $\pm$ 18,481	113,989 $\pm$ 9,305	170,584 $\pm$ 18,568
Cardiomyopathy	50,390 $\pm$ 10,008	55,183 $\pm$ 5,047	162,887 $\pm$ 18,623	108,512 $\pm$ 10,249	105,825 $\pm$ 3,020
Region					
Northeast	19,700 $\pm$ 1,215	33,478 $\pm$ 4,543	33,810 $\pm$ 951	48,942 $\pm$ 2,375	64,086 $\pm$ 5,008
Midwest	24,786 $\pm$ 990	28,148 $\pm$ 2,083	48,582 $\pm$ 2,977	61,911 $\pm$ 3,234	77,668 $\pm$ 4,801
South	27,944 $\pm$ 2,889	32,500 $\pm$ 994	51,690 $\pm$ 3,596	59,044 $\pm$ 3,562	70,396 $\pm$ 2,906
West	23,289 $\pm$ 2,697	31,730 $\pm$ 2,205	55,516 $\pm$ 5,778	76,759 $\pm$ 4,759	108,380 $\pm$ 5,341
High volume center status	24,677 $\pm$ 2,130	27,676 $\pm$ 1,770	37,839 $\pm$ 1,257	53,829 $\pm$ 3,699	69,414 $\pm$ 4,984
Length of stay					
0 days	17,971 $\pm$ 1,947	21,435 $\pm$ 1,157	30,661 $\pm$ 1,417	38,627 $\pm$ 1,386	50,790 $\pm$ 1,406
1 day	18,008 $\pm$ 1,428	25,844 $\pm$ 1,397	32,431 $\pm$ 1,530	44,555 $\pm$ 1,457	52,405 $\pm$ 950
2 days	25,065 $\pm$ 1,912	32,384 $\pm$ 1,539	45,950 $\pm$ 1,229	66,681 $\pm$ 5,363	81,835 $\pm$ 5,771
3 days	51,644 $\pm$ 4,182	65,343 $\pm$ 5,485	113,367 $\pm$ 7,761	122,864 $\pm$ 4,922	147,105 $\pm$ 5,399
Complications	46,334 $\pm$ 5,816	62,733 $\pm$ 3,362	126,866 $\pm$ 13,966	114,744 $\pm$ 10,160	173,248 $\pm$ 8,910
No Complications	21,771 $\pm$ 1,123	29,985 $\pm$ 1,576	38,202 $\pm$ 1,534	55,114 $\pm$ 2,002	65,254 $\pm$ 1,716

[†] Cells based on 10 or fewer observations were suppressed due to the HCUP data use agreement.

TABLE 3

Multivariable Model for Predictors of Increased Charges and Costs for Pediatric Catheter Ablation

Variable	Change in Charges (R ² = 0.52)	P Value	Change in Costs (R ² = 0.43)	P Value
	% (95% CI)		% (95% CI)	
Year		<0.0001		<0.0001
1997	−65 (−69, −62)		− [†]	
2000	−53 (−57, −47)		− [†]	
2003	−34 (−39, −28)		−13 (−20, −6)	
2006	−10 (−17, −3)		+2 (−6, +10)	
2009	0 [‡]		0 [‡]	
Age				
<4 years	0 (−8, +9)	0.98	+1 (−8, +12)	0.76
4 years	0 [‡]		0 [‡]	
Payer		0.0002		0.003
Medicaid	−3 (−10, +6)		+1 (−6, +9)	
Private	0 [‡]		0 [‡]	
Self pay	+12 (+3, +23)		+15 (+4, +28)	
Other	+7 (−2, +16)		+9 (0, +19)	
Arrhythmia diagnosis				
Supraventricular tachycardia	0 [‡]	0.06	0 [‡]	0.59
Atrial fibrillation/flutter	+3 (−5, +11)	0.17	−2 (−10, +7)	0.35
Other cardiac diagnosis				
Congenital heart disease	+17 (+8, +27)	<0.0001	+13 (+4, +23)	<0.0001
Valvular heart disease	+13 (+3, +24)	0.0004	+23 (+12, +35)	<0.0001
Cardiomyopathy	+10 (0, +20)	0.0009	+15 (+4, +27)	<0.0001
Length of stay		<0.0001		<0.0001
0 days	0 [‡]		0 [‡]	
+ 1 day	+13 (+6, +21)		+12 (+4, +19)	
+ 2 days	+28 (+19, +37)		+25 (+17, +33)	
Complications				
Yes	+20 (+6, +37)	<0.0001	+31 (+18, +47)	<0.0001
No	0 [‡]		0 [‡]	
Volume by region		<0.0001		<0.0001
High volume center				
Northeast	−27 (−32, −21)		−26 (−34, −17)	
Midwest	+47 (+20, +80)		+16 (+9, +24)	
South	+37 (+21, +54)		−13 (−22, −3)	
West	−15 (−23, −7)		+17 (+10, +24)	
Not-high volume center				
Northeast	0 [‡]		0 [‡]	

Variable	Change in Charges (R ² = 0.52)	P Value	Change in Costs (R ² = 0.43)	P Value
Midwest	+12 (+5, +20)		−7 (−11, −2)	
South	+19 (+11, +27)		−8 (−13, −3)	
West	+35 (+25, +44)		+15 (+6, +24)	

[†]No cost data available.

[‡]Reference: 2009, age 4 years, private payer, SVT diagnosis, lack of structural cardiac disease, length of stay 0 days, no complications, not a high volume center, and Northeast region.