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Accuracy of the All Patient Refined Diagnosis Related Groups Classification System in Congenital Heart Surgery

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Abstract

Background—Administrative data is increasingly used to evaluate clinical outcomes and quality of care in pediatric congenital heart surgery (CHS) programs. Several published analyses of large pediatric administrative datasets have relied on the All Patient Refined Diagnosis Related Groups (APR-DRG, version 24) diagnostic classification system. The accuracy of this classification system for patients undergoing CHS is unclear.

Methods—We performed a retrospective cohort study of all 14,098 patients 0-5 years of age undergoing any of six selected congenital heart operations, ranging in complexity from isolated closure of a ventricular septal defect to single ventricle palliation, at 40 tertiary care pediatric centers in the Pediatric Health Information Systems database between 2007 and 2010. Assigned APR-DRGs (cardiac versus non-cardiac) were compared using chi-squared or Fisher's exact tests between those patients admitted during the first day of life versus later and between those receiving extracorporeal membrane oxygenation support versus not. Recursive partitioning was used to assess the greatest determinants of APR-DRG type in the model.

Results—Every patient admitted on day of life 1 was assigned to a non-cardiac APR-DRG ($p < 0.001$ for each procedure). Similarly, use of extracorporeal membrane oxygenation was highly associated with misclassification of congenital heart surgery patients into a non-cardiac APR-DRG ($p < 0.001$ for each procedure). Cases misclassified into a non-cardiac APR-DRG experienced a significantly increased mortality ($p < 0.001$).

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Conclusions—In classifying patients undergoing congenital heart surgery, APR-DRG coding has systematic misclassifications, which may result in inaccurate reporting of CHS case volumes and mortality.

Keywords

Congenital Heart Disease, CHD; Pediatric; Neonate; Extracorporeal Membrane Oxygenation, ECMO; Outcomes

Introduction

Public reporting of outcome data will soon be mandated of pediatric medicine. The field of congenital heart surgery (CHS) will not be exempt from this expectation and may face significant challenges in providing transparent yet meaningful reporting [1-3]. Accurate reporting regarding CHS case volumes and outcomes requires accurate classification of cases and appropriate risk adjustment. Previous studies have illustrated problems with case ascertainment in administrative datasets [4-8]. The All Patient Refined Diagnosis Related Groups (APR-DRG) diagnostic classification system is employed in many large pediatric administrative databases, which are often used in clinical research [9-14]. The APR-DRG system is a classification system developed by a third party company and widely used by many hospital administrators and reimbursement entities to evaluate the severity of illness and risk of mortality across all patients admitted for inpatient care for the purpose of reimbursement and financial planning. While there have been some studies evaluating the ability of APR-DRG severity of illness scores to predict mortality [15-17], to our knowledge, there have been no studies evaluating the accuracy of the APR-DRG classification system in classifying patients for the purpose of reporting clinical outcomes. In the population undergoing CHS, misclassification of patients into incorrect APR-DRGs may impact the reporting of case volumes and mortality.

We therefore sought to evaluate the accuracy of the APR-DRG (version 24) classification system in patients undergoing CHS. We identified 6 separate cohorts of patients who underwent CHS during admission on the basis of their diagnoses and procedures. We principally evaluated the assigned APRDRG for each patient to determine if they were accurately assigned into cardiac versus non-cardiac APRDRGs. We also performed secondary analyses to determine the effect of hospital case volume on misclassification and to evaluate the impact misclassification had on mortality in the assigned APR-DRG groups.

Patients and Methods

Institutional Review Board Oversight

Our IRB determined that this study of a de-identified dataset did not meet the definition of human subjects research (45 CFR 46.102(f)).

Data Source

Data was obtained from the Pediatric Health Information System (PHIS) database, maintained by the Children's Hospital Association, CHA (Kansas City, Kansas). The PHIS

database is a large inpatient administrative database containing discharge data from 43 freestanding children's hospitals representing most major metropolitan areas in the United States. A joint effort between participating hospitals, a data manager (Thomson-Reuters, Durham, NC), and the CHA ensures maintenance of data quality and reliability. Three hospitals without detailed clinical services information were excluded from this study.

Study Population

All patients 0-5 years of age undergoing isolated closure of a ventricular septal defect (VSD), arterial switch operation for d-transposition of the great vessels, with or without VSD (D-TGA), Tetralogy of Fallot repair (TOF), or surgical palliation for hypoplastic left heart syndrome (HLHS) via stage 1 palliation (stage 1), superior cavopulmonary anastomosis (stage 2), or Fontan completion (Fontan) at 40 tertiary care pediatric centers in the PHIS database between January 2007 and December 2010 were included (n = 14,098). Patients were identified using International Classification of Diseases, 9th edition, Clinical Modification (ICD9) diagnosis and procedure codes. Patients were included in the VSD cohort if they had a combination of the ICD9 diagnosis code for VSD (745.4) and one of the following procedure codes for VSD repair: prosthetic repair of VSD, open (35.53), prosthetic repair of VSD, closed (35.55), tissue repair of VSD (35.62), or unspecified repair of VSD (35.72). Patients were included in the TOF cohort if they had a both an ICD9 diagnosis code for TOF (745.2) and one of the following procedure code combinations: TOF complete repair (35.81), prosthetic or tissue repair of VSD and placement of an RV to PA conduit (35.53 and 35.92 or 35.62 and 35.92), prosthetic or tissue repair of VSD and infundibulectomy (35.53 and 35.34 or 35.62 and 35.34). Patients were included in the D-TGA cohort if they had a diagnosis code for transposition of the great vessels (745.10) and a procedure code for an arterial switch operation (35.84). Patients were included in the HLHS stage 1 cohort if they had a diagnosis code for HLHS (746.7) and one of the following procedure codes: systemic to pulmonary artery shunt (39.0) or RV to PA conduit (35.92). Patients were included in the HLHS stage 2 cohort if they had a diagnosis code for HLHS (746.7) and a procedure code for cavopulmonary anastomosis (39.21). Patients were included in the Fontan cohort if they had a diagnosis code for HLHS (746.7) and a procedure code for Fontan completion (35.94).

Exclusion Criteria

Patients were excluded if they were diagnosed with pulmonary hypertension or bronchopulmonary dysplasia, as these patients were likely to have extreme prematurity and extended NICU admission length, higher rate of tracheostomy, and more likely need for ECMO support. Inclusion of these patients would potentially have biased our results given that our primary independent variables included being admitted on DOL1 and receiving ECMO.

Data Collection

Data elements collected from the PHIS database included: age at admission, race, gender, payer source, US region, hospital volume, ECMO status, in-hospital mortality, assigned service line (such as cardiac or neonatology), and assigned APR-DRG. APR-DRGs were classified as cardiac or non-cardiac according to an internal classification algorithm (within

the PHIS database) assigning patients to specific service lines, including a medical cardiac service line and a surgical cardiac service line. Cardiac APR-DRGs were defined as any APR-DRG within the medical or surgical cardiac service lines.

Variables

The dependent variable was APR-DRG type (cardiac versus non-cardiac). The primary independent variables were dichotomous variables defined as whether the patient was admitted on DOL1 versus after and whether the patient received ECMO during the hospitalization or not. Internal data survey performed for quality improvement purposes strongly suggested that these variables may be important in determining APR-DRG classification. Other variables included patient gender, payer source, US region, and mortality (categorical variables) as well as hospital case volume and patient age in days (continuous variables).

Statistical Analyses

Population demographics were described using standard summary statistics. Assigned APR-DRGs (cardiac versus non-cardiac) were compared using chi-squared or Fisher's exact tests. The relationship between both the hospitals' volume of each cardiac cohort as well as the mortality rate by hospital and the percent of cases for each cohort that was coded as a cardiac APR-DRG was tested using linear regression. Secondary analyses were performed on all 6 individual cohorts and the overall combined cohort including those patients initially excluded due to a diagnosis of bronchopulmonary dysplasia or pulmonary hypertension. We set statistical significance for all tests at $p < 0.05$. All of the above analyses were performed using Stata 12.1 (Stata Corp, College Station, TX).

To identify factors associated with the patients' final APR-DRG coding status (as cardiac or non-cardiac), we used recursive partitioning (using the Gini coefficient to determine optimal partitions) via Decision Tree in SAS Enterprise Miner 4.3 (SAS Institute Inc., Cary, NC, USA). Predictors included categorical variables (patient gender, payer source, US region, whether the patient was admitted on DOL1, and whether the patient received ECMO) and one continuous variable (patient age in days). All of the analyses described above were performed in each of six individual cohorts, defined by diagnosis and procedure type (VSD, D-TGA, TOF, stage 1, stage 2, Fontan) as well as on the combined cohort containing all 6 of these individual cohorts.

Results

Study Population

A total of 14,098 admissions from 40 centers (23% Midwest, 19% Northeast, 33% South, 25% West) were included. Combining all 6 individual cohorts, individual hospital case volumes ranged from 8 to 890 (IQR 290, 679). The overall mean unadjusted mortality rate for all cohorts was 3.59%. 15.2% ($n = 2150$) were admitted on the first day of life and 84.8% ($n=11,948$) were admitted after the first day of life. 3.7% ($n=526$) received ECMO support during their hospitalization and 96.3% ($n=13,572$) did not. Study population characteristics are displayed in Table 1.

Patient Characteristics and APR-DRG coding

In each individual cohort evaluated, every patient admitted on DOL1 for the hospitalization in which their surgical repair occurred was classified as non-cardiac according to the APR-DRG coding schema utilized by the PHIS database (Table 2). In each individual cohort as well as the group combined as a whole, the association between admission on the first day of life and non-cardiac APR-DRG assignment was statistically significant ($p < 0.001$).

Clinical Characteristics and APR-DRG coding

In all 6 individual cohorts, every patient receiving ECMO support during their hospitalization (except one patient in TOF cohort) was classified as non-cardiac according to the APR-DRG coding schema (Table 2). In all 6 cohorts as well as the group combined as a whole, the association between ECMO support and non-cardiac APR-DRG assignment was statistically significant ($p < 0.001$). As the percent of patients receiving ECMO support increased, the number of patients coded as non-cardiac increased.

Hospital Case Volume and APR-DRG coding

In the overall combined cohort (Figure 1), as the hospital case volume increased, the percentage of cases coded as cardiac APR-DRG significantly decreased ($p < 0.001$), with notable variation across the hospitals. The same relationship was observed in the individual cohorts (Figures 2a and 2b).

Mortality Rate and APR-DRG Coding

APR-DRG type (cardiac versus non-cardiac) was significantly associated with individual patient's mortality outcome: cardiac APR-DRG patients had 0.67% mortality, while non-cardiac APR-DRG patients had 10.61% mortality ($p < 0.001$). Accordingly, among the hospitals, as the percentage of patients coded as cardiac APR-DRG decreased, hospital mortality of cardiac APR-DRG patients increased significantly ($p = 0.017$) (Figure 3; The circle size in this figure represents the relative hospital volume.)

Empirical Algorithm for APR-DRG Classification

We used recursive partitioning to identify factors associated with classifying patients into cardiac versus non-cardiac APR-DRGs. When all 6 groups were combined and analyzed as a single cohort, 2 factors were highly informative: whether the patient was admitted before or after day of life 7 (using the continuous variable of age in days, the model identified a threshold of 7 days as an important determinant of classification into cardiac or non-cardiac APR-DRG), and whether or not the patient received ECMO support, both of which were associated with classification into non-cardiac APR-DRGs (Figure 4). In the D-TGA cohort, the only factor predicting classification into non-cardiac APR-DRG was admit age ≥ 7 days (Figure 5a). In the VSD, TOF, HLHS stage 1, and HLHS stage 2 cohorts the primary factor predicting a non-cardiac APR-DRG classification was admit age ≥ 7 days, followed by receipt of ECMO support (Figure 5a and Figure 5b). For the Fontan cohort, the primary predictor for classification as a non-cardiac APR-DRG was ECMO support, followed by admit age in days < 131 days (Figure 5b). In all 6 cohorts, as well as in the combined group,

we found that the mortality was significantly higher in the patients classified as non-cardiac APR-DRG as compared to those classified as cardiac.

Cardiac Versus Non-Cardiac Service Line and APR-DRG Coding

In the overall cohort, nearly 30% of patients were classified into a non-cardiac APR-DRG (Table 3). Within this non-cardiac group, a large proportion were assigned APR-DRGs in a neonatology service line. Of note, in the D-TGA and the HLHS stage 1 cohorts, each had >80% of patients classified in a neonatology service line and a greater mortality in the non-cardiac as compared to the cardiac APR-DRG patients.

Analysis of the Impact of Exclusion Criteria

To ensure that our exclusion of patients with pulmonary hypertension and bronchopulmonary dysplasia did not bias our results, we performed a secondary analysis including these patients in all 6 individual cohorts. The results of these repeat analyses were consistent with those of the initial sample which excluded these patients. With these patients included, the overall sample size increased in each individual cohort, most notably in the VSD and D-TGA cohorts (from 6281 to 7201 cases for the VSD cohort and from 1360 to 1443 cases for the D-TGA cohort). We again found the following: every patient admitted on DOL1 was assigned to a non-cardiac APR-DRG ($p < 0.001$ for each cohort); the use of ECMO was highly associated with misclassification of CHS patients to a non-cardiac APR-DRG ($p < 0.001$ for each cohort); and the misclassification as a non-cardiac APR-DRG was significantly associated with increased mortality ($p < 0.001$).

Comment

In our study we found that a significant proportion of patients undergoing surgical repair or palliation for a congenital heart defect were classified into non-cardiac APR-DRGs. We demonstrated a significant association between assignment of non-cardiac APR-DRGs and either admission on DOL1 or the use of ECMO. We found that in nearly every cohort, there was a significant association between greater hospital case volume and a larger percent of cases coded as non-cardiac APR-DRGs. One plausible explanation for this might be increased utilization of ECMO at larger hospitals as well as the increased likelihood for larger hospitals having birthing centers for infants with prenatally diagnosed cardiac disease or having a level III nursery receiving newborn referrals on DOL1 of infants with suspected congenital heart disease.

This study provides a novel approach to the evaluation of the accuracy of the APR-DRG classification system in patients undergoing CHS. The analysis was performed in 6 individual cohorts of patients undergoing different surgical procedures and found consistent results across all individual cohorts and as a combined group.

The APR-DRG risk of mortality and severity of illness categories have been used in research for risk adjustment purposes when analyzing outcomes. These measures were created, however, for risk adjustment purposes in the setting of reimbursement, resource allocation, and financial planning. Little is known about the accuracy of these measures when utilized for risk adjustment in clinical research studies or quality reporting. The risk of

mortality and severity of illness categories are assigned within each APR-DRG category and are not comparable across different APR-DRG groups. The fact that many patients undergoing CHS are not classified into cardiac APR-DRGs makes utilizing the risk of mortality and severity of illness scores for risk adjustment in clinical research and quality reporting inaccurate.

The problem with misclassification identified in this study may not be limited to the population of patients undergoing CHS. Given that a large proportion of these patients, and often those with the highest mortality, are classified into APR-DRGs in a neonatology service line, this suggests that these inaccuracies may have ripple effects on reporting of outcome data in other clinical realms. In addition, these misclassifications may also lead to inaccurate data provided to hospital administrators for the purpose of determining appropriate resource allocation across service lines.

Limitations

The major limitation of our study is due to the manner of ICD9 coding in regard to congenital heart defects and congenital heart surgeries. Specifically, there is currently no ICD9 code for the Norwood procedure (one approach used for HLHS stage 1 palliation). We were able to address this limitation, however, by utilizing a rigorous search strategy combining both ICD9 diagnosis codes for HLHS and procedure codes for individual components of the operation. More importantly, the results of the analyses in the HLHS stage 1 cohort were similar to those in the other 5 cohorts. We therefore believe that it is unlikely that this search strategy resulted in any significant selection bias causing the cohort to be systematically different than the other 5 cohorts.

Conclusions

APR-DRG coding has important inaccuracies in the classification of patients undergoing CHS. Admission on DOL1 and use of ECMO support are significantly associated with non-cardiac APR-DRG assignment. These systematic misclassifications will result in inaccurate reporting of CHS case volumes and outcomes.

Furthermore, in nearly every cohort, as hospital volume increases, the percent of cases coded as cardiac decreases. This may be due to the influence of increased ECMO use and a larger proportion of inborn or early admissions at larger centers. Additionally, as the percent of cases coded as cardiac APR-DRGs decreases, the mean mortality by hospital increases, demonstrating a statistically significant inverse association between hospital mortality and cardiac APR-DRG status. This data suggests that public reporting of outcomes, particularly for center comparison, utilizing the APR-DRG classification system might lead to flawed conclusions. The nature and implications of these issues warrant further scrutiny, as the effects of APR-DRG misclassification likely reach far beyond the population of patients undergoing CHS.

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Abbreviations and Acronyms

APR-DRG	All Patient Refined Diagnosis Related Groups
CHS	congenital heart surgery
DOL1	day of life 1 admission
D-TGA	D-transposition of the great arteries, with or without VSD
ECMO	extracorporeal membrane support oxygenation
Fontan	Fontan palliation completion
HLHS	hypoplastic left heart syndrome
ICD9	using International Classification of Diseases, 9 th edition Clinical Modification
PHIS	Pediatric Hospital Information Systems
Stage 1	Stage 1 in Fontan palliation for HLHS
Stage 2	Stage 2 in Fontan palliation for HLHS
TOF	Tetralogy of Fallot
VSD	ventricular septal defect

Figure 1.

Scatter plots illustrating the relationship between hospital case volume and APR-DRG coding for overall cohort (Figure 1) and individual cohorts (Figures 2a and 2b). [Lines fitted and p value obtained using linear regression]

Figure 2.

a and b. Scatter plots illustrating the relationship between hospital case volume and APR-DRG coding for overall cohort (Figure 1) and individual cohorts (Figures 2a and 2b). [Lines fitted and p value obtained using linear regression]

Figure 3. Scatter plot illustrating the relationship between APR-DRG coding status and mean hospital mortality. [Lines fitted and P value obtained using linear regression. Circle sizes are proportional to the hospitals' volume of cardiac cases.]

Figure 4.

Schematic representations of recursive partitioning analysis illustrating variables most predictive of non-cardiac APR-DRG status for the overall cohort (Figure 4) and for individual cohorts (Figures 5a and 5b).

Figure 5.

a and b. Schematic representations of recursive partitioning analysis illustrating variables most predictive of non-cardiac APR-DRG status for the overall cohort (Figure 4) and for individual cohorts (Figures 5a and 5b).

Table 1
Study population characteristics for the combined overall cohort as well as for each of the 6 individual cohorts included in the study

	Overall	VSD	D-TGA	TOF	Stage 1	Stage 2	Fontan
No. hospitals	40	40	39	39	39	39	38
No. patients	14,098	6281	1360	3168	1778	1216	1004
Case volume	8 – 890	5 –413	2-76	6-216	1-145	1-108	1-129
(IQR)	(290,679)	(130,283)	(29,61)	(65, 154)	(35, 97)	(27, 64)	(17, 51)
<u>Gender N (%)</u>							
Female	6006 (43)	2998 (48)	418 (31)	1367 (43)	687 (39)	438 (36)	373 (37)
Male	8091 (57)	3282 (52)	942 (69)	1801 (57)	1091 (61)	778 (64)	631 (63)
<u>Race N (%)</u>							
White	9012 (64)	3845 (61)	884 (65)	1973 (62)	1171 (66)	858 (71)	731 (73)
Black	1719 (12)	813 (13)	111 (8)	431 (14)	198 (11)	123 (10)	127 (13)
Asian	480 (3)	273 (4)	45 (3)	129 (4)	33 (2)	17 (1)	10 (1)
American Indian	233 (2)	94 (2)	17 (1)	51 (2)	30 (2)	26 (2)	19 (2)
Other	1990 (14)	937 (15)	231 (17)	434 (14)	257 (14)	143 (12)	88 (9)
Missing	664 (5)	319 (5)	72 (5)	150 (5)	89 (5)	49 (4)	29 (3)
<u>Admit age, days N (%)</u>							
7	3764 (27)	1090 (17)	1184 (87)	271 (9)	1522 (86)	62 (5)	9 (1)
8-30	536 (4)	327 (5)	85 (6)	105 (3)	55 (3)	3 (0)	1 (0)
31-180	4661 (33)	2223 (35)	50 (4)	1588 (50)	107 (6)	799 (66)	30 (3)
181-365	2353 (17)	1234 (20)	19 (1)	819 (26)	48 (3)	288 (24)	28 (3)
366-730	1101 (8)	738 (12)	12 (1)	272 (9)	16 (1)	16 (1)	71 (7)
>730	1683 (12)	669 (11)	10 (1)	113 (4)	30 (2)	48 (4)	865 (86)
<u>DOLI Admit N (%)</u>							
YES	2150 (15)	473 (8)	726 (53)	135 (4)	984 (55)	46 (4)	4 (0)
NO	11948 (85)	5808 (92)	634 (47)	3033 (96)	794 (45)	1170 (96)	1000(100)
<u>ECMO support N (%)</u>							
YES	526 (4)	113 (2)	75 (6)	64 (2)	276 (16)	42 (3)	16 (2)
NO	13572 (96)	6168 (98)	1285 (94)	3104 (98)	1502 (84)	1174(97)	988 (98)

Table 2
Association between admission on day of life 1 or ECMO utilization and APR-DRG coding

<i>All patients admitted on DOLI, by individual cohort</i>			
	CARDIAC APR-DRG	NON-CARDIAC APR-DRG	P value
VSD	0	473	<0.001
TOF	0	135	<0.001
D-TGA	0	726	<0.001
Stage 1	0	984	<0.001
Stage 2	0	46	<0.001
<i>All patients receiving ECMO support, by individual cohort</i>			
	CARDIAC APR-DRG	NON-CARDIAC APR-DRG	P value
VSD	0	113	<0.001
TOF	1	63	<0.001
D-TGA	0	75	<0.001
Stage 1	0	276	<0.001
Stage 2	0	42	<0.001
Fontan	0	16	<0.001

P values obtained using Chi² or Fisher's exact test.

Table 3
Assigned service lines as a result of APR-DRG coding in patients undergoing CHS

	All 6 cohorts combined	VSD	TOF	d-TGA	Stage 1	Stage 2	Fontan
Cardiac Care	9961 (70.66)	5016 (79.86)	2810 (88.70)	158 (11.62)	221 (12.43)	1099 (90.38)	974 (97.01)
Neonatal Care	3656 (25.93)	1069 (17.02)	263 (8.30)	1157 (85.07)	1458 (82.00)	57 (4.69)	9 (0.90)
Other Surgery	282 (2.00)	130 (2.07)	69 (2.18)	14 (1.03)	28 (1.57)	37 (3.04)	21 (2.09)
Ungroupable	119 (0.84)	32 (0.51)	14 (0.44)	30 (2.21)	55 (3.09)	3 (0.25)	0 (0.00)
Other service lines[*]	80(0.58)	34(0.54)	12 (0.37)	1 (0.07)	16 (0.9)	20 (1.64)	0 (0.00)

All data reported as N (column %).

* Other service lines represented include respiratory service, solid organ transplants, infectious disease, digestive disease, other medicine, and neuroscience service. Less than 2% of total in each cohort is distributed among these other service lines.