Diagnostic Errors in Pediatric Echocardiography
Development of Taxonomy and Identification of Risk Factors

Oscar J. Benavidez, MD, MPP; Kimberlee Gauvreau, ScD; Kathy J. Jenkins, MD, MPH; Tal Geva, MD

Background—Despite increased interest in complications within pediatric cardiology, the domain of imaging-related diagnostic errors has received little attention. We developed a new taxonomy for diagnostic errors within pediatric echocardiography that categorizes errors by severity, preventability, and primary contributor. Our objectives were to examine its findings when applied to diagnostic error cases and to identify risk factors for preventable or possibly preventable diagnostic errors.

Methods and Results—Diagnostic errors were identified at a high-volume academic pediatric cardiac center from December 2004 to August 2007. Demographic, clinical, and situational variables were collected from these cases and controls. During the study period, 18,000 echocardiograms were performed. Among the 87 diagnostic error cases identified, 70% affected clinical management or the patient was at risk of or experienced an adverse event. One third of the errors were preventable and 46% were possibly preventable; 69% of preventable errors were of moderate severity or greater. Univariate analysis demonstrated that preventable or possibly preventable errors were more likely to involve younger patients, lower body weight, study location, sedated/anesthetized patients, studies performed and interpreted at night, uncommon diagnoses, and greater anatomic complexity than controls. Multivariate analysis identified the following risk factors: rare or very rare diagnoses (adjusted odds ratio [AOR], 9.2; \(P < 0.001\)), study location in the recovery room (AOR, 7.9; \(P < 0.001\)), moderate anatomic complexity (AOR, 3.5; \(P = 0.004\)), and patient weight <5 kg (AOR, 3.5; \(P = 0.031\)).

Conclusions—A diagnostic error taxonomy and knowledge of risk factors can assist in identification of targets for quality improvement initiatives that aim to decrease diagnostic error in pediatric echocardiography. (Circulation. 2008;117:2995-3001.)

Key Words: diagnostic errors ■ echocardiography ■ congenital heart disease ■ pediatrics

Congenital heart disease (CHD) is among the most prevalent malformations among infants and is the leading cause of death from congenital malformations.1 Echocardiography is the first line of investigation in this patient population, and timely treatment depends on this test. Delayed or inaccurate diagnoses place children with CHD at risk for adverse outcome. Despite increased interest in complications within pediatric cardiology, the domain of imaging-related diagnostic errors has received little attention.2–4 Previous studies examining the diagnostic accuracy of pediatric echocardiography were published mostly during the era when the modality was being established as a valid means for diagnosing CHD.5–8 However, none of these studies has systematically examined severity, preventability, and root causes for diagnostic error, and currently, no method exists to categorize diagnostic errors.

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The lack of methods to categorize pediatric echocardiography diagnostic errors and their causes is a barrier to quality improvement for patients with CHD.9 A taxonomy for pediatric/congenital echocardiography diagnostic errors may lead to improved quality of patient care by identifying and prioritizing areas in need of improvement.9

In this study, we describe a taxonomy for diagnostic errors within pediatric echocardiography to categorize errors by type, severity, preventability, and primary contributor. Our objectives were to examine its application to diagnostic error cases identified in a high-volume pediatric echocardiography laboratory and to identify risk factors for preventable or possibly preventable diagnostic errors.

Data Source

The Echocardiography Laboratory at Children’s Hospital Boston performs ~18,000 echocardiograms annually, including transthoracic, transesophageal, fetal, and intraoperative examinations. These studies are performed in myriad locations, including echocardiogra-
Dextrocardia, superior-inferior ventricles with criss-cross arteries, and rarely complex anatomic diagnoses or rare, complex anomalies, such as hypoplastic left heart syndrome, transposition of the great arteries, and ventricular septal defect. The diagnostic echocardiography staff cardiologists interpret all studies and issue a report, which is stored electronically in the electronic medical record records of the hospital. The pediatric echocardiography staff cardiologists’ interpretations were the focus of this study.

**Diagnostic Error Case Ascertainment**

Since December 2004, as part of a quality improvement initiative in the Noninvasive Cardiology Division, data related to diagnostic error cases were collected prospectively through a voluntary reporting mechanism and active quality assurance mechanisms. The latter comprised a secondary review of echocardiograms of all patients before undergoing cardiac surgery. A diagnostic error was defined as a diagnosis that is unintentionally delayed, wrong, or missed as judged from eventual appreciation of the existing data or more definitive information. The sources of diagnostic error case discovery included information gleaned from other tests (eg, cardiac catheterization, magnetic resonance imaging), operative observations, subsequent echocardiographic examinations, and autopsy.

**Data Collected**

The following patient demographic and case data were collected: age, referral diagnosis, weight, race, prematurity, anatomy involved in the diagnostic error, and study question. Other data obtained included study location, use of sedation or anesthesia, level of experience of the interpreting cardiologist (junior cardiologist was defined as having ≤3 years of experience), comments on image quality, and day of week and time of day that the study was performed and interpreted. Data related to the number of interim studies or procedures performed before the diagnostic error discovery, including the method of discovery and time from event to discovery, also were noted.

Diagnostic frequency, defined as the frequency a diagnosis is noted in the Echocardiography Laboratory, was categorized as follows: (1) frequent (diagnosis is observed more than once per week, eg, patent ductus arteriosus), (2) less frequent (diagnosis is observed more than once a month but less than once weekly, eg, coarctation of the aorta), (3) rare (diagnosis is observed more than once per year but less than once monthly, eg, inferior-type sinus venous defect), and (4) very rare (diagnosis is observed less than once yearly, eg, aortic–left ventricular tunnel).

Anatomic complexity data were divided into 3 categories: (1) low (no significant heart disease or a single, simple structural cardiovascular anomaly, eg, atrial septal defect or single membranous ventricular septal defect), (2) moderate (abnormalities involving >1 cardiovascular structure or diagnoses with moderately common characteristics, eg, complete common atrioventricular canal, hypoplastic left heart syndrome, and transposition of the great arteries), and (3) high (uncommon variants of moderately complex anatomic diagnoses or rare, complex anomalies, eg, dextrocardia, superior-inferior ventricles with criss-cross atrioventricular relations, hypoplastic right ventricle, and straddling mitral valve).

**Diagnostic Error Case Review Process**

Diagnostic error cases were reviewed by staff pediatric echocardiographers, including review of medical records and other diagnostic images in addition to the images of the study in question. Interviews with sonographers, trainees, cardiologists, and other involved health care providers were conducted to understand the conditions and the context in which the examination was performed and interpreted, to determine the clinical impact, and to identify a primary cause of the diagnostic error.

The relevant clinical and image data were presented at a monthly noninvasive morbidity and mortality conference. Case discussion included categorization of diagnostic error type, severity, preventability, and contributors or root causes. Participants in the conference include attending physicians, trainees, and technical staff from the noninvasive division, as well representatives from other divisions within the Department of Cardiology and other disciplines (eg, cardiacaesthesia and cardiovascular surgery). A consensus based on a review of the case and the ensuing discussion was used to finalize categorization of the diagnostic error type, severity, preventability, and root cause.

**Definitions and Classification of Diagnostic Errors**

Categorization framework for diagnostic errors was adapted and modified from the method used by the Program for Patient Safety and Quality at Children’s Hospital Boston and a review of current literature pertaining to diagnostic errors. Diagnostic error is defined as a diagnosis that is unintentionally delayed, wrong, or missed as judged from eventual appreciation of the existing data or more definitive information.

**Diagnostic Error Categorization**

**False Negative**

A false negative is an error that omits a finding or states that a finding is normal (or absent) when an abnormality is present or the reader failed to include a significant diagnostic possibility; eg, patent ductus arteriosus is ruled out or omitted when a patent ductus arteriosus is present.

**False Positive**

A false positive is an error that reports an abnormality but no abnormality is present or the reader overemphasized the significance of a finding; eg, an atrial septal defect is diagnosed when no atrial septal defect is present.

**Discrepant Diagnosis**

The actual diagnosis is different from the diagnosis made; eg, a diagnosis of double-inlet left ventricle is made when the actual diagnosis is tricuspid atresia.

**Severity Categorization**

**Minor**

The minor severity category includes diagnostic errors or discrepancies that do not change patient management or affect clinical course with little or no potential for adverse event, eg, a missed left superior vena cava to an intact coronary sinus in a patient with an otherwise structurally normal heart.

**Moderate**

The moderately severe category includes diagnostic errors or discrepancies with an impact on management in which the patient may be placed at risk for and/or have experienced a transient adverse event, eg, a missed primum atrial septal defect in an infant.

**Major**

This diagnostic error discrepancy has an impact on management that results in an adverse event, including performance of an unnecessary invasive procedure or long-lasting or permanent adverse event, eg, false-positive diagnosis of an atrial septal defect leading to an unnecessary surgery to close a defect that was not present.

**Catastrophic**

In this category, the diagnostic error or discrepancy contributed to patient death. An example is a missed anomalous coronary artery from the pulmonary artery that resulted in intraoperative myocardial ischemia and lead to patient demise.
Categorization of Preventability

Not Preventable
Diagnostic error is not preventable if the images, imaging modality, or imaging conditions do not permit diagnosis, eg, failure to image a ligamentum arteriosum contributing to a vascular ring.

Possibly Preventable
A diagnostic error is possibly preventable if an accurate diagnosis may be expected by the imaging modality and imaging conditions but may have required a different technique or condition, eg, an aortic arch anomaly that was missed because the aortic arch branching was incompletely examined.

Preventable
A diagnosis is preventable if an accurate diagnosis is expected by the available images, imaging modality, and imaging conditions. For example, an echocardiogram clearly demonstrates a patent ductus arteriosus, but the study is interpreted as no patent ductus arteriosus.

Diagnostic Error Cause Categorization
Table 1 catalogs factors contributing to diagnostic errors. The underlying causes of or contributors to the diagnostic error belong to one of the following rubrics: administrative error, procedural error, communication error, cognitive error, technical factor, and patient- or disease-related factors.

Administrative or Data Entry Errors
These errors typically precede the actual examination, eg, entering an examination report under an incorrect patient name.

Procedural or Conditional Factors
Procedural or conditional factors relate to the performance of the study or the conditions under which the examination is performed, eg, failure to adequately interrogate the entire ventricular septum by color Doppler in a cooperative patient, resulting in a missed apical ventricular septal defect.

Communication or Information Errors
Errors in information transfer to those performing and interpreting the examination or from those interpreting the study to the referring clinician. For example, the treating cardiologist is concerned about an intracardiac thrombus in a patient after Fontan palliation; however, this information was not communicated to those performing or interpreting the study. Instead, they were asked to rule out pericardial effusion. As a result, a limited echocardiogram is performed, leading to a missed diagnosis of an intracardiac thrombus.

Cognitive Errors
Cognitive errors occur during the analysis of the imaging and clinical data. For example, an echocardiogram is requested to estimate the pressure gradient across a right ventricle-to-pulmonary artery conduit in a patient who had an endovascular stent placed in the conduit. The conduit gradient is reported correctly; however, the readily apparent free-floating fractured stent in the right ventricle is not noted.

Technical Factors
These factors involve equipment malfunction or inherent limitations of echocardiography. Examples include an imaging artifact that creates the appearance of a vascular structure, which is then interpreted as an anomaly. Postoperative changes and obesity are examples of technical factors that can result in “poor acoustic windows,” which produce degraded or nondiagnostic image quality.

Patient- or Disease-Related Factors
These factors are related to the patient’s underlying diagnosis or physiology. For example, a tortuous left atrial appendage is mistaken for an aneurysm of the left coronary artery in a patient with Kawasaki disease.

Table 1. Contributors to Diagnostic Error

<table>
<thead>
<tr>
<th>Not Preventable</th>
<th>Possibly Preventable</th>
<th>Preventable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect name assigned to imaging data</td>
<td>Scheduling error</td>
<td>Incorrect data entry</td>
</tr>
<tr>
<td>Incorrect data entry</td>
<td>Procedural or conditional factors</td>
<td>Failure to confirm patient identity or diagnosis</td>
</tr>
<tr>
<td>Failure to image complete examination of anatomy or physiology</td>
<td>Poor imaging environment</td>
<td>Failure to improve imaging conditions when possible</td>
</tr>
<tr>
<td>Communication or information errors</td>
<td>Lacking or misleading patient history</td>
<td>No access to prior studies</td>
</tr>
<tr>
<td>Failure to report critical findings in a timely fashion to referring physician</td>
<td>Incorrect requisition (unintended or no clinical question asked)</td>
<td></td>
</tr>
</tbody>
</table>

Cognitive errors
- Insufficient knowledge base
- Insufficient technical skills
- Faulty data synthesis
  - Lack of consideration of a patient’s situation/condition that is relevant to diagnosis
  - Misidentification/interpretation of a finding on echocardiography
  - Premature closure of case
  - Distraction by other diagnoses, findings, or focused question
  - Underappreciation/consideration of a finding
  - Overappreciation of a finding
  - Confirmation bias
  - Incorrect or improper calculation

Technical factors
- Artifact
- Modality limitation
- Poor acoustic windows
- Equipment malfunction
- Patient- or disease-related factors
  - Rare or complex anatomy
  - Misleading anatomy or physiology

Statistical Analysis
The primary goal of the analysis was to identify factors associated with diagnostic errors related to postnatal echocardiography, including transesophageal, transesophageal, and intraoperative epicardial studies. Control cases were randomly selected (ratio of ~2.5 controls per diagnostic error case) by a statistical program (Stata/SE 9.2 for Windows, Stata Corp LP; College Station, Tex) from other cases undergoing an echocardiogram during the same calendar week that the diagnostic error occurred. The imaging data, reports, and medical records of those cases selected as controls were examined for the presence of unrecognized diagnostic errors and were excluded from the control group if an error was identified.

The findings from the categorization of diagnostic error type, preventability, severity, anatomic factors, and potential contributors were tabulated and reported as percentages of all cases of diagnostic error. Univariate and multivariate analyses were focused on those cases that were categorized as preventable or possibly preventable errors because these cases are likely to be more responsive to a quality improvement initiative. Demographic and situational variables were compared for preventable or possibly preventable diag-
nostic error cases versus the randomly selected controls by use of Fisher's exact test. Variables with values of \( P < 0.2 \) in univariate analysis were considered for inclusion in a multivariable logistic regression model. Adjusted odds ratios (AORs) for having a pre-preventable or possibly preventable diagnostic error with 95% confidence intervals (CIs) were calculated for variables retained in the final model.

The Scientific Review Committee of the Department of Cardiology and the Institutional Review Board at Children's Hospital Boston approved this study.

The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

Results

Between December 2004 and August 2007, 87 postnatal echocardiographic diagnostic error cases were identified. During that period, \( \approx 50,660 \) postnatal echocardiograms were performed and interpreted in our laboratory.

Diagnostic Error Categorization

Of the 87 diagnostic error cases identified, 60% were false negative, 20% were false positive, and 20% were discrepant diagnoses.

Diagnostic Error Severity

Only 30% of the diagnostic errors were of minor severity and had no impact on patient management. Of the 70% that affected patient management, 63% were moderate severity, 6% were major severity, and 1% was catastrophic.

Diagnostic Error Preventability

Only 21% of the errors were not preventable. One third of the errors were preventable, and 46% were possibly preventable.

The majority of preventable errors (69%) were of moderate severity or greater.

Contributors to Diagnostic Errors

Factors contributing to diagnostic error are listed in Table 2. The 3 most common contributors to events were cognitive errors, technical factors, and patient-specific factors. A table summarizing severity, preventability, and diagnostic error contributor categorization, as well as clinical context, is provided in the online-only Data Supplement.

Anatomy Involved With Diagnostic Error

Table 3 illustrates the anatomy involved with diagnostic errors. Vascular anatomy (coronary arteries, aortic arch and branches, and systemic veins) made up the top 3 anatomic segments involved in diagnostic errors.

Diagnostic Error Discovery

The median time to discovery of diagnostic errors was 5 days (range, 0 days to 11.8 years). The correct diagnosis was discovered by echocardiography in 33% of cases (from either a new study or reexamination of the initial study), intraoperative inspection in 21%, cardiac magnetic resonance imaging in 18%, cardiac catheterization in 17%, transthoracic echocardiogram in 6%, and another modality in 5%.

Of the 87 cases, 44% had interim imaging studies before the error was identified: 21% had 1 interim echocardiogram, 16% had 2 to 4 interim echocardiograms, and 7% had \( \geq 5 \). Only 1 case had an interim cardiac magnetic resonance imaging. A number of patients had an interim invasive procedure before discovery of the diagnostic error; 9% had at least 1 interim cardiac surgery, and 3% had an interim cardiac catheterization.
Comparison of Preventable and Possibly Preventable Cases and Controls

Results of univariate analysis, focusing on preventable and possibly preventable cases, are summarized in Table 4. Compared with controls, cases of preventable or possibly preventable errors were more likely to involve younger patients, lower body weight, acute care study location, sedated or anesthetized patients, studies performed and interpreted at night, uncommon diagnoses, and greater anatomic complexity.

Risk Factors for Preventable or Possibly Preventable Errors

Multivariate analysis identified the following variables as risk factors for preventable or possibly preventable diagnostic errors (Table 5): rare or very rare diagnoses (AOR, 9.2; 95% CI, 3.8 to 22; \( P<0.001 \)); study location in the recovery suite (AOR, 7.9; 95% CI, 1.4 to 43; \( P<0.001 \)); moderate level of anatomic complexity (AOR, 3.5; 95% CI, 1.5 to 8.1; \( P=0.004 \)); and patient weight <5 kg (AOR, 3.5; 95% CI, 1.1 to 10.6; \( P=0.031 \)). Patient age, sedation status, and studies performed and interpreted at night were not significant predictors in the multivariate analysis.

Discussion

To the best of our knowledge, this is the first report within pediatric cardiology that not only examined the presence of a diagnostic error but also categorized severity, preventability, and causes of diagnostic errors. This study also identified patient-related and situational risk factors for a diagnostic error. Previous studies have examined diagnostic accuracy; however, these reports have focused on targeted patient populations, specific anatomic diagnoses, and studies performed by nonpediatric cardiologists.

Diagnostic Error Taxonomy and Quality Improvement

Knowledge of errors is an important component of improving quality of patient care. Although collecting and counting diagnostic errors is an initial step in improving quality of diagnostic imaging, it is insufficient. A taxonomy to categorize diagnostic errors by preventability and severity allow centers to identify and prioritize specific aspects of diagnostic errors that might lend themselves to a quality improvement initiative. As depicted in the Figure, cases in quadrant A are diagnostic errors that are severe and preventable. Potentially modifiable factors associated with errors that occupy this quadrant could be targeted for a quality improvement initiative, whereas issues related to errors assigned to quadrant B would receive a lower priority.

A taxonomy for diagnostic error contributors also can help a center identify concrete causes of errors and adjust their practice accordingly. For example, if incomplete anatomic or functional examination is found to be a significant contributor to errors assigned to quadrant A, a center may consider a change in practice to reduce the number of focused (incomplete) examinations. Moreover, a center may evaluate the root causes of performing a large number of focused examinations (eg, the time allotted for the examination is too short) and

<table>
<thead>
<tr>
<th>Preventable Events Versus Controls</th>
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<tbody>
<tr>
<td>Cases (n=69), n (%)</td>
</tr>
<tr>
<td>Study type</td>
</tr>
<tr>
<td>Transthoracic</td>
</tr>
<tr>
<td>Transesophageal</td>
</tr>
<tr>
<td>Epicardial</td>
</tr>
<tr>
<td>Age at examination</td>
</tr>
<tr>
<td>≤30 d</td>
</tr>
<tr>
<td>30 d–≤1 y</td>
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<tr>
<td>1–5 y</td>
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<tr>
<td>≥6 y</td>
</tr>
<tr>
<td>Weight, kg</td>
</tr>
<tr>
<td>&lt;5</td>
</tr>
<tr>
<td>5–20</td>
</tr>
<tr>
<td>&gt;20</td>
</tr>
<tr>
<td>Unknown</td>
</tr>
<tr>
<td>Race</td>
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<tr>
<td>White</td>
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<tr>
<td>Black</td>
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<tr>
<td>Hispanic</td>
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<tr>
<td>Asian</td>
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<tr>
<td>Other</td>
</tr>
<tr>
<td>Unknown</td>
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<tr>
<td>Premature</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Study location</td>
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<tr>
<td>Echocardiography laboratory</td>
</tr>
<tr>
<td>CICU</td>
</tr>
<tr>
<td>NICU</td>
</tr>
<tr>
<td>PICU</td>
</tr>
<tr>
<td>Recovery suite</td>
</tr>
<tr>
<td>Other</td>
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<tr>
<td>Junior staff</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
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<tr>
<td>Day of week</td>
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<tr>
<td>Weekday</td>
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<tr>
<td>Weekend (saturday or sunday)</td>
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<tr>
<td>Time of day study performed</td>
</tr>
<tr>
<td>7 AM–12:59 PM</td>
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<tr>
<td>1 PM–6:59 PM</td>
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<tr>
<td>7 PM–6:59 AM</td>
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<tr>
<td>Time of day study interpreted</td>
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<td>7 AM–12:59 PM</td>
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<td>1 PM–6:59 PM</td>
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<tr>
<td>7 PM–6:59 AM</td>
</tr>
<tr>
<td>Unknown</td>
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<tr>
<td>Frequency diagnosis observed in laboratory</td>
</tr>
<tr>
<td>Frequent</td>
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<tr>
<td>Less frequent</td>
</tr>
<tr>
<td>Rare</td>
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<tr>
<td>Very rare</td>
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<tr>
<td>Anatomic complexity</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>Moderate</td>
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<tr>
<td>High</td>
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</tbody>
</table>

NICU indicates neonatal intensive care unit; PICU, pediatric intensive care unit.
address those issues specifically. Another example is if a center finds that many errors occur because of incomplete clinical information. In that circumstance, evaluation of pre-examination procedures might reveal gaps in communication between referring physicians and the Echocardiography Laboratory, and steps can be taken to minimize such gaps. Additionally, the finding that cognitive factors were the most common contributors to diagnostic errors in our laboratory suggests that our center should target educational initiatives designed to address areas of deficient knowledge in CHD anatomy and pathophysiology. Such initiatives should subsequently be monitored for evidence of reduction in errors related to cognitive factors.

### Risk Factors for Preventable and Possibly Preventable Diagnostic Errors

We identified both patient-related and situational risk factors for a diagnostic error. Lower patient weight has been previously reported as a risk factor for diagnostic errors, in agreement with our findings. Study location, which may be the result of suboptimal imaging conditions, was another risk factor. For example, we found that a number of the errors in studies performed in the recovery suite were due to poor image quality and incomplete examinations. This may suggest a time constraint, which leads to incomplete studies and greater risk for error. Complex cardiac anatomy is an intuitive risk factor for a diagnostic error. Interestingly, although moderate anatomic complexity was a predictor for error, in the highest category of complexity only a trend existed toward having a diagnostic error. One possible explanation is that readers are more likely to seek a second opinion from an experienced colleague when faced with a highly complex case, whereas the likelihood of seeking consultation in moderately complex studies might be lower. Another possible explanation is that the number of highly complex cases is not large enough to detect a statistically significant risk.

Recognition of these risk factors may alert echocardiographers to have a higher index of suspicion for diagnostic errors. Identification of risk factors also may assist cardiac centers in adjusting procedures when a case with ≥1 risk factors is identified. For example, echocardiograms in newborns and infants with a lower body weight and complex diagnoses might benefit from a second reviewer (“double read”).

### Study Limitations

Selection bias and incomplete case ascertainment are notable limitations of this study. The majority of cases were identified by a second imaging study or procedure. Patients without a second imaging study or procedure may have had a diagnostic error that was not identified. Therefore, the study likely underestimates the total number of diagnostic errors and is probably biased toward selecting errors with a greater clinical impact. Finally, the sample size limits the statistical power for subgroup analysis.

### Conclusions

A diagnostic error taxonomy and knowledge of risk factors can assist in the identification of targets for quality improvement initiatives that aim to reduce diagnostic errors in pediatric echocardiography. This report represents a first step toward the development of methods to improve the quality of diagnostic imaging for CHD.

### Sources of Funding

This study was supported by the Higgins Family Noninvasive Cardiac Imaging Research Fund and a charitable grant from the Hill Family.

### Disclosures

None.
References


CLINICAL PERSPECTIVE

Echocardiography is the first line of investigation among patients with congenital heart disease; timely treatment depends on accurate diagnosis. Inaccurate diagnoses place children with congenital heart disease at risk for adverse outcomes. Despite increased interest in complications within pediatric cardiology, the domain of imaging-related diagnostic errors has received little attention. We developed a new taxonomy for diagnostic errors within pediatric echocardiography that categorized errors by severity, preventability, and primary contributor. Our objectives were to examine its findings when applied to diagnostic error cases and to identify risk factors for preventable or possibly preventable diagnostic errors. Diagnostic errors were identified at a high-volume academic pediatric cardiac center from December 2004 to August 2007. Demographic, clinical, and situational variables were collected from these cases and controls. Among the diagnostic error cases identified, 70% affected clinical management or the patient was at risk of or experienced an adverse event. One third of the errors were preventable and 46% were possibly preventable; 69% of preventable errors were of moderate severity or greater. Multivariate analysis identified the following risk factors for preventable or possibly preventable echocardiography diagnostic errors: rare or very rare diagnoses (odds ratio [OR], 9.2; P<0.001), study location in the recovery room (OR, 7.9; P<0.001), moderate anatomic complexity (OR, 3.5; P=0.004), and patient weight <5 kg (OR, 3.5; P=0.031). A diagnostic error taxonomy and knowledge of risk factors can assist in identifying and prioritizing targets for quality improvement initiatives that aim to decrease diagnostic error in pediatric echocardiography.
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