Using Improvement Methodology to Optimize Echocardiographic Imaging of Coronary Arteries in Children

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Background: According to the American Society of Echocardiography, coronary artery (CA) imaging is recommended in pediatric examinations to identify CA anomalies. A review of the authors' center's echocardiographic studies revealed that CA images were often nondiagnostic. The aim of this study was to utilize quality improvement methodology to increase the percentage of first-time pediatric studies with definitive CA identification from a baseline of 45% to a goal of at least 75% in 9 months.

Methods: A scoring system was developed to characterize the completeness of CA imaging. One point was scored for demonstration of each of the following: right CA origin by two-dimensional imaging, right CA origin by color flow Doppler imaging, left CA origin by two-dimensional imaging, and left CA origin by color flow Doppler imaging. A score of 4 was considered to represent definitive imaging. A baseline was obtained on 100 first-time echocardiograms with normal findings. During the intervention, 10 randomly selected first-time studies with normal findings were scored weekly for assessment of CA imaging. Interventions were focused on the following domains: excellence in image quality, shared ownership, transparency, and effective communication. Key interventions included labeling CA images, requiring two-dimensional and color Doppler images, optimization of settings, and elimination of macros for CA reporting.

Results: The percentage of definitive CA identification increased from 45% to 82.5% over 4 months and was sustained for 7 months. Accurate reporting of incomplete CA imaging increased from 17% to 77.5%.

Conclusions: Improved pediatric CA imaging and reporting were achieved through the implementation of key interventions. (J Am Soc Echocardiogr 2016;29:247-52.)

Keywords: Echocardiography, Pediatrics, Coronary artery imaging, Quality improvement

According to the American Society of Echocardiography, routine coronary artery (CA) imaging is included in the recommended imaging protocol for pediatric patients.[1,2] CA anomalies have been reported in 1% to 2% of the population, with some reports showing up to a 5.6% incidence.[3,4] Some of these anomalies, including high ostia, multiple ostia, and single CA, are benign and carry a low potential for life-threatening events. In contrast, there are anomalies of CA origin, which can be identified on echocardiography, that place patients at risk for life-threatening myocardial infarction, arrhythmia, or sudden death.[5] These anomalies include anomalous origin of the left CA from the pulmonary artery, anomalous origin of the right CA from the pulmonary artery, and anomalous origin of the left CA from the right coronary sinus. Anomalous origin of the right CA from the left coronary sinus may be clinically significant, but this remains an area of debate.[3,6]

Within our cardiac imaging division at Cincinnati Children's Hospital Medical Center (CCHMC), imaging of the CAs is included in the examination protocol for patients without prior echocardiograms. Multiple cardiologists noted that this part of the evaluation was often incomplete and inconclusive, with sonographers often focusing on the area and taking clips without actually showing the CAs. This issue was brought to the attention of leadership after the occurrence of an adverse patient outcome related to anomalous coronary origins, in which the CAs were not well visualized on the echocardiogram.

The aims of this project were first to develop a method to assess the quality of CA imaging on echocardiography and to define the current state of CA imaging at our institution and then to use quality improvement (QI) methods[7] to increase the percentage of studies with adequate CA imaging. Specifically, our aim was to increase the percentage of first-time pediatric studies with definitive CA identification from a baseline of 45% to >75% by June 1, 2013, or 9 months' time. Our hypothesis was that the frequency of studies with definitive CA imagining would be enhanced by the application of QI principles.

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0894-7317/$36.00

http://dx.doi.org/10.1016/j.echo.2015.08.019

METHODS

Setting

The Heart Institute is a large tertiary pediatric cardiology department at CCHMC. The echocardiography laboratory performs >14,000 echocardiographic examinations a year. A group of 14

Abbreviations

CA = Coronary artery

CCHMC = Cincinnati Children's Hospital Medical Center

PDSA = Plan-do-study act

QI = Quality improvement

SMART = Specific, measurable, achievable, relevant, and timely

2D = Two-dimensional

registered pediatric cardiac sonographers perform these examinations, which are all reviewed and interpreted by imaging faculty members at CCHMC. Only echocardiograms obtained by sonographers were reviewed. The images are all uploaded as Digital Imaging and Communications in Medicine images to a server and accessed using AMICAS VERICIS (Merge Healthcare, Chicago, IL). Reports are entered and accessed using the EchoIMS reporting system (Merge Healthcare).

Human Subjects Protection

This initiative fell within the CCHMC Institutional Review Board's guidance for QI projects and did not constitute human subjects research. This project did involve human subjects, but as a QI project rather than clinical research, it did not require documentation of informed consent. The physicians and sonographers who took part in this project were aware that this was part of a QI process and chose to be involved.

Planning the Intervention

A multidisciplinary team including pediatric cardiologists, pediatric cardiac sonographers, and QI experts was formed to map the process of CA image acquisition and reporting and to examine the key drivers on which to focus interventions. A key driver diagram (Figure 1) is a graphic used to plan interventions on the basis of key elements—key drivers—that may affect the process subject to intervention. In Figure 1, the "SMART aim," or the goal that is specific, measureable, achievable, relevant, and timely, is noted on the left side. In the row of boxes directly to the right of the SMART aim are the key drivers. Key drivers are the components or areas within the process, identified by the improvement team, that are most likely to affect the process and result in moving toward the SMART aim. The third row of boxes are examples of the specific changes that were implemented relating to each key driver.[8]

Our team first developed CA imaging criteria on the basis of previous expert opinion about the elements that constitute adequate CA imaging.[1,2] A scoring system was developed to characterize completeness of CA imaging, with 1 point given for demonstration of each of the following:right CA origin by two-dimensional (2D) imaging, right CA origin by color flow Doppler imaging, left CA origin by 2D imaging, and left CA origin by color flow Doppler imaging.

Right and left CA 2D imaging was considered adequate if the coronary lumen could be visualized as clearly communicating with the appropriate aortic sinus. Color flow Doppler imaging for both the right and left CAs was considered adequate if the color could be connected from the lumen of the aorta into the lumen of the CA during diastole and was flowing in the expected direction. A composite score of 4 was considered to represent definitive imaging. The report for each echocardiogram was accessed, and the description of the CAs was reviewed. If the report correlated to the CA origin score, the report was scored as correct. If the score was <4 and the CAs were read as normal, the report was deemed incorrect.

To establish a baseline, 100 first-time studies with normal findings performed before the conception of this project were reviewed and scored per the above scoring system. One important attribute of any scoring system or assessment tool is that it assess a treatment without any bias in the results. The two issues of interest are whether there is an age bias or a provider reading bias with this assessment tool. Twenty-five studies in each of the following age ranges were reviewed to assess for a potential patient age–related limitation in completing CA imaging: 0 to 2, 2 to 8, 8 to 14, and >14 years. To measure any review bias, two reviewers, a junior- and a senior-level imaging faculty member, each read the same 100 studies. This analysis confirmed that there was no age or reviewer bias. Analysis-of-variance models, paired comparison techniques, and two-sample hypothesis testing were used to evaluate differences between reader and age bias. There was no significant difference across age groups or between readers, as indicated by the nonsignificant *P* values (Table 1).

Across the 100 baseline studies, the percentage of studies with definitive CA identification was 45%. Accurate reporting of incomplete CA imaging occurred only 17% of the time (Figures 2 and 3).

Improvement Activities

Interventions focused on the three key drivers: (1) optimizing imaging quality; (2) shared ownership, buy-in, and communication among physicians and sonographers; and (3) transparency of team performance (Figure 1). Changes were made and tested through a series of plan-do-study-act (PDSA) cycles. PDSA cycles are used in improvement science to make rapid changes to a system and to act on them accordingly. The first step of the cycle is plan, in which the details of the test are determined and predictions of what will occur are made. The do step of the cycle involves performing the change and collecting the data. The study part of the cycle is when results are compared with predictions and what was learned from the do step is determined. Finally, the act step allows action to be taken on the basis of the new knowledge gained. During the act step, the change is adapted (adjusted for a future PDSA cycle), adopted (implemented on a larger scale), or abandoned (discarded entirely).[8]

Optimizing Imaging Quality. *Education of Sonographers in CA Imaging Techniques.* Within the echocardiography laboratory, there are 14 registered pediatric cardiac sonographers with varying levels of skill, speed, and experience. Those sonographers with more experience or those who routinely obtained adequate imaging of the CAs were asked to provide tips on image acquisition, such as angle and imaging plane. For example, many of the less experienced sonographers were not aware that the origin of the right CA can be demonstrated in the parasternal long-axis view, and this view often reveals a better image to demonstrate color Doppler imaging of the origin of the right CA. The sonographers were also encouraged to use a high-frequency probe and seek assistance in real time from experienced sonographers if they experienced difficulties with an examination.

Standardization of CA Echocardiographic Settings. Our improvement team noted that many of the sonographers used different image acquisition settings to image the CAs. An informal poll was conducted, and the two most popular settings for CA image acquisition were identified. In an attempt to standardize image acquisition, the remaining unused settings were removed from the machines, and the sonographers were encouraged to use only the available settings when acquiring CA images. In the most frequently used settings, the 2D settings were adjusted slightly by turning down the compression. The color Doppler settings were adjusted by decreasing the color scale to 20