Cardiology in the Young

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Implementation of paediatric three-dimensional echocardiography: a quality improvement intervention and process analysis

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Brief Report

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Abstract

We performed a quality improvement intervention to increase three-dimensional transthoracic echocardiography performance for high-yield paediatric patient populations undergoing pre-procedural echocardiograms. Following implementation, the percentage of eligible patients receiving three-dimensional imaging increased significantly from a baseline of 20.3% to a maximum of 90.9%, with minimal impact on workflow. For programmes interested in increasing three-dimensional imaging, we recommend (1) establishing a core group of champions, (2) targeting a clear and measurable goal, and (3) developing a robust system for identifying candidates for three-dimensional imaging.

Introduction

Transthoracic echocardiography aids in the diagnosis and management of CHD and acquired heart disease.[1] Two-dimensional transthoracic echocardiography is limited in part by the heart's complex three-dimensional geometry. Three-dimensional transthoracic echocardiography has emerged as a useful tool to evaluate specific cardiovascular structures, such as atrioventricular valves, and may add particular value when used to help guide strategy for cardiovascular interventions.[2–5] Broad uptake of three-dimensional transthoracic echocardiography has been slowed by various factors, including cost, training, and challenges in incorporating three-dimensional imaging into routine clinical workflows.[6] While some protocols have been published to allow for wide-scale adoption,[7] the practical experience and potential pitfalls of incorporating three-dimensional transthoracic echocardiography into established workflows is not well documented. By sharing our experience, we aim to provide a framework to paediatric heart centres both for increasing three-dimensional transthoracic echocardiography utilisation and evaluating progress towards this effort.

Methods

We performed a quality improvement intervention at our high-volume institution to increase three-dimensional transthoracic echocardiography imaging in clinically important populations. Through iterative discussion among cardiologists and sonographers and reference of consensus guidelines,[3] we targeted the following populations as those who would benefit from three-dimensional transthoracic echocardiography during dedicated pre-interventional or pre-surgical imaging: patients planned for atrial septal defect closure, atrioventricular valve repair or replacement, atrioventricular septal defect repair, and Fontan procedure. Three-dimensional imaging of the atrial septal defect was undertaken in patients undergoing atrial septal defect closure; in all other patients, including those planned to undergo Fontan, three-dimensional imaging of the atrioventricular valve was undertaken. We targeted completion of three-dimensional imaging in >80.0% of eligible patients. All studies were performed on General Electric Vivid E95 and Philips Epiq ultrasound machines. Post-processing was performed on the cart. Three-dimensional images were typically acquired using a single-beat acquisition with satisfactory temporal and spatial resolution, but in older patients who were able to complete a breath hold, 2–3 beat acquisitions were occasionally used. Image procurement and interpretation were not limited to a specific group of sonographers and cardiologists during the study period.

The implementation period extended from 5/1/2024 to 1/31/2025, with 6 months of pre-implementation data collected as a baseline. Variables collected included the date of the transthoracic echocardiogram, performance of three-dimensional imaging, cardiac structures analysed with three-dimensional imaging, and planned procedure or operation. Transthoracic

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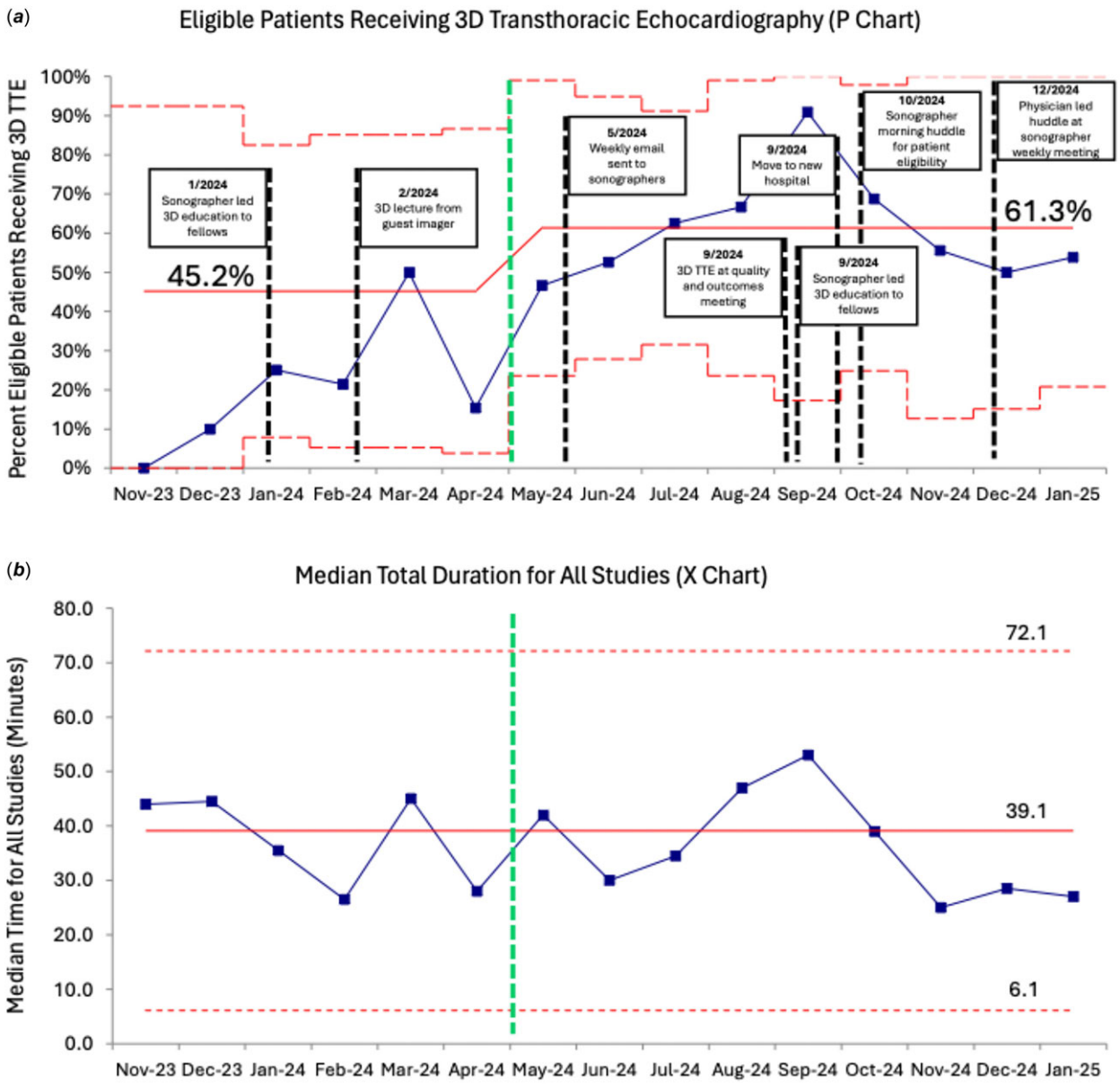


Figure 1. Intervention results. (***a***) *P* chart describing percentage of eligible patients in whom 3D transthoracic echocardiography was completed by month (blue line). The horizontal solid red line indicates average percentage. The horizontal dotted red lines indicate upper and lower control limits. The vertical dotted green line indicates intervention start time. (***b***) *X* chart describing median duration for all eligible studies. The horizontal solid red line indicates average study duration. The horizontal dotted red lines indicate upper and lower control limits. The vertical dotted green line indicates intervention start time.

echocardiogram total duration, three-dimensional imaging duration, and transthoracic echocardiogram interpretation time were obtained in a standardised fashion at baseline and during implementation as balancing measures (Online Supplement: Additional Methods). We also acquired deidentified survey data before and after implementation from major stakeholders, including paediatric cardiologists with non-invasive imaging expertise, cardiac sonographers, and cardiology fellows.

Multiple educational and logistical interventions were employed during implementation, including three-dimensional transthoracic echocardiography educational conferences, weekly email reminders of eligible patients to sonographers from sonographer champions, and daily morning huddles among sonographers and attendings. Sonographers and attending three-dimensional champions routinely trained sonographers in both three-dimensional scanning at the bedside and post-processing for the duration of the implementation period.

Results

Over the entire intervention period, there were 209 eligible transthoracic echocardiograms (mean = 15 per month, range = 9–24 per month), including 77 pre-and 132 post-implementation studies. Of all patients, 85 transthoracic echocardiograms were before the Fontan procedure, 80 before atrial septal defect closure, 38 before atrioventricular septal defect repair, and 6 before atrioventricular valve repair or replacement. The average monthly performance of three-dimensional imaging for eligible patients prior to implementation was 20.3%. Following implementation, the percentage of eligible patients receiving three-dimensional imaging increased

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Figure 2. Survey results. (***a***) Pre-implementation survey results regarding barriers to 3D transthoracic echocardiography performance among cardiologists (green) and sonographers/fellows (orange). Results are presented on a Likert scale with 0 representing minimal barrier and 5 representing maximal barrier. (***b***) Change in cardiologist comfort acquiring 3D imaging, sonographer and fellow comfort in acquiring 3D imaging, and cardiologist comfort in interpreting 3D imaging both before (blue) and at conclusion of quality improvement period (purple). Results are presented on a Likert scale with 0 representing minimal comfort and 10 representing maximal comfort.

each month, reaching a maximum of 90.9% in September 2024 (Figure 1(***a***)). There was a subsequent decrease in three-dimensional imaging, although the proportion of patients with three-dimensional imaging remained significantly increased compared to baseline, maintaining a centre line shift of 45.2 to 61.3%. There was no significant change in median transthoracic echocardiogram total duration (Figure 1(***b***)), median three-dimensional imaging duration (Supplemental Figure 1), or median transthoracic echocardiogram interpretation time (Supplemental Figure 2) during the intervention. All three-dimensional studies were signed on the same day as image acquisition.

There were 30 pre-implementation survey respondents (cardiologists, $n = 8$; sonographers and fellows, $n = 22$) and 27 post-implementation respondents (cardiologists, $n = 10$; sonographers and fellows, $n = 17$). Survey data prior to implementation identified inadequate training, lack of an independent post-processing workstation, and multiple vendor platforms as the largest barriers to completing transthoracic echocardiography (Figure 2(***a***)). At the end of the intervention, comfort acquiring three-dimensional transthoracic echocardiography increased 47.1% among cardiologists and 34.7% among sonographers and fellows. There was a 26.8% increase in comfort interpreting three-dimensional transthoracic echocardiography among cardiologists (Figure 2(***b***)). No responders reported decreased comfort with three-dimensional transthoracic echocardiography.

Discussion

Decrement in three-dimensional transthoracic echocardiography completion in October 2024 was felt to be related in part to the transition to a new hospital. The larger physical footprint of our new hospital extended demands on sonographers' time, affecting their opportunity for acquiring three-dimensional transthoracic echocardiography. Therefore, physicians joined daily morning huddles to troubleshoot challenges and create opportunities for sufficient time for three-dimensional transthoracic echocardiography to be performed in eligible patients. Direct support from the sonographer and attending three-dimensional champions was fundamental to building an efficient system. Repeated exposure to three-dimensional images in different formats, including formal

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lectures, bedside practice, and patient management conferences, were all important components of sonographer and fellow education on three-dimensional echocardiography. Specific to fellows, future studies should evaluate three-dimensional echocardiography educational strategies and how they impact comfort with three-dimensional imaging as attendings. While periodic educational sessions were helpful in accelerating the learning curve related to three-dimensional transthoracic echocardiography imaging, we found that assigning responsibility to core team members to identify candidates for three-dimensional transthoracic echocardiography and communicate in a weekly email to stakeholders led to sustained improvement in three-dimensional transthoracic echocardiography completion percentage. Additionally, newer tools, such as two-click crop and dual crop, have improved post-processing efficiency for many lesions, including atrial septal defects and atrioventricular valve disease, and helped facilitate three-dimensional imaging performance at our centre. We also plan to integrate technology that will enable real-time post-processing off the cart to bolster efficiency further.

For programmes interested in increasing three-dimensional transthoracic echocardiography imaging, we recommend (1) establishing a core group of champions, (2) targeting a clear and measurable goal, and (3) developing a robust system for identifying candidates for three-dimensional imaging. While we focused on increasing utilisation of three-dimensional imaging in clinically important patient populations in this effort, we now plan to focus on image quality, standardisation of protocols, and evaluating the impact of three-dimensional transthoracic echocardiography implementation on clinical, interventional, and surgical decision-making and outcomes at our institution. Specifically, we seek to understand if improved diagnostic accuracy provided by three-dimensional imaging affects the classification of atrioventricular valve disease and its management, reduces intraoperative imaging discrepancies, and improves communication and clarity for cardiologists, interventionalists, and cardiothoracic surgeons.[8–10]

Limitations to our analysis include the inability to more precisely account for three-dimensional post-processing time because we are dependent on aspects of the process which are time-stamped within our echocardiography software. However, interpretation time calculation included time dedicated to three-dimensional post-processing and was measured consistently for all patients.

Conclusion

In summary, three-dimensional transthoracic echocardiography performance in targeted populations with CHD increased at our institution following intervention with minimal impact on workflow. Improved three-dimensional transthoracic echocardiography utilisation relied upon careful identification of patient groups who would derive clinical benefit, sonographer and physician champions to support ongoing education and encouragement, and dynamic strategies during the intervention period to adapt to changes and optimise opportunities for completing high-quality three-dimensional imaging in targeted populations. Sustainable implementation of three-dimensional transthoracic echocardiography depends on broad support from all involved stakeholders. Paediatric heart centres interested in incorporating three-dimensional transthoracic echocardiography into clinical workflows should prioritise these key elements to promote successful implementation.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1047951126111433.

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