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ORIGINAL ARTICLE

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Educational intervention for improving the appropriateness of transthoracic echocardiograms ordered by pediatric cardiologists

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Abstract

Objective: The objective of this study was to evaluate effectiveness of educational intervention (EI) in the Pediatric Appropriate Use of Echocardiography (PAUSE) study to improve appropriateness of transthoracic echocardiograms (TTEs) ordered in pediatric cardiology clinics.

Design: Data were prospectively collected after the publication of the Appropriate Use Criteria (AUC) document during 2 phases: the pre-EI phase (1/1/15 to 4/30/15) and the post-EI phase (7/1/15 to 10/30/15). Pre-EI, site-investigators (SI) determined AUC indications, by reviewing the clinic records. Post-EI, providers assigned indications prior to obtaining TTE.

Setting: Pediatric cardiology clinics at six centers.

Patients: Those $\leq$18 years old, receiving initial outpatient TTE.

Interventions: EI included (i) sharing the pre-EI appropriateness ratings with providers, (ii) lecture on AUC, (iii) providers self-assigning indications, and (iv) monthly e-mail feedback by SI to individual providers.

Outcome: The primary outcome measure was a change in the proportion of studies for indications rated R following EI.

Results: Of the 4542 TTEs (1907 pre-EI, 2635 post-EI) ordered by 90 physicians, overall comparison of appropriateness ratings before and after EI showed an increase in Appropriate (72.5%–76.2%, $P = .004$), no change in May Be Appropriate, and a decline in Rarely Appropriate (R) from 9.6% to 7.4%, $P = .008$. Following EI, a significant decline in R was observed only in three centers and EI did not affect the variation in TTEs ordered for R indications among physicians ($P = .467$). Physicians with the highest proportion of TTEs ordered for R before EI, showed the most significant decline in R.

Conclusions: Appropriateness of pediatric outpatient TTE varies substantially by center. A customized EI resulted in modest improvement in the appropriateness of TTEs in the PAUSE study, with an increase in Appropriate and a decrease in R TTEs. Multifaceted EIs are required to improve adherence to national standards such as AUC.

KEYWORDS
appropriate use criteria, echocardiography, outpatient, quality improvement

1 | INTRODUCTION

The American College of Cardiology Foundation published the first pediatric appropriate use criteria (AUC) in 2014 to provide guidance to clinicians for appropriate use of transthoracic echocardiography (TTE) during initial outpatient evaluation of children.[1] This document provided a comprehensive list of various clinical scenarios leading to ordering a TTE in outpatient clinics, along with their corresponding appropriateness ratings. Prior to this document, there were no standards to guide physicians with their decision making in ordering TTEs in pediatric clinics. TTE is the most common imaging modality used in the outpatient setting in pediatric cardiology clinics given that it is readily available, noninvasive, a highly accurate diagnostic tool, and it does not require radiation. However, previous studies have shown a low-yield of abnormalities when TTE is used in many common scenarios in outpatient settings.[2–5] In the current healthcare environment with rising concerns over imaging related healthcare spending, it is prudent to make efforts to quantify and reduce unnecessary testing.

Studies using adult cardiology AUC documents have shown varying amount of success in improving appropriateness of TTE orders with different forms of educational intervention (EI) that have ranged from passive to active interventions.[6–8] It is known that active interventions such as the audit and feedback method are more effective in changing physician behavior than passive didactic education, though the former may be harder to implement and sustain.[9] The first multicenter Pediatric Appropriate Use of Echocardiography (PAUSE) study was designed to study the implementation of the pediatric AUC document and the effectiveness of a multifaceted EI in improving appropriateness of TTE utilization in outpatient pediatric cardiology clinics. The initial phase of this study reported that prior to release of the AUC document, 71% of studies were done for indications rated Appropriate (A) while 12% were for indications rated Rarely Appropriate (R).[10] Even though the rate of R was not alarming, there was a significant variation among the six centers and the physicians within the same center. The purpose of this study was to evaluate the effectiveness of a multifaceted EI in reducing the proportion of R, increasing that of A, and reducing the variability in appropriateness among the various centers and the physicians within each center participating in the PAUSE study.

2 | METHODS

2.1 | Study design

Data were prospectively collected from all patients ≤18 years old undergoing initial outpatient TTEs at the six centers participating in the PAUSE study, including Emory University School of Medicine and Children's Healthcare of Atlanta, Children's Hospital at Montefiore, Mayo Clinic Rochester, Massachusetts General Hospital, Nicklaus Children's Hospital, and NewYork-Presbyterian, Morgan Stanley Children's Hospital. This project was presented to the respective Institutional Review Boards of the participating centers and did not qualify as a research project for all centers except for NewYork-Presbyterian, Morgan Stanley Children's Hospital, where the study was approved by their Institutional Review Board. Patients with previous evaluation by TTE or those who were referred to a cardiology clinic for a TTE alone without any clinical evaluation by the pediatric cardiologist were excluded due to lack of clinical information to assign the AUC indication. In addition, patients seen by the site investigators (SI) of this study were excluded to avoid bias in assigning AUC indication for their own TTEs. All de-identified data were entered into the REDCap system (Research Electronic Data Capture) that was maintained by the core-site at Emory University School of Medicine and Children's Healthcare of Atlanta. Enrollment logs were maintained by individual sites with their corresponding REDCap assigned identification numbers. In order to keep the centers de-identified in the results section, centers were randomly assigned numbers from 1 to 6 that were unrelated to the order in which the centers are listed above.

2.3 | Data collection and assignment of AUC indication

Data were prospectively collected after the publication of the AUC document during two phases that were separated by 2 months: the pre-EI phase (1/1/15 to 4/30/15) and the post-EI phase (7/1/15 to 10/30/15). The data collection sheet used for pre-EI phase included patient name, age, name of the ordering physician and the reason for TTE. This sheet was filled by the provider, but the AUC indication was assigned by the SI after reviewing the clinic notes. Based on the indication, corresponding appropriateness rating was selected from the AUC document [A, May Be Appropriate (M), or R]. If the clinical scenario did not fit into any of the 113 indications listed in the document, it was considered "Unclassifiable" (U). Following the pre-EI phase, a two-month period was allowed for SIs to implement EI before the start of post-EI phase. The data collection sheet for post-EI phase was modified and included all nine tables from the AUC document and TTE findings. In contrast to the pre-EI phase, the AUC indications were self-assigned by the providers during the post-EI phase using the tables on the data collection sheet.

2.4 | Educational intervention

A multifaceted EI with active and passive components was implemented at all centers after completion of pre-EI phase. This included (i) SI sharing the individual, center and overall study appropriateness ratings from pre-EI phase via e-mail with the individual providers within their center, (ii) a uniform Power Point–based lecture at a staff meeting by SIs on how to use the AUC document and sharing the results of the overall study and de-identified centers with the providers, (iii) providers assigning AUC indications themselves prior to ordering TTE by using the AUC tables provided on the data collection sheet, (iv) audit and feedback method where SIs provided monthly e-mail feedback to individual providers with their appropriateness ratings in comparison to those for the center and provided specific feedback for the studies done for indications rated R.

2.5 | Classification of TTE findings

The SIs reviewed the findings on TTE for studies with abnormal findings and graded the severity of the abnormal findings using the grading system described previously.[10] Briefly, TTE findings were classified as normal, incidental, or abnormal. The abnormal findings were classified based on their clinical relevance as minor, moderate, or severe. These were further classified into those that were related to the indication and those that were not.

2.6 | Study outcomes

The primary outcome measure was an overall change in the proportion of studies for indications rated R following EI. Secondary outcome measures were (i) change in proportion of R for individual centers and physicians, (ii) reproducibility in assignment of indications between the providers and SI for a 15% random sample during post-EI phase, (iii) change in the yield of abnormal TTE findings over the study period, and (iv) identification of gaps in the AUC document.

2.7 | Statistical analysis

Statistical analyses were performed using SAS version 9.4 (Cary, NC, USA). Statistical significance was assessed at the .05 level. Descriptive statistics were calculated for all variables of interest and included medians with 25th–75th percentiles or counts with percentages when appropriate. Normality of continuous variables was assessed using histograms, normal probability plots, and the Anderson-Darling test for normality. Chi-square tests were used to compare the proportion of appropriateness ratings and U studies between pre- and post-EI phase. A subgroup analysis was performed using a select group of physicians that ordered at least 20 TTEs in each phase using the Wilcoxon signed-rank test to account for paired data. Random effects models adjusted for clustering of physicians within center was used to obtain the adjusted *P* value for the comparison of appropriateness ratings following EI in this select group of physicians.

Variation in the effect of EI at each center was visually assessed using a box-and-whisker plots using physicians that ordered at least 20 TTEs in each phase. Variation in the effect of EI among the centers was examined using random effects models to control for clustering of physicians within centers and by modeling the interaction terms between EI phase (pre/post) and center in our model. To see if EI decreased variation in TTEs rated as R (both overall and within center), the Brown–Forsythe test was used to compare the pre-EI and post-EI variability in the percentage of physician's TTEs rated as R. For physicians with the highest rate of R in pre-EI phase (top 25%), the potential relationship between pre-EI proportion of R and change in proportion of R from pre- to post-EI phase was assessed using Spearman correlation with 95% CI.

Since the AUC indications were assigned by SI in pre-EI phase and providers in post-EI phase, a 15% random sample of post-EI TTEs was provided to the SI for reassigning AUC indications. The percent agreement and the kappa statistic with 95% CI for this 15% random sample were used to assess inter-rater agreement for AUC indications and ratings. Odds ratios (OR) and 95% CI were used to compare the proportion of abnormal findings in different patient subgroups by using generalized linear mixed models. These models accounted for the clustering of multiple studies from the same site over both pre- and post-EI phase. When assessing the impact of TTE rating on the odds of an abnormal finding, indications rated R were treated as the reference group and compared with those with indications rated A or M. In a multivariate model, the impact of phase and age on the yield of abnormal finding was examined, while controlling for clustering of patients within centers.

TABLE 1 Overall comparison of the proportion of TTEs based on appropriateness during pre- and post-EI phase

	Pre-EI N (%)	Post-EI N (%)	*P* value
Appropriate	1382 (72.5%)	2008 (76.2%)	**.004**
May Be Appropriate	221 (11.6%)	324 (12.3%)	.469
Rarely Appropriate	183 (9.6%)	195 (7.4%)	**.008**
Unclassifiable	121 (6.3%)	108 (4.1%)	**<.001**
Total TTEs	1907	2635	

3 | RESULTS

Of the 4542 TTEs included in the study, 1907 were from pre-EI and 2635 from post-EI phase. A total of 90 physicians participated in the study (77 in pre-EI phase, 77 in post-EI phase and 64 in both phases). The median (25th–75th percentile) number of patients seen by each physician was 18 (7–39) in pre-EI, and 26 (10–45) in post-EI phase.

TABLE 2 Comparison of the proportion of studies based on appropriateness during pre- and post-EI phase for physicians that saw at least 20 physicians in each phase ($N = 32$)

Overall	Pre-EI median (25th–75th)	Post-EI median (25th–75th)	*Unadjusted *P* value	**Adjusted *P* value
Appropriate	74.2% (71.1%–81.2%)	82.1% (70.1%–86.9%)	**.012**	**.019**
May Be Appropriate	10.7% (7.8%–15.3%)	9.7% (7.1%–14.9%)	.870	.813
Rarely Appropriate	6.6% (3.6%–10.2%)	2.9% (0.0%–8.4%)	**.038**	**.024**
Unclassifiable	5.7% (2.4%–10.8%)	2.8% (0.0%–7.5%)	.074	.157

*Wilcoxon signed-rank test.
**Random effects model (adjusted for clustering of physicians within center).

The median age of patients seen during each phase was similar, 9 years (2–14) pre-EI, and 10 years (3–14) post-EI, $P = .07$.

3.1 | Change in the proportion of appropriateness ratings following EI

The overall comparison of the proportion of appropriateness ratings and U studies for pre- and post-EI phase are shown in Table 1. Following EI, the proportion of studies ordered for indications rated A increased from 72.5% to 76.2% ($P = .004$) and for those rated R declined from 9.6% to 7.4% ($P = .008$). Thirty-two physicians ordered at least 20 studies in each phase (3 from Center 1, 19 from Center 2, 5 from Center 3, 3 from Center 4, 2 from Center 5, and none from Center 6). A subgroup analysis including this selected group of physicians showed an increase in A ($P = .012$), decline in R ($P = .038$), and no change in M and U (Table 2). Further, random effects model adjusting for clustering of physicians within centers also showed similar results with an increase in A ($P = .019$) and a decline in R ($P = .024$). Overall the proportion of studies ordered for indications rated R was significantly reduced in three of the six centers (Figure 1). Subgroup analysis of the selected physicians showed that only two centers had a significant decline in the proportion of R (Figure 2).

3.2 | Variability among centers and physicians

A visual inspection of the box-and-whisker plot in Figure 2 indicated that EI effect appeared to be different among the different centers even though the overall effect of EI on reducing the proportion of TTEs for indications rated R remained significant. In a random effects model, the interaction between EI and the center was noted to be statistically significant ($P < .001$). Therefore, the analysis was further stratified by center and showed a significant effect of EI in decreasing TTEs for indications rated R at Centers 2 ($P = .036$) and Center 5 ($P = .037$). Although Center 5 only had two physicians, they experienced a large reduction in the proportion of TTEs for R indications. No other centers showed a statistically significant change likely due to the small number of physicians that ordered at least 20 TTEs both pre- and post-EI.

Physicians with the highest rate of R in pre-EI phase (top 25%), showed the most significant decline [$r = -.87$, 95% CI (-0.95 to -0.65), $P < .001$] (Figure 3). Given the small number of physicians that saw more than 20 patients at each center, decrease in variability within center could not be assessed. However, among this select group of physicians, there was no change in variability of TTEs ordered for indications rated R following EI ($P = .467$).

3.3 | Reproducibility of rankings

Overall agreement for a 15% random sample with providers' indications reassigned by SI was 87% (344/395), and for appropriateness rating was 92% (363/395), kappa = 0.82, 95% CI: (0.75–0.88). The most common mismatched rating was A (15/32) and was reclassified by SI as M (5), R (3) and U (7). The three studies reclassified by SI from A to R were for presumptively innocent murmur (2), and probable neurocardiogenic syncope (1). Four of the seven studies reclassified as U were for family history other than in a first degree relative, where the provider had chosen the AUC indication from the document which applied only to first degree relatives.

3.4 | Findings on TTE

Majority of the studies had normal or incidental findings (Table 3). There were no significant changes in the yield of abnormal findings or their severity between the two phases. The odds of finding an abnormality was the highest when a study was performed for an indication rated A or M versus R when adjusting for center and age (pre-EI: adjusted OR = 17.7, (95% CI: 4.3-72.6, $P < .001$), and post-EI: adjusted

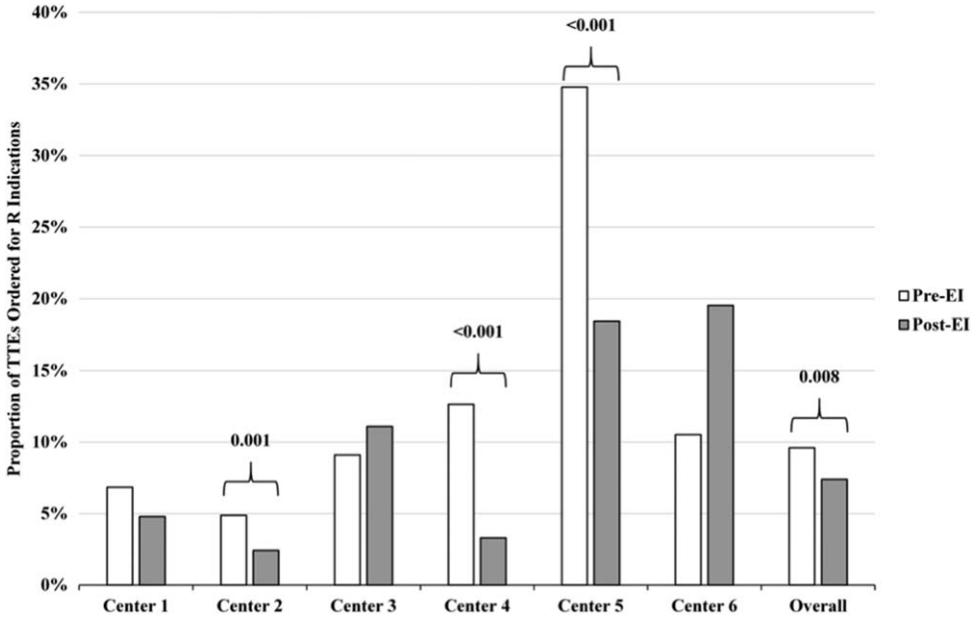

FIGURE 1 Proportion of transthoracic echocardiograms ordered for indications rated R at each of the six participating centers

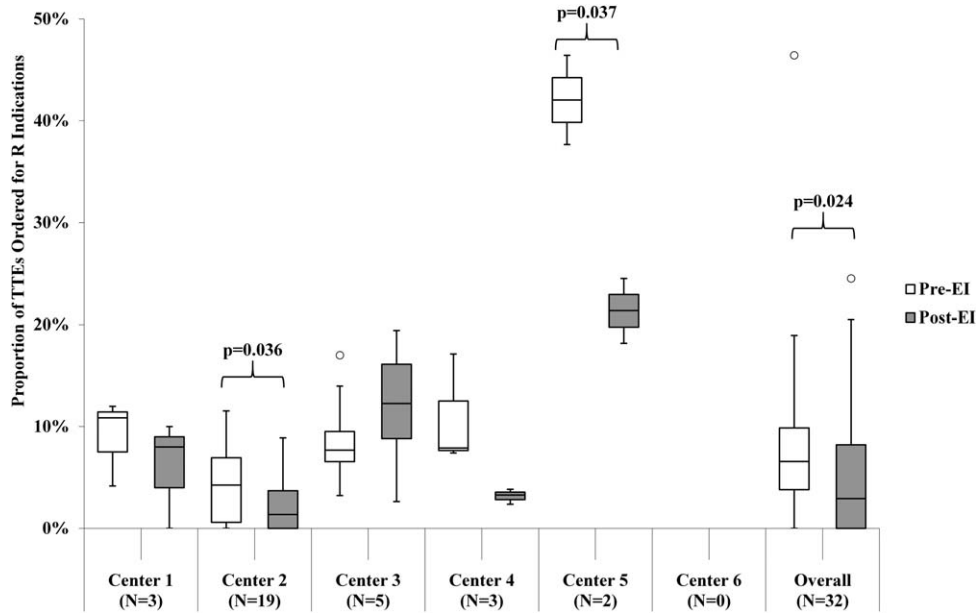

FIGURE 2 Box-and-whisker plots showing the effect of EI on the proportion of TTE ordered for indications rated Rarely Appropriate (R) in the six participating centers including physicians who ordered at least 20 TTEs in each phase ($N = 32$). Note that there were no physicians in center 6 that ordered more than 20 studies in each phase

OR = 12.7, (95% CI: 4.0–40.9, $P < .001$). There was no significant difference in the OR between the two phases ($P = .536$).

3.5 | Change in the use of AUC indications

The use of various indication categories was similar in the two phases except a decline in those included in the AUC document table for "other symptoms and signs" and an increase in those for "family history" (Table 4). The five most commonly used indications rated A in both phases were similar and included pathologic murmurs; exertional chest pain; abnormal ECG; presumptively innocent murmur with signs, symptoms, or findings of cardiovascular disease; and systemic hypertension (AUC indication # 40, 30, 52, 40, and 74, respectively). The five most commonly used indications rated R in both phases included presumptively innocent murmur; syncope with no other symptoms or signs of cardiovascular disease, a benign family history, and a normal ECG; palpitations with no other symptoms or signs of cardiovascular disease, a benign family history, and a normal ECG; chest pain with no other symptoms or signs of cardiovascular disease, a benign family history, and a normal ECG; and probable neurocardiogenic (vasovagal) syncope (AUC indication # 39, 18, 2, 28, and 23, respectively).

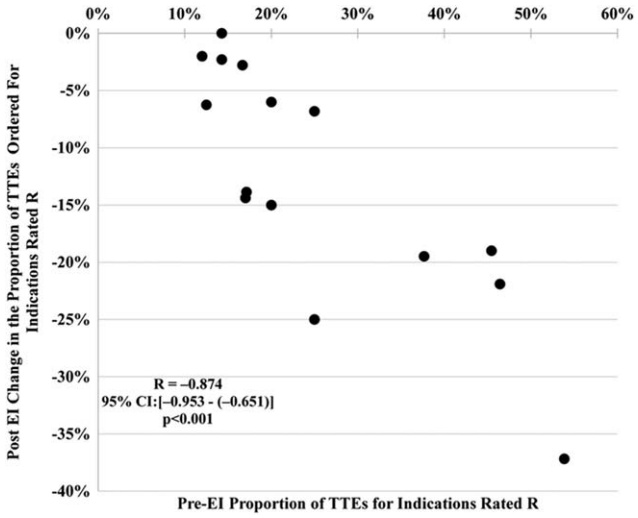

FIGURE 3 Change in the proportion of TTEs ordered for indications rated R for the top 25% physicians that had the highest proportion of TTEs ordered for indications rated R during the pre-EI phase

3.6 | Gaps in AUC document

Auscultatory click (48) and family history in someone other than a first degree relative (8) were the most common unclassifiable indications. In addition, other abnormal physical exam findings such as widely split S2 (4), and poor pedal pulses or significant arm-leg blood pressure difference (4) were unclassifiable based on the current AUC document. Some other unclassifiable scenarios included abnormal imaging tests such as abnormal carotid ultrasound (1) or computed tomography (2),

TABLE 3 Comparison of findings on TTE between pre- and post-EI phase

TTE findings	Pre-EI, *N* (%)	Post-EI, *N* (%)	*P* value
Normal and Incidental	1689 (89)	2368 (90)	.162
Abnormal	218 (11)	267 (10)	
Minor	145 (67)	175 (66)	.822
Moderate	66 (30)	87 (33)	.586
Severe	7 (3)	5 (2)	.345
Total TTEs	1907	2635	

TABLE 4 Comparison of the proportion of transthoracic echocardiograms ordered for various indication categories during pre- and post-EI phase

AUC indication category	Pre-EI $N = 1907$	Post-EI $N = 2635$	*P* value
Palpitations and arrhythmias	84 (4.4%)	130 (4.9%)	.407
Syncope	136 (7.1%)	199 (7.6%)	.593
Chest pain	315 (16.5%)	446 (16.9%)	.716
Murmur	534 (28.0%)	759 (28.8%)	.554
Other symptoms and signs	47 (2.5%)	42 (1.6%)	**.037**
Prior test results	279 (14.6%)	390 (14.8%)	.873
Systemic disorders	231 (12.1%)	293(11.1%)	.301
Family history	154 (8.1%)	263(10.0%)	**.028**
Outpatient neonates	6 (0.3%)	5 (0.2%)	.543

clinical concerns for a vascular ring such as wheezing or dysphagia (2), inappropriate sinus tachycardia (4), request by primary care physician (4), parental request (2), anorexia nervosa (2), and apparent life-threatening event (2).

Twenty AUC indications were not used in either phase (AUC indication # 4, 5, 8, 12, 16, 55, 59, 60, 62, 68, 70, 79, 88, 103, 104, 105, 108, 110, 111, and 112).

4 | DISCUSSION

This is the first study reporting the impact of an EI on the appropriate utilization of TTE in pediatric cardiology clinics. The multifaceted EI used in the PAUSE study was effective in reducing the proportion of TTEs ordered for indications rated R, especially among those physicians who had the highest rates of R prior to EI. However, there remained significant variation among centers and their physicians.

Implementation of AUC in pediatric cardiology is a relatively new concept compared with adult cardiology where the first AUC document was launched a decade ago. A systematic review based on 59 published studies assessing temporal changes in appropriateness of cardiac imaging modalities in adult patients, reported improvement in rates of appropriate use for TTE.[11] The pooled proportion of TTE studies for indications rated A improved from 80% to 85%, but there was no significant change in those rated R (8% vs. 9%) when comparing studies using the initial versus the revised AUC document, respectively.[11–13] This was likely due to the ability to classify previously unclassifiable indication as "appropriate" indications, following the revision of adult AUC TTE document in 2011.[11] In the present study the baseline rate of R is similar to that reported in adult studies, though the rate of A is lower compared with adult studies. Similar to the observations in adult cardiology, perhaps revision of the pediatric AUC document by including the common unclassifiable indications identified through the pediatric implementation studies would help increase the proportion of A studies.[10,14]

Following initial reports of implementation studies using adult AUC documents that benchmarked appropriate use of various imaging modalities, reports from quality improvement projects using various EI to reduce the rate of R started to emerge.[6–8,15] These studies used a wide variety of EI including passive interventions such as lectures, pocket cards and webinars to the more active ones including an audit and feedback mechanism and point of care decision support tools with varying results.[6–8,16–18] Chaudhuri et al. performed a meta-analysis to assess the effectiveness of various forms of EI to reduce the rate of unnecessary noninvasive cardiovascular imaging based on adult cardiology AUC documents.[19] The study included all forms of noninvasive cardiac imaging including echocardiography, single photon emission computed tomography, myocardial perfusion imaging, cardiac computed tomography angiography and cardiac magnetic resonance imaging.[19] They reported that overall the EI were associated with a significantly lower odds of testing for indications rated R. But, it is important to note that two of the seven studies included in the analysis reported no such effect of EI.[16,17,20] Importantly, the most effective EI were those including an audit and feedback method. Although the passive interventions such as a lecture are much easier to implement, they have been shown to be ineffective.[16] A recent randomized control trial, that was published after the meta-analysis by Chaudhuri et al reported the use of an audit and feedback EI involving 65 adult cardiologist at a single center.[21] Following EI, the proportion of TTEs rated R was significantly lower in the EI versus control group (143 of 1359 [10.5%] vs. 285 of 1728 [16.5%]). Our study used a combination of both active and passive interventions and was able to detect an overall modest improvement in TTE utilization. While the overall small change with an increase in the proportion of studies rated A by 3.7% and decline in those rated R by 2.2% may not appear to be meaningful despite the statistical significance, it is important to note that some centers had a dramatic decline in the proportion of R. Center 5 had a nearly 50% drop in the proportion of TTEs ordered for indications rated R from 34.8% to 18.5%.

The significant variation in appropriateness among centers that was noted at baseline, persisted despite the efforts to provide uniform EI at each center. This is not surprising, since the physician test ordering behavior may be driven by a multitude of factors including their training, personal experiences, financial incentives, Relative Value Unit based assessment of productivity, fear of medico-legal issues, institutional protocols mandating use of TTE for certain indications that may be rated R in the AUC document or simply due to relatively easy availability of the technology. In addition, even though we attempted to keep the EI uniform in all centers, it is possible that the attendance of the lecture and the timeliness and comprehensiveness of the monthly feedback to the individual physicians was variable depending on the SI. We did not collect physician variables to study their effect on appropriateness. We are in the process of surveying the physicians that participated in the PAUSE study to further understand their attitudes toward the pediatric AUC document and impact of their engagement with EI on change in the appropriateness of their TTE orders. Hopefully, this could help explain the variability being observed among centers and the physicians in the PAUSE study.

The active EI components of our study included feedback from the baseline data from Pre-EI phase followed by monthly audit and feedback during post-EI phase. This component was quite onerous on the SIs and likely not sustainable over a prolonged period of time unless there is protected time, manpower and funding dedicated to such processes. A unique approach adopted in our study was allowing the providers to assign the AUC indications themselves, in contrast to the pre-EI phase where the SI assigned the indication after reviewing the clinic notes. The rationale behind doing this was to assure that the AUC indication was chosen by the provider using the tables provided on the modified data collection sheet prior to obtaining the TTE. This was a "forced education" where the providers were required to look at the AUC tables. A better alternative to the manual method used in our study would be the use of a self-directed point of care decision-making tool integrated with the electronic ordering system and an audit and feedback mechanism. One such example is the Formation of Optimal Cardiovascular Utilization Strategies (FOCUS) program by American College of Cardiology Foundation that has an online self-directed application for radionuclide imaging performance improvement module that the providers can use themselves.[22] A study reporting use of this program by 55 participating centers showed significant reduction in the rate of testing for indications rated R from 10% to 5% within 1 year.[22] Perhaps similar modules could be made available for other imaging modalities. It is important to recognize that implementation of such broad initiatives through academic societies not only requires resources but also acceptance from the providers and other stakeholders.

Comparison of indications, appropriateness and yield of abnormal findings before and after EI, showed that even though the appropriateness was improved, the yield of abnormal findings remained the same. Given the significantly increased odds of detecting an abnormal finding with indications rated A or M compared with R, one would have expected a higher yield of abnormal findings following EI. However, it is important to acknowledge that the yield of abnormal findings is best determined by the indication of the study and not merely its appropriateness. It is well known that the yield of common outpatient indications related to chest pain, syncope, and palpitations is quite low compared with that of a murmur. In the current study, there was no significant difference between the proportions of studies performed for most of the indications including a murmur, before and after EI. The only indication that was used more following EI were related to family history, which again are known to have a low-yield. Moreover, the most common indications that were subjected to reclassification from A or M to U in the 15% random sample reviewed by SIs were related to family history. This was likely due to unawareness of the participating physicians self-assigning the AUC indication that the pediatric AUC document addresses family history related only to the first-degree relatives and not those in the extended family members. While it was encouraging to see that there was a 92% agreement for appropriateness between the SI and providers despite the providers self-assigning AUC indications, further education regarding definitions and assumptions that need to be taken into consideration while applying the AUC document is needed.

In addition to the gaps reported by the previous implementation study, some additional case scenarios were identified that could not be classified based on the current document.[10] Moreover, there were 20 AUC indications that were not used, and 16 of the 20 overlapped with the ones already identified in the first implementation study.[10] These findings should be taken into consideration when the AUC document is revised.

An important limitation of our study is the small number of physicians that ordered a substantial number of TTEs in each phase. Another important limitation is that we were unable to obtain an accurate number for initial clinic encounters at all the centers during the study period. This would be important to know if the volume of TTEs performed for indications rated R actually declined and not just the proportion. A change in the number of TTEs for indications rated R would be a better surrogate for a change in physician test ordering behavior than a change in proportion. The decline in the proportion could be a result of fewer patients presenting with indication rated R during the defined study period or an increase in those with A, M and/or U indications. The change in proportions could also reflect an artificial change in appropriateness due to a mere change in documentation or bias due to self-assignment of indications by the ordering physicians. A Hawthorne effect could have played a role since the clinicians in the study were aware of the data collection. A study using adult TTE AUC showed that after a nearly 2.5 month gap following EI, the proportion of inappropriate TTEs increased to the pre-EI level.[23] A sustained effort is therefore required for evaluating any long-term impact of such interventions.

5 | CONCLUSION

A multifaceted EI resulted in an overall improvement in the appropriateness of TTE utilization in the PAUSE study, with the most significant improvement in physicians with the highest rate of R. However, the EI did not decrease the variability between centers and physicians. More education on AUC document may improve appropriateness, reduce misclassification of indications and possibly reduce variability of TTE orders by physicians. Further studies are needed to evaluate the long-term impact of such interventions, their sustainability and integration with routine workflow.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest with the contents of this article.

AUTHOR CONTRIBUTIONS

Ritu Sachdeva, MD: Principal investigator (PI) of the study. Involved with the conception and design of the study and interpretation of the data, drafting the original manuscript, revising it based on the feedback from co-authors, and finalizing and submitting the manuscript.

Pamela S. Douglas, MD: Provided her expert guidance at every step right from the time of conception of the study. Played an important role in designing the study, interpretation of the data and critical review of the manuscript and approval of final submission.

Michael S. Kelleman MS, MSPH: Helped with study design and performed analysis of the data. Helped write the statistics section of the methods, critically revised the manuscript and approved the final submission.

Courtney E. McCracken, PhD: Helped with study design and supervised the analysis of the data. Helped revise the statistics section of the methods, critically revised the manuscript and approved the final submission.

Leo Lopez, MD: Helped with designing the study, critically revising the manuscript and approving the final manuscript.

Kenan W.D. Stern, MD: Site PI. Helped with designing the study, critically revising the manuscript and approving the final manuscript.

Benjamin W. Eidem, MD: Site PI. Helped with designing the study, critically revising the manuscript and approving the final manuscript.

Oscar J. Benavidez, MD: Site-PI. Helped with designing the study, critically revising the manuscript and approving the final manuscript.

Rory B. Weiner, MD: Provided his expertise in designing the study given his experience with similar studies using adult echo AUCs. Critically revised the manuscript and approved the final submission.

Elizabeth Welch, MD: Site PI. Helped with designing the study, critically revising the manuscript and approving the final manuscript.

Robert M. Campbell, MD: Helped with designing the study, critically revising the manuscript and approving the final manuscript.

Wyman W. Lai, MD, MPH: Senior mentor and site-PI. Instrumental in conception of the study and helped with designing the study and interpretation of the results. Critically reviewed the original draft and approved the final manuscript.

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