Received: 26 April 2018 | Revised: 30 July 2018 | Accepted: 28 August 2018

DOI: 10.1111/chd.12679

ORIGINAL ARTICLE

WILEY Congenital Heart Disease

Appropriateness of pediatric outpatient transthoracic echocardiogram orders following cessation of an active educational intervention

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Financial disclosure
The authors have no financial relationships relevant to this article to disclose.

Abstract

Objective: The educational intervention (EI) through the Pediatric Appropriate Use of Echocardiography (PAUSE) multicenter study resulted in improved appropriateness of transthoracic echocardiogram (TTE) orders at our center. The current study evaluated if this pattern persisted after cessation of EI and the potential physician characteristics influencing appropriateness.

Design: Outpatients (≤18 years old) seen for initial evaluation during the EI (July to October, 2015) and 6-month post-EI (May to August, 2016) phases were included. Comparison was made between TTE rates and appropriateness ratings during EI and post-EI phase. Association between TTE rate and appropriateness with physician characteristics (age, experience, patient volume, and area of practice) was determined using odds ratio.

Results: The study included 7781 patients (EI: N = 4016; post-EI: N = 3765) seen by 31 physicians. Comparison of appropriateness ratings in a randomized sample (EI: N = 1270; post-EI: N = 1325 patients) showed no significant differences between the two phases (appropriate: 75.2% vs 74.9%, P = .960; rarely appropriate 4.1% vs 6.5%, P = .065). Though there was significant variability among physicians for TTE order appropriateness (P = .044) and ordering rate (P < .001), none of their characteristics were associated with appropriateness and only a higher patient volume was associated with decreased odds of TTE ordering (OR = 0.7).

Conclusion: The PAUSE study EI resulted in maintaining appropriate utilization of TTEs at our center for 6 months following its cessation. Though not statistically significant, there was a trend toward increase in the proportion of studies for indications designated rarely appropriate (R). There was significant physician variability in TTE ordering and appropriateness during both phases. Development of EI to reduce physician variability and integration of EI with provider workflow may help sustain appropriate TTE utilization.

KEYWORDS
appropriate use, educational intervention, pediatric cardiology, transthoracic echocardiography

Abbreviations: A, appropriate; AUC, appropriate use criteria; EI, educational intervention; M, may be appropriate; PAUSE, Pediatric Appropriate Use of Echocardiography Study; R, rarely appropriate; TTE, transthoracic echocardiogram.

1 | INTRODUCTION

Given the exponential rise in the use of advanced cardiovascular imaging with a relatively stable disease rate in adult cardiology, appropriate use criteria (AUC) for cardiovascular imaging were introduced to improve resource utilization and provide improved patient care.[1] AUC have been used as benchmark for various quality improvement endeavors.[2,3] The first pediatric AUC addressing the initial outpatient use of transthoracic echocardiography (TTE) were introduced in 2014.[4] These criteria provide appropriateness ratings for various clinical indications.[4]

The PAUSE (Pediatric Appropriate Use of Echocardiography) study, was the first large multiphase, multicenter study reporting the baseline appropriateness of TTE orders in pediatric cardiology clinics prior to the release of the AUC document.[5] This study further reported that a passive release of the AUC document had only a very modest impact in improving appropriateness of TTE orders, while use of a multifaceted educational intervention (EI) resulted in a significant improvement.[6,7] The multifaceted approach in the PAUSE study used both passive and active components. The passive component included lectures and email feedback on individual appropriateness rates from earlier study phases. The active component included the audit and feedback method, where site investigators provided monthly feedback on appropriateness ratings of specific TTE orders.[7] Though the EI resulted in improvement in appropriateness, it was not known if these effects were sustainable in the absence of such acute interventions.

The purpose of this study was to evaluate if the observed improvement in appropriateness of initial pediatric outpatient TTE orders seen during active EI of the multicenter PAUSE study would persist within our single center 6 months after cessation of the active EI. Additional aims were to evaluate for any change in TTE ordering rate after cessation of the active EI and to determine if there were any physician characteristics influencing change in TTE ordering patterns.

2 | METHODS

2.1 | Study design

This single center study was approved by the Institutional Review Board of the Children's Healthcare of Atlanta. The study was designed to compare a 4-month EI phase (July 1, 2015 to October 30, 2015) with a 4-month post-EI phase (May 1, 2016 to August 30, 2016), separated by a 6-month period in between. The 6-month time frame was chosen based on findings from a prior study demonstrating loss of effect of an EI within a group when studied over a range of 3-10 months post-EI.[8] The 6-month mark was an estimated time point at which persistence of the EI effect may start to experience significant decline. Data obtained for the EI phase were from that collected for our center for the PAUSE study. Physicians were included if they were attending physicians, saw 50 new consult patients or more per study phase, and were not involved in the design of the PAUSE study. The group of physicians was the same in both the EI and post-EI phase. There was active physician participation for the educational intervention during the EI phase. Data collection for the PAUSE study ended on October 30, 2015 and there was no EI following that. For the post-EI phase, data were retrospectively collected 6 months following the end of PAUSE study and the physicians were unaware of this data collection. Patients ≤18 years old seen for an initial outpatient evaluation at our center during the two study phases were included. Patients were excluded if they were previously evaluated by a cardiologist, had previously undergone echocardiography, or were seen by a physician who either saw fewer than 50 patients per study phase or was involved in the design of the PAUSE study.

The EI phase has been described in detail in a previous publication.[2] Briefly, it consisted of four components (1) sharing of individual and institution pre-EI TTE appropriateness ratings with each individual via email, (2) a Power Point–based lecture at a staff meeting on how to use the AUC document, (3) providers utilizing AUC documents in clinic to assign an AUC indication prior to ordering an initial TTE, (4) audit and feedback intervention via a monthly email to individual providers with their appropriateness ratings in comparison to appropriateness ratings of the center as well as specific feedback for studies done for indications rated R.[5] During the post-EI phase, all four of these components had ceased 6 months prior. While the AUC document was not distributed to physicians in the post-EI phase as in the EI phase, there was no active removal of AUC documents from physicians at the end of the EI phase. The AUC document was publicly available during both phases for potential review by physicians on their own volition.

2.2 | Data collection and assignment of AUC indications

While data from the entire study population were utilized to assess TTE ordering rates and for associated physician characteristics, a random subset of patients was selected for assigning AUC ratings to clinical findings due to the time-intensive nature. Random samples were generated for each physician using PROC SURVEYSELECT in SAS statistical software (SAS, Cary, North Carolina) and sampling was done without replacement to ensure that each patient was only selected one time. As previously described in the study design, physicians had to see at least 50 new consultation patients during each time period to be included in the study. For included physicians, a random sample of 50 patients was selected from among their cohort of new consultation patients per study phase. Patients were excluded from the randomized sample if they did not meet study criteria; the remaining patients were included in appropriateness analyses. AUC indication was determined by reviewing the documentation in the chart during the clinic encounter. AUC ratings corresponding to the clinical indication were assigned using the AUC document[4] as appropriate (A), may be appropriate (M), rarely appropriate (R), or unclassifiable (U) if the indication was unavailable in the AUC document. All indications

for both phases were assigned by a single reviewer (SA). A single reviewer was used in order to ensure consistency in the method of AUC indication assignment across phases. Physician characteristics including age, experience in terms of years since fellowship, volume of patients seen per year, and area of practice (general pediatric cardiology vs other subspecialty within cardiology) were collected.

2.3 | Study outcomes

The primary outcome of interest was the change in appropriateness ratings between the EI and post-EI phase. Additional outcomes were changes in TTE ordering rate and physician characteristics associated with changes in appropriateness or ordering rate, if such a change was observed.

2.4 | Statistical analysis

Statistical analyses were performed using SAS 9.4 and statistical significance was assessed at the .05 level. Descriptive statistics were calculated for all variables of interest. Means and standard deviations or medians and ranges were used for continuous variables and counts and percentages for categorical variables. Differences in categorical variables (eg, TTE ordered, patient gender, and insurance status) were compared between the two phases using chi-square tests. Continuous variables, such as patient age, were compared using two-sample *t* tests or Wilcoxon rank-sum tests. Comparisons within physicians across study phases were made using paired *t* tests or Wilcoxon signed-rank tests to account for paired observations. Logistic regression was used to determine the association of provider characteristics with appropriateness of TTEs. To account for the clustering of patients within provider, generalized linear mixed models were used to further analyze the correlation between physician characteristics and appropriateness. These models used a physician-specific random intercept and compared TTEs ordered for indications rated A vs other appropriateness ratings. Associations are presented as odds ratios with 95% confidence intervals. Similar analyses were performed to determine provider characteristics associated with TTEs rated as R and whether or not a TTE was ordered.

3 | RESULTS

3.1 | Study population

Of the 8910 patients seen for an initial cardiology consultation by 40 physicians at our clinics, the study criteria were met by 7781 patients (4016 for the EI phase and 3765 for the post-EI phase) and 31 physicians. The same 31 physicians were included in each phase. The mean clinic volume per physician and patient characteristics were similar between the two phases (Table 1). The random selection of patients obtained for assigning appropriateness ratings resulted in inclusion of 1270 patients in the EI and 1325 in the post-EI phase. While each physician could contribute up to 50 patients per phase for analysis, after applying study criteria, the 31 physicians contributed a median of 41 patients (range: 34-47) and 43 patients (37-49) for assigning appropriateness ratings during the EI and post-EI phases, respectively.

3.2 | Change in the proportion of appropriateness ratings

For the overall study, there were no significant differences in the proportion of appropriateness ratings of the TTEs between the two phases (A: 75.2% vs 74.9%, P = .960; M: 8.5% vs 7.3%, P = .460;

TABLE 1 Comparison of patient characteristics between the educational intervention (EI) and post-EI phase

	Total patients (N = 7781)		
	EI phase	Post-EI phase	
	N = 4016 patients	N = 3765 patients	
Patient characteristics	N = 31 providers	N = 31 providers	P value[a]
Age (y)			
Median (25th-75th)	10.6 (4.1-14.7)	10.8 (3.8-14.9)	.381
Sex			
Male, *n* (%)	2109 (52.8)	1992 (52.9)	.936
Insurance status			
Insured, *n* (%)	3988 (99.3)	3738 (99.3)	.917
Clinic volume			
# of patients seen per physician			
Mean (±SD)	130 (±60)	121 (±56)	.147
Range	49-282	52-277	

[a]Chi-square test.

R 4.1% vs 6.5%, *P* = .065 or U: 12.4% vs 11.2%, *P* = .584, for EI vs post-EI phase, respectively) (Table 2). Although the change was not statistically significant between phases, there was a small trend upward in TTEs with an R designation. There were no significant differences between the two phases for the individual physician's proportion of appropriateness ratings for TTEs ordered for indications rated A or R. However, there was a wide range of appropriateness indicating significant variability among providers (Table 2).

Three of the top four most common R indications for TTEs ordered in the EI and post-EI phase were the same and were: presumptively innocent murmur, chest pain or syncope with no symptoms, signs, or findings of cardiovascular disease and a benign family history (AUC indications 39, 28, and 18, respectively). Palpitations with no symptoms, signs, or findings of cardiovascular disease, a benign family history and normal ECG (AUC indication 2) was among the top R indications in the EI but not post-EI phase and nonexertional chest pain with a normal ECG (AUC indication 32) was in the top R indications post-EI but not in the EI phase. Among the 728 patients in the EI and 711 patients in the post-EI phase for whom a TTE was not ordered, 34 (4.7%) in the EI phase and 33 (4.6%) in the post-EI phase had a clinical finding designated as an AUC A indication. The most common clinical findings with an AUC A designation and no associated TTE order during the EI and post-EI phase were: systemic hypertension (AUC indication 74), exertional chest pain (AUC indication 30), and an abnormal ECG without symptoms (AUC indication 52).

TABLE 2 Comparison of appropriateness of TTEs ordered in the educational intervention (EI) and post-EI phase[a]

	Randomized sample (N = 2595)		
	EI Phase	**Post-EI Phase**	
	N = 1270 patients	**N = 1325 patients**	
	N = 540 TTEs ordered	**N = 614 TTEs ordered**	
Center			
Proportion of all TTE orders with an AUC indication[c]	Frequency (%)		*P* value[b]
A	406 (75.2)	460 (74.9)	.960
M	46 (8.5)	45 (7.3)	.460
R	22 (4.1)	40 (6.5)	.065
U	67 (12.4)	69 (11.2)	.584
Physicians			
Proportion of each physician's TTE orders with AUC indication[c]	Mean (±SD)/range		*P* value[d]
A	74.1% (±10.5)	76.5% (±11.2)	.377
	50.0%-95.7%	38.5%-93.3%	
R	4.3% (±5.4)	5.9% (±6.94)	.210
	0.0%-16.7%	0.0%-24.1%	

Abbreviations: A, appropriate; M, may be appropriate; R, rarely appropriate; TTE, transthoracic echocardiogram; U, unclassifiable.

[a]A representative randomized sample was used for appropriateness analyses.

[b]Chi-square test.

[c]AUC indication was assigned by a single reviewer (SA).

[d]Paired *t* test.

3.3 | Change in TTE ordering rate between the EI and post-EI phase

There was no difference in the mean physician TTE ordering rate between the two phases (EI phase: 43.7% ± 11.2%, post-EI phase: 47.6% ± 12.0%; *P* = .134). Further analysis showed variability among providers with a majority having minimal change or a decrease in ordering rate between the phases and a minority with a greater than 5% increase in ordering rate (TTE ordering rate within 5%: 38.7% (*n* = 12), decreased by 5% or more: 22.6% (*n* = 7), increased by 5% or more 38.7% (*n* = 12)).

3.4 | Impact of physician characteristics on TTE ordering patterns

A secondary aim of this study was to assess for any physician characteristics associated with a change between the two phases in TTE appropriateness or ordering rate. However, since there were no significant differences noted between the two phases, this could not be evaluated. Since we did observe a wide range of appropriateness for individual providers in both the phases, we further evaluated for physician characteristics associated with appropriateness for both the EI and post-EI phases together. For all TTEs ordered in either phase, we found no significant associations between physician age, experience following fellowship, patient volume or area of subspecialty and appropriateness of TTEs ordered for indications rated A or R (Table 3). However, the provider-specific random intercept was significant (*P* = .044) indicating significant variation in A ratings among providers. In regard to physician characteristics associated with a change in ordering rate, with only 31 physicians, the study was underpowered to compare subgroups of physicians based on their change in ordering rate between the two phases. Instead, we analyzed physician characteristics associated with the likelihood of ordering a TTE in either study phase. There were lower odds of ordering a TTE by physicians who saw a higher volume of patients per year (Table 4). Similar to the models for TTE appropriateness, there was a significant random effect for provider (*P* <.001), indicating significant variability in TTE order rates among providers.

4 | DISCUSSION

This is the first study to demonstrate a sustained impact of a multifaceted EI on improvement in appropriateness of pediatric outpatient TTE orders for at least 6 months following cessation of the

TABLE 3 Association of physician characteristics with appropriate use criteria appropriateness ratings

	A Indication		R Indication	
Characteristic	**OR (CI)**	***P* value**	**OR (CI)**	***P* value**
Physician age (<40 vs ≥40 y)	0.98 (0.66-1.47)	.941	1.57 (0.75-3.29)	.231
Clinical experience (<10 vs ≥10 y)	1.25 (0.85-1.83)	.254	1.27 (0.60-2.71)	.525
Patient volume (<500 vs ≥500 pts/y)	1.36 (0.802-2.29)	.254	0.58 (0.19-1.76)	.337
Area of practice (General cards vs subspecialty)	1.16 (0.78-1.71)	.474	1.35 (0.61-2.97)	.455

TABLE 4 Association of physician characteristics with likelihood of transthoracic echocardiogram ordering

Characteristics	**Odds ratio**	**95% CI**	***P* value**
Physician age (Per every 5 year increase)	0.97	(0.88-1.07)	.525
Years of experience after fellowship Per every 5 year increase	0.96	(0.86-1.06)	.383
Volume of patients per year <500 vs ≥500 per/year	0.70	(0.50-0.97)	.031
Area of practice General vs subspecialized cardiologist	1.30	(0.95-1.78)	.100

EI.[7,9,10] The multicenter PAUSE study showed that a multifaceted EI resulted in an increase in the proportion of TTEs from the pre-EI to the EI phase designated A (from 72.5% to 76.2%, $P = .004$) and a decline in those designated R (from 9.6% to 7.4%, $P = .008$).[7] The present study showed that there was no significant change in the proportion of TTEs ordered between our center's EI and post-EI phase, so that 6 months following EI cessation 74.9% of TTEs ordered were designated A and 6.5% R. Similar to other studies, this study found substantial variation in appropriateness of TTE ordering practices between providers.[5,7,8] Physicians with a larger yearly patient volume had a lower likelihood of ordering a TTE at an initial pediatric cardiology outpatient encounter.

The persistence of the improved appropriateness of TTEs following cessation of the multifaceted EI emphasizes the important role of EI on informing physicians, impacting clinical practice and resource utilization, and advancing quality improvement.[3,7,11] In a survey of pediatric cardiologists participating in the PAUSE study, 57% of respondents reported a change in practice following EI. While all components of EI were felt to be helpful, the monthly audit and feedback was the most helpful.[12] Audit and feedback methods are considered to be two of the most effective forms of EI for modifying physician ordering behavior.[2,9,13,14] Interestingly, in contrast to our findings, a single-center study on an adult cardiology inpatient population reported an increase in TTEs ordered for rarely appropriate indications following cessation of EI, to that of the pre-intervention levels.[8] This study had used a similar multifaceted approach during their EI phase including the audit and feedback method. While our study included only pediatric cardiologists, this study in adult patients primarily included internal medicine residents on an inpatient service. The differences in the level of interest, attitude toward education on AUC, training and clinical experience between the providers in these two studies could explain the varying outcome. This is supported by the PAUSE survey findings that centers whose physicians had higher rates of reading the AUC document and centers with physicians who had a positive attitude toward the AUC and perceived EI to be helpful, had higher rates of appropriateness.[12] The Echo WISELY (Will Inappropriate Scenarios for Echocardiography Lessen Significantly) Trial,[13] is a large multicenter randomized control trial using education and feedback intervention in centers in United States and Canada to reduce unnecessary echocardiograms. While there is a lack of data regarding medical residents' attitudes toward AUC, this trial reported that among adult cardiology and primary care attendings in an outpatient setting, the majority of providers (61%) demonstrated interested in the AUC-based EI by accessing online training materials, specifically the feedback reports.[15] Feedback with specific areas of improvement has been shown to be a highly effective method for modifying physician behavior.[14] Potential feedback to include in future AUC-based EI would be listing the provider's top five rarely appropriate AUC indications designated of their TTEs ordered.

Despite the overall sustained improvement in AUC appropriateness found in our study, there was substantial variability among providers in regard to appropriateness and ordering rate

that was not explained by the physician factors evaluated in our study.[7,8,16] We found that a minority of providers had an increase in TTE ordering rate after cessation of the EI. Interestingly, physicians with a higher volume of patients in their clinics had a lower rate of ordering TTEs in our study. This could either be explained by their increased clinical experience related to the higher volume of patients they are seeing or due to workflow issues that could result from ordering excessive TTEs in a busy clinic. Prior studies have reported that younger and less experienced physicians tend to have higher rates of TTE orders during initial evaluation in clinics, though our study did not find that.[17,18] The physician factors explored in our study do not fully explain the variability noted among physicians.

The most common R AUC indications for which a TTE was ordered in this study were similar to that in other phases of the PAUSE study. These indications are related to presumptively innocent murmur, benign syncope, or palpitations and nonexertional chest pain that are all very common referrals to outpatient pediatric cardiology.[5,6] We also noted that TTEs were not ordered for some common indications rated A such as systemic hypertension (AUC indication 74), exertional chest pain (AUC indication 30), and an abnormal ECG without symptoms (AUC indication 52). Differences in the reviewer designated clinical AUC indication and TTE ordering practice could relate to incomplete documentation; where the providing physician had additional information that may not have been apparent on review of the documentation in the medical records. It is also important to recognize that differences in AUC indication appropriateness rating and TTE ordering do not equate to a lack of adherence to clinical guidelines. The emphasis of the AUCs is on appropriate TTE utilization rather than being a prescriptive guideline for clinical care. For example, a patient presenting with exertional chest pain, which carries an AUC A indication, may have a clear history suggestive of exercise-induced asthma leading the provider not to order a TTE for further evaluation. Although this study was underpowered to support this conclusion, another explanation for discrepancies in AUC ratings and TTE orders is that perhaps experienced clinicians are able to make a reasonable clinical judgment of which scenarios will have a high yield of usefulness in TTE ordering that cannot be fully captured in a document. As the writers of the AUC document state, "AUC publications are an ongoing effort to critically and systematically create, review, and categorize" common clinical situations where diagnostic tests are utilized in patients with known or suspected cardiovascular disease.[4] The document was designed as a tool to help guide clinical decision making regarding TTE use with the anticipation that dynamic editions post-implementation would be required to reflect ongoing research, clinical practices, and expert opinion.

Despite our study showing a sustained effect of EI 6 months after cessation, it remains to be seen if the effect lasts for longer than the 6-month period included in this study. In the absence of knowing exactly when the effect of an EI may start to decline, the EchoWISELY trial and other studies suggest that implementing an ongoing EI as a continual quality improvement process is a worthwhile endeavor to ensure sustained improvement in appropriateness.[3,15] It is important to appreciate that conducting multifaceted quality improvement projects, especially ongoing ones, necessitates a well-formed infrastructure and optimal funding and manpower to implement the EI. The EI component of this study required significant manual effort on part of the investigators to perform the education, audit and feedback, however, studies have shown that integration of EI into electronic formats and use of an online educational tracking tool is an effective means of improving appropriateness of test orders and may minimize the effort needed to supply individualized feedback.[15,19] In these studies, the AUC EI was integrated into provider workflow as point-of-care decision support tools. Tools included echocardiogram ordering platforms within the electronic medical record that incorporated AUC indication and mobile device applications with access to the AUC document.

The main limitations of this study relate to its relatively small sample size. While our physician specific analyses of ordering trends enabled detection of an association between providers with a higher yearly patient volume and a decreased likelihood of TTE ordering, there was substantial variability among providers. Further subanalysis evaluating the relation between change in TTE ordering rate and appropriateness category could not be performed given the relatively small numbers per physician. Detection of additional physician characteristics influencing ordering trends was also likely limited by our physician sample size. Consequently, results of this study still do not explain the significant physician variability in appropriateness ratings of TTE orders. A formal power calculation was not performed a priori for this study. Our post hoc power calculation, however, demonstrated that for our appropriateness analyses using a randomized sample with 1270 patients in the pre-EI phase and 1325 patients in the post-EI phase, our study had 75.1% power to demonstrate a statistical significance change in the rarely appropriate rate at the .05 significance level. We recognize that a difference may exist in the rarely appropriate rating between the two phases just below the power of our study to detect. This study also has limitations in generalizability; it was completed in a pediatric, academic center that potentially possesses a higher level of interest in educational tools and knowledge of current topics such as pediatric AUC compared to nonacademic or adult settings. An additional limitation is that the study did not control for the frequency with which physicians accessed the publicly available AUC document or AUC educational material in either the EI or post-EI phase. Persistence of appropriateness, therefore, may also relate to frequency of AUC document referencing in addition to the effect of the EI. A potential control for this would have been to conduct a physician survey at the end of each phase inquiring about frequency of viewing AUC material during each time period. A retrospective survey of this nature, however, likely would be impacted by the "Hawthorne effect" and recall bias.

5 | CONCLUSION

The PAUSE study EI has had a lasting impact in maintaining appropriate utilization of pediatric outpatient TTEs at our center for at least 6 months following its cessation. The longer-term impact remains to be seen. Though not statistically significant, a small trend upward in the proportion of TTEs with an R designation was noted. Identifying institution and physician-specific characteristics that influence appropriateness and TTE order rate can be helpful in giving individualized feedback and designing focused EI to ensure sustained improvement in appropriate TTE utilization. Given the resources required to implement such EIs, efforts should be made to integrate AUCs within the clinical workflow through electronic health record platforms. AUC integration into the electronic health record will enable providers with easy accessibility to AUC while ordering TTEs and permit easy data retrieval for use in automated feedback systems.

FUNDING SOURCE

No external funding for this manuscript.

ACKNOWLEDGMENT

We acknowledge the Emory + Children's Pediatric Biostatistics Core for their help with analysis of the data.

CONFLICT OF INTEREST

The authors have no conflicts of interest relevant to this article to disclose.

AUTHOR CONTRIBUTIONS

Shae Anderson, 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.
Courtney E McCracken, PhD: Helped with survey design and performed analysis of the data. Wrote the statistics section of the methods, critically revised the manuscript and approved the final submission.
Ritu Sachdeva, MD: Senior author of the study. Involved with the conception and design of the study and interpretation of the data, critically revised the manuscript and approved the final submission.

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How to cite this article: Anderson S, McCracken CE, Sachdeva R. Appropriateness of pediatric outpatient transthoracic echocardiogram orders following cessation of an active educational intervention. *Congenital Heart Disease*. 2018;13:1050–1057. https://doi.org/10.1111/chd.12679