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Improving Adherence to Echocardiogram Reporting Guidelines in Patients with Repaired Tetralogy of Fallot: A Quality Improvement Initiative

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Abstract:

In patients with repaired tetralogy of Fallot (TOF), key echocardiogram report elements have been identified, but poor adherence has been demonstrated, particularly for quantitative assessment. We report a quality improvement effort to improve adherence at our institution, with a focus on increasing quantitative assessment of right ventricular (RV) function. Baseline compliance was established by a 3-month retrospective review of outpatient echocardiogram reports. Intervention 1 included presenting baseline data and reviewing the guidelines with echocardiogram lab staff (physicians and sonographers). Intervention 2, chosen to focus on quantitative assessment of RV function, involved recommending measurement of tricuspid annular plane systolic excursion (TAPSE) for all echocardiograms. Reporting rates were prospectively analyzed for 1 month after each intervention. To evaluate sonographer versus physician compliance, both study images (acquisition of TAPSE images) and reports were reviewed. At baseline, adherence was poor (median 65% of elements reported), with lower rates for measurements vs descriptive elements (median 40% vs 78%, p<.0001). Following intervention 1, total reported elements improved (median 71% vs 65%, p=0.02) due to increase in measurements (median 50% vs 40%, p=0.02). Reports of quantitative RV function did not significantly change after either intervention, but sonographer compliance improved after intervention 1 (33% vs 14%, p=0.03), with further improvement after intervention 2 (53% vs 14%, p=0.001). While education on lesion-specific guidelines may modestly improve adherence, standardization has a greater effect. However, interventions may have differential impact on sonographers vs attendings, and iterative interventions may be required to change practice patterns.

Keywords: quality improvement, repaired tetralogy of Fallot, right ventricular function, TAPSE

Introduction

Tetralogy of Fallot (TOF) is the most common cyanotic congenital heart lesion[1], with excellent long-term outcomes[2]. However, these patients require lifelong surveillance[3], as

residual lesions can lead to complications such as biventricular dysfunction, conduction abnormalities, heart failure, and sudden cardiac death[4,5]. Transthoracic echocardiography (TTE) remains the first-line non-invasive imaging modality for surveillance, with guidelines for evaluation of the right heart[6,7].

In 2014, multimodality imaging guidelines for patients with repaired TOF identified key reporting elements for routine TTE to optimize data acquisition and guide clinical decision making[8]. However, adapting existing protocols to recommendations can be a slow process at the institutional level[9,10]. A multicenter study found poor adherence to these guidelines across 8 large congenital cardiac centers[11], with lowest reporting rates for quantifying right ventricular (RV) size and function. Barriers to change and strategies to improve compliance were not evaluated.

We report a quality improvement (QI) effort to increase adherence to the guidelines at our institution with a specific focus on increasing rates of quantitative assessment of RV function. We hypothesized that adherence could be improved through education of sonographers and cardiologists and standardization of RV function quantification.

Methods:

This quality improvement initiative consisted of a retrospective baseline cohort, as well as two prospective cohorts to evaluate the impact of each of two targeted interventions. Each cohort included all patients with repaired TOF who underwent routine outpatient echocardiogram at the University of Michigan Congenital Heart Center during the designated timeframe. Inpatient echocardiograms were excluded to avoid focused studies in the postoperative period, or studies intended to evaluate a specific clinical concern. This initiative was approved by the University of Michigan Institutional Review Board as a QI project, and the requirement for informed consent was waived.

Baseline cohort

The baseline cohort comprised all patients meeting inclusion criteria from August 1, 2018, through October 31, 2018. A single reviewer evaluated all echocardiogram reports for 17

elements identified in the imaging guidelines (Table 1). Elements were scored as included, absent, or not applicable (e.g. if the report indicated imaging limitations secondary to patient factors). Analysis of the reports evaluated the percentage of complete reports (i.e. all 17 elements) and reporting rates for each individual element. Elements were also categorized as descriptive (e.g. presence or absence of right ventricular aneurysm), measurement (e.g. branch pulmonary artery dimensions), or Doppler (e.g. RVOT peak gradient) to further characterize compliance. There were 9 descriptive elements, 6 measurement elements, and 2 Doppler elements.

Interventions

The design of the interventions was a two-stage approach that included an educational phase to highlight our lab's current practice in relation to the guidelines, as well as implementation of a new standardized reporting practice. **A plan, do, study, act (PDSA) diagram is included to detail the evolution of these interventions (Figure 1).** The first intervention involved presenting baseline data and reviewing the TOF-specific imaging guidelines at **a monthly** echocardiography lab **staff** meeting that included both sonographers and attending physicians. **The majority of the 10 sonographers and 13 attendings were present. Following the meeting, meeting minutes that included the presented data and goal to increase adherence were sent to the echocardiography group. In addition, the TOF-specific guidelines were posted to the group's internal website, and a reminder regarding the goal to increase TOF specific guideline adherence was sent.** Goals were defined to increase overall compliance with all elements, as well as a targeted goal of increasing quantitative measurement of RV function. Following this intervention, a prospective cohort was collected to review reporting rates for all 17 elements in echocardiogram reports during a 1-month period from May 20, 2019, through June 14, 2019.

Results of the initial intervention were reviewed and discussed with sonographers and attendings at a subsequent monthly staff meeting, with a decision to focus attention on increasing reporting of quantitative RV function. The second intervention thus recommended

routine measurement of tricuspid annular plane systolic excursion (TAPSE) for all echocardiograms performed by the lab. Of the measures included in the guidelines to quantify RV function, TAPSE was chosen given its reproducibility and relative ease of measurement. Following this intervention, a second prospective cohort was evaluated in the 1-month period from September 19, 2019, through October 18, 2019. To assess potential differences between attending and sonographer compliance, echocardiogram images were also reviewed, in addition to reports, to identify studies where TAPSE had been evaluated by the sonographer but not reported. **Finally, a post-hoc analysis of TAPSE reporting by physician stage of career was performed. Stage of career was dichotomized as early or mid-career versus late, based on academic rank and years since fellowship completion.**

Statistical Analysis

Data are presented as frequency (percent), mean ± standard deviation, or median (interquartile range [IQR]) as appropriate. The baseline cohort was compared to each of the two post-intervention cohorts. Categorical variables were compared with Chi-square test or Fisher's exact test; continuous variables were compared with Wilcoxon rank-sum test or two-sample t-test. A p-value less than 0.05 was considered statistically significant. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Results

A total of 124 studies from 115 patients were reviewed through the course of the initiative (Table 2). In 9 patients, 2 echocardiograms were included among the cohorts. Patient characteristics were not significantly different from baseline to post-intervention cohorts, other than a trend toward a younger population post intervention 2, with corresponding lower height, weight and body surface area (but similar body mass index). The vast majority of studies were performed by sonographers (114/124, 91.9%), with no significant difference among cohorts.

Baseline cohort

In the baseline cohort, no reports included all 17 elements, with a median of 64.7% (IQR 58.8-70.6%) of elements reported per study. Report completion by element is shown in Figure 2. Measurements were included less frequently than descriptive elements (median 40% vs 77.8%, $p < .0001$). Of the elements classified as measurements, RV function and RVOT/MPA dimension were the least frequently reported. Elements related to the branch pulmonary arteries (dimension 8/78, 10.3%; obstruction 10/78, 12.8%) and atrial septum (16/28, 20.5%) were the most frequently reported as unable to be assessed secondary to patient factors.

Post Intervention 1

Following intervention 1 (Figure 3), there was improvement in total percentage of reported elements from baseline (median 70.6% vs 64.7%, p= 0.02) (Table 3), although no reports contained all elements. This change was predominantly due to an increase in reporting of measurements (median 50% vs 40%, p= 0.02); reporting of descriptive elements was unchanged (median 77.8% vs 77.8%, p= 0.2). Despite the increase in reporting other measurement elements, reporting of quantitative RV function did not significantly improve following the first intervention (11.1% vs 14.1%, p= 1.0). However, several studies did have TAPSE images recorded by sonographers but not reported, with TAPSE images available in 9 of 27 studies (33.3%). Including these studies, the sonographer's quantitative evaluation of RV function did improve in this cohort (14.1% vs 33.3%, p= 0.03) (Figure 4).

Post Intervention 2

The second intervention focused on improving reporting of quantitative RV function. The small potential improvement in reporting of quantitative RV function was not statistically significant in this small cohort (26.3% vs 14.1%, p= 0.30) (Table 3). However, when including TAPSE images collected by sonographers, the increase post intervention 1 continued and

potentially further increased post intervention 2 (52.6% vs 14.1%, p = 0.001) (Figure 4). However, the apparent increase between the first and second interventions was not statistically significant (33.3% vs 52.6%, p= 0.19). Of studies with TAPSE images available, 33% were reported after the first intervention, and 50% following the second intervention. **Post-hoc analysis of physician TAPSE compliance showed no difference after intervention 1 (33% in both subgroups). However, after intervention 2, early/mid-career attendings increased reporting of TAPSE 70%, while late career attending reporting remained at 33% (not statistically significant).**

Discussion

Despite suboptimal baseline compliance with imaging guidelines, adherence at our institution increased following the two interventions in our quality improvement initiative. The initial educational intervention increased reporting of measurement elements, and quantitative assessment of RV function further improved with protocol standardization, although this increase was more notable among sonographers than physicians. Although previous studies have identified a similar gap between publication and adoption of guidelines[11,10], to our knowledge, this is the first study to demonstrate the potential for a combination of educational initiatives and focused protocol changes to improve adherence to these guidelines at a large pediatric cardiac center.

Baseline adherence rates at our institution were similar to a prior multicenter study, which reported median overall adherence 61% (IQR 53-70), with the lowest adherence rates also noted for quantitative RV function (median 20%)[11]. The similarities between our institution and the eight centers included in the previously studied cohort highlight the universal challenges faced by high volume centers in adopting new protocols and the need for strategies to address barriers to adherence. Delays in implementation of guidelines may stem from many reasons: a lack of awareness of the guidelines, overestimation of baseline compliance or quality, difficulty in changing protocols, increased (or perceived increased) time to generate reports when incorporating additional elements, patient related factors interfering with image acquisition, or physician disagreement with guideline recommendations.

The interventions for this quality improvement initiative were chosen to address these barriers, focusing on increasing awareness and standardizing a new protocol. An educational initiative was chosen as the first intervention, as similar initiatives to change physician practice patterns have been shown to be effective[12], and it is a straightforward and low cost strategy that can be easily implemented at any institution. To address quantitative assessment of RV function, TAPSE was chosen from the guideline's recommended measurements. We recognize the conflicting data on the use of TAPSE for assessing RV function, with some studies finding good correlation to RV ejection fraction on cardiac MRI[13,14] and other studies demonstrating limited correlation[15,16]. For the purposes of an initial quantitative echocardiographic measure, however, we chose TAPSE for the simplicity of measurement, high reproducibility[17], and assessment of longitudinal contraction of RV free wall, the component of RV function which relates to exercise capacity and functional health status[18,19].

Standardization of TAPSE measurement for all echocardiograms allowed assessment of the impact of a focused intervention that did not rely on practitioners remembering lesion-specific guidelines. This did demonstrate a significant continued increase in quantitative assessment of RV function compared to baseline, however only when including TAPSE images (i.e. compliance by sonographers), which were not necessarily incorporated into physician reports. There was no significant change in quantitative assessment of RV function following either intervention when evaluating physicians alone. The significance of this gap between sonographer and physician compliance is unclear. **In an informal survey of sonographers and attendings after the second intervention, sonographers cited forgetfulness, concerns about TAPSE accuracy, uncertainty around normal TAPSE values, and variable attending acceptance of TAPSE (and thus measuring but not necessarily reporting). Physicians reported including TAPSE if measured and included in the preliminary report by the sonographer, but were otherwise limited by forgetfulness, concerns about TAPSE accuracy or normal values, and inadequate time. Given these responses, the gap in reporting** may be **primarily** related to **physician discomfort with** conflicting data regarding TAPSE, as physician practice patterns did change for reporting measurement elements following the educational intervention. **The reporting gap** may also identify variable resistance to change in physicians relative to

sonographers, with a need to agree with change rather than simply complying with a protocol. A previous study on improving appropriate ordering of TTE found that physician attitude towards the guidelines predicted adherence rates[20], so potential disagreement with guideline recommendations could also have influenced this outcome. **Although sample size limited statistical analysis of attending TAPSE reporting, qualitatively, early to mid-career attendings improved compliance with TAPSE reporting following intervention 2, while late career attendings did not. This discrepancy may reflect a greater openness changing practice patterns amongst earlier career attendings and suggests alternative strategies may need to be employed to change compliance in late career attendings. As forgetfulness was cited as a barrier to adherence by both sonographers and attendings, adding an automatic reminder or reporting template would likely have a significant impact on compliance and would also counteract the expected drop off in adherence following the end of the study period.** Further investigation into effective strategies for changing physician practice patterns is warranted, as quantitative assessment of RV function was the least reported element across multiple institutions despite its importance in long-term monitoring of patients with repaired TOF.

Of note, while there appeared to be a further increase in quantitative assessment of RV function compared to baseline following the second intervention, the improvement between the first and second intervention was not statistically significant. This may have been related to a relatively small sample size of reports following the second intervention. At the time of the second intervention, several months had passed since the educational intervention. It is reasonable to consider the further increase is more likely related to the second intervention rather than a continued effect from the first intervention (which if anything may have attenuated), and suggests a potential role for standardizing changes to echocardiogram protocols to increase guideline adherence.

Several limitations should be acknowledged. This study had a limited sample size, but was still appropriate to detect significant change. Although it was a single center study, the similarities in baseline data to other institutions and the ease of replicating our study's interventions, suggest these results should be broadly applicable. Finally, only one month of echocardiogram reports were analyzed following each intervention, and it is possible that the

effects of the interventions may attenuate over time. Further follow up studies to assess the long-term impact of these interventions may be warranted.

Conclusion

This quality improvement study demonstrated improvement in adherence rates to published imaging guidelines, both overall and in a targeted fashion toward an identified gap of quantitative assessment of RV function. Both an educational initiative and protocol standardization improved rates of reporting for measurement elements and quantitative assessment of RV function. Limited physician compliance relative to sonographers remains an important barrier to consider. This study demonstrates that simple interventions can have a significant effect on implementing new guidelines at an institutional level, though further interventions may be necessary to change physician practice patterns.

Conflicts of interest: The authors have no relevant financial or non-financial interests to disclose.

Author Contributions:

Charlotte M. Srnka, MD: Design of study, data collection and interpretation, drafting and revision of article

Courtney M. Strohacker, MD: Assistance with study design and data interpretation

Sowmya Balasubramanian, MD: Assistance with study design and data interpretation

Sunkyung Yu, MS: Statistical analysis

Ray Lowery, BA: Database management

Jimmy C. Lu, MD: Concept and design of study, analysis of data, critical revision of article

All authors discussed the results and contributed to editing of the manuscript.

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Table 1. Echocardiogram reporting elements

RVOT/MPA (dimension measured)
RVOT/MPA (location/mechanism of obstruction described)
RVOT/MPA (presence of aneurysm)
RVOT or RV-PA conduit (peak/mean gradient by 2D, color, and spectral Doppler)
Degree of PR (described)
Branch PAs (dimensions of narrowest and/or maximal segments)
Branch PAs (location and severity of obstruction by 2D, color, and spectral Doppler)
TR (degree and mechanism) and Vena contracta width (measured if more than mild TR)
RV pressure (measured via any of: TR jet velocity, if noted that TR envelope is insufficient; trans-VSD gradient; or systolic septal configuration)
RV size (quantified via diameter of RV, indexed end-diastolic cross-sectional area, TV annular diameter, or diastolic septal flattening)
RV function (measured with any of: EF, FAC, Dp/Dt, Tei index, TAPSE, 3D EF, TDI Ś)

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361
362

Residual VSDs (described)

Residual ASDs (described)

Aortic dimensions (measured)

Aortic regurgitation (described)

Systemic-to-pulmonary collateral vessels on the basis of color Doppler interrogation and spectral doppler evaluation of the abdominal aorta for diastolic runoff

LV size and function (quantified with some measurement of EF)

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Table 2. Patient characteristics by cohort

	All (N=124)	Baseline (N=78)	Post intervention 1 (N=27)	Post intervention 2 (N=19)	P-value*	P-value†
Male sex	75 (60.5)	49 (62.8)	17 (63.0)	9 (47.4)	0.99	0.22
Caucasian race	103 (83.1)	65 (83.3)	24 (88.9)	14 (73.7)	0.76	0.34
Age at repair, years	0.7 (0.3-2.1)	0.7 (0.3-2.5)	0.7 (0.3-1.5)	0.6 (0.2-1.5)	0.65	0.36
Age at Echo, years	21.8 (12.0-33.4)	22.7 (12.6-33.5)	25.4 (11.8-34.8)	13.7 (6.1-29.9)	0.72	0.08
Weight, kg	60.8 ± 31.2	64.2 ± 32.1	61.5 ± 28.0	46.1 ± 28.5	0.70	**0.03**
Height, cm	151 ± 31.3	154 ± 28.9	153 ± 32.6	135 ± 36.0	0.79	**0.02**
Body surface area, m^2	1.57 ± 0.57	1.63 ± 0.56	1.59 ± 0.55	1.29 ± 0.58	0.79	**0.02**
Body mass index, kg/m^2	24.2 ± 7.6	24.8 ± 8.4	24.2 ± 5.8	21.8 ± 5.6	0.68	0.14

Data are presented as N (%), median (interquartile range) or mean ± standard deviation.

*Comparison between retrospective cohort and the first prospective cohort.

†Comparison between retrospective cohort and the second prospective cohort.

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Table 3. Percentage of Elements Completed Across Cohorts

	Retrospective (N=78 studies)	Prospective 1 (N=27 studies)	P-value*	Prospective 2 (N=19 studies)	P-value†
Percent Completion of all 17 elements	64.7 (58.8-70.6)	70.6 (60.0-82.4)	**0.02**	---	---
Percent Completion by category					
Descriptive (in 9 elements)	77.8 (66.7-77.8)	77.8 (71.4-88.9)	0.20	---	---
Measurement (in 6 elements)	40.0 (33.3-50.0)	50.0 (33.3-66.7)	**0.02**	---	---
Number of studies including RV size	27 (34.6)	14 (51.9)	0.08	6 (31.6)	0.80
Number of studies including RV function	11 (14.1)	3 (11.1)	1.00	5 (26.3)	0.30
Total RV function (reported and TAPSE images)	N/A	9 (33.3)	**0.03**	10 (50.0)	**0.001**

* Data are presented as N (%) for categorical variables and Median (interquartile range) for continuous variables.

*Comparison between retrospective cohort and first prospective cohort.

†Comparison between retrospective cohort and second prospective cohort.

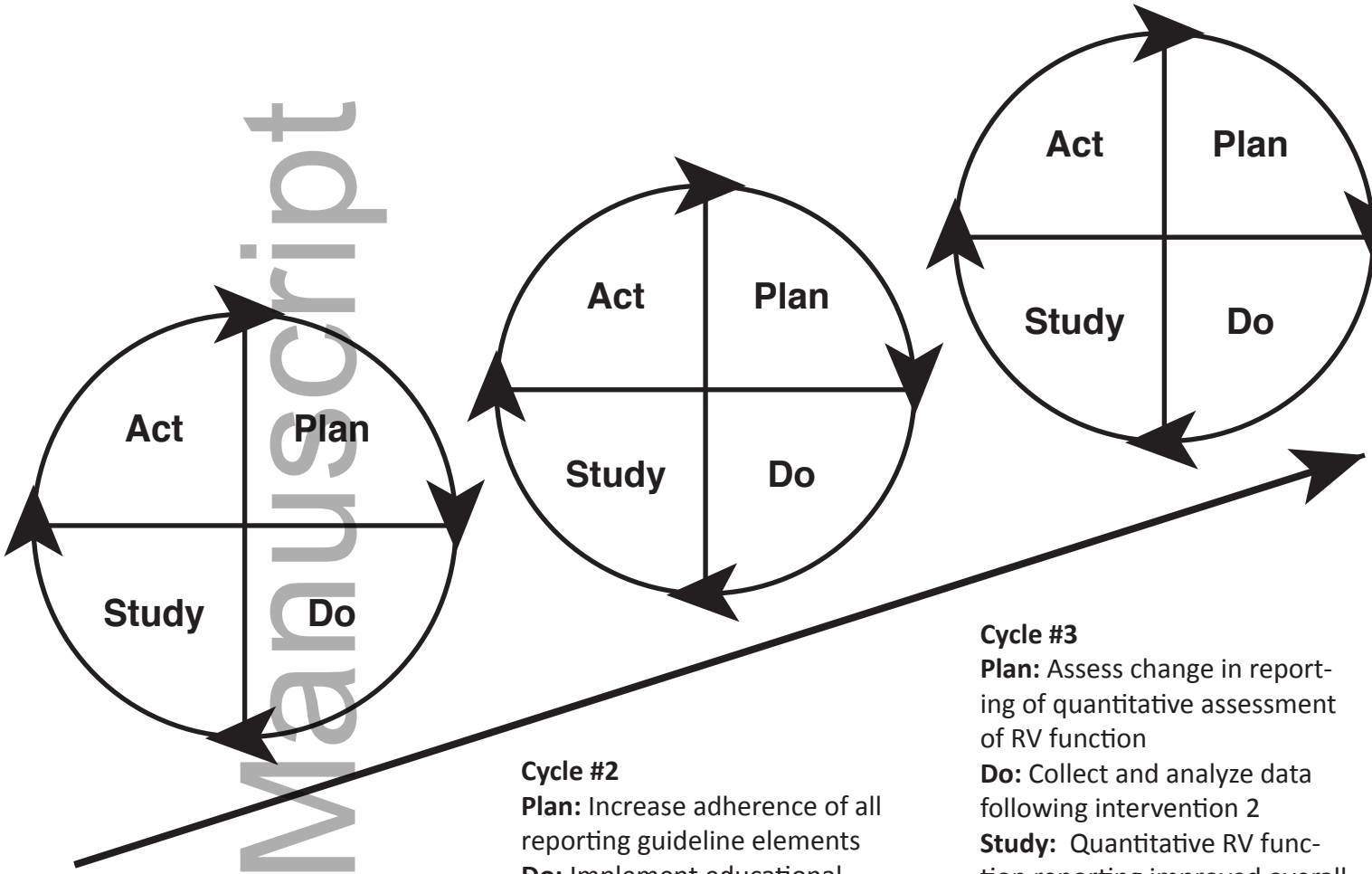
Figure legends:

Fig.1 PDSA ramp cycles to increase guideline adherence.

Fig. 2 Percentage of baseline reports including each element. Measurements are denoted in black; descriptive elements are denoted in gray

Fig. 3 Comparison of reporting rates of all elements to baseline following intervention 1. Baseline percentages are denoted in black; post intervention 1 percentages are in gray

Fig. 4 Quantification of RV function using TAPSE at baseline, post intervention 1 and post intervention 2. Inclusion in reports is denoted in black; studies with recording of TAPSE images but not reported are in gray



Cycle #1
Plan: Assess institutional adherence to echocardiogram reporting guidelines in patients with repaired tetralogy of Fallot
Do: Baseline data collected and analyzed for areas of improvement
Study: No complete studies found. One of lowest reporting rates for quantitative RV function
Act: Design educational intervention 1 to help increase adherence of all elements

Cycle #2
Plan: Increase adherence of all reporting guideline elements
Do: Implement educational intervention. Collect and analyze data following intervention.
Study: Found improvement in descriptive elements. Reporting of measurement elements including quantitative RV function did not improve.
Act: Design and implement targeted intervention 2 with protocol change for universal TAPSE measurement

Cycle #3
Plan: Assess change in reporting of quantitative assessment of RV function
Do: Collect and analyze data following intervention 2
Study: Quantitative RV function reporting improved overall but a greater effect noted in sonographers compared to attendings
Act: Discuss results with echocardiograpy lab staff. Continue protocol for universal TAPSE measurement.

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