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The Value of Quality Improvement Process in the Detection and Correction of Common Errors in Echocardiographic Hemodynamic Parameters in a Busy Echocardiography Laboratory

Zaher Fanari, M.D.¹, Usman I Choudhry, D.O., M.P.H.¹, Vivek K Reddy, M.D.¹, Chete Eze-Nliam, M.D., M.P.H., Sumaya Hammami, M.D., M.P.H., Paul Kolm, PhD², William S. Weintraub, M.D.^{1,2}, and Erik S Marshall, M.D.¹

¹ Division of Cardiology, Christiana Care Health System, Newark, DE

² Value Institute, Christiana Care Health System, Newark, DE

Abstract

Background—Accurate assessment of cardiac structures, ventricular function, and hemodynamics are essential for any echocardiographic laboratory. Quality Improvement (QI) processes described by the American Society of Echocardiography (ASE) and the Intersocietal Commission (IAC) should be instrumental in reaching this goal.

Methods—All patients undergoing transthoracic echocardiogram (TTE) followed by cardiac catheterization within 24 hours at Christiana Care Health System in 2011 and 2012 were identified, with 126 and 133 cases respectively. Hemodynamic parameters of diastolic function, Pulmonary Artery Systolic Pressure (PASP) on TTE correlated poorly with catheterization in 2011. An educational process was developed and implemented at quarterly QI meetings based on ASE and IAC recommendations to target frequently encountered errors and provide methods for improved performance. The hemodynamic parameters were then re-examined in 2012 post-intervention.

Results—Following the QI process, there was significant improvement in the correlation between invasive and echocardiographic hemodynamic measurements in both systolic and diastolic function, and PASP. This reflected in significant better correlations between echo and cath LVEF [$R = 0.88$, $ICC=0.87$ vs. $R = 0.85$, $ICC=0.85$; $p < 0.001$], Average E/E' and of left Ventricle End Diastolic Pressure (LVEDP) [$R = 0.62$ vs. $R = 0.09$, $p = 0.006$] and a better correlation for PASP [$R = 0.77$, $ICC=0.77$ vs. $R = 0.30$, $ICC=0.31$; $p = 0.05$] in 2012 compared to 2011.

Conclusion—The QI process, as recommended by ASE and IAC, can allow for identification as well as rectification of quality issues in a large regional academic medical center hospital.

Keywords

Quality Improvement; Doppler echocardiography; Left ventricular end-diastolic pressure; Left ventricular function; Pulmonary artery hypertension

Introduction

The utility of echocardiography in the evaluation of cardiovascular disease has proven to be both essential and ubiquitous since its inception and incorporation into medicine. In addition to providing structural information obtained by 2-D echocardiography, Doppler echocardiography has allowed for further insight into cardiac hemodynamics without the need for invasive testing as compared to cardiac catheterization. Though clinically important and useful, it is a method not completely free of error despite well-elucidated techniques for measurement. Inaccuracies in both hemodynamics and structural measurements can lead to significant quality deficits that have spurred discussions on improvement from issues of appropriate utilization to technical measurement standards.¹⁻³ Teaching interventions have been shown to help improve the accuracy of these variables and pose a viable approach to quality improvement.⁴ As the healthcare system in general moves towards corrections in inefficiencies, whether from a utilization or performance standpoint, so too must the field of echocardiography.

Among other recommendations, the American Society of Echocardiography (ASE) and Intersocietal Accreditation Commission (IAC) have called for improvement of laboratory performance through regular and continuous Quality Improvement (QI) reviews.^{5,6} This study seeks to assess whether the addition of a QI review process to a non-invasive laboratory can help identify problems in the evaluation of echocardiographic parameters. This work further assesses once having identified a problem via the QI process, if a relatively simple educational strategy is capable of producing meaningful improvements in echocardiographic reading and reporting.

Methods

Christiana Care is a large system that comprises two hospitals with more than 1,100 beds as well as a variety of outpatient and other services in facilities that provides the majority of cardiovascular care in Delaware, with an estimated 12,000 echocardiograms performed annually which makes an effective reproducible QI process very crucial. As part of the QI process, IAC requires the performance of correlation with other imaging studies on a minimum of 2 echocardiographic studies per operator each quarter.⁶ We extended this to include all patients who underwent an echocardiogram followed by a cardiac catheterization within 24 hours for the year 2011. We excluded patients who had the cardiac catheterization first followed by the echocardiography within 24 hours to exclude the potential bias resulting from echo reader knowing the content of the cardiac catheterization reports. Patient with atrial fibrillation were excluded as well. We proceeded to examine a number of structural and hemodynamic parameters on echocardiography for their correlation with catheterization parameters. We noted that some of the echocardiographically predicted hemodynamic parameters, namely evaluation of diastolic function and estimation of

pulmonary artery systolic pressure (PASP), correlated poorly with their catheterization derived counterparts. In order to correct this problem, we began an educational process whereby frequently encountered errors in calculating hemodynamic parameters were identified and the ways to perform them correctly were addressed and communicated. These were presented at a quarterly QI meeting in January 2012 and repeated at all subsequent quarterly QI meetings. As part of IAC standards, sonographers and reading physicians were required to attend two of these meetings per year.⁶ We then re-evaluated our echo-cath correlations for the year 2012 to see if there were improvements. Because hemodynamic measurements can change with time, we limited our observations to those who had an echocardiogram followed by a catheterization within 24 hours. The echocardiogram was performed and interpreted before the catheterization, thus eliminating any potential bias for the echo readers to have reviewed the catheterization data.⁷

All the included studies were chosen depending on the occurrence of an echocardiography and cardiac catheterization hemodynamic assessment within 24 hours. The details of the compared on quarterly basis with regular assessment of common and specific errors in echocardiography hemodynamic assessment identified and documented. All echocardiograms were performed on similar echocardiographic equipment (IE33, Philips Medical Systems, Andover, MA). Left Ventricle Ejection fraction (LVEF) was obtained from visual estimate in the majority of cases. Hemodynamic measurements were performed based on ASE recommendations. Diastolic parameters were based predominantly on the 2009 ASE guidelines on diastolic function.⁸ Pulmonary artery systolic pressure (PASP) was calculated using the peak pressure gradient across the tricuspid valve as derived by the modified Bernoulli equation then adding an estimated right atrial pressure. Right atrial pressure (RAP) was estimated based on the July of 2010 ASE guidelines for evaluating the right heart in adults.⁹ RAP was estimated to be 3, 8 or 15 mmHg depending on inferior vena cava size and respiratory variation.

Querying our electronic databases identified echocardiograms and corresponding catheterizations that were done within 24 hours from each others. The information gathered was obtained from the final echocardiogram and catheterization reports. Catheterization LVEF was based on visual estimation of the operator. For purposes of this study, an LVEDP > 15 was considered to be elevated. Analysis was performed for the following echocardiographic variables: 1) Left ventricular ejection fraction (EF), 2) Diastolic measurements including septal, lateral and average E/E', 3) Estimated PASP. Some Diastolic measurements that are known not to correlate well between the two modalities were compared as a control to see whether any trend of improvement can be based on chance alone. These included diastolic grade, deceleration time, E: A ratio and change in E:A ratio with Valsalva maneuver.

Quality Improvement Protocol

The teaching methods that were employed included 2 interventions: First a personal letter for each sonographers and reading physicians in regards of their deficiencies and/or common error with suggestions for self improvements recommendation related to the specific deficiency. Second a series of educational lectures regarding commonly recognized

themes of deficiencies were presented repeatedly at quarterly QA meetings. The content of these slides was also forwarded to those who did not have the chance to attend the meetings. The teaching interventions concentrated on reviewing the ASE guidelines concerning evaluation of LVEF, diastolic indices, PASP and estimating RAP. The slides point out examples of the most common errors identified during 2011 in calculating and reporting LVEF, diastolic indices, PASP and estimating RAP. The intervention also demonstrated the importance of watching for the technical quality of the 2 D images, the angle of tissue doppler when evaluating diastolic dysfunction, the quality of the tricuspid regurgitation jet used to calculate RVSP and PASP, the quantification of RAP based on the assessment of IVC diameter and collapse and the needed adjustment for quantification in patients with atrial fibrillation. Readers were encouraged to delete any inaccurate assessment and re-measure the required assessment if feasible. The detailed personal feedback to individuals included some of these remarks if applicable to the peer review assessment. Table-1 shows the most common errors and checklist for sonographers and readers to follow. A simplified chart for grading diastolic function and estimating left ventricular end diastolic pressure (LVEDP) was generated incorporating many of the variables defined by the 2009 ASE guidelines for evaluating diastolic function (table-2).⁸ This simplified chart is presented at quarterly meetings and is also present in all workstations for sonographers and reading physicians. In addition to the specific intervention regarding the commonly noticed error, an educational program with a yearly curriculum that consist of bimonthly lectures for technologists, fellows and attendings reviewing the literature on all the aspects of echocardiography with some emphasis on the common errors that may be encountered in each step. The content of these lectures are made available on a shared file for all technologists, fellows and attendings.

Our slides generally follow the most recent ASE guidelines. The diastology chart was created to help simplify the 2009 ASE guidelines on diastology.⁸ In order to combine grading with estimating filling pressures in those with normal LV function and those with abnormal function, it was necessary to modify some of the parameters slightly. In our reports, dysfunction is reported as grade I with a suggestion of normal filling if the $E/E' < 8$, grade I with indeterminate filling pressure if the $E/E' 8 - 15$, and grade I with a suggestion of elevated filling pressure if the $E/E' > 15$. Using our chart, grades II, III and IV imply high filling pressure whereby the E/E' should not be < 8 . Grade 0 implies normal filling pressure with the $E/E' < 8$ but could be $8 - 15$.

Similarly, the evaluation of the RAP was based on the IVC dilation and response of IVC diameter to respiration and sniff. The normal IVC diameter is less 2.1 cm with more than 50% collapse in response to respiration and sniff. The presence of both criteria correlated with RAP of 3 mmHg. The presence of one abnormal of these 2 criteria corresponds with RAP of 8 mmHg. The absence of both abnormal criteria will indicate an elevated RAP of 15 mmHg. If the diameter of IVC and its response to respiration cannot be verified, then an estimated RAP of 8 mmHg was used.

Statistics

The number of patients having had a parameter defined between 2011 and 2012 was compared using chi-squared analysis and the averages were compared using student t-tests. Echo variables were compared to their cardiac catheterization analogues via linear regression analysis. In these analyses, the procedure (echo vs. cath) by year (2011 vs. 2012) interaction was included to evaluate interventional related decrements and/or improvements. .

Correlation of echocardiography and catheterization measurement in 2011 and 2012 were assessed by linear regression analysis and by variance component analysis. The Pearson correlation (r) derived from linear regression, assesses the rank ordering of variable values whereas the intra-class correlation (ICC), derived from variance component analysis assesses the degree of agreement between variable values. The ICC is the appropriate statistic for assessing agreement between tests purporting to measure the same thing on the same scale of measurement. The ICC ranges between 0, indicating no agreement, and 1, indicating perfect agreement. Scatter plots of the paired echo and cath variables included the regression line as well as a 45 degree line of equality along which the paired variables would lie if there was perfect agreement between echo-cath measurements (as would the regression line). Bland-Altman plots were also constructed as complementary assessments of LVEF and PASP echo-cath measurements.

Results

Two hundred fifty nine patients met the criteria of having an echocardiogram first and then catheterization within 24 hours that measured at least one hemodynamic parameter between January 1, 2011 and December 31, 2012. One hundred and twenty six studies in 2011 met these criteria and 133 in 2012. There are 30 physicians who interpret echocardiograms with varying levels of training (Level II & III) and years of experience. There are 14 sonographers, all of whom are board-certified in adult echocardiography (American Registry of Diagnostic Medical Sonographers) with varying years of experience. Of the 126 patients who met the criteria in 2011, the average number of these studies performed per sonographer was 9.0 (range 1 -9) and studies read per physician was 4.2 (range 0-9). Of the 133 in 2012, these values were 9.5 (range 1-17) and 5.3 (range 0-10) per sonographer and physician respectively. There were no major changes in staffing between 2011 and 2012 and there were no changes in equipment in that time period.

Compared to before and after the intervention, there were improved hemodynamic correlations between the catheterization and echocardiography in each of the studied hemodynamic assessments. The correlation between echocardiographic and catheterization derived ejection fraction is shown in Figure 1. In 2011, the correlation was fairly strong between the two modalities. Two metrics for quality improvement of visual EF estimation were introduced. The first metric is comparing each of the reader's EF assessment to echo lab director assessments on 2 randomly chosen echocardiograms in each quarter and comparing the available echocardiographic/cardiac catheterization assessment as described above. The intervention employed in response to that was towards showing examples of the

most common errors identified during 2011 in calculating and reporting LVEF in addition to providing a personal peer review reports including both metrics to each reader and sonographer. In 2012 there was a significant improvement in the correlation between echocardiographic and catheter derived ejection fraction in 2012 compared to 2011 [$R = 0.88$, $ICC=0.87$ vs. $R = 0.85$, $ICC=0.85$; $p = 0.04$]

As echocardiography and catheterization assessment of diastolic function evaluate two different sets of measurements, a correlation between the two modalities was harder to define. The best comparison that can be made was potential correlation between different E/E' values and LVEDP. In 2011, the correlation between septal, lateral and average E/E' and LVEDP was poor. However, in 2012 this correlation between LVEDP and each of the E/E' measurements was significantly improved: [septal ($R = 0.63$ vs. $R = 0.12$, $p < 0.001$), lateral ($R = 0.59$, vs. $R = 0.11$, $p = 0.012$) and average ($R = 0.62$ vs. $R = 0.09$, $p = 0.006$); Figure 2-A-C)]. This improvement in correlation between LVEDP and each of the E/E' measurements was observed in both patient with $EF > 50\%$ and $EF < 50\%$ (Figure 3 A-C and Figure 4 A-C).

Other echocardiography measurements of diastolic dysfunction do not correlate well with LVEDP. As it is known that LVEDP does not correlate well with echocardiography diastolic grade, average E/E' of 8 to 15, E:A ratio, deceleration time, septal and lateral E' or change in E:A with Valsalva, we ignored these correlations with LVEDP as QI goals. However, we checked the correlation in both years as a control measure to see whether any improvement in correlation can result from secular trends. There was a weak correlation between the diastolic grade and the LVEDP and that this correlation was similar in 2012 and 2011. Similarly there was a weak correlation in both years between LVEDP and an average E/E' of 8 to 15, the E:A ratio, deceleration time, septal and lateral E' and change in E:A with Valsalva.

In patients who underwent a right heart catheterization for determination of PASP, after the intervention there was improvement with better correlation between echocardiographic estimated and catheterization derived PASP in 2012 compared to 2011 [$R = 0.77$, $ICC=0.77$ vs. $R = 0.30$, $ICC=0.31$; $p = 0.05$; Figure 5].

Discussion

This study shows the potential benefit of a defined QI process in improving the LV function and hemodynamic assessment of echocardiography. It also shows the potential benefit of using a more objective comparison of readily available catheterization data to validate the potential improvement. After a rigorous QI process that included comprehensive peer review and teaching intervention, there was significant improvement in the correlation between invasive and echocardiographic hemodynamic measurements in both systolic, diastolic function and PASP.

Accurate assessment of cardiac structures, ventricular function and hemodynamics are the primary goal of any echocardiographic laboratory. The QI processes set forth by the ASE and the IAC should be instrumental in reaching this goal. Comparing many of the

measurement using two different modalities as recommended may offer a more reliable indicator of quality improvement than other indicators as compared with subjective echo lab director review, peer review survey, or decrease intra-observer variability implied by other QI process.^{1,3,10,11} Many of the published interventions were selected towards one outcome like LVEF,^{3,10} or diastolic dysfunction.⁴ Furthermore, most interventions measured subjective outcomes as improved intra- observers variability or comparison to the peer review reader. The IAC recommended a more objective quality assurance approach to compare the results of echocardiography with another imaging modalities. The minimum QI correlation required by the IAC, which is 8 studies per year, this number might be reasonable for small outpatient echocardiography lab with small number of sonographers and echocardiography readers. But this is probably not enough to show a trend of improvement in an echocardiography lab with large number of cases, sonographers and echocardiography readers. Choosing a second modality should allow evaluation of the proposed correlation with a large number of cases in many measurements at the same time. Some quality improvement compared LVEF between echocardiography to a good gold standard, which is cardiac MRI.¹⁰ However, comparing with MRI will be limited to systolic function and is related to a limited number of cases depending on the size of the affiliated hospital and referral base.

Another option for comparison is cardiac catheterization. Cardiac catheterization offers data to compare more than one measurement. Although cardiac catheterization probably offers an inferior assessment of LVEF, the correlation coefficient is still reasonable to use for objective assessment of improvement. Similarly, although cardiac catheterization and echocardiography assess different measurements, the known association between LVEDP values and average E/E' of <8 and > 15 can be used as a marker for objective progress. Also, while many argue about the comparative hemodynamic assessment of PASP between echocardiography and cardiac catheterization and the factors affecting each modality, an improvement in the correlation between both assessments after our intervention can be used as a tool to assess the success of the proposed QI process. Furthermore, the cardiac catheterization measurements are more readily available for comparison across different hospital systems than other imaging modalities.

Using cardiac catheterization for comparison provides a reasonable option for quality improvement. Our study offers the possibility of using this comparison to identify errors and help guide potential interventions to improve the quality of study performance and reporting. It is worth noting that had we done the minimum QI correlation required by the IAC, which is 8 studies per year, rather than looking at all the patients who had an echocardiogram and then a catheterization, it would have been very easy to miss quality issues in a high volume laboratory.

The teaching methods we employed were designed to be simple, repeatable, and sustainable. The specific intervention slides with example of common errors and the potential ways to improve it were easily presented and well received in the quarterly QI meetings. The quarterly report for each sonographer and echocardiography readers was detailed to explain the specific deficiency with suggestions to improve performance and interpretation were provided consistently. In addition, adding results in individual feedback reports, integrating

many of these concepts in bimonthly didactic teaching conferences attended by many echocardiography readers and all sonographers and making the content available for everyone make this process sustainable. This intervention helps in reducing the variability in reporting important and vital echocardiography concepts among the large number of physicians with variable degrees of training and experience interpreting echoes. The teaching intervention helps to equalize the average skill set of the readers and set an example for the next generation of fellows we are training.

We observed not only an improved correlation with hemodynamic parameters, but also an increase in the numbers of patients who had these parameters reported (table-2). This may be due to an increased confidence in reporting these parameters, though other factors probably play in as well. The teaching methods were likely not the only reason for improvements. Some sonographers and physicians may have been motivated by a collective sub-optimal performance in 2011 and sought additional independent education. Perhaps self-motivation was sparked through our intervention.

Potential pitfalls to this study include a bias due to variation in reader training and experience. While there is a potential that certain readers may have been over represented, the average and range of studies read per physician would suggest these studies were fairly equally distributed. The same idea applies for our sonographers as well. Furthermore, we do not have information on whether these physicians and sonographers gained further knowledge either formally or informally over that duration. It is also unclear whether announcements about the initiation of QI sessions led to higher quality reads by the very nature that readers were more cognizant of a problem. A second limitation in the echocardiography assessment of LVEF using visual estimation, as this subjective assessment will suffer from potential intra-reader variability compared to a more objective assessment using the biplane method of disks (modified Simpson's rule).

Another limitation deals with our comparison standard, cardiac catheterization. The physician performing the catheterization was aware of the echocardiographic results prior to the catheterization. This would certainly introduce diagnostic inclusion bias, especially on a subjective measurement such as visual estimation of catheterization EF.⁷ However, it will have much less impact on objective hemodynamic measurements. As this was a real world study, this bias is almost impossible to avoid. We excluded patients who had a catheterization within the 24 hours prior to the echocardiogram to avoid a potential bias of the echo reader finding out the catheterization data on the expense of limiting the number of patients included in the QI process. Also, cardiac catheterization LVEF suffers from large intra-reader variability as well. Furthermore, both LVEDP and RAP could change dramatically with medical therapy including diuresis within the 24 hours window. In addition, catheterization assessment of LVEDP, RVSP and PASP and their correlation to echocardiography can vary depending on sedation, loading condition and positioning. Finally, using 24 hours as a cutoff was arbitrary. It is not known how long after an echocardiogram the predicted hemodynamic measurements remain valid. We chose 24 hours because it seemed reasonable. Certainly, some of the hemodynamic measurements can change even within 24 hours due to diuresis, fluid administration, evolving myocardial infarctions, etc.

Conclusion

In conclusion, the QI processes set forth by the ASE and the IAC can help to identify inadequacies in an echocardiographic laboratory. This sometimes will require labs to go beyond what is recommended. Combining educational intervention, peer review process with subjective correlation with other modalities may offer a more objective tool to improve the quality of echocardiography reporting. Although it is difficult to determine with certainty whether being made more cognizant of the issues or the teaching processes employed are what helped correct the inadequacies, applying this approach offered a significant improvements in both the reporting of hemodynamic variables and their accuracy. Although this approach may require a more resources and a continuous effort, but the results may well justify the effort.

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Figure 1.
Correlation of echocardiographic ejection fraction with catheter derived ejection fraction for 2011 and 2012

Figure 2.

A-C. Correlation of septal (A), lateral (B) and average (C) E/E' with catheter derived LVEDP for 2011 and 2012.

Figure 3.

A-C Correlation of septal (A), lateral (B) and average (C) E/E' with catheter derived LVEDP for 2011 and 2012 in patients with EF ≥ 50

Figure 4.

A-C Correlation of septal (A), lateral (B) and average (C) E/E' with catheter derived LVEDP for 2011 and 2012 in patients with EF < 50

Figure 5.
Correlation of echocardiographic and catheter derived PASP for 2011 and 2012.

Table-1

Common errors identified and checklist for sonographer and echocardiography readers.

Most Common errors	Checklist for sonographer related to this QI.	Checklist for echocardiography readers related to this QI.
<ul style="list-style-type: none"> -Not Considering all views when evaluating LV Function. -Misclassification of stage II Diastolic Dysfunction as normal diastology. -Misclassification of normal diastology as stage II Diastolic Dysfunction. -Using diastology assessment when transducer angle >20. -Using incomplete TR envelope to evaluate RVSP. -Using less than 5 TR envelopes in those with atrial fibrillation. -Using TR envelope when transducer angle >20. -Misclassification of RA Pressure 	<ul style="list-style-type: none"> -Acquire all required parasternal, apical, subcostal and suprasternal views. -Acquire mitral inflow at 4-chamber view with PW-Doppler sample volume at the tips of the mitral. -Acquire Tissue Doppler Imaging (TDI) with sample volume placed at the level of the medial and lateral mitral annulus. -Acquire TDI in views allowing for a jet-beam angle <20. -Acquire TR jet in views allowing for a jet-beam angle <20. - Determine RVSP based on 3 TR envelopes in those with sinus rhythm and 5 TR envelopes in those with atrial fibrillation. - Using only complete envelopes to perform measurement. - Assess IVC diameter at end expiration and proximal to the junction of the hepatic vein. - Access IVC collapse with a sniff and with quite respiration. 	<ul style="list-style-type: none"> -LVEF is assessed based on all views, wall motions abnormalities are described when appropriate. -Delete measurements when done inappropriately and if feasible perform new measurements (i.e. appropriate beam angle, appropriate sample site when acquiring mitral inflow, appropriate sample site at the levels of medial and lateral mitral annulus, inappropriate acquiring of beam -TR jet angle, RVSP measurements from incomplete TR envelopes, inappropriate IVC measurement). - Considering all parameters when assigning diastolic grade. If unclear, classify as indeterminate. - When assessing RVSP, use the highest TR measurements in patients with sinus rhythm and average of 5 measurements in those with atrial fibrillation. - If IVC measurements unreliable, use RAP value of 8 mmHg instead.

Table-2

A Simplified Approach for Diastology Assessment:

Diastolic Stage	0	I	II	III	IV
Normal LA Size	+	+/-	-	-	-
Septal E 8 Lateral E 10	+	+/-	-	-	-
E: A	0.8-1.5	< 0.8	0.8-1.5	2	2
Deceleration Time	160-200	>200	160-200	160	
Average E/ E	<8	< 8 Normal filling 8-15 unclear 15 High Filling	8	8	8
E: A 0.5 with Valsalva	-	-	+	+	-

Table-3

The indication of Echocardiography, Echocardiography heart rate and cardiac catheterization hear rate in 2011 and 2011.

	2011 (N=126)	2012 (N=133)	P Value
Indication of Echocardiography			
Chest pain	40 (32%)	43 (32%)	0.9
Post Myocardial Infarction	1 (0.7%)	5 (3.7%)	0.3
Suspected Congestive Heart Failure Exacerbation	36 (29%)	43 (32%)	0.7
Evaluation of Left ventricle function.	26 (21%)	24 (18%)	0.6
Pericardial Effusion	4 (3%)	2 (1.5%)	0.3
Vegetation	2 (1.5%)	2 (1.5%)	0.9
Stroke	1 (0.7%)	2 (1.5%)	0.7
Palpitation	8 (6%)	7 (5%)	0.6
New Murmur	4 (3%)	2 (1.5%)	0.4
Others	4 (3%)	4 (3%)	0.9

Average Heart Rate in Echocardiography and Catheterization.					
Average Heart Rate in Echocardiography	76 ± 8	P=0.4	73 ± 8	P=0.07	N/A
Average Heart Rate in Cardiac catheterization	75 ± 9		75 ± 9		