Association Between Echocardiography Laboratory Accreditation and the Quality of Imaging and Reporting for Valvular Heart Disease

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Background—It is presumed that echocardiographic laboratory accreditation leads to improved quality, but there are few data. We sought to compare the quality of echocardiographic examinations performed at accredited versus nonaccredited laboratories for the evaluation of valvular heart disease.

Methods and Results—We enrolled 335 consecutive valvular heart disease subjects who underwent echocardiography at our institution and an external accredited or nonaccredited institution within 6 months. Completeness and quality of echocardiographic reports and images were assessed by investigators blinded to the external laboratory accreditation status and echocardiographic results. Compared with nonaccredited laboratories, accredited sites more frequently reported patient sex (94% versus 78%; $P<0.001$), height and weight (96% versus 63%; $P<0.001$), blood pressure (86% versus 39%; $P<0.001$), left ventricular size (96% versus 83%; $P<0.001$), right ventricular size (94% versus 80%; $P=0.001$), and right ventricular function (87% versus 73%; $P=0.006$). Accredited laboratories had higher rates of complete and diagnostic color (58% versus 35%; $P=0.002$) and spectral Doppler imaging (45% versus 21%; $P<0.0001$). Concordance between external and internal grading of external studies was improved when diagnostic quantification was performed (85% versus 69%; $P=0.003$), and in patients with mitral regurgitation, reproducibility was improved with higher quality color Doppler imaging.

Conclusions—Accredited echocardiographic laboratories had more complete reporting and better image quality, while echocardiographic quantification and color Doppler image quality were associated with improved concordance in grading valvular heart disease. Future quality improvement initiatives should highlight the importance of high-quality color Doppler imaging and echocardiographic quantification to improve the accuracy, reproducibility, and quality of echocardiographic studies for valvular heart disease. **(*Circ Cardiovasc Imaging*. 2017;10:e006140. DOI: 10.1161/CIRCIMAGING.117.006140.)**

Key Words: accreditation ■ echocardiography ■ quality ■ valvular heart disease

Echocardiography has become the dominant modality for the assessment of known or suspected valvular heart disease (VHD) because of its ability to provide valuable information about heart valve function, cardiac size and function, and volume status. It is noninvasive, free of radiation, portable, and relatively inexpensive compared with other imaging modalities. As with other imaging modalities,[1] there has been an important movement to ensure quality, reproducibility, and value in echocardiograms that are performed in the multitude of laboratories throughout the country.[1–4]

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The Intersocietal Accreditation Commission (IAC) provides laboratory accreditation in echocardiography with the goal of ensuring quality patient care and ultimately improving healthcare through accreditation.[5–7] To achieve accreditation, sites are required to submit a minimum number of self-selected cases that demonstrate all necessary components of the examination along with corresponding final reports.[8] Submitted studies undergo confidential peer review by the IAC to assess adherence to published *IAC Standards and Guidelines for Adult Echocardiography Accreditation*.[9] Laboratories also undergo an internal self-assessment where they are encouraged to identify and correct potential deficiencies and are provided specific feedback on how to improve quality. Sites that do not initially meet quality standards defined by the IAC are allowed to undergo repeat reviews ≤3 times before being denied accreditation status. Accredited laboratories may also be subject to random site visits and audits to assess continued

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compliance with IAC Standards. Accreditation is granted for a maximum 3-year period at which point laboratories can apply for reaccreditation.[8]

Despite the perceived benefits, there is little published evidence that the accreditation process results in increased echocardiographic quality, and some insurers have adopted a strategy of reimbursement that is tied to the accreditation status of the performing laboratory.[10] The process of accreditation is rigorous, expensive, and time-consuming, and can be challenging for many laboratories. These challenges are highlighted by a recent analysis, which indicated that accreditation is delayed in 62% of laboratories because of perceived major deficiencies or noncompliance.[11] We sought to compare the quality of echocardiographic imaging studies and reports from accredited versus nonaccredited laboratories for the evaluation of VHD.

Methods

Enrollment

This study was approved by the Mayo Clinic Institutional Review Board. We prospectively recruited subjects between November 2013 and May 2015 referred from external institutions to the Mayo Clinic Valvular Heart Disease Clinic. Inclusion criteria included an external transthoracic echocardiogram (from an accredited or nonaccreditated laboratory) and a transthoracic echocardiogram performed at our institution within 6 months. Subjects signed a release of records, and external digital images, and reports were requested for studies that were not initially available. The accreditation status of each external site was determined using the IAC website.[12] Referral diagnosis was reviewed using the medical record.

Review of External Studies

Standards for echocardiographic imaging studies and reporting were defined based on current IAC Standards and guidelines published by the American Society of Echocardiography and the American College of Cardiology.[9,13–16] Criteria for grading 2-dimensional (2D), color Doppler, and spectral Doppler image quality are shown in Table 1. Digitized images of external studies were interpreted by an experienced echocardiographer (Drs Thaden, Tsang, Pellikka, Nkomo, Ayoub, Padang) at Mayo Clinic who had completed level III training and was blinded to the external interpretation and accreditation status of the laboratory. Echocardiographers used an integrated, multiparametric approach as recommended by current American Society of Echocardiography guidelines[14–16] to grade valve lesion severity.

External echocardiograms were also evaluated for quantification of the valve lesion of interest. Quantification included estimation of regurgitant orifice area and volume for regurgitant lesions and mean transvalvular gradient and valve area for stenotic lesions. Quantification was graded performed if it was performed and of diagnostic quality, nondiagnostic if it was attempted but of poor technical quality that could result in inaccurate or indeterminate results, and not performed if it was not attempted. Examples of technically suboptimal quantification for mitral regurgitation included a single still frame image of a flow convergence that did not match the timing of the regurgitant peak velocity and was used for a proximal isovelocity surface area (PISA) calculation, a PISA radius measurement using a wide-field (nonzoomed) image of the mitral regurgitation, which precluded accurate measurement of the PISA diameter, and suboptimal or incomplete continuous wave Doppler tracing of the mitral regurgitation, which did not allow for accurate time velocity integral measurement. Examples of suboptimal quantification for aortic stenosis included inadequate images to accurately measure the left ventricular outflow tract diameter, improper positioning of the pulse-wave sample volume for left ventricular outflow tract time velocity integral, and poor spectral Doppler quality, which limited the ability to accurately measure a time velocity integral.

External echocardiographic reports were reviewed and scored based on the current IAC Standards.[9]

Changes in Clinical Management

We reviewed cases with discordant grading of the severity of VHD between the external echocardiogram and the echocardiogram performed at our institution to determine whether discordant grading altered current guideline-based patient management.[13] This predominantly involved reclassification of valve lesions from severe to moderate or, in other patients, from moderate to severe.

Statistical Analysis

χ^2 tests were used to compare the completeness of the reports and images between external accredited and nonaccredited laboratories and our accredited laboratory versus other laboratories, as well as to examine differences in interpretation between observers from our laboratory and from the laboratory where the study was performed. Inter- and intraobserver variability using a dichotomous scale of ≤moderate versus >moderate was performed using κ coefficients in a sample of 30 internal and external studies. Statistical analyses were performed using JMP version 10 (SAS Institute Inc). Given the large number of χ^2 tests performed, to reduce the chance of type I error, a *P* value <0.01 was considered statistically significant.

Results

Among 335 patients enrolled, 253 (76%) had external echocardiograms performed at an accredited laboratory. Availability of external echocardiographic images and reports, time between external examination and referral consultation, and referral diagnoses are listed in Table 2. External reports were obtained in 326 (97%) patients, external images in 302 (90%), and both the external report and images in 294 (88%). Among 129 patients referred for aortic stenosis, 108 (84%) patients were graded moderate–severe or severe stenosis by the external report. Of the 116 patients referred for mitral regurgitation, 92 (79%) were graded moderate–severe or severe mitral regurgitation on external reports.

Completeness of External Echocardiographic Reports

Data regarding the completeness of external echocardiographic reports are shown in Table 3. Accredited laboratories were more likely to include patient sex (94% versus 78%; *P*=0.0002), height and weight (96% versus 63%; *P*<0.0001), and blood pressure (86% versus 39%; *P*<0.0001). Accredited sites were also more likely to report left ventricular end-diastolic dimension (99% versus 93%; *P*=0.008), end-systolic dimension (97% versus 89%; *P*=0.005), an interpretation of left ventricular size (96% versus 83%; *P*=0.0002), and right ventricular size and systolic function (94% versus 80% and 87% versus 73%, respectively; *P*<0.006 for both).

Review of External Echocardiographic Images

Measurement of left ventricular end-diastolic diameter (99% versus 89%; *P*=0.007) and end-systolic diameter (92% versus 79%; *P*=0.004) was more often feasible for studies from accredited versus nonaccredited sites. An assessment of right ventricular systolic function was obtainable in a similar number of accredited versus nonaccredited laboratories (96% versus 92%; *P*=0.12), but accredited sites were more likely to obtain quantitative parameters, including either tricuspid

Table 1. Required Echocardiographic Views and Image Quality Grades

Modality	Required Views	Image Quality Criteria: Complete	Image Quality Criteria: Suboptimal Quality	Incomplete/Nondiagnostic
2D imaging	Parasternal window	All images acquired and of diagnostic image quality.	All images acquired Suboptimal visualization of valve anatomy Foreshortened or off-axis imaging planes Suboptimal endocardial definition (echo contrast not used) Suboptimal use of 2D gains	One or more required images omitted OR Required views attempted but relevant anatomy not visualized.
	Long axis			
	Short axis			
	Basal			
	Mid			
	Apical			
	Apical window			
	Long axis			
	4 chamber			
	2 chamber			
	Visualization of cardiac valves			
	Visualization of the inferior vena cava			
Color Doppler	Color Doppler of all 4 valves	All images acquired and of diagnostic image quality.	All required images acquired Lack of zoomed views on abnormal color Doppler Suboptimal use of color gains or scale Abnormal color flow poorly visualized	One or more required images omitted OR Color Doppler image quality not sufficient to make a definitive diagnosis
	Visualization of the atrial septum with color Doppler			
	Display of abnormal color Doppler in at least 2 views			
Spectral Doppler	Left ventricular outflow tract peak velocity	All images acquired and of diagnostic image quality.	All required images acquired Suboptimal use of spectral gain or scale Suboptimal placement of pulse wave sample box	One or more required images omitted OR Spectral Doppler quality not sufficient to make a definitive diagnosis
	Interrogation of ≥moderate regurgitant or stenotic lesions with continuous wave Doppler			
	Interrogation of the tricuspid regurgitant signal for right ventricular systolic pressure			
	Interrogation of aortic valve stenosis or aortic prosthesis peak systolic velocity from at least 3 imaging windows with at least 1 diagnostic signal using a nonimaging transducer			

2D indicates 2-dimensional; and echo, echocardiogram.

annular plane systolic excursion or tricuspid annulus tissue Doppler velocity to support this assessment (27% versus 14%; P=0.01).

Diagnostic quantification of VHD severity was performed in 188 (62%) of 302 available studies, and this was similar for accredited versus nonaccredited sites (63% versus 59%; P=0.49). For aortic stenosis, accredited versus nonaccredited sites were similarly likely to calculate aortic valve area (95% versus 96%; P=0.80) and mean systolic gradient (100% versus 100%; p>0.99), but accredited laboratories were more likely to interrogate the aortic stenosis continuous wave Doppler signal from ≥3 imaging windows (77% versus 32%; P<0.0001) and use a pedof transducer (nonimaging continuous wave pencil transducer; 85% versus 50%; P=0.0005). There was a trend for increased rates of diagnostic quantification of mitral regurgitation from accredited versus nonaccredited laboratories (44% versus 22%; P=0.07). Quantification of mitral regurgitation was of suboptimal quality and nondiagnostic in 27% of studies, and this proportion was similar (P=0.11) between accredited and nonaccredited sites.

Among patients with available external images, 26% had a body mass index ≥30 kg/m^2 and 15% had chronic obstructive pulmonary disorder, and distributions were similar for accredited versus nonaccredited laboratories (26% versus 25% and 15% versus 15%; P>0.99 for each). Nonobese subjects were more likely to have complete and diagnostic 2D image quality (61% versus 41%; P=0.01), and there was a trend for more complete and diagnostic color Doppler image quality (57% versus 41%; P=0.03). There was no statistical difference in complete/diagnostic 2D (57% versus 45%; P=0.22) or color Doppler (53% versus 50%; P=0.86) image quality in those without versus with chronic obstructive pulmonary disorder.

Grading of overall study quality according to laboratory accreditation status is shown in Figure 1A through 1C.

Table 2. Comparison of Availability of Reports and Images, Referral Diagnosis, and Time Between Echocardiography and Evaluation at Our Institution According to Accreditation Status

Parameter	All Laboratories (N=335)	Accredited Laboratories (n=253)	Nonaccredited Laboratories (n=82)	*P* Value
Availability of external reports	326 (97)	246 (97)	80 (98)	>0.99
Availability of external images	302 (90)	227 (90)	75 (91)	0.83
Availability of both external images and reports	294 (88)	221 (87)	73 (89)	0.85
Time between external echo and consultation, mo	2.5±1.3	2.5±1.3	2.6±1.3	0.60
Referral diagnosis				
Aortic stenosis	129 (40)	98 (40)	31 (39)	0.90
Mitral regurgitation	116 (36)	87 (35)	29 (36)	0.90
Aortic regurgitation	27 (8)	20 (8)	7 (9)	0.90
Aortic prosthetic valve dysfunction	21 (6)	16 (6)	5 (6)	0.90
Mitral stenosis	12 (4)	8 (3)	4 (5)	0.90
Tricuspid regurgitation	11 (3)	10 (4)	1 (1)	0.90
Mitral prosthetic valve dysfunction	3 (1)	2 (1)	1 (1)	0.90
Other	16 (4)	12 (5)	4 (5)	0.90

Values are mean±SD or n (%). Echo indicates echocardiogram.

Laboratory accreditation was associated with increased completeness and quality of color Doppler and spectral Doppler image acquisition. Studies from nonaccredited sites were more likely to be graded as an incomplete spectral Doppler examination (49% versus 21%; *P*<0.0001). Among those with aortic stenosis and incomplete spectral Doppler examinations, 83% did not attempt to image the aortic stenosis signal from multiple imaging windows and 55% did not obtain a spectral Doppler signal with a pedof transducer.

When stratified by body mass index, accredited laboratories showed a strong trend for more complete and diagnostic color Doppler image quality in obese and nonobese subjects (48% versus 16% and 62% versus 41%, respectively; *P*=0.03 and 0.02, respectively) and were less likely to be graded incomplete or nondiagnostic for spectral Doppler image quality in obese and nonobese subjects (20% versus 68% and 21% versus 43%, respectively; *P*<0.002 for both). There was a trend for increased rates of complete and diagnostic 2D image quality among accredited laboratories in obese (48% versus 21%; *P*=0.07) but not nonobese subjects (63% versus 52%; *P*=0.29).

External Versus Internal Interpretation of External Studies

A comparison between the external interpretations of the severity of VHD lesions with our internal review of the external echocardiographic images is shown in Figure 2. In 16% of echocardiograms, VHD graded >moderate (moderate–severe or severe) by external interpretation was graded ≤moderate severity by our internal review of the same images. In 35% of echocardiograms, VHD graded ≤moderate severity by external interpretation was graded >moderate disease based on our review of the same study.

The concordance of the external and internal echocardiographic grading of external studies is shown in Figure 3. Echocardiographic grading of the severity (≤moderate versus >moderate) was discordant in 62 (21%) of 294 patients; discordance was present in 16% of subjects with aortic stenosis and 26% of subjects with mitral regurgitation. Rates of discordant VHD severity grading were similar between accredited and nonaccredited laboratories (Figure 3A), but discordance was less frequent when diagnostic quantification was present (15% versus 31%; *P*=0.003; Figure 3B).

Overall, inter-rater concordance for grading the severity of VHD was not associated with 2D, color Doppler, or spectral Doppler image quality. However, in the subset of patients with a primary referral for mitral regurgitation, there was a strong trend for improved inter-rater concordance with improved color Doppler image quality (incomplete/nondiagnostic [67%]; suboptimal quality [62%]; complete/diagnostic [84%]; *P*=0.04). κ Statistics for interobserver variability (≤moderate versus >moderate) were 0.44 (95% confidence interval [CI], 0.32–0.56) for all sites, 0.45 (95% CI, 0.31–0.59) for accredited sites, 0.42 (95% CI, 0.20–0.65) for nonaccredited sites, 0.48 (95% CI, 0.31–0.65) when diagnostic quantification was present, and 0.36 (95% CI, 0.19–0.53) when diagnostic quantification was not present. Intra-observer variability for ≤moderate versus >moderate among our internal reviewers was 0.73 (95% CI, 0.45–1.00).

Comparison With Echocardiograms Performed at Our Institution

Repeat echocardiograms were performed at our institution 2.5±1.3 months after the initial external echocardiogram, and the time between external and internal exams was similar in accredited versus nonaccredited sites (*P*=0.60). Interobserver variability among our internal readers was 0.53 (95% CI, 0.16–0.91) for internal studies. Discordant grading of VHD severity (≤moderate versus >moderate) between the external examination (external interpretation)

Table 3. Completeness of External Echocardiographic Reports in Accredited Versus Nonaccredited Laboratories

Report Component	All Laboratories (N=326)	Accredited Laboratories (n=246)	Nonaccredited Laboratories (n=80)	*P* Value
Report data				
Indication for study	315 (97)	241 (98)	74 (93)	0.03
Patient sex	292 (90)	230 (94)	62 (78)	0.0002
Height and weight	286 (88)	236 (96)	50 (63)	<0.0001
Blood pressure	242 (74)	211 (86)	31 (39)	<0.0001
End-diastolic diameter	317 (97)	243 (99)	74 (93)	0.008
End-systolic diameter	310 (95)	239 (97)	71 (89)	0.005
Left ventricular wall thickness	316 (97)	241 (98)	75 (94)	0.07
Left atrial diameter or volume	302 (93)	231 (94)	71 (90)	0.22
Ascending aorta diameter	300 (92)	230 (94)	70 (89)	0.22
Stenotic valve area*	173 (90)	132 (92)	41 (85)	0.26
Stenotic valve gradient*	189 (98)	144 (100)	45 (94)	0.01
Severity of valve regurgitation†	310 (99)	237 (99)	73 (99)	0.42
Estimated RV systolic pressure	284 (87)	214 (87)	70 (88)	0.15
Report impressions				
LV size	302 (93)	236 (96)	66 (83)	0.0002
LV ejection fraction	322 (99)	243 (99)	79 (99)	>0.99
LV regional wall motion	218 (67)	166 (67)	52 (65)	0.68
RV size	294 (90)	230 (94)	64 (80)	0.001
RV function	271 (83)	213 (87)	58 (73)	0.006
Mitral valve morphology	313 (96)	239 (97)	74 (93)	0.09
Mitral valve prolapse‡	56 (51)	44 (54)	9 (33)	0.08
Flail mitral leaflet‡	29 (27)	21 (26)	8 (30)	0.80
Degenerative‡	9 (8)	7 (9)	2 (7)	>0.99
Secondary (functional)‡	16 (15)	12 (15)	4 (15)	>0.99
Rheumatic‡	4 (4)	2 (2)	2 (7)	0.26
Other‡	3 (3)	2 (2)	1 (4)	>0.99
Aortic valve morphology	312 (96)	235 (96)	77 (96)	>0.99
Tricuspid valve morphology	258 (79)	204 (83)	54 (68)	0.004
Pulmonary valve morphology	258 (79)	205 (83)	53 (66)	0.002
Impression of pericardium or pericardial effusion	295 (90)	229 (93)	66 (83)	0.008
Impression of ascending aorta	291 (90)	229 (93)	62 (78)	0.0006
Summary of final impressions	320 (98)	244 (99)	76 (95)	0.03

Values are n (%). LV indicates left ventricular; and RV, right ventricular.
*n=192 subjects with valve stenosis.
†n=312 subjects with valve regurgitation.
‡n=109 subjects with a referral for mitral regurgitation.

and our internal study was present in 22% of subjects (70/325), and this was not statistically different according to laboratory accreditation status or the presence of quantification. However, in patients with mitral regurgitation, diagnostic concordance was associated with the quality of color Doppler images on the initial external echocardiogram (Figure 4B). Subjects with improved color Doppler image quality by the criteria in Table 1 were more likely to have concordant grading of VHD severity with the subsequent internal echocardiogram. Diagnostic concordance for the severity of mitral regurgitation was not linked to the quality of 2D or spectral Doppler imaging.

Discordant grading resulted in changes in clinical management in 39 patients (12%), and this was not statistically

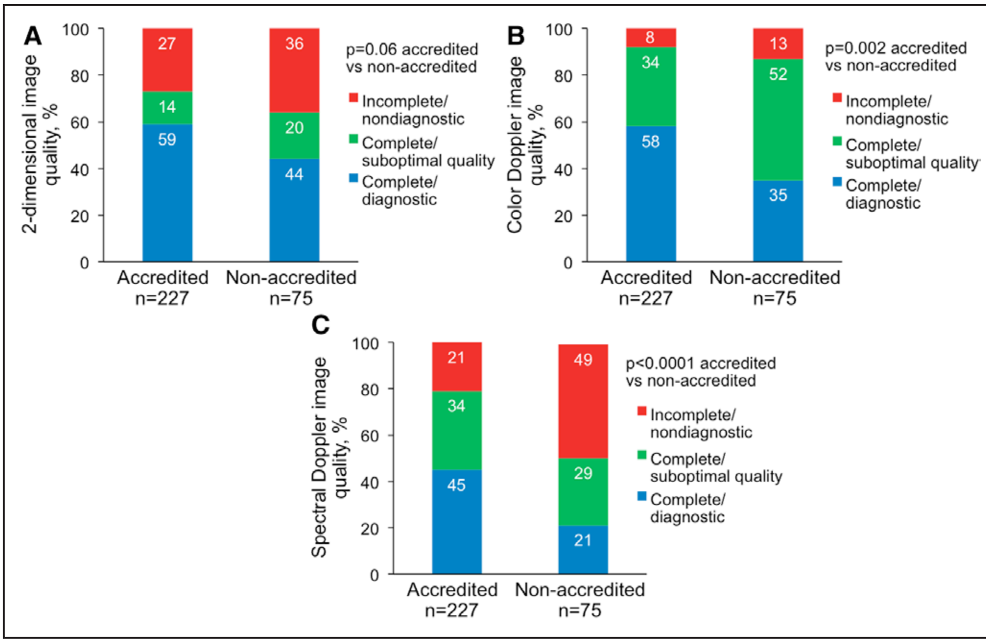

Figure 1. The quality of 2-dimensional (2D), color Doppler, and spectral Doppler echocardiographic images according to laboratory accreditation status. On internal review of the external echocardiographic images, there was a trend for improved 2D image quality among accredited laboratories (**A**). Color Doppler (**B**) and spectral Doppler (**C**) examinations from accredited sites were more frequently complete with diagnostic image quality. The percentage of nonaccredited sites with complete and diagnostic spectral Doppler examinations was only 21%.

different between accredited versus nonaccredited laboratories (10% versus 16%; *P*=0.17). In 31 (79%) of 39 patients with discordant grading, the planned operation was canceled because the valve lesion was felt to be less than severe. In 6 (15%) patients, the valve lesion was graded severe by the echocardiogram performed at our institution, which led to an operation that would not have been indicated based on the external interpretation of the study performed elsewhere. In 1 (3%) patient, suspected aortic prosthetic valve thrombosis was discovered, resulting in

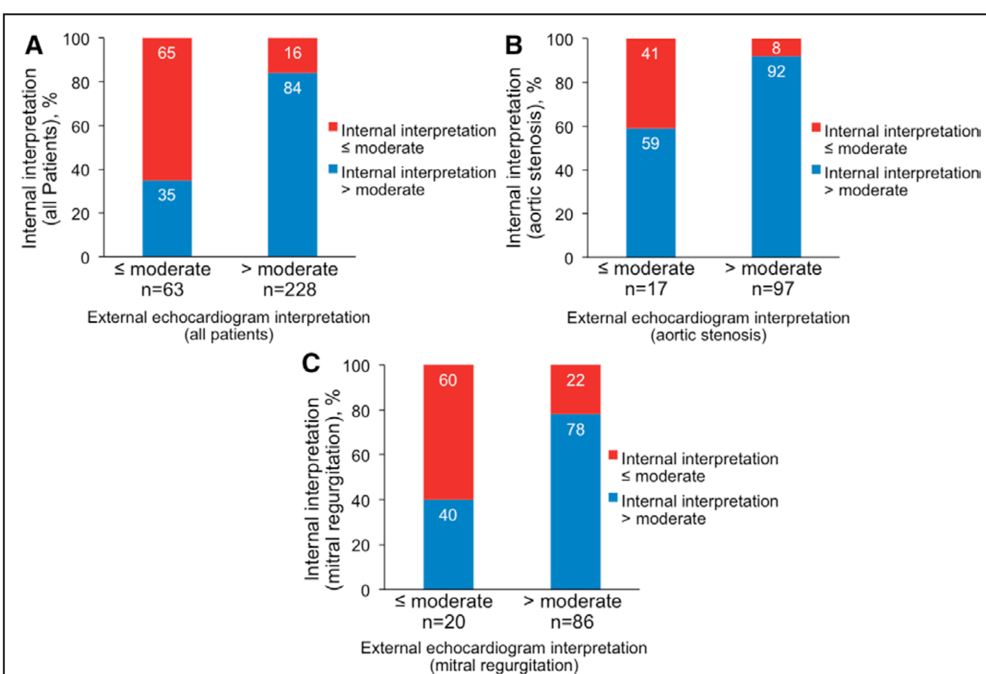

Figure 2. External and internal interpretation of the severity of valvular heart disease (VHD) based on external echocardiographic images. There was substantial inter-rater discordance in grading the severity of VHD using the external echocardiographic images. Sixteen percent of subjects felt to have >moderate severity VHD were graded as ≤moderate when graded internally (**A**). Among subjects referred with ≤moderate aortic stenosis (**B**) and mitral regurgitation (**C**), 59% and 40%, respectively, were felt to have >moderate severity lesions on internal review of the same images. The severity of the VHD lesion was not reported in 3 of the external examination reports.

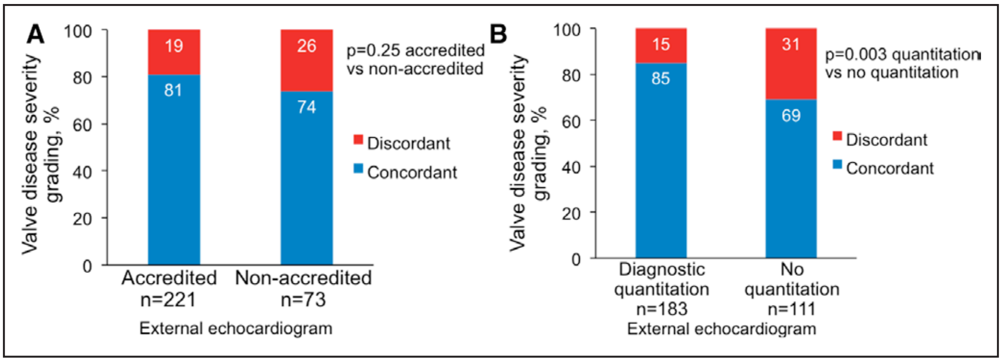

Figure 3. Diagnostic concordance and discordance in grading the severity of valvular heart disease (VHD): external and internal interpretation of external images. Discordant inter-rater grading of VHD severity (≤moderate versus >moderate) was present in 21% of subjects using the external echocardiographic images. There was not a statistical difference in discordant grading between accredited vs nonaccredited sites (**A**). However, when diagnostic quantification was present, inter-rater concordance was improved (85% vs 69%; *P*=0.003; **B**).

anticoagulation therapy and normalization of the mean gradient. In 1 (3%) patient, a concomitant valve lesion was felt to be less severe, which substantially altered the planned operation.

Among patients with aortic stenosis, the measured mean systolic gradient was 3.3±9.9 mm Hg higher at the time of the study at our institution. The difference in gradient between the 2 examinations exceeded 10 mm Hg in 30 (24%) patients with aortic stenosis. The difference in mean aortic systolic gradient was greater when multiple imaging windows were not interrogated with continuous wave Doppler on the initial examination (7±10 versus 1±9 mm Hg; *P*=0.002). The largest difference was 43 mm Hg in 2 echocardiograms that were performed 28 days apart. On the initial referring echocardiogram, a mean systolic gradient of 39 mm Hg was recorded from the apical window, and no additional windows were interrogated. The repeat echocardiogram demonstrated a similar mean systolic gradient from the apical window (41 mm Hg), but a mean gradient of 82 mm Hg was obtained from the right parasternal window.

Discussion

Our study is one of the few evaluating the relationship between echocardiographic laboratory accreditation and quality and the only study to our knowledge specifically evaluating echocardiographic assessment of VHD.[17] We found that echocardiographic laboratory accreditation was associated with (1) more complete echocardiographic reports; (2) improved color and spectral Doppler examination quality; and (3) improved adherence to guideline-based quantification for aortic stenosis. In addition, however, all sites had relatively low rates of diagnostic quantification for mitral regurgitation. Inter-rater variability for the assessment of VHD severity was improved considerably in the presence of diagnostic quantification and high-quality color Doppler images in subjects with mitral regurgitation.

Accredited sites were more likely to communicate pertinent demographics and examination findings, which are essential for assessment of patients with VHD (Table 3). Accredited sites more often reported an interpretation of left ventricular size, right ventricular size and function, and a summary of the final impressions of the examination, among others. Generation of a complete and accurate report is an important component of the examination process for communicating relevant findings to cardiologist and noncardiologist providers. Our data support that echocardiographic reports from accredited laboratories offer a more complete representation of the patient's cardiac status.

In addition, laboratory accreditation was associated with improved color Doppler and spectral Doppler image quality

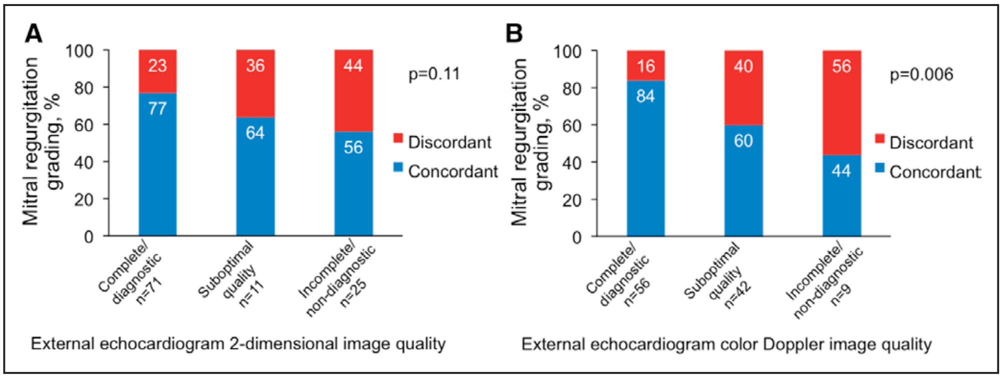

Figure 4. Diagnostic concordance and discordance in grading the severity of mitral regurgitation: external echocardiogram (external interpretation) vs internal echocardiogram. There was a statistical trend for improved concordance with better 2-dimensional (2D) image quality, but this did not reach statistical significance (**A**). However, concordance progressively improved with improved color Doppler image quality (**B**). Provided *P* values were derived from contingency tables and χ^2 analysis of 2D (**A**) and color Doppler (**B**) image quality vs inter-rater concordance.

(Figure 1B and 1C). However, even among accredited sites, 27% were missing ≥1 2D images that were required by the IAC standards or were graded as having nondiagnostic 2D image quality. Another 8% of color Doppler examinations from accredited sites were incomplete or nondiagnostic, and 34% were felt to be diagnostic but had suboptimal image quality that could limit confidence in the interpretation. Our data indicate that even among accredited sites, techniques to optimize color Doppler image quality, such as optimization of color gain and scale, visualization of abnormal color flow in >1 view, and utilization of zoomed views (Table 1), are likely underutilized.

Spectral Doppler examinations were graded incomplete or nondiagnostic in 21% of accredited laboratories and 49% of nonaccredited laboratories. This was frequently related to a lack of interrogation from multiple imaging windows for the evaluation of aortic stenosis and omitting the use of the nonimaging transducer for evaluation of a stenotic lesion. Additionally, even among complete spectral Doppler examinations at accredited laboratories, 34% were graded suboptimal for image quality. This was frequently related to suboptimal adjustment of spectral Doppler gain and scale, which may limit accuracy of the reported findings and may also contribute to the observed low reproducibility on subsequent exams.

Using a binary scale of ≤moderate versus >moderate severity, we found that our internal interpretation of the external echocardiograms was discordant with the external interpretation in 21% of studies. Discordance was not linked to accreditation status, but was improved when diagnostic quantification was present (Figure 3A and 3B). Additionally, in patients with mitral regurgitation, discordance was less with higher quality color Doppler images (Figure 4B). It is important to note that the observed discordance is likely related to a variety of factors, including changes in cardiac hemodynamics and cardiac function in addition to interobserver variability. We also recognize that the evaluation of VHD severity, despite multiple objective parameters, is in many cases inherently subjective. Interestingly, despite the multiple potential confounders, our data support the notion that high-quality imaging and adherence to guideline-based evaluation of VHD are important elements that improve reproducibility.

We also found that adherence to guideline-based recommendations for quantification of aortic stenosis improved concordance in measured mean systolic gradient between the external and internal echocardiograms. The mean aortic systolic gradient was slightly higher at the time of our echocardiogram, which may in part be because of the natural progression of aortic stenosis in this group. However, the difference was larger when multiple imaging windows were neglected on the initial echocardiogram, suggesting that the original mean systolic gradient was underestimated in at least some of these cases. The largest difference observed was 43 mm Hg, and the difference exceeded 10 mm Hg in 24% of subjects. Published standards from the IAC emphasize the importance of interrogation of multiple imaging windows with continuous wave Doppler for the evaluation of aortic stenosis.[9] Our laboratory has found that omitting these extra windows can, in some cases, cause considerable underestimation of aortic stenosis severity.[18] Accredited sites were more likely to interrogate multiple imaging windows, and when this was done, there was improved concordance in mean systolic gradient between the referring and our internal echocardiograms.

In contrast to aortic stenosis, the assessment of mitral regurgitation is not specifically addressed in the IAC standards, and quantification was infrequent among accredited and nonaccredited laboratories. Additionally, quantification of mitral regurgitation was felt to be nondiagnostic in 27% of cases, and this was similar between accredited and nonaccredited laboratories. Areas for improvement for PISA measurements include using a zoomed view to more precisely measure the PISA shell radius (errors in the radius measurement are squared) and including an appropriately timed PISA shell measurement that corresponds to the timing of the peak jet velocity found on the continuous wave Doppler signal.[15]

While the evaluation of mitral regurgitation is certainly more complex and challenging than aortic stenosis,[15,19–21] the observed low rate of quantification also supports the notion that accredited sites are actively engaged in specific recommendations made by the IAC to improve quality. Importantly, inter-rater concordance improved in the presence of guideline-based quantification of VHD severity and with high-quality color Doppler images, which we defined as appropriate adjustment of color Doppler gain and scale, interrogation of abnormal color flow in multiple views, and zoomed views of abnormal valve lesions. Moving forward, it will be important to further identify quality metrics such as these that can be incorporated into daily practice to improve efficiency, quality, and value in the diagnostic tests we perform. Ultimately, this will be critical to successfully transition into a healthcare delivery system where there is an emphasis on value-based care.

Limitations

The design of the study limits our ability to determine a true cause–effect relationship between accreditation and quality, but we did find a significant association between the two. Potential confounders include site-specific echocardiographic laboratory volume, sonographer credentialing, physician experience, and duration of laboratory accreditation. However, the observation that sites are more frequently following recommendations for quantification that are addressed in the IAC Standards (eg, aortic stenosis) than those that are not (eg, mitral regurgitation) supports the notion that accredited laboratories are actively engaged in specific standards recommended by the IAC.

We recognize the challenges and inherent subjectivity of grading the severity of VHD lesions. Some of the observed discordance may be related to inter-rater variability between the external and internal echocardiographer and, particularly for mitral regurgitation, could be influenced by alterations in preload and afterload. Recent studies have also pointed out some of the limitations of echocardiographic quantification, particularly using the PISA method.[20–23] Despite these limitations, the presence of high-quality echocardiographic quantification and echocardiographic images seem to be important in increasing reproducibility.

Given that our institution is a large referral center, there is potential for bias in our results. Some patients in our cohort may have been referred because of complex VHD, for a second opinion, or because of a complex diagnostic or therapeutic dilemma, which may limit the generalizability of our findings. Finally, although we found statistical differences between accredited and nonaccredited sites, it will be important to replicate these findings in larger studies, in part, because of the relatively small number of studies from nonaccredited sites in our cohort.

Conclusions

Laboratory accreditation was associated with more complete echocardiographic reports and improved echocardiographic image quality. Accredited sites were more likely to interrogate the aortic stenosis Doppler signal from multiple imaging windows and use a nonimaging transducer for interrogation of stenotic lesions. Inter-rater concordance for grading VHD severity was similar between accredited and nonaccredited laboratories but was improved when diagnostic quantification was performed and, particularly for mitral regurgitation, was improved with increased quality of color Doppler imaging. Consideration should be given for improving adherence to guideline-supported echocardiographic quantification and high-quality 2D and Doppler imaging to improve the diagnostic accuracy, reproducibility, and quality of echocardiograms performed for the assessment of VHD.

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Disclosures

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CLINICAL PERSPECTIVE

The process of echocardiographic laboratory accreditation is rigorous, time-consuming, and can be challenging for many laboratories. There are few data evaluating the impact of accreditation on the quality of echocardiographic imaging and reporting. Our data indicate that in patients with valvular heart disease, laboratory accreditation was associated with more complete echocardiographic reporting and color and spectral Doppler image quality. Accredited laboratories were more likely to adhere to guideline-based recommendations for quantification of aortic stenosis. Reproducibility for grading valvular heart disease severity was not influenced by accreditation status, but was improved with high quality quantitative echocardiography and, for mitral regurgitation, when high quality color Doppler imaging was present. Diagnostic quantification of mitral regurgitation was relatively uncommon in accredited and nonaccredited laboratories and likely represents an area of improvement in the future. Particularly as our healthcare system continues to emphasize value-based care, it will be important to identify metrics of high quality echocardiographic examinations that improve the efficiency, quality, and value in the studies we perform.

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