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Research Article

In Search of Quality: Echocardiographic Mitral Regurgitation Evaluation Discrepancies

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Abstract

Introduction: Two-dimensional (2D) transthoracic echocardiography (TTE) for mitral regurgitation (MR) evaluation plays a vital role in choosing the adequate type of treatment. Considerable undertreatment prevalence suggests a possible knowledge gap. The aim of the present study was to assess physician diagnostic adherence according to clinical echocardiographic guidelines.

Methods: 438 echocardiographically confirmed MR cases evaluated by 60 beginner, intermediate, or expert level physicians were enrolled. MR *eyeballing* tendencies, quantitative method application accuracy, and guideline adherence were analyzed.

Results: Main discrepancies were unjustified *eyeballing* (66.95%; $p<0.001$), inaccurate application of methods (22.46%, $p=0.002$), and misinterpretation of diagnostic criteria (10.59%). Female patient gender ($p=0.026$) and lower physician competence levels ($p<0.001$) were identified as predictors for eyeballing discrepancy possibility. The latter was also a predictor quantitative method discrepancy ($p=0.043$). Method choice had the most substantial correlation to discrepancies when determining moderate–severe MR ($p<0.001$).

Conclusions: Echocardiographic evaluation of hemodynamically significant MR discrepant in 53.88% of cases as non-quantitative evaluation of hemodynamically significant MR, methodological inaccuracies, and misinterpretation of diagnostic criteria compile the largest proportion of discrepancies. Female gender, lower physician competence, and downgraded diagnostic method application were the most substantial predictors of discrepancy occurrence.

Keywords: transthoracic echocardiography; mitral regurgitation

Introduction

Mitral regurgitation (MR) is described as failure of normal valve function resulting in abnormal reversal blood flow and represents almost a quarter of all valvular heart diseases [1, 2]. In addition, the prevalence and severity is increasing with age, due to which the number of hospitalizations and interventions are rising. It is estimated that the incidence of MR will be doubled in the next 30 years [3].

According to European Society of Cardiology (ESC) and American College of Cardiology (ACC), 2D TTE is the gold standard for MR evaluation [4, 5]. MR severity determined with TTE plays a vital role in choosing the type of intervention and treatment sometimes undermining the patient's asymptomatic status [6]. Unfortunately, up to half of moderate-severe MR related referrals for surgical treatment are denied due to poor access to healthcare and comorbidities [7]. However, even with good access to care and no apparent cause, surgical intervention is still withheld to some while others are left undiagnosed or undertreated, possibly contributing to significantly higher mortality rates [3, 8, 9].

To address the mentioned lack of research in objective MR assessment, the aim of this study is to analyze physician diagnostic compliance according to ESC and ACC provided guidelines.

Materials and Methods

468 echocardiographically confirmed hemodynamically significant MR cases were acquired from the Cardiology department database at Hospital of Lithuanian University of Health Sciences (LUHS) Kaunas Clinics, Lithuania, from 1st July 2019 to 31st December 2019. This study was approved by the LUHS Research Ethics Board. 30 cases were excluded due to poor visual quality indicated by the physician who performed the evaluation.

Physicians were stratified into three different competence groups. Out of sixty physicians, 35 of them were beginners (residency program students), 16 intermediates (cardiologists not sub – specializing in echocardiography), and 9 experts. Demographic patient variables like age and gender were recorded.

Mitral regurgitation diagnostic criteria

According to echocardiography guidelines, moderate and severe regurgitation must be objectively measured using at least one semi-quantitative (*vena contracta* width (VCW)) or quantitative (proximal isovelocity surface area (PISA) radius, effective regurgitant orifice area (EROA), regurgitant volume (RVol)) method. These methods are not compulsory when the physician is certain that the regurgitation grade is mild.

Cases were divided into two groups according to MR hemodynamic significance. II grade and higher MR considered as hemodynamically significant (VCW ≥ 0.30 cm or/and EROA ≥ 0.20 cm^2 or/and RVol ≥ 30 ml).

Mitral regurgitation evaluation inaccuracy criteria

The quality of a MR evaluation was assessed according *eyeballing* tendencies, quantitative method application accuracy, and diagnostic criteria fulfillment. Not using any quantitative methods (*eyeballing*) in hemodynamically significant MR cases was considered as a discrepancy. Other inaccuracies were related to the application of a particular method or interpretation of the measured results. A methodologically correct simplified PISA, EROA, or RVol assessment must indicate a PISA radius value, which falls within an interval between 4 and 10 millimeters. If PISA radius value was not indicated in the echocardiographic evaluation sheet or it did not fall into the necessary interval, it was acknowledged as a discrepancy (Table 1).

Discrepancy	r ∈ [4; 10]	V_a
No. 1	–	–
No. 2	+	–
No. 3	–	+

r – hemisphere radius, V_a – aliasing velocity,

"–" indicates that either r does not fall into the necessary interval between 4 and 10 mm or V_a is unspecified,

"+" indicates that both r falls into the necessary interval between 4 and 10 mm or V_a is specified.

Table 1. *Discrepancies related to simplified proximal isovelocity surface area method application*

If the MR severity determined by the physician using VCW, EROA, or RVol does not match the corresponding guideline MR grade intervals, it was regarded as an inaccuracy (Table 2). Discrepancy cases were excluded, if a physician noted spectrometry and color doppler features (e.g., regurgitant flow duration, multiple and/or eccentric jets).

Discrepancy	r ∈ [4; 10]	Underdiagnosed MR severity	Accurate MR severity	Overdiagnosed MR severity
No. 4 or 9	+	–	–	+
No. 5 or 10	+	+	–	–
No. 6 or 11	–	–	+	–
No. 7 or 12	–	–	–	+
No. 8 or 13	–	+	–	–

r – hemisphere radius, MR – mitral regurgitation

Discrepancy No. 4 or 9: r falls into the necessary interval but the physician diagnoses a higher MR grade than it actually is according to EROA or RVol diagnostic values.

Discrepancy No. 5 or 10: r falls into the necessary interval but the physician diagnoses a lower MR grade than it actually is according to EROA or RVol diagnostic values.

Discrepancy No. 6 or 11: r does not fall into the necessary interval even though the physician diagnoses an accurate MR grade according to EROA or RVol diagnostic values.

Discrepancy No. 7 or 12: r does not fall into the necessary interval and the physician diagnoses a higher MR grade than it actually is according to EROA or RVol diagnostic values.

Discrepancy No. 8 or 13: r does not fall into the necessary interval and the physician diagnoses a lower MR grade than it actually is according to EROA or RVol diagnostic values.

Table 2. *Discrepancies related to effective regurgitant orifice area and/or regurgitant volume method application and interpretation*

Statistical analysis

Chi-Square and Fisher's exact tests were used to evaluate the association between competence and echocardiographic MR evaluation discrepancies. In cases of statistical significance, the quantitative connection was evaluated using Spearman's correlation. Multivariate binary logistic regression analysis was used to identify the predictors for incorrect echocardiographic MR evaluation. Mann Whitney test was used comparing two non-normal distributed data.

Results

20.55% of hemodynamically significant MR cases were diagnosed by beginners, 21.00% by intermediates, and 58.45% by experts. The most frequently applied technique among all physician groups was the combination of EROA and RVol methods ($p<0.001$) which matched the expert's decision ($p<0.001$) (Table 3).

Quantitative Method	Competence level			Total N=438
	Beginner N=90	Intermediate N=92	Expert N=256	
r+V_a	–	19	6	25 (5.71%)
VCW	1	–	1	2 (0.46%)
EROA	17	7	35	59 (13.47%)
r+Va+VCW	–	–	1	1 (0.23%)
EROA+RVol	9	17	148	174 (39.73%)
EROA+VCW	6	–	1	7 (1.59%)
EROA+RVol+VCW	3	–	9	12 (2.74%)
Total	36 (40%)	43 (46.74%)	201 (78.52%)	280 (63.93%)

r – hemisphere radius, V_a – aliasing velocity, VCW – *vena contracta* width, EROA – effective regurgitant orifice area, RVol – regurgitant volume

Table 3. *Quantitative methods application distribution among competence groups in significant mitral regurgitation*

Beginners choose EROA or EROA and RVol measuring approaches equally frequently (p=0.169) while there was no method selection differences among intermediates.

Analyzing how examiners comply with recommendations of echocardiographic MR evaluation, the discovered discrepancies were divided into three large groups. The most common discrepancy was estimation of a hemodynamically significant MR without using any quantitative methods (66.95%, p<0.001), followed by inaccurate application of methods (22.46%, p=0.002) and misinterpretation of diagnostic criteria (10.59%) (Table 4).

Source of a discrepancy	Competence level			Total N=438 (100%)
	Beginner N=90	Intermediate N=92	Expert N=256	
Eyeballing	54	49	55	158 (66.95%)
Inaccurate implementation of a particular quantitative method	4	23	26	53 (22.46%)
Estimation of a lower MR severity than measured	–	–	2	2 (0.85%)
Estimation of a higher MR severity than measured	3	1	19	23 (9.75%)
Frequency of discrepancies	**61 (67.78%)**	**73 (79.35%)**	**102 (39.84%)**	**236 (53.88%)**

Table 4. *Discrepancy types and their distribution among competence groups in significant mitral regurgitation*

There were significant differences between discrepancy frequency and physician competence (p<0.001). Experts were less inaccurate (39.84%) while cases evaluated by beginners and intermediates had discrepancies of 67.78% and 79.35% respectively. No difference between the non-expert groups was found. There is a moderate negative correlation between physician competence and discrepancies in hemodynamically significant MR evaluation (r=0.303; p<0.001).

158 (66.95%) hemodynamically significant MR cases were diagnosed with *eyeballing*. 141 (89.84%) of them were grade II. There was a negative correlation between *eyeballing* frequency and physicians' competence level (p<0.001). Cases evaluated by experts contained statistically significantly fewer discrepancies (21.48%) than in non – expert groups (60.00% and 53.26% among beginners and intermediates respectively) (r=0.360; p<0.001).

In hemodynamically significant MR, simplified PISA application discrepancies were discovered in four-fifths of cases. Simplified PISA method was statistically significantly more frequently applied inaccurately (p=0.003) by intermediates and experts (Table 5).

Case	Competence level		Total N=25
	Intermediate N=19	Expert N=6	
Correct	1	4	5
Discrepancy No. 1	6	–	6
Discrepancy No. 2	11	–	11
Discrepancy No. 3	1	2	3
Frequency of discrepancies	**18 (94, 74%)**	**2 (33, 33%)**	**20 (80, 00%)**

Discrepancy No. 1: neither r falls into the necessary interval nor V_a is specified,

Discrepancy No. 2: r falls into the necessary interval, but V_a is not specified,
Discrepancy No. 3: r does not fall into the necessary interval, but V_a is specified.
r – hemisphere radius, V_a – aliasing velocity

Table 5. *Discrepancies distribution among competence groups in simplified proximal isovelocity surface area method application for significant mitral regurgitation assessment*

In cases, in which EROA and/or RVol were indicated, more than one fifth of them were either inaccurate or executed incorrectly (Table 6).

Case	Competence level			Total
	Beginner	Intermediate	Expert	
EROA application				
	N=23	**N=7**	**N=36**	**N=66**
Correct	19	5	34	58
Discrepancy No. 4	3	–	1	4
Discrepancy No. 5	–	–	–	0
Discrepancy No. 6	–	2	1	3
Discrepancy No. 7	1	–	–	1
Discrepancy No. 8	–	–	–	0
Frequency of discrepancies	**4 (17, 39%)**	**2 (40, 00%)**	**2 (5, 56%)**	**8 (12, 12%)**
EROA + RVol application				
	N=12	**N=17**	**N=157**	**N=186**
Correct	9	13	115	137
Discrepancy No. 9	–	1	18	19
Discrepancy No. 10	–	–	1	1
Discrepancy No. 11	3	1	22	26
Discrepancy No. 12	–	1	1	2
Discrepancy No. 13	–	1	–	1
Frequency of discrepancies	**3 (25, 00%)**	**4 (23, 53%)**	**42 (26, 75%)**	**49 (26, 34%)**

Discrepancy No. 4 or 9: r falls into the necessary interval, but the physician diagnoses a higher MR grade than it is according to EROA or combined EROA and RVol diagnostic values;

Discrepancy No. 5 or 10: r falls into the necessary interval, but the physician diagnoses a lower MR grade than it is according to EROA or combined EROA and RVol diagnostic values;

Discrepancy No. 6 or 11: r does not fall into the necessary interval even though the physician diagnoses an accurate MR grade according to EROA or combined EROA and RVol diagnostic values;

Discrepancy No. 7 or 12: r does not fall into the necessary interval and the physician diagnoses a higher MR grade than it is according to EROA or combined EROA and RVol diagnostic values;

Discrepancy No. 8 or 13: r does not fall into the necessary interval and the physician diagnoses a lower MR grade than it is according to EROA or combined EROA and RVol diagnostic values.

r – hemisphere radius, EROA – effective regurgitant orifice area, RVol – regurgitant volume

Table 6. *Discrepancy distribution among competence groups in effective regurgitant orifice area, combined effective regurgitant orifice area regurgitant volume method application for significant mitral regurgitation assessment*

Despite methodologically precise MR diagnostic method application, 25 (9.41%) case conclusions disagreed with the MR diagnostic guidelines. Most of them (96.00%) were overestimations. In general, both isolated EROA as well as the EROA and RVol method combinations did not present any differences among competence groups and discrepancies. In both cases, echocardiographic MR evaluation was done accurately ($p<0.001$)

A regression model revealed that gender is a predictor for incorrect usage of *eyeballing* to assess the severity of regurgitation in moderate or severe MR ($p=0.026$). It was 1.645 (95% CI 1.060-2.554) times more likely for a physician to apply no quantitative method when determining a hemodynamically significant MR, if the patient was female. Higher competence level had an inverse relationship with *eyeballing* discrepancies in moderate or severe MR ($p<0.001$; OR=0.403, 95% CI 0.312-0.522). Physicians' competence level was also a predictor for

quantitative method discrepancies, (p=0.043; OR=0.651, 95% CI 0.429-0.986). Diagnostic method choice had the most substantial correlation (p<0.001) to discrepancies when determining moderate-severe MR. Downgrading from EROA or RVol methods increases the probability of a discrepancy 5.177 times (95% CI 2.794-9.590).

Discussion

This research is one of the first analyzing both guideline adherence and methodological accuracy. As some authors report significant knowledge gaps in quantitative MR assessment, our goal was to evaluate the extent guideline non-adherence and identify the main factors that could explain the origin of the discrepancies.

In most research articles, competence was the primary factor for guideline adherence. Chan et al. found that cardiovascular physicians select patients who require initial echocardiographic evaluation better than internal medicine and primary care specialists, directly contributing to positive long-term health outcomes [10]. Iung et al. findings provide the same conclusions and adds the importance of subspecialization within a cardiovascular specialty which is related to the results of our research [11]. Even then, some cases still require magnetic resonance imaging to achieve a definite diagnosis and subsequent treatment plan [12].

During a subjective echocardiographic method application questionnaire, most primary care, internal medicine, and cardiovascular specialists noted good adherence to echocardiographic guidelines although majority of interviewed physicians reported lack of quantitative indices of MR severity [13]. As such overconfidence is a universal aspect, incidence of non-compliance can be even more prevalent [14]. Another interesting aspect of current MR evaluation is the grading margins between different quantitative methods, especially in more severe cases [15]. According to authors, constant application of all methods in every echocardiographic case is a practical preventive measure applied only a few times in our study.

Patient's gender, competence level of the physician, and selected diagnostic method were leading factors influencing the occurrence of discrepancies in MR assessment. Increased inadequate *eyeballing* with female patients could be associated with gross anatomy differences, the psychosocial experience of a given environment, and physician's expertise. As TTE requires direct access to the thorax, such conditions can cause psychological discomfort to patients [16]. As it can affect physical patient examination, there is a possibility that inconsistencies occur in TTE as well [17, 18]. Physician's reaction could be the cause of a hurried visual MR evaluation, especially if the observed regurgitation is moderate. In 89.84% of cases, regurgitation was grade II when hemodynamically significant MR was diagnosed using only *eyeballing*, illustrating the physician's decision to end the diagnostic procedure prematurely.

Mantovani *et al*. found that standardization in accordance with body surface area in women is related to a higher degree MR which in turn could eventually determine a different treatment plan [19]. Therefore, the correct assessment of regurgitation severity comprises not only of the appropriate adherence to guidelines but individual evaluation, emphasizing the problem of prematurely diagnosing MR based solely on *eyeballing* found in the present study. Despite it being unreliable, unjustified *eyeballing* was found to be the most prevalent type of discrepancy in both genders, adding to the widespread problem reported by other authors [9].

Beginners and intermediates were significantly more likely to assess the severity of MR with discrepancies, mostly due to illicit *eyeballing*, representing 88.5%, 67.12%, and 53.92% of cases among beginners, intermediates, and experts, respectively. The disproportional distribution arises from unequal usage quantitative methods among physicians. Beginners and intermediates used at least one quantitative measurement in less than half of MR cases. Wang *et al*. also found that application of quantitative measures for MR evaluation were significantly linked to echocardiography expertise [10]. Simplified PISA method application is the most apparent example, as discrepancies among experts occurred in 33% of the cases, intermediates were correct only once. Observed inaccuracies are thought to be a part of the mentioned interobserver variability and physician competence regarding quantification and interpretation of MR [10, 11, 19]. However, due to lack of simplified PISA application cases in our study, these assumptions would be inconsiderate (Table 3).

Variance in applied diagnostic methods is the most prominent predictor of diagnostic inconsistencies. It is over five times more likely for a discrepancy to occur when MR is evaluated without the combination of EROA and RVol. However, result interpretation is not straightforward, as physician competence and the evaluation bias within the frames of guidelines are important aspects of the factor. Nonetheless, methodology impact on discrepancies may stem from the discordance between measured parameters and corresponding intervals within the guidelines. Uretsky *et al*. found that only 6% of cases had complete agreement on all diagnostic parameters, suggesting significant limitations of 2D PISA methodologies [14]. In our study, less than three percent of cases with hemodinamically significant MR had measurements of VCW, RVol, and EROA which should yield unequivocal precision. Quite a few limitations within 2D PISA methodologies have been observed. According to various authors, novel 3D PISA methods not only allow a more accurate valve evaluation, but it also closely corresponds to subsequent magnetic resonance imaging findings which is not the case with 2D PISA [20 – 25].

To summarize, expert supervision, consistent quantitative method application or even rapid integration of mentioned more effective techniques in everyday practice is needed to resolve the persisting MR and, possibly, other valvular abnormality evaluation guideline non-adherence, methodology limitations, and complications arising from insufficient standardization.

Conclusions

Echocardiographic evaluation of hemodynamically significant MR discrepant in half of cases as non-quantitative evaluation of hemodynamically significant MR, methodological inaccuracies, and misinterpretation of diagnostic criteria compile the largest proportion of discrepancies. Female gender, lower physician competence, and downgraded diagnostic method application were the most substantial predictors of discrepancy occurrence. This study demonstrates the importance of echocardiographic quality control studies in each clinical practice, expert supervision, and quantitative method application are mandatory to ensure accurate evidence-based diagnostic and treatment decisions.

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