JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY VOL. 65, NO. 11, 2015
© 2015 BY THE AMERICAN COLLEGE OF CARDIOLOGY FOUNDATION ISSN 0735-1097/$36.00
PUBLISHED BY ELSEVIER INC. http://dx.doi.org/10.1016/j.jacc.2014.12.047

Discordance Between Echocardiography and MRI in the Assessment of Mitral Regurgitation Severity

A Prospective Multicenter Trial

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ABSTRACT

BACKGROUND The decision to undergo mitral valve surgery is often made on the basis of echocardiographic criteria and clinical assessment. Recent changes in treatment guidelines recommending surgery in asymptomatic patients make the accurate assessment of mitral regurgitation (MR) severity even more important.

OBJECTIVES The purpose of this study was to compare echocardiography and magnetic resonance imaging (MRI) in the assessment of MR severity using the degree of left ventricular (LV) remodeling after surgery as the reference standard.

METHODS In this prospective multicenter trial, MR severity was assessed in 103 patients using both echocardiography and MRI. Thirty-eight patients subsequently had isolated mitral valve surgery, and 26 of these had an additional MRI performed 5 to 7 months after surgery. The pre-surgical estimate of regurgitant severity was correlated with the postoperative decrease in LV end-diastolic volume.

RESULTS Agreement between MRI and echocardiographic estimates of MR severity was modest in the overall cohort ($r = 0.6$; $p < 0.0001$), and there was a poorer correlation in the subset of patients sent for surgery ($r = 0.4$; $p = 0.01$). There was a strong correlation between post-surgical LV remodeling and MR severity as assessed by MRI ($r = 0.85$; $p < 0.0001$), and no correlation between post-surgical LV remodeling and MR severity as assessed by echocardiography ($r = 0.32$; $p = 0.1$).

CONCLUSIONS The data suggest that MRI is more accurate than echocardiography in assessing the severity of MR. MRI should be considered in those patients when MR severity as assessed by echocardiography is influencing important clinical decisions, such as the decision to undergo MR surgery. (J Am Coll Cardiol 2015;65:1078–88) © 2015 by the American College of Cardiology Foundation.

Echocardiography is the most commonly used method for determining the severity of mitral regurgitation (MR) (1). In patients with severe MR, American College of Cardiology/American Heart Association guidelines advise surgery when there is left ventricular (LV) dysfunction, even in the absence of symptoms (1). Recently, physicians have debated whether these guidelines should be relaxed further, with proponents arguing that results are superior when there is earlier surgical intervention (2,3).

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Manuscript received July 4, 2014; revised manuscript received December 21, 2014, accepted December 22, 2014.

In such cases, accurate assessment of MR severity becomes even more important.

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Many studies have been published regarding the ability of echocardiography to assess the severity of MR, either qualitatively or quantitatively. A common weakness of many of these studies is that they lack comparison with a "gold" or reference standard to validate their accuracy. Although several early studies compared echocardiography with invasive ventriculography (4–7), the consensus today is that echocardiography is superior to ventriculography for determining the severity of MR (1).

Current American Society of Echocardiography (ASE) guidelines for quantification of MR recommend an integrated approach that relies on multiple echocardiographic techniques (8). However, the guidelines are silent on the weighting of individual components and do not provide an approach to reconciling situations in which individual measures are inconsistent. In addition, there are limitations to echocardiographic techniques when regurgitant jets are noncircular, eccentric, or nonholosystolic.

Magnetic resonance imaging (MRI) is an alternative imaging modality that can accurately quantify the severity of MR (9–11). Using MRI, we previously demonstrated a tight coupling between regurgitant volume and LV end-diastolic volume (EDV) in patients with chronic primary MR (12). This is consistent with the notion that LV enlargement is an important compensatory mechanism that augments stroke volume and maintains constant forward flow in the setting of MR (13,14).

Previous studies have shown that after mitral valve (MV) repair or replacement, the left ventricle decreases in size as it remodels (15–18). The purpose of this study is to compare MRI with echocardiography in the assessment of MR severity and to determine the extent to which these modalities can predict the degree of LV remodeling after isolated MV surgery.

METHODS

This prospective multicenter study included 103 patients (age 61 ± 14 years, 57% male) with MR on echocardiography. Patients were recruited from the echocardiography laboratories of the participating institutions and from physician referrals. Exclusion criteria included more than mild aortic regurgitation, aortic stenosis, or mitral stenosis; planned coronary revascularization; intracardiac shunt; hypertrophic cardiomyopathy; pregnancy; and contraindication to MRI. Patients with incomplete or suboptimal echocardiographic studies were excluded. The institutional review board of each participating institution approved this research protocol.

ECHOCARDIOGRAMS. Echocardiograms were obtained and viewed using commercially available ultrasound machines (Acuson Sequoia, Siemens, Mountain View, California; iE33 xMATRIX, Philips, Andover, Massachusetts) and software (ProSolv, Fujifilm, Indianapolis, Indiana). Comprehensive echocardiograms were obtained to allow an integrated approach to the assessment of MR severity, as recommended by the ASE (8). Components included were mitral regurgitant jet dimensions, regurgitant volume and regurgitant orifice area calculated using the proximal isovelocity surface area (PISA) technique, mitral E wave, vena contracta, left atrial volume, LV dimensions, and pulmonary vein systolic flow characteristics. Transthoracic echocardiograms were acquired using the standard imaging views: parasternal long and short axes and the apical 2-, 3-, and 4-chamber views. Transesophageal echocardiograms were acquired in patients (n = 38, 37%) when the transthoracic evaluation was inadequate or technically difficult or when there was a need to further define MV morphology (1). Color Doppler interrogation of the MR jet was performed in multiple views. Vena contracta was measured in the modified parasternal long-axis view as the narrowest portion of the jet (8). PISA was measured in the apical 2-, 3-, and 4-chamber views with the lower Nyquist limit set at 32 to 42 cm/s and zoomed in on the area of flow convergence (8). Peak MR jet velocity and velocity time integral were determined using continuous-wave Doppler across the MV (8). MR volume and effective regurgitant orifice area were calculated based on the PISA measurement as previously described (8). For eccentric MR jets, angle correction was applied to improve the accuracy of the effective regurgitant orifice area and the regurgitant volume quantification (19). Pulmonary vein systolic flow was recorded using pulsed-wave Doppler interrogation of the right upper pulmonary vein and left-sided veins when possible (8). Pulmonary vein flow was categorized as either systolic predominant, systolic blunting, or systolic reversal (20). Mitral inflow velocities were determined per ASE guidelines (20). LV volumes were determined using the modified Simpson biplane method (21). Tricuspid regurgitant velocity was measured as the highest peak continuous-wave Doppler velocity as determined in multiple views. MV prolapse was defined as an abnormal systolic

ABBREVIATIONS AND ACRONYMS

ASE = American Society of Echocardiography
CI = confidence interval
EDV = end-diastolic volume
FOV = field of view
ICC = intraclass correlation coefficient
LV = left ventricular
MR = mitral regurgitation
MRI = magnetic resonance imaging
MV = mitral valve
PISA = proximal isovelocity surface area
TR/TE = repetition time/echo time

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displacement (billowing) of 1 or both leaflets ≥2 mm above the mitral annulus plane in any long-axis view (1). Flail mitral leaflet was defined as unrestricted systolic motion of the mitral leaflet tip between the left atrium and the left ventricle (1). All 103 transthoracic and 38 transesophageal echocardiograms were read in a blinded manner by experienced echocardiographers in a central core laboratory and graded qualitatively as mild, moderate, or severe by integrating all echocardiographic information, including PISA, effective regurgitant orifice area, vena contracta, left atrial and LV size, pulmonary vein flow pattern, and MR Doppler jet characteristics such as color Doppler area, eccentricity, and temporal variation (8). MR volume was calculated using the PISA method for all patients (8). All echocardiograms were assessed for quality and scored as follows: 1 = excellent, 2 = good, 3 = fair, and 4 = poor. Readers blinded to the patient's clinical data and the initial study interpretation assessed the interobserver variability of MR severity in a subset of 93 patients.

MAGNETIC RESONANCE IMAGING. Patients were imaged at 1.5- or 3.0-T. Images were acquired with a cardiac coil, electrocardiographic gating, and breath holding. At 1.5-T, short- and long-axis cine images were acquired using steady-state free precession with nominal parameters: repetition time/echo time (TR/TE), 3.3 ms/1.4 ms, 20 views per segment; field of view (FOV), 35 × 35 cm; matrix, 192 × 160; slice thickness, 8 mm; and flip angle, 45°. Phase contrast images were acquired perpendicular to the proximal pulmonary artery and/or aorta to quantify flow using nominal parameters: TR/TE, 7.5 ms/2.9 ms, 6 views per segment; velocity encoding (Venc) 250 cm/s; FOV, 35 × 35 cm; matrix, 256 × 128; slice thickness, 4 mm; and flip angle, 20°. At 3.0-T, short- and long-axis images were acquired using steady-state free precession with nominal parameters: TR/TE, 3.7 ms/1.4 ms, 20 views per segment; FOV, 36 × 31 cm; matrix, 168 × 208; slice thickness, 8 mm; and flip angle, 60°. Phase contrast images were acquired using nominal parameters: TR/TE, 6.8 ms/3.0 ms, 6 views per segment; Venc, 250 cm/s; FOV, 35 × 30 cm; matrix, 256 × 128; slice thickness, 5 mm; and flip angle, 15°.

Images were analyzed using SuiteHeart software (NeoSoft, Pewaukee, Wisconsin). All MRI studies were assessed for quality and scored as follows: 1 = excellent; 2 = good; 3 = fair; and 4 = poor. Left and right ventricular volumes were determined by manual segmentation of the short-axis images using a long-axis image to define the position of the left and right ventricular bases. Aortic and pulmonary artery flow values were determined using the resident semiautomated algorithm. Correction for baseline flow offsets was performed as described previously (22). Flow measurements from 2 or 3 acquisitions were averaged. MR volume was determined as the difference between the LV stroke volume and forward flow (12). MR volume was categorized per American Heart Association/American College of Cardiology guidelines: mild, <30 ml; moderate, 30 to <60 ml; and severe, ≥60 ml (1). Blinded experienced readers in a central core laboratory interpreted all MRI studies. Readers blinded to the patients' clinical data and the initial study interpretation assessed the interobserver variability of MR severity in a subset of 83 patients.

COMPARISON OF MRI AND ECHOCARDIOGRAPHY. The severity of MR, as determined by MRI and

TABLE 1 Baseline Patient Clinical and Demographic Data (N = 103)

Age, yrs	61 ± 14
Male	59 (57)
Hypertension	51 (51)
Diabetes mellitus	13 (13)
Hyperlipidemia	33 (32)
Smoking history	17 (17)
Coronary artery disease	10 (10)
Myocardial infarction	5 (5)
Stroke	2 (2)
Dyspnea	39 (38)
Degenerative mitral regurgitation	49 (47)
Mitral valve prolapse	30 (29)
Mitral valve flail	19 (18)
Functional MR	19 (18)
Regurgitant jet type	
Eccentric	59 (57)
Central	44 (43)

Values are mean ± SD or n (%).

TABLE 2 Interobserver Variability for MRI and Echo

		MRI Reader 1			
		Mild	Moderate	Severe	Total
MRI reader 2	Mild	41	6	0	47
	Moderate	1	25	1	27
	Severe	0	0	9	9
	Total	42	31	10	83
		Echo Reader 1			
		Mild	**Moderate**	**Severe**	**Total**
Echo reader 2	Mild	9	7	0	16
	Moderate	5	14	15	34
	Severe	0	9	34	43
	Total	14	30	49	93

Echo = echocardiography; MRI = magnetic resonance imaging.

echocardiography, was compared using: 1) categories of mild, moderate, and severe; and 2) calculated regurgitant volume. Substantial discordance was defined as a difference of 2 grades.

POST-SURGICAL OUTCOMES. Patients who had isolated MV surgery underwent follow-up MRI 5 to 7 months after surgery. Pre-surgical estimates of MR volume were correlated with the change in LV EDV after isolated MV surgery.

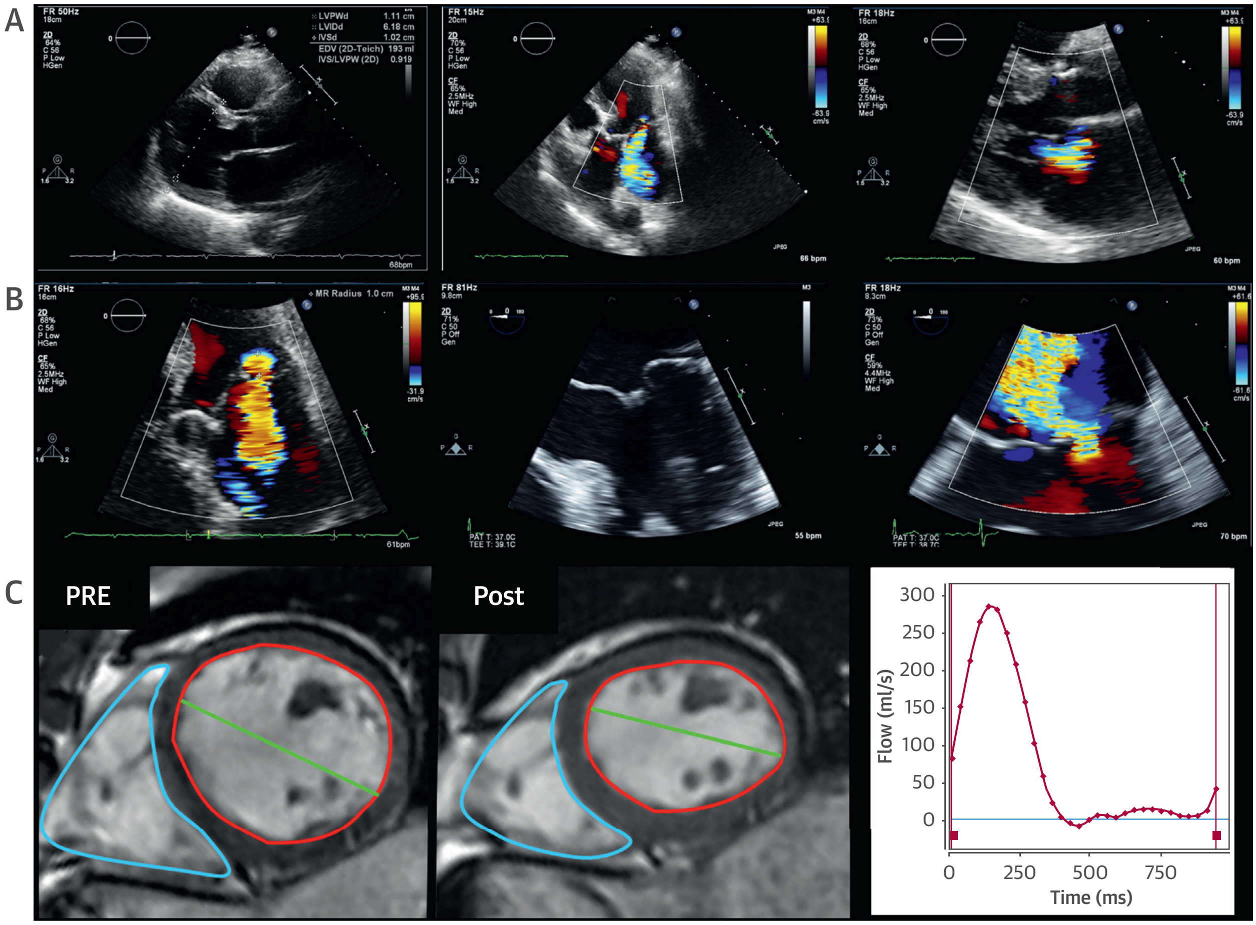
STATISTICAL ANALYSIS. Continuous data are presented as mean ± SD or as median with 25th and 75th percentiles. Categorical data are presented as absolute numbers or percentages. Continuous data were analyzed, where applicable, using the Student *t* test and paired Student *t* test. The Student *t* test and Mann-Whitney *U* test were used to compare 2 groups of unpaired data of Gaussian and non-Gaussian distribution, respectively. Categorical variables were

TABLE 3 Comparison of MR Severity: MRI Versus Echo

	MRI			
	Mild	Moderate	Severe	Total
Echo				
Mild	14	0	0	14
Moderate	19	10	2	31
Severe	20	25	13	58
Total	53	35	15	103

MR = mitral regurgitation; other abbreviations as in Table 2.

FIGURE 1 A Patient With Severe MR by Echocardiography (Regurgitant Volume = 62 ml) and Mild MR by MRI (Regurgitant Volume = 15 ml) Who Had Isolated Mitral Valve Surgery



(A) Transthoracic echocardiogram: parasternal long axis with left ventricular end-diastolic dimension = 6.2 cm, eccentric MR jet: Nyquist limit = 63.9 cm/s, vena contracta = 0.7 cm. **(B)** Transesophageal echocardiogram: proximal isovelocity surface area radius = 1.0 cm: Nyquist limit = 31.9 cm/s, mitral valve prolapse, MR jet hugging the left atrial wall: Nyquist limit = 61.6 cm/s. **(C)** MRI: short axis (pre-surgical end-diastolic volume **[PRE]** = 216 ml and end-systolic volume = 126 ml), short axis (post-surgical end-diastolic volume **[Post]** = 172 ml), forward flow = 75 ml. MR = mitral regurgitation; MRI = magnetic resonance imaging.

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analyzed using a chi-square test. Linear regression analysis (Pearson correlation) was used to evaluate the relationship between MR volume quantified by echocardiography and MRI and the pre-surgery to post-surgery change in LV EDV. Bland-Altman plots were used to compare MR volumes between echocardiography and MRI. To test the degree of concordance between echocardiography and MRI for the quantification of MR severity, the intraclass correlation coefficient (ICC) for a 2-way random-effects model with absolute agreement was calculated. One-way analysis of variance with a post-hoc Bonferroni test was used to compare means of continuous variables among multiple groups. To test the interobserver reproducibility for the quantification of mitral regurgitant severity, the ICCs were calculated, and the mean bias and 95% limits of agreement were calculated with Bland-Altman analysis. Good correlation was defined as an ICC >0.8. All statistical analyses were performed using SPSS for Windows version 16 (SPSS Inc., Chicago, Illinois). A probability value <0.05 was considered statistically significant.

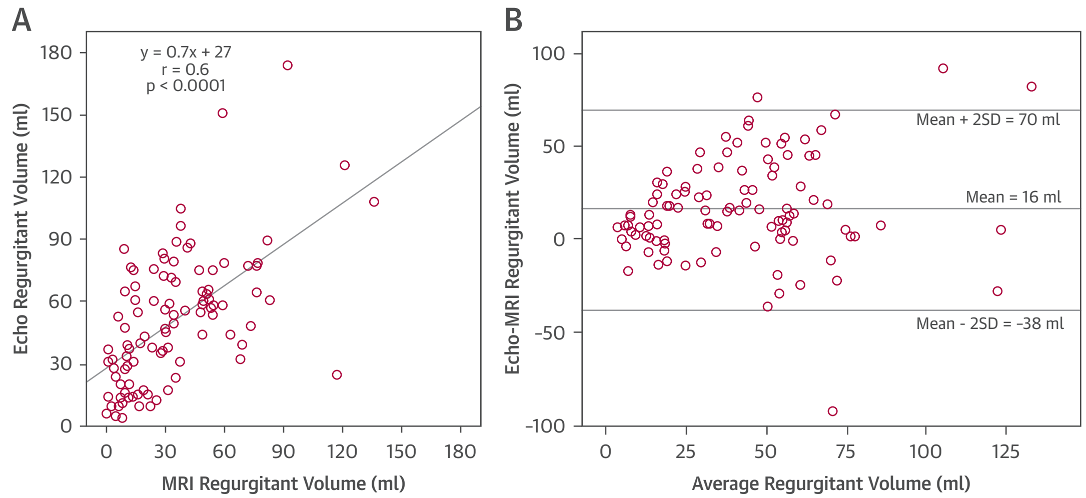
RESULTS

Table 1 lists baseline patient clinical and demographic data. Of the 103 patients enrolled in this study, 49 patients (47%) had degenerative disease (prolapse/flail), and 19 patients (18%) had functional disease. Fifty-nine patients (57%) had eccentric MR jets. The median time between echocardiography and MRI was 15 days (25th, 75th percentiles: 7, 35). There was no clinically significant difference between the systolic blood pressure (126 ± 16 mm Hg vs. 128 ± 13 mm Hg; p = 0.3), diastolic blood pressure (74 ± 11 mm Hg vs. 75 ± 10 mm Hg; p = 0.3), or heart rate (77 ± 17 beats/min vs. 74 ± 14 beats/min; p = 0.04) at the time of initial evaluation with echocardiography and MRI, respectively. Blinded reviewers scored the echocardiograms and the MRIs as generally of good-to-excellent quality (1.7 ± 0.6 vs. 1.5 ± 0.8, respectively; p = 0.2).

INTEROBSERVER VARIABILITY. Table 2 shows the interobserver variability of MRI and echocardiography. Reproducibility for MRI was excellent, with agreement in 90% of patients (ICC = 0.90; 95% confidence interval (CI): 0.85 to 0.93; p < 0.0001). Reproducibility for echocardiography was moderate, with agreement in 61% of patients (ICC = 0.65; 95% CI: 0.51 to 0.75; p < 0.0001).

CONCORDANCE BETWEEN MRI AND ECHOCARDIOGRAPHY. Table 3 shows a comparison of categorical assessments of MR severity between echocardiography and MRI. There was agreement in 37 of 103 patients (36%). There was a significant, but modest, correlation between the 2 modalities (r = 0.4; p < 0.0001; ICC = 0.43; 95% CI: −0.11 to 0.69; p < 0.001). If patients were characterized as having either severe or nonsevere MR, the concordance improved to 56 of 103 patients (54%). When considering patients who had severe MR on echocardiography, only 13 of

FIGURE 2 Quantitative Comparison of Regurgitant Volume as Determined by MRI and Echo



(A) Quantification of MR severity: echocardiography versus MRI. **(B)** Bland-Altman plot. Echo = echocardiography; other abbreviations as in Figure 1.

58 patients (22%) had severe MR on MRI. This finding was consistent across echocardiographers. In the subset of 93 patients reviewed by 2 additional echocardiographers for interobserver variability, 9 of 43 patients (21%) and 10 of 50 patients (20%) characterized as having severe MR on echocardiography actually had severe MR on MRI.

Discordance between echocardiography and MRI was sometimes substantial. In 20 of 58 patients (34%) with severe MR on echocardiography, MR severity was mild on MRI. There were no cases of substantial discordance in which echocardiography graded the MR as mild and MRI graded it as severe. Figure 1 shows a patient who underwent MV surgery and who had severe MR by echocardiography and mild MR by MRI. Concordance between MRI and echocardiography was similar when considering patients with central MR jets (37%) and eccentric MR jets (34%). A quantitative comparison of MR severity between echocardiography and MRI is shown in Figure 2, revealing a modest correlation ($r = 0.6$; $p < 0.0001$; ICC = 0.67; 95% CI: 0.36 to 0.81; $p < 0.0001$) with wide limits of agreement (−38 to 70 ml).

LV REMODELING AFTER SURGICAL CORRECTION. Table 4 shows the American College of Cardiology/American Heart Association indication, mitral regurgitant severity, and LV dimensions as measured by echocardiography for each of the 38 patients who underwent isolated MV surgery. The majority had a class I indication for MV surgery, and a small number had a class IIa indication. Figure 3 shows the type of MV surgery and the severity of MR as quantified by MRI. Of the 38 patients who had MV surgery, 11 (30%) had severe MR by MRI.

Twenty-six patients were evaluated with follow-up MRI 5 to 7 months after surgery. Of the remaining 12 patients, 7 were not yet due for their post-surgery MRI evaluation, and 5 did not have a follow-up MRI (2 patients died, 2 received a permanent pacemaker, and 1 refused). Table 5 shows left and right ventricular parameters before and after surgery. In general, after surgery, LV volumes and LV ejection fraction decreased. When comparing post-surgery changes in LV EDV, there was a significant difference in the decrease in LV EDV among the categories of mild, moderate, and severe by MRI (mild, −31 ml; moderate, −55 ml; severe, −140 ml; $p < 0.0001$). There was a nonsignificant trend in the post-surgery decrease in LV EDV when using categories of mild, moderate, and severe, as determined by the ASE integrated echocardiographic method (mild, −45 ml; moderate, −59 ml; severe, −73 ml; $p = 0.8$). Figure 4 shows a strong correlation between regurgitant volume, as determined by MRI, and the change in LV EDV after surgery ($r = 0.85$; $p < 0.0001$). Figure 4 also shows no correlation between regurgitant volume, as quantified by echocardiography, and the change in LV EDV following surgery ($r = 0.32$; $p = 0.1$).

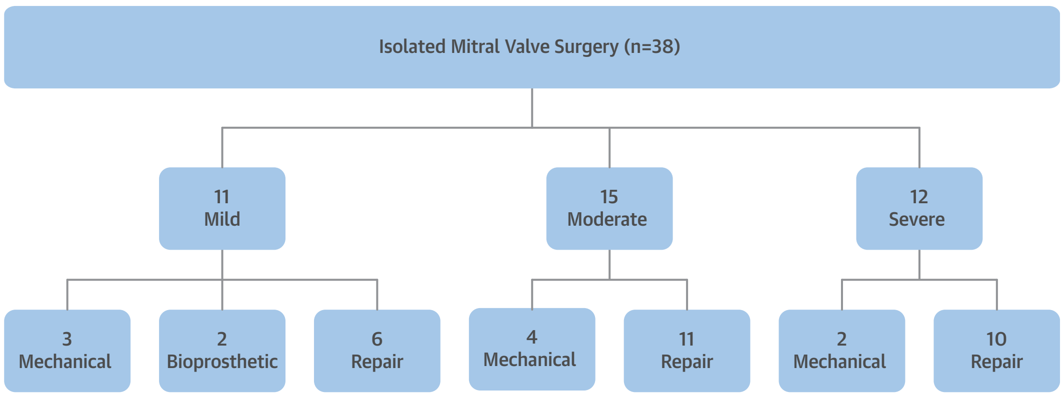
We also looked at the correlation between post-surgical LV remodeling and preoperative left atrial volume and LV EDV. For echocardiography, the relationship was significant for LV EDV ($r = 0.59$; $p = 0.0002$), but not for left atrial volume ($r = 0.23$; $p = 0.4$). For MRI, the correlation was stronger and

TABLE 4 ACC/AHA Class Indications, MRI Regurgitant Severity, the Presence of Symptoms, and Echocardiographic LV Dimensions in 38 Patients Referred for Isolated Mitral Valve Surgery

Patient #	ACC/AHA Class	MRI MR Severity	Dyspnea	Echocardiography LV EDD, cm	Echocardiography LV ESD, cm	Echocardiography LV EF, %
1	I	Moderate	No	4.3	2.3	38
2	I	Severe	No	5.5	3.2	54
3	I	Mild	Yes	4.9	3.7	42
4	I	Moderate	Yes	3.9	2.5	78
5	I	Severe	No	6.4	4.9	31
6	I	Mild	No	5.3	4.2	53
7	I	Mild	No	5.5	3.9	53
8	I	Moderate	No	5.1	3.5	53
9	I	Mild	No	4.7	3.2	59
10	IIa	Mild	No	4.3	3.2	66
11	I	Moderate	Yes	6.1	4.0	60
12	IIa	Mild	No	4.5	2.6	67
13	I	Moderate	No	6.0	4.4	56
14	I	Moderate	No	5.1	4.2	60
15	I	Moderate	Yes	5.0	3.2	70
16	I	Severe	Yes	6.0	3.7	42
17	I	Moderate	No	6.3	4.3	40
18	I	Severe	Yes	6.8	4.5	59
19	I	Moderate	Yes	5.3	4.1	72
20	I	Moderate	Yes	5.2	2.8	73
21	IIa	Moderate	No	4.5	2.8	69
22	I	Severe	Yes	5.6	3.4	51
23	I	Severe	No	6.1	4.1	56
24	I	Moderate	No	6.0	4.1	63
25	I	Moderate	Yes	5.0	2.8	68
26	I	Severe	No	5.8	4.2	62
27	I	Mild	Yes	4.7	2.7	71
28	I	Moderate	Yes	5.5	3.7	58
29	I	Mild	No	6.2	3.4	57
30	I	Mild	Yes	5.8	3.6	63
31	I	Severe	Yes	7.3	5.2	61
32	I	Severe	No	6.7	4.3	64
33	I	Mild	Yes	5.0	3.6	60
34	I	Mild	No	5.2	4.1	53
35	I	Severe	No	5.7	3.7	60
36	I	Severe	Yes	6.1	4.3	61
37	I	Moderate	No	5.2	2.7	73
38	I	Severe	No	5.3	3.9	58

ACC/AHA = American College of Cardiology/American Heart Association; EDD = end-diastolic dimension; EF = ejection fraction; ESD = end systolic dimension; LV = left ventricular; other abbreviations as in Tables 2 and 3.

FIGURE 3 Clinical Outcomes After Isolated Mitral Valve Surgery



In our surgical cohort, 26 of 38 patients who underwent isolated mitral valve surgery had nonsevere mitral regurgitation on the basis of magnetic resonance imaging. Some of these patients had mitral valve replacement.

more significant: LV end-diastolic volume ($r = 0.84$; $p < 0.0001$) and left atrial volume ($r = 0.78$; $p < 0.0001$).

DISCUSSION

In our study, there was only a modest agreement between echocardiography and MRI in the assessment of MR severity, whether one uses a categorical or quantitative approach. Of 58 patients with a diagnosis of severe MR by echocardiography, 45 (78%) had nonsevere MR by MRI. Discordance was sometimes substantial, with 20 patients (34%) with a diagnosis of severe MR on echocardiography having only mild MR according to MRI.

Although there are a number of possible explanations for this disparity, it is unlikely that the poor correlation between MRI and echocardiography is due to poor-quality images. The echocardiographic and MRI studies were rated good to excellent by experienced readers. Experienced echocardiographers considered the echocardiograms adequate for the analysis of MR severity on the basis of a comprehensive approach that integrates several well-recognized and distinct criteria, including the size of the color flow jet, the width of the vena contracta, and the PISA-derived regurgitant volume and regurgitant orifice area.

It is unlikely the poor correlation between MRI and echocardiography is due to inaccuracy of the MRI data. Previous studies using identical methods yielded a tight coupling ($r^2 = 0.8$) between MR regurgitant volume and LV EDV (12). This coupling suggests that MRI accurately determines LV EDV, LV end-systolic volume, as well as forward and regurgitant flows. Furthermore, in the current study, the quantitative determination of MR severity before surgery showed a good correlation ($r = 0.85$) with LV negative remodeling after surgery (Figure 4). Finally, the curve fit in Figure 4 passes near the origin, suggesting that there is little significant systematic error in the MRI data.

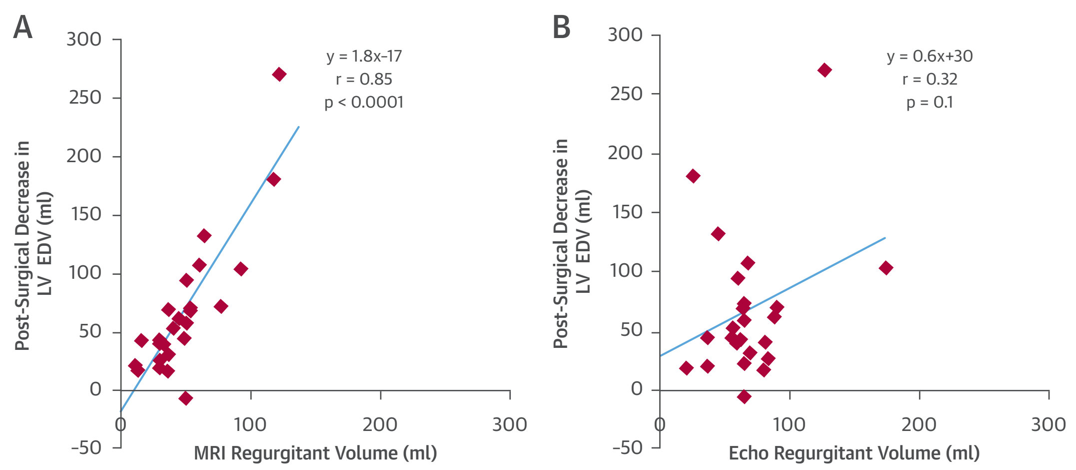
It is also unlikely that the difference in MR severity is due to the nonsimultaneous acquisition of the 2 imaging tests. Dynamic changes in MR severity are generally ascribed to changes in loading conditions, LV systolic performance, and/or the presence of transient ischemia. That there was no significant difference in blood pressure between the MRI and echocardiographic studies suggests that differences

TABLE 5 Comparison of Pre-Surgical and Post-Surgical Left and Right Ventricular Indexes, as Quantified by Magnetic Resonance Imaging

	Pre-Surgery	Post-Surgery	p Value
Left ventricle			
End-diastolic volume, ml	226 ± 74	158 ± 41	<0.0001
End-systolic volume, ml	102 ± 40	83 ± 28	<0.0001
Stroke volume, ml	124 ± 44	75 ± 23	<0.0001
Ejection fraction, %	55 ± 9	48 ± 9	<0.0001
End-diastolic dimension, mm	6.2 ± 0.8	5.3 ± 0.5	<0.0001
End-systolic dimension, mm	4.4 ± 0.7	4.0 ± 0.7	0.05
Right ventricle			
End-diastolic volume, ml	143 ± 56	139 ± 44	0.4
End-systolic volume, ml	68 ± 30	71 ± 30	0.9
Stroke volume, ml	72 ± 30	67 ± 19	0.07
Ejection fraction, %	53 ± 8	49 ± 8	0.05

Values are mean ± SD.

FIGURE 4 **Post-Surgical Decrease in LV EDV Versus Pre-Surgical Regurgitant Volume**



(A) MRI. **(B)** Echocardiography. LV EDV = left ventricular end-diastolic volume; other abbreviations as in Figures 1 and 2.

in afterload are not an important consideration. Regarding the possibility of transient ischemia, in our subpopulation of surgical patients, the correlation between echocardiography and MRI was equally poor ($r = 0.4$; $p = 0.01$). Yet all of these patients had preoperative cardiac catheterization, and none had obstructive coronary artery disease. Finally, the strong correlation between regurgitant volume, as determined from pre-surgical MRI, and the degree of post-surgical LV remodeling, which was assessed months later, suggests that uncorrelated transient changes in the severity of MR of any cause are not an important factor in the majority of patients.

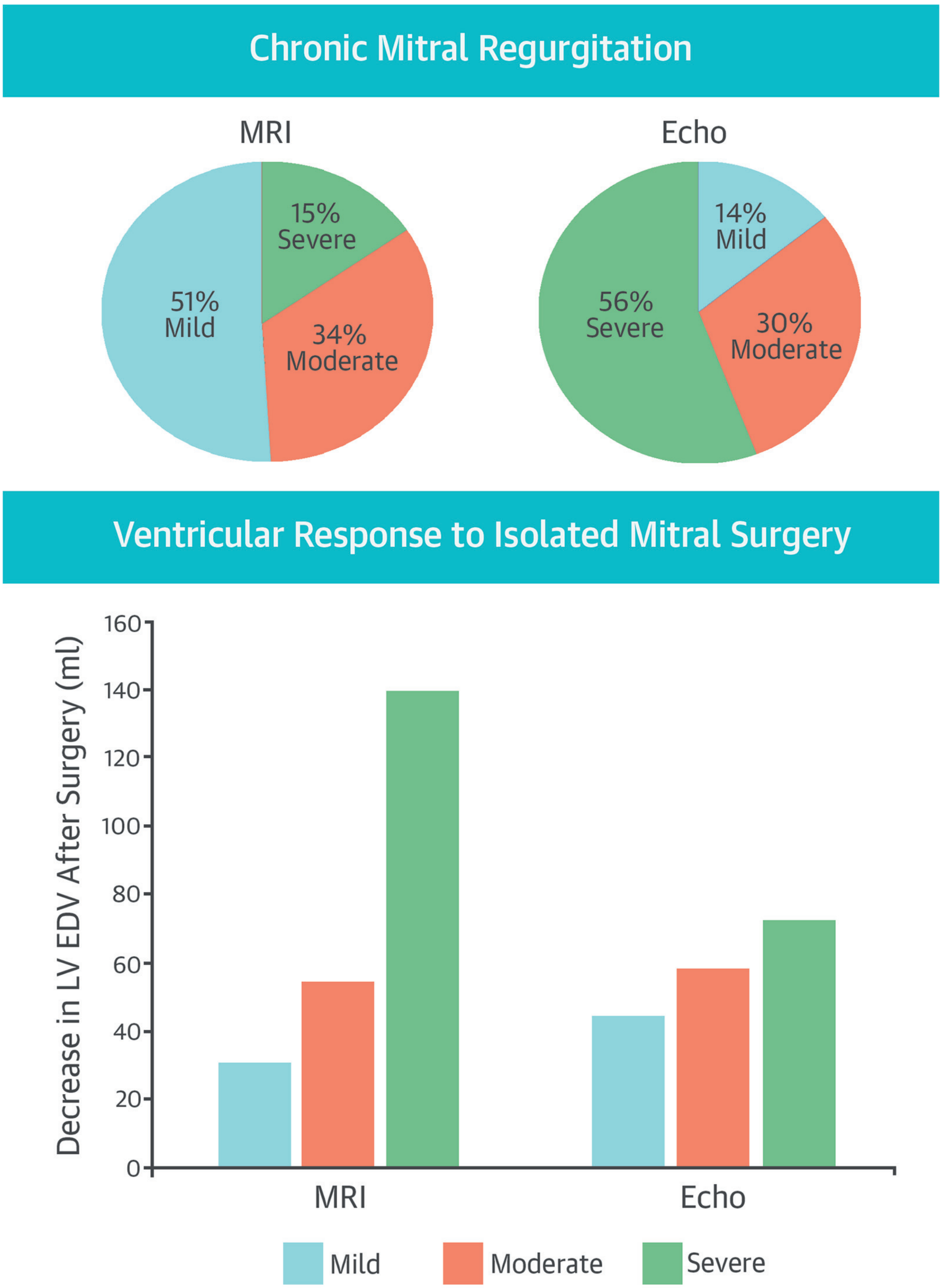
This study is not the first to report discordance between MRI and echocardiography when assessing the severity of MR. Gelfand et al. (23) similarly concluded that MRI consistently shows MR to be less severe than echocardiography does. Assuming echocardiography as the standard of reference, the investigators proposed altering thresholds for grading MR severity by MRI to ensure concordance between the 2 modalities (23). However, they had no additional data to determine which modality was more accurate. In comparing the degree of postoperative negative remodeling with preoperative regurgitant volume, our study provides an independent reference. Subsequent studies by other investigators (11,24,25) have also shown varying degrees of discordance between MRI and echocardiography, but without a reference standard, no conclusion could be drawn as to which test was more accurate.

In the subset of patients who had surgery and underwent postoperative MRI, there was good correlation between LV remodeling and MR severity as assessed by MRI, but not when assessed by echocardiography, either categorically or quantitatively, using PISA. This suggests that the MRI determination of mitral regurgitant volume is more accurate (**Central Illustration**). Our hypothesis that post-surgical LV remodeling is related solely to the severity of MR before surgery is an oversimplification but is a justified approximation on the basis of our previously published results, which show tight coupling between regurgitant volume and LV EDV in patients with chronic, isolated MR (12). Others have also used post-surgical LV remodeling as an outcome marker after MV surgery (26). Other variables, such as changes in cardiac rhythm, medications, and athletic conditioning, could potentially affect LV volumes. However, to the extent that these and other variables play a role in decoupling the pre-surgical MR regurgitant volume with post-surgically observed LV remodeling, one would expect the observed strong correlation to be worse, not better.

Many echocardiographic methods for assessing MR severity rely on analysis of a single systolic frame when the regurgitation is most severe. However, as we previously demonstrated, MR rate often varies substantially during systole (27). The ratio of the peak regurgitant rate to the mean regurgitant rate often varies by a factor of 2 to 3. As a result, there is substantial overlap in the peak regurgitant rate when comparing patients with mild, moderate, and severe MR (27). The ASE has acknowledged the importance of considering the temporal variation of

JACC VOL. 65, NO. 11, 2015
MARCH 24, 2015:1078–88

CENTRAL ILLUSTRATION **Discordance Between MRI and Echo for Assessing Chronic Mitral Regurgitation**



Uretsky, S. et al. J Am Coll Cardiol. 2015; 65(11):1078–88.

MRI and Echo are substantially discordant when grading the severity of mitral regurgitation in 103 patients **(top)**. MRI is better than Echo for predicting the ventricular response to surgery, suggesting that it is more accurate than Echo for assessing the severity of mitral regurgitation **(bottom)**. Echo = echocardiography; LV EDV = left ventricular end-diastolic volume; MRI = magnetic resonance imaging.

the systolic jet when determining MR severity (8). However, there is no agreed-on method for adjusting MR regurgitant severity according to the temporal variability of the regurgitation. The difficulty of assessing nonholosystolic jets is considered most pronounced in patients with degenerative MR. However, exclusion of patients with degenerative MR did not improve the agreement between MRI and echocardiography ($r = 0.3$; $p = 0.03$), nor did the exclusion of patients with eccentric MR jets.

The possibility of overestimation of MR severity has important clinical implications. Current American College of Cardiology/American Heart Association guidelines advise surgery in patients with chronic severe MR when there is LV dysfunction or an enlarged end-systolic dimension, even in the absence of symptoms. Patients with nonsevere MR who are incorrectly diagnosed as having severe MR could undergo inappropriate surgery (1). In our study, all of the patients undergoing isolated MV surgery had a Class I or IIa indication for surgery on the basis of echocardiography. However, on the basis of MRI, only 32% of surgical patients had a Class I or IIa indication. Furthermore, 29% of patients who had isolated MV surgery had only mild MR.

Agreement between echocardiography and MRI is good when diagnosing mild MR. In our study, all patients receiving a diagnosis of mild MR by echocardiography were found to have mild MR by MRI. Discordance between echocardiography and MRI was limited to patients who echocardiographically had moderate or severe regurgitation. An inherent problem with the American Heart Association/American College of Cardiology guidelines is the assumption that MR is accurately characterized as severe (1). If that diagnosis has been made incorrectly, it is possible that a patient could undergo inappropriate surgery (1).

STUDY LIMITATIONS. This was a small multicenter trial. A larger trial is needed to determine the extent to which these results can be generalized. The limitation of nonsimultaneous acquisition of MRI and echocardiography data has been noted. Quantification of regurgitant volume by echocardiography was based on the PISA method, which has well-recognized limitations. The MRI method for quantifying MR severity is most analogous to the quantitative Doppler method of assessing MR severity with echocardiography, a method that was not used in this study. Although quantitative Doppler assessment of MR severity is technically challenging and not routinely performed in clinical practice, a direct comparison between MRI and echocardiography based on the same physical principles would be of interest. Finally, this study does not include an outcomes analysis to assess changes in the functional or symptomatic status of patients after MV surgery.

CONCLUSIONS

MRI and echocardiography have only a modest correlation in the assessment of MR severity. The strong correlation between MR severity and post-surgical LV remodeling suggests that MRI is more accurate. Should the results of this study be confirmed, there are important clinical implications, notably related to the timing or indications for surgery.

ACKNOWLEDGMENTS The authors are grateful to Lissa Sugeng, MD, and Tawai Ngernsritrakul, MD, for assisting with some of the blinded echocardiographic interpretations.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: Cardiac magnetic resonance imaging may be more accurate than echocardiography for assessing the severity of mitral regurgitation.

TRANSLATIONAL OUTLOOK: Future studies should assess the symptomatic and functional outcomes of patients selected for valve surgery when cardiac magnetic resonance imaging is used to assess the severity of mitral regurgitation.

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KEY WORDS mitral valve insufficiency, mitral valve surgery, observer variation, quantification, remodeling, reproducibility of results