Quantification of Mitral Regurgitation by the Proximal Flow Convergence Method—Comparison of Transthoracic and Transesophageal Echocardiography

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Summary

Background: No data exist to indicate whether transthoracic (TTE) and transesophageal echocardiography (TEE) are of comparable value for the detection and quantification of mitral regurgitation using the proximal flow convergence method.

Hypothesis: The study was performed to compare the value of TTE and TEE for the detection and quantification of mitral regurgitation using this method.

Methods: The study included 57 patients with and 11 patients without mitral regurgitation. In all patients, the proximal flow convergence region was imaged by transthoracic and transesophageal color Doppler echocardiography, and proximal isovelocity surface area radii were determined. In 19 patients, monoplane TEE and in 49 patients multiplane TEE was performed. Thirty-one patients with mitral regurgitation underwent cardiac catheterization.

Results: Both methods had a comparable sensitivity for the detection of mitral regurgitation. Proximal isovelocity surface area radii derived from TTE and TEE agreed moderately (mean difference -0.5 ± 1.3 mm). TTE and TEE correlated significantly with the angiographic grade (rank correlation coefficients 0.83 and 0.81), and both differentiated mild to moderate from severe mitral regurgitation with an accuracy of 90%. Regurgitant volumes derived from both echocardiographic techniques and cardiac catheterization correlated moderately (correlation coefficients between 0.67 and 0.81).

Conclusions: TTE and TEE were of comparable value for the detection and quantification of mitral regurgitation using the proximal flow convergence method.

Key words: mitral regurgitation, transthoracic echocardiography, transesophageal echocardiography, color Doppler imaging, proximal flow convergence region

Introduction

Color Doppler echocardiography is routinely used for non-invasive quantification of mitral regurgitation.^{1,2} In addition to measuring the spatial distribution of the regurgitant jet within the left atrium, color Doppler imaging of the flow convergence region proximal to the regurgitant orifice has been applied for quantification of mitral regurgitation using transthoracic (TTE) or transesophageal echocardiography (TEE).^{3–10} Since TEE is a semi-invasive approach for diagnosis and quantification of mitral regurgitation, a noninvasive method would be preferable in clinical routine. Thus far, no data exist to indicate whether TTE may be comparable with TEE for the detection and quantification of mitral regurgitation using the proximal flow convergence method, and the purpose of this study was to make such a comparison.

Methods

Patients

In 68 consecutive patients, age 55 ± 15 years, range 20–79 years (38 men, 30 women), TTE and TEE were performed during the same examination. Of these, 51 patients had sinus rhythm, 17 had atrial fibrillation, and 57 had mitral regurgitation defined by a typical color-coded regurgitant jet or by a systolic continuous wave (CW) Doppler signal during TTE and/or TEE. Eleven patients had no signs of mitral regurgitation (Fig. 1). All patients gave informed and written consent concerning echocardiography and cardiac catheterization. The study was in accordance with the Declaration of Helsinki.

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FIG. 1 Study profile. MR = mitral regurgitation, TTE = transthoracic echocardiography, TEE = transesophageal echocardiography.

All patients underwent TEE due to clinical indications: evaluation for source of an embolus in 31; for mitral valve morphology in 16; for endocarditis in 9; for aortic valve disease or aortic dissection in 10; and evaluation for an atrial septal defect in 2 patients. In 31 patients with mitral regurgitation, cardiac catheterization was performed within 3 days before or after echocardiography.

Forty-five patients suffered from an organic mitral regurgitation: valve sclerosis with or without annular calcification ($n = 26$), a prolapse of the posterior and/or anterior valve leaflet ($n = 12$), endocarditis (without prolapse) ($n = 3$), no clearly definable valvular lesion ($n = 4$). In these last four patients without signs of functional regurgitation, a minor lesion of the mitral valve was assumed, which was not detected by echocardiography.¹¹ Eight of the 45 patients had an associated mitral stenosis. In 12 patients the cause of mitral regurgitation was functional. Concomitant cardiac diseases were coronary artery disease in four, aortic valve disease in eight, dilated cardiomyopathy in four, and atrial septal defect in two patients. In the 31 patients who underwent angiography, 23 had organic and 8 functional mitral regurgitation.

Doppler Examination

Transthoracic and transesophageal echocardiography were performed with a commercially available system (Toshiba SSH 160A or SSH 140A, Toshiba Corp., Tokyo, Japan) operating with a 3.75 MHz transthoracic transducer and 5 MHz transesophageal probes. The 68 patients were investigated using a monoplanar ($n = 19$) or a multiplanar ($n = 49$) transesophageal probe (Fig. 1).

Color Doppler imaging was performed using a 30° sector angle. Wall filter was adjusted at 600 Hz. Optimal gain setting was defined as the maximal gain level possible without artificial color outside of flow areas. A pulse repetition frequency of 3/3.5 kHz was used. A scanning rate of 13/14 frames/s was obtained during TTE/TEE. Continuous wave Doppler spectra of mitral regurgitation were obtained. Measurements were performed at least five-fold using the cineloop-mode and recordings

from VHS videotapes. An electrocardiogram was recorded simultaneously.

Doppler Measurements

The flow convergence region proximal to the mitral valve was visualized by color Doppler in the apical 4/2-chamber view during TTE and in a monoplane view or continuous multiplane views during TEE by the same experienced investigator. The proximal isovelocity surface area in the flow convergence region was imaged for the blood flow velocity of 29/27 cm/s during TTE/TEE by the corresponding first aliasing border, obtained by baseline shifting⁴ (Fig. 2). The proximal isovelocity surface area radius was defined as the maximum distance (mm) between the aliasing border and the regurgitant orifice during systole (frame-by-frame analysis) measured parallel to the direction of the Doppler beam. During multiplane TEE, the proximal isovelocity surface area radii were measured in the imaging plane between 0° and 180° that showed the maximally extended flow convergence region.

For comparison of TTE and TEE, the maximally extended flow convergence regions derived from both techniques were measured.

Regurgitant volume (RV) (ml) was calculated in 20 patients (in whom regurgitant volume was also calculated during cardiac catheterization) as $RV = 2\pi \times r^2 \times v_a \times VTI/v_p$, where r is the radius of the proximal isovelocity surface area for the flow velocity v_a , and VTI/v_p is the quotient of the time velocity integral and the peak regurgitant velocity obtained by CW Doppler.

FIG. 2 Color flow Doppler images of the proximal flow convergence region in the left ventricle. Example of a transthoracic examination (left panel) with the proximal isovelocity surface area for a flow velocity of 29 cm/s defined by the color reversal from blue to red/yellow. TEE (right panel) with the proximal isovelocity surface area for a flow velocity of 27 cm/s. Notice that the color reversal was from red to blue/green since the flow was directed toward the transducer. Both images are from the same patient with a grade III mitral regurgitation. LV = left ventricle, LA = left atrium. Arrows point at the mitral valve leaflets.

An eccentric proximal flow convergence region was defined as one that was constrained by an adjacent ventricular wall in at least one transthoracic or transesophageal plane.⁸ Otherwise, the proximal flow convergence region was classified as central. In the case of an eccentric proximal flow convergence region, regurgitant volume was corrected by (1) $RV \times \alpha/180$ (assuming a one-dimensional flow constraint) and (2) $RV \times [1 - \cos(\alpha/2)]$ (assuming a funnel-like constraint). α was determined as the minimum angle between the two sides of the proximal flow convergence region derived from the two transthoracic and from the transesophageal view(s). Determination of α was described in detail by Pu *et al.*⁸

To determine intraobserver variability, the proximal isovelocity surface area radii from TTE and TEE were reexamined by the same investigator in 15 randomly selected study patients from video tapes more than 6 months after the first echocardiographic examination. Data from TTE and TEE were analyzed independently on two different occasions. To calculate interobserver variability, a second independent observer determined the proximal isovelocity surface area radii from video tapes.

Cardiac Catheterization

Cardiac catheterization was performed for clinical reasons in 31 of the 57 patients with mitral regurgitation. Biplane left ventricular angiograms were obtained in a 30° right anterior oblique and a 60° left anterior oblique view with injection of 35 ml Solustrast® at 18 ml/s. The severity of mitral regurgitation was graded according to Sellers *et al.* (grade I–grade IV).¹² The angiograms were interpreted by two observers blinded to the results of the echocardiographic examination. In six patients, in whom grading of the two observers differed by one grade, grading was determined by a third independent observer. There was no difference of more than one grade between the initial two observers.

Regurgitant volume was determined as the difference between left ventricular stroke volume according to angiography and according to Fick's principle in 20 of the 31 patients who underwent cardiac catheterization. In 10 controls without valvular or congenital heart disease, the angiographically determined left ventricular stroke volume (67.1 ± 13 ml) correlated closely with the stroke volume according to Fick's principle (62.1 ± 12.4 ml) ($y = 0.85 \times + 5.25$ ml, $r = 0.89$, standard error of estimate [SEE] = 6.2 ml, $p < 0.001$).

Statistical Analysis

Values are given as mean $\pm$ standard deviation. Paired data were compared using the Wilcoxon signed rank test and unpaired data the Kruskal-Wallis test. The correlation between angiographic grading and color Doppler measurements was calculated by the Spearman's rank correlation method. Continuously distributed data were correlated by linear regression analysis. Bland-Altman plots were constructed for the comparison of proximal isovelocity surface area radii obtained by the different echocardiographic techniques.¹³ The chi-square

test (contingency table) was used to compare the sensitivity of TTE and TEE. Intra- and interobserver variability was obtained by calculating coefficients of variation. A p -value of < 0.05 was considered significant.

Results

Hemodynamic Data

Heart rate during TTE was 84 ± 13 min⁻¹, 87 ± 17 min⁻¹ during TEE, and 87 ± 16 min⁻¹ during cardiac catheterization ($p < 0.05$ by Kruskal-Wallis test). Neither systolic blood pressure (128 ± 24 vs. 126 ± 25 mmHg) nor diastolic blood pressure (75 ± 5 vs. 74 ± 4 mmHg) differed significantly between echocardiography and cardiac catheterization.

Comparison between Transthoracic and Transesophageal Echocardiography

In the 11 patients without mitral regurgitation, no flow convergence region was present during TTE and TEE. Among the 57 patients with mitral regurgitation, a proximal flow convergence region could be imaged in 45 (79%) by TTE versus 50 (88%) by TEE ($p = \text{NS}$). Three of the seven patients with mitral regurgitation, in whom a flow convergence region could not be detected by TEE, had a sclerotic mitral valve. The proximal isovelocity surface area radius in the 57 patients with mitral regurgitation was 5.4 ± 5.2 mm using TTE versus 6.2 ± 5.2 mm using TEE. The correlation between transthoracic and transesophageal measurements was $y = 0.94 \times + 1.15$ ($r = 0.95$, SEE = 1.6 mm, $p < 0.001$). The mean difference for the comparison of proximal isovelocity surface area radii between TTE and TEE was -0.5 ± 1.3 mm. The Bland-Altman limits were -3.1 to 2.1 mm. The Bland-Altman range was 5.2 mm (Fig. 3). The difference between transthoracic and transesophageal values was ≤ 1 mm in 61% of the measurements.

In the patients with organic mitral regurgitation, the correlation between transthoracic and transesophageal measurements yielded a correlation coefficient $r = 0.96$ (SEE = 1.4 mm, $p < 0.001$). The mean difference between the proximal isovelocity surface area radii obtained by TTE and TEE was -0.5 ± 1.4 mm. Bland-Altman limits were -3.3 to 2.3 mm and Bland-Altman range was 5.6 mm (Fig. 3). In patients with mitral valve prolapse, correlation coefficient r was 0.96 (SEE = 1.6 mm, $p < 0.001$), mean difference was -0.1 ± 1.5 mm, Bland-Altman limits were -3.1 to 2.9 mm, and Bland-Altman range was 6 mm. In patients with functional mitral regurgitation, correlation coefficient r was 0.93 (SEE = 1.1 mm, $p < 0.001$), mean difference was -0.7 ± 1.2 mm, Bland-Altman limits were -3.1 to 1.7 mm, and Bland-Altman range was 4.8 mm.

Catheterization Results

The severity of mitral regurgitation was classified as grade I in 12, grade II in 7, grade III in 8, and grade IV in 4 patients.

FIG. 3 Bland-Altman plots for the relationship between proximal isovelocity surface area radii (PISA radii) derived from TTE and PISA radii derived from TEE in all patients with mitral regurgitation, in whom a flow convergence region could be imaged during TTE and TEE (A). Comparison of the proximal isovelocity surface area radii derived from TTE and TEE in the patients with organic mitral regurgitation (B). Mean = mean difference, SD = standard deviation. Other abbreviations as in Figure 1.

Comparison between Echocardiography and Cardiac Catheterization

Among the 31 patients with angiographically documented mitral regurgitation, a proximal flow convergence region could not be imaged in 5 patients (grade I regurgitation in all cases) by TTE, but was imaged in all patients by TEE ($p < 0.05$). The proximal isovelocity surface area radii measured by TTE and TEE (7.0 ± 5.4 and 7.7 ± 5.2 mm, respectively) correlated significantly ($r = 0.96$, $SEE = 1.4$ mm, $p < 0.001$). The mean difference in the comparison of proximal isovelocity surface area radii between TTE and TEE was -0.4 ± 1.3 mm. The Bland-Altman limits were -3.0 to 2.2 mm and the Bland-Altman range was 5.2 mm.

The proximal isovelocity surface area radii obtained by TTE and TEE for the different angiographic grades of mitral

regurgitation are given in Table I. The rank correlation coefficient between angiography and the proximal isovelocity surface area radii obtained from TTE/TEE was 0.83 ($p < 0.001$)/ 0.81 ($p < 0.001$). A correct differentiation between mild to moderate (grade I/II) and severe (grade III/IV) mitral regurgitation was achieved in 28 of 31 patients (accuracy 90%) by TTE and TEE for a cut-off value of the proximal isovelocity surface area radius of 9.0 mm (Fig. 4).

The regurgitant volume was 44.9 ± 30.4 ml during cardiac catheterization. The uncorrected regurgitant volume derived from TTE and TEE was 48.2 ± 52.3 and 52.1 ± 57.9 ml, respectively (Table I). In 5 of the 20 patients, the flow convergence region was eccentric and an angle correction was applied. The regurgitant volume $\times \alpha/180$ was $40.7 \pm 39.4/42 \pm 37.3$ ml and the regurgitant volume $\times [1 - \cos(\alpha/2)]$ was $36.9 \pm 34/37.1 \pm 29.9$ ml at TTE/TEE, respectively. Regurgitant vol-

TABLE I Values of the PISA radius and the regurgitant volume for the angiographic grades I–IV of mitral regurgitation

	Angiographic Grade				p Value ^a
	I	II	III	IV	
PISA radius _{TTE}	2.8 ± 3.7	5.4 ± 1.5	10.0 ± 3.2	15.9 ± 2.8	< 0.01
PISA radius _{TEE}	4.0 ± 3.4	6.2 ± 2.2	10.6 ± 2.9	16.2 ± 3.9	< 0.01
RV _{TTE}	12.4 ± 26.6	17.7 ± 11.5	53.1 ± 33.7	125.2 ± 47.7	< 0.01
RV($\alpha/180$) _{TTE}	12.4 ± 26.6	16.9 ± 10.6	45.3 ± 23.3	102.8 ± 19.8	< 0.01
RV($1 - \cos(\alpha/2)$) _{TTE}	12.4 ± 26.6	16.7 ± 10.4	41.3 ± 20.6	91.0 ± 7.2	< 0.01
RV _{TEE}	14.4 ± 23.9	19.6 ± 14.1	58.1 ± 33.7	130.8 ± 74.0	< 0.01
RV($\alpha/180$) _{TEE}	14.4 ± 23.9	19.0 ± 13.4	49.1 ± 20.3	96.3 ± 29.2	< 0.01
RV($1 - \cos(\alpha/2)$) _{TEE}	14.4 ± 23.9	18.6 ± 13.1	44.9 ± 17.5	79.8 ± 13.4	< 0.01
RV _{cc}	12.5 ± 9.9	36.0 ± 12.9	46.0 ± 19.1	86.3 ± 31.2	< 0.01

Values are mean $\pm$ standard deviation.

^a p Value = significance of Kruskal-Wallis test.

Abbreviations: TTE = transthoracic echocardiography; TEE = transesophageal echocardiography; PISA radius_{TTE} = proximal isovelocity surface area radius derived from TTE (mm), PISA radius_{TEE} = proximal isovelocity surface area radius derived from TEE (mm); RV_{TTE}, RV($\alpha/180$)_{TTE}, RV($1 - \cos(\alpha/2)$)_{TTE} = uncorrected and corrected regurgitation volumes derived from TTE (ml); RV_{TEE}, RV($\alpha/180$)_{TEE}, RV($1 - \cos(\alpha/2)$)_{TEE} = uncorrected and corrected regurgitation volumes derived from TEE (ml); RV_{cc} = regurgitation volume derived from cardiac catheterization (ml).

FIG. 4 Comparison of the proximal isovelocity surface area radii (PISA radii) derived from TTE (A) and from TEE (B) with the angiographic grade of mitral regurgitation. Solid line, cut-off value at 9 mm for the differentiation of grade I–II from grade III–IV mitral regurgitation. r_{Sp} = Spearman's rank correlation coefficient.

FIG. 5 Linear regression analysis between the regurgitant volumes (RV) of mitral regurgitation derived from cardiac catheterization (catheter) and that derived from TTE. (A) Uncorrected echocardiographic regurgitant volumes. (B) Corrected echocardiographic regurgitant volumes ($RV \times (\alpha/180)$). SEE = standard error of estimate.

umes derived from echocardiography and cardiac catheterization correlated moderately (Fig. 5). The correlation coefficients are given in Table II.

Variability of Echocardiographic Measurements

Intraobserver variability: Coefficients of variation for the proximal isovelocity surface area radius derived from TTE/TEE were 8.3%/7.9%, respectively.

Interobserver variability: Coefficients of variation for the proximal isovelocity surface area radius derived from TTE/TEE were 8.5%/11.0%, respectively.

Discussion

Present Study

In this study, TTE and TEE had a comparable sensitivity for the detection of mitral regurgitation using the proximal flow convergence method. The high imaging quality of TEE was in part offset by attenuation of the color Doppler signal behind a morphologically altered mitral valve. The specificity of TTE and TEE using the flow convergence method for detection of mitral regurgitation was high.

Data obtained by TTE and TEE correlated significantly. However, Bland-Altman analysis revealed only a moderate agreement between TTE and TEE. This agreement was independent of the etiology of mitral regurgitation.

Both techniques showed a close correlation to the angiographic grade of mitral regurgitation. Transthoracic echocardiography and TEE had a similar intra- and interobserver variability. The regurgitant volumes derived from TTE and TEE

TABLE II Correlation coefficients between regurgitation volumes derived from cardiac catheterization and from echocardiography

	RV _{cc} (ml)	p Value
RV _{TTE}	0.79 (33.1)	<0.001
RV($\alpha/180$) _{TTE}	0.81 (23.5)	<0.001
RV(1-cos($\alpha/2$)) _{TTE}	0.80 (20.6)	<0.001
RV _{TEE}	0.67 (44.9)	<0.01
RV($\alpha/180$) _{TEE}	0.72 (26.9)	<0.001
RV(1-cos($\alpha/2$)) _{TEE}	0.70 (21.9)	<0.001

First number, correlation coefficient. Number in parentheses, standard error of estimation. p Value, significance of correlation.

Abbreviations as in Table I.

overestimated the invasively determined regurgitation volume to a similar extent. This overestimation could be avoided by the use of correction algorithms. However, even the corrected regurgitant volumes obtained by TTE and TEE correlated only moderately with the values determined invasively.

Comparison between Transthoracic and Transesophageal Echocardiography

Studies using TTE reported a good sensitivity of the proximal flow convergence method for the detection of mitral regurgitation.⁴⁻⁶ All patients in whom the diagnosis of mitral regurgitation was missed had only a mild or angiographically grade I regurgitation. This was also the case in our patients for TTE and TEE. These false negative results of both techniques are unlikely to be of any clinical relevance. Kolev *et al.*, using TEE, could image a flow convergence region even in all patients with grade I mitral regurgitation.¹⁰ However, the authors used lower aliasing velocities (20–25 cm/s) than the ones applied in our study.

The only moderate agreement between transthoracic and transesophageal measurements in our study may be in part due to the variability of echocardiographic techniques. However, TEE revealed greater proximal isovelocity surface area radii than TTE. An exact mechanism for this difference cannot be inferred from our data. Smith *et al.* observed greater jet areas in the left atrium by TEE than by TTE in patients with mitral regurgitation.¹⁴ They discussed several reasons such as different loading conditions during TTE and TEE, different color flow machine settings, and technical aspects, that could explain their results.¹⁴ A direct comparison of proximal isovelocity surface area radii obtained by TEE and by TTE was not reported by other authors.

Comparison between Echocardiography and Cardiac Catheterization

The proximal isovelocity surface area radii correlated closely with the angiographic grade of mitral regurgitation and allowed a correct differentiation of grade I–II from III–IV mitral regurgitation, which is crucial for clinical management,¹⁵ in 90% of our patients irrespective of the echocardiographic technique used. Former studies using either TTE or TEE demonstrated comparable results.^{4, 7, 9, 10, 16} Neither TTE nor TEE was able to differentiate between grades I and II or between grades III and IV mitral regurgitation because of a broad overlap of the measurements. This also agrees with data from the studies mentioned above.^{4, 9, 10, 16} Methodological limitations of the flow convergence method as well as of angiography, the reference method in our study, probably contributed to these results.^{17, 18}

The flow convergence method allows calculation of regurgitant volumes in mitral regurgitation.^{3, 5} However, previously published studies using TTE or TEE demonstrated an overestimation of the regurgitant volume by the proximal flow convergence method.^{4, 8, 9, 17} This corroborates our findings show-

ing greater regurgitant volumes obtained by TTE and TEE than by cardiac catheterization. Since the invasively determined value itself probably overestimated the true regurgitant volume,¹⁹ there may be a considerable overestimation of the true regurgitant volume by the flow convergence method.

To avoid this overestimation, a geometric correction for the flow convergence method was proposed by others to compensate for the nonplanar surroundings of the regurgitant orifice in mitral regurgitation leading to a proximal flow constraint.^{8, 20} In four of the five patients, in whom a geometric correction had to be applied in our study, a prolapse of the mitral valve with a grade III or IV mitral regurgitation was present. It can be inferred from previously published data that the flow convergence method overestimated the regurgitant volume, especially in patients with mitral valve prolapse and severe regurgitation.^{8, 17} As expected, the correction algorithm assuming a funnel-like geometry of the surroundings of the regurgitant orifice led to a more pronounced correction than the algorithm assuming a one-dimensional flow constraint.⁸

Although overestimation of the regurgitant volume could be avoided by the correction algorithms, corrected regurgitant volumes correlated only moderately with the values determined invasively. The correction algorithms applied are likely to oversimplify the complex geometry of the area around the regurgitant orifice in mitral regurgitation, thus potentially explaining this finding.^{8, 21} In addition, the uncertain location of the regurgitant orifice,^{17, 22} the temporal variation of the regurgitant flow during systole,²³ the noncircular geometry of the regurgitant orifice itself,^{24, 25} and the variable geometry of the flow convergence region independent of a proximal flow constraint^{26, 27} probably affected determination of the regurgitant volume. These factors were not taken into account when regurgitant volumes were calculated in our study.

Study Limitations

Angiographic quantification of mitral regurgitation has several limitations; it depends on subjective interpretation of angiograms with limited accuracy.^{18, 28} To diminish these problems, angiograms were graded by at least two experienced independent investigators in our study. Moreover, methodological limitations of the determination of regurgitant volumes from cardiac catheterization have been mentioned above.¹⁹

The severity of mitral regurgitation might have been altered by different hemodynamic conditions,²⁹ since echocardiographic examination and catheterization were not performed simultaneously. However, hemodynamic parameters measured in our study did not change substantially between echocardiography and catheterization. Furthermore, this study intended to compare the value of different echocardiographic techniques for the quantification of mitral regurgitation. In this regard, problems of the reference method or changing hemodynamic conditions do not necessarily falsify the study conclusions.

Transthoracic echocardiography and TEE were performed on the same occasion by one investigator. Therefore, the results of both techniques might have influenced the investiga-

tor's judgment. However, data from TTE and TEE of 15 patients were reexamined independently from each other and a low intraobserver variability for both echocardiographic techniques was found.

It has to be pointed out that our study did not provide any data to indicate whether TTE and TEE were of comparable value in assessing the anatomy of mitral regurgitant lesions. In this regard, TEE is probably superior to TTE.³⁰

Clinical Implications and Conclusion

The data presented here suggest that TTE and TEE are of comparable sensitivity for the diagnosis of mitral regurgitation using the flow convergence method. In the majority of patients, both TTE and TEE were able to differentiate mild to moderate from severe mitral regurgitation; this is crucial for the clinical management of this valvular dysfunction. Both echocardiographic techniques, however, were of limited value for the determination of regurgitant volumes of mitral regurgitation despite the use of correction algorithms. Thus, the noninvasive technique of TTE should be preferred to the semi-invasive TEE for detection and quantification of mitral regurgitation using the flow convergence method during clinical routine.

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