Comparison of the Diagnostic Power of Transthoracic and Transesophageal Echocardiography to Detect Ruptured Chordae Tendineae

Takako MINAMI,[1] MD, Hiroaki KAWANO,[1] MD, Shiro YAMACHIKA,[2] MD, Akira TSUNETO,[1] MD, Masayuki KANEKO,[3] MD, Yasuko KAWANO,[4] MD, Shigeki MINAMI,[5] MD, Kiyoyuki EISHI,[6] MD, *and* Koji MAEMURA,[1] MD

SUMMARY

Preoperative information concerning the severity and etiology of MR is very important for selecting the most appropriate surgical strategy. Ruptured chordae tendineae (RCT) are one of the most important preoperative findings. We compared the diagnostic power of transesophageal echocardiography (TEE) and transthoracic echocardiography (TTE) to detect RCT in patients with MR. We studied 61 patients with MR (30 men, 31 women; mean age, 61 ± 12 years) who underwent mitral valve repair or replacement. Both TTE and TEE were performed before the operations, and the sensitivity and specificity of TTE and TEE to detect RCT were determined. In addition, other factors that influenced the detection of RCT by these two methods were investigated. At the time of an operation, RCT was confirmed in 39 of 61 cases. Transesophageal echocardiography had a higher sensitivity than TTE (74% versus 44%; $P = 0.006$) to detect RCT, although the specificity was not significantly different. In patients with a body mass index (BMI) > 22 ($P = 0.023$) or MR grade 4 ($P = 0.026$), TEE had a significantly higher diagnostic sensitivity than TTE, although there was no significant difference in patients with BMI < 22 or MR grade ≤ 3. In the lateral and medial segments of the mitral valve, TEE had a significantly higher diagnostic sensitivity to detect RCT than TTE ($P = 0.0012$), although there was no significant difference in the middle segments. There was no significant difference between TTE and TEE with respect to the sensitivity to detect RCT in myxomatous mitral valves. Although the sensitivity of TEE was higher than that of TTE to detect RCT, it was affected by BMI, MR grade, the RCT-presenting segments, and the etiology of MR. (Int Heart J 2012; 53: 225-229)

Key words: Chorda tendineae, Mitral regurgitation, Myxomatous change, Rupture

Mitral valve repair, which is one of the surgical treatments for mitral regurgitation (MR), was developed by Carpentier to overcome the potential complications of mitral valve replacement.[1)] Recently, mitral valve repair has become one of the most common cardiac surgical procedures, accounting for more than half of all mitral valve procedures.[2)] Preoperative information concerning the severity and etiology of MR is very important in order to select the most appropriate surgical strategy. Ruptured chordae tendineae (RCT) are one of the most important preoperative findings. Echocardiography is useful for the detection of RCT in MR. Previous reports have shown that the accuracy of transesophageal echocardiography (TEE) to detect RCT in patients with MR is higher than the accuracy of transthoracic echocardiography (TTE).[3-9)] However, these studies did not evaluate the factors that influenced the diagnostic power of TEE and TTE to detect RCT. Therefore, the purpose of the present study was to investigate the factors that influence the diagnostic power of TTE and TEE to detect RCT.

METHODS

We studied 61 patients with MR (30 men, 31 women; age range, 22 to 77 years, mean, 61 ± 12 years) who underwent mitral valve repair or replacement. In all patients, both TTE and TEE studies were performed prior to the operation. This study was approved by an institutional review committee and all patients gave informed consent before participation in the study.

Cardiac catheterization was performed in all patients. The severity of MR (0 to 4) was assessed semiquantitatively by TTE based on maximum jet area of color Doppler of MR as follows: grade 1 < 4 cm^2; grade 2 ≧ 4 cm^2 and < 8 cm^2; grade 3 ≧ 8 cm^2 and < 12 cm^2, and grade 4 ≧ 12 cm^2. The presence or absence of RCT was confirmed in all patients during the operation. In patients with RCT, the etiology of MR was determined from the results of clinical evaluation, echocardiography, cardiac catheterization, surgical inspection, and pathological examination. We also evaluated the classification

From the [1] Department of Cardiovascular Medicine, Nagasaki University Graduate School of Biomedical Sciences, [2] Cardiology Division, Shunkaikai Inoue Hospital, Nagasaki, [3] Department of Cardiology, Cardiovascular Center, Oita Oka Hospital, Oita, [4] Cardiology Division, Shunkaikai Nagasaki Kita Hospital, Departments of [5] Surgery and [6] Cardiovascular Surgery, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan.

Address for correspondence: Hiroaki Kawano, MD, Department of Cardiovascular Medicine, Nagasaki University Graduate School of Biomedical Science, 1-7-1 Sakamoto, Nagasaki, Nagasaki 852-8501, Japan.

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of RCT according to their attachment between the free margin and the base of the leaflets, ie, primary (marginal) chorda and secondary (body) chorda.

Transthoracic echocardiography was performed using a Toshiba Power Vision 8000 ultrasound system with a 2.5 to 3.5 MHz transducer. All transthoracic examinations included standard parasternal, apical, and subcostal transducer positions. The entire mitral valve was carefully examined by sweeping the two-dimensional echocardiographic planes laterally to medially. In addition, multiplane TEE was performed using a Toshiba Power Vision 8000 ultrasound system with a 5 MHz transducer. Local anesthesia was applied to the hypopharynx by spraying it with xylocaine. An endoscope was introduced into the esophagus with the patient in the left lateral position. A complete scan of the entire mitral valve was performed by tilting, and alternately withdrawing and advancing the tip of the endoscope. When fluctuating chordae tendineae were detected in the left atrial cavity by TTE or TEE, we diagnosed it as RCT.

We evaluated the sensitivity and specificity of TEE and TTE to detect RCT based on the results of surgical inspection in these cases. Five of the 39 patients had two RCT confirmed by surgical inspection. In these patients, we counted positive cases for detection of RCT by echocardiography when echocardiography was able to detect at least one of the two RCT. Next, we compared the diagnostic sensitivity of TEE with that of TTE based on several factors that included body mass index (BMI) and MR grade.

In addition, we evaluated the sensitivity of TTE and TEE to detect RCT in different segments of the mitral valve. Because five of 39 patients with RCT had two RCT, there were 44 RCT in the present study. The anterior mitral leaflet has 3 segments: A1, anterolateral; A2, middle; and A3, posteromedial (Figure 1). Similarly, the posterior mitral leaflet has 3 segments: P1, anterolateral; P2, middle; and P3, posteromedial. The anterior and posterior mitral leaflets are fused from 3 to 8 mm medially and laterally at the trigones, and they usually form the anterolateral commissure (AC) and posteromedial commissure (PC). The border of each segment is sometimes difficult to determine, and it is also difficult for echocardiography to detect the precise segment presenting RCT, especially in segment complexes (ie, A1-AC-P1, and A3-PC-P3) because the structure of medial and lateral segments of the mitral leaflets (A1, A3, P1, P3, AC and PC) is more complicated than that of middle segments (A2 and P2 segments). Thus, we compared the diagnostic sensitivity of TTE and TEE to detect RCT between the middle areas of anterior and posterior mitral leaflets (A2 and P2 segments) and medial and lateral areas of the anterior and posterior mitral leaflets (A1, A3, P1, P3, AC and PC).

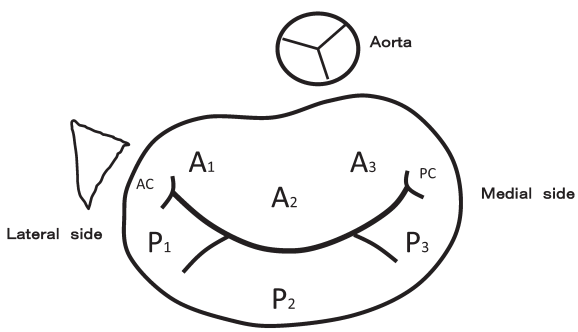

Figure 1. Schema of segments of the mitral valve. The anterior mitral leaflet has 3 segments: A1, anterolateral; A2, middle; and A3, posteromedial. Similarly, the posterior mitral leaflet has 3 segments: P1, anterolateral; P2, middle; and P3, posteromedial. The anterior and posterior leaflets are fused from 3 to 8 mm medially and laterally at the trigones, and they usually form distinct commissures (AC, anterolateral comissure; PC, posteromedial comissure).

The etiology of RCT was defined by surgical findings and/or pathological examination as follows: only RCT, ie, without any specific findings of the mitral valve, RCT with a myxomatous mitral valve, and RCT with infective endocarditis. A myxomatous mitral valve was defined by a redundant and floppy mitral valve upon surgical inspection and/or myxomatous degeneration upon pathological examination. Infective endocarditis was defined by inflammatory changes including cell infiltration upon pathological examination. Next, we compared the diagnostic sensitivity of TEE with that of TTE based on the etiology of RCT (RCT with and without a myxomatous mitral valve).

Analysis of data: All echocardiographic studies were analyzed by more than two observers. The sensitivity and specificity of both TTE and TEE were calculated to detect RCT. Statistical comparisons of the data between the two groups were performed using Fisher's exact test or unpaired *t*-test. A probability value < 0.05 was considered to indicate a significant difference.

Results

The New York Heart Association functional class was II in 28 patients, class III in 21, and class IV in 5. Although 7 patients were in class I, they underwent the operation according to the guidelines of the Japanese Circulation Association for the treatment of MR. None of the patients had ischemic heart disease. The MR grade was 4 in 30 patients, grade 3 in 26, and grade 2 in 5. Of the 61 patients, 54 underwent mitral valve repair and 7 underwent replacement of the mitral valve. Of the 54 patients with mitral valve repair, 12 had chordal replacement. During surgery, RCT were identified in 39 of 61 (64%) patients, and all RCT were primary chordate tendineae.

General aspects: The diagnostic sensitivity of TEE to detect RCT in the study subjects was 74% and the specificity was 82% (Table I). For the detection of RCT in the mitral valve by TTE, the sensitivity was 44% and the specificity was 100% (Table II). The sensitivity of TEE to detect RCT was signifi-

Table I. Detection of RCT by TEE

Operation	TEE		
	RCT (+)	RCT (-)	Total
RCT (+)	29	10	39
RCT (-)	4	18	22
Total	33	28	61

RCT indicates ruptured chordae tendineae and TEE, transesophageal echocardiography.

Table II. Detection of RCT by TTE

Operation	TEE		
	RCT (+)	RCT (-)	Total
RCT (+)	17	22	39
RCT (-)	0	12	22
Total	17	44	61

RCT indicates ruptured chordae tendineae and TTE, transthoracic echocardiography.

Table III. Comparison of Detection of RCT by TEE and TTE in Patients With High and Low BMI

BMI	Ruptured Chordae Tendineae		
	Total patients $n = 39$	Detected by TEE $n = 29$	Detected by TTE $n = 17$
≥ 22	11	10 (91%)	4 (36%)
< 22	28	19 (68%)	13 (46%)

BMI indicates body mass index; TEE, transesophageal echocardiography; and TTE, transthoracic echocardiography.

Table IV. Comparison of Detection of RCT by TEE and TTE in Patients With High and Low MR Grade

MR grade	RCT		
	Total patients $n = 39$	Detected by TEE $n = 29$	Detected by TTE $n = 17$
4	22	18 (82%)	10 (59%)
≤ 3	17	11 (64%)	7 (41%)

RCT indicates ruptured chordae tendineae; MR, mitral regurgitation; TEE, transesophageal echocardiography; and TTE, transthoracic echocardiography.

Table V. Comparison of Detection of RCT by TEE and TTE Between Middle Segments, and Medial and Lateral Segments of the Mitral Valves

Segments of MV	RCT		
	Total number $n = 44$	Detected by TEE $n = 29$	Detected by TTE $n = 17$
Middle segments	16	12 (75%)	9 (56%)
Medial and lateral segments	28	17 (61%)	8 (28%)

RCT indicates ruptured chordae tendineae; TEE, transesophageal echocardiography; and TTE, transthoracic echocardiography.

cantly higher than that of TTE ($P = 0.011$), although the specificity did not differ significantly ($P = 0.108$).

We evaluated the influence of obesity on the diagnostic sensitivity of TEE and TTE to detect RCT. Although there were only a few obese patients, the diagnostic sensitivity of TEE was significantly superior to that of TTE in patients with a BMI > 22 (TEE, 10/11 versus TTE, 4/11; $P = 0.023$) (Table III). However, there was no significant difference between the two methods in patients with a BMI < 22 (TEE, 19/28 versus TTE, 13/28; $P = 0.17$).

MR severity: We also compared the diagnostic sensitivity of the two methods after stratifying the patients based on the severity of MR (Table IV). In patients with MR grade 4, the diagnostic sensitivity of TEE was higher than that of TTE (TEE, 18/22 versus TTE, 10/22; $P = 0.026$), although there was no significant difference between TEE and TTE in patients with MR grade ≤ 3 (4 cases were MR grade 2 and 13 cases MR grade 3) (TEE, 11/17 versus TTE, 7/17; $P = 0.30$). There was no significant difference in the RCT presenting segment and RCT etiology between patients with MR grade 4 and MR grade ≤ 3 (segments A1, A3, P1, P3, AC and PC; 19/28 versus 9/16; $P = 0.65$: RCT without myxomatous mitral valve; 13/22 versus 9/17; $P = 0.70$).

RCT-presenting segments: In the medial and lateral segments of anterior and posterior mitral leaflets (A1, A3, P1, P3, AC and PC), TEE had a significantly higher diagnostic sensitivity to detect RCT than TTE (TEE 17/28 versus TTE 8/28, $P = 0.015$). However, there was no significant difference in the diagnostic sensitivity between TTE and TEE in the middle segments of anterior and posterior mitral leaflets (segments A2 and P2) (TEE, 12/16 versus TTE, 9/16, $P = 0.26$) (Table V).

Etiology of RCT: In the present study, the etiology of MR was RCT in 20 patients, RCT with a myxomatous mitral valve in

Table VI. Comparison of Detection of RCT by TEE and TTE in Patients With RCT Without Myxomatous Mitral Valve and in Those With RCT With Myxomatous Mitral Valve

Etiology of RCT	RCT		
	Total patients $n = 39$	Detected by TEE $n = 29$	Detected by TTE $n = 17$
RCT without myxomatous MV	22	17 (81%)	8 (38%)
RCT with myxomatous MV	17	12 (71%)	9 (41%)

RCT indicates ruptured chordae tendineae; MV, mitral valve; TEE, transesophageal echocardiography; and TTE, transthoracic echocardiography.

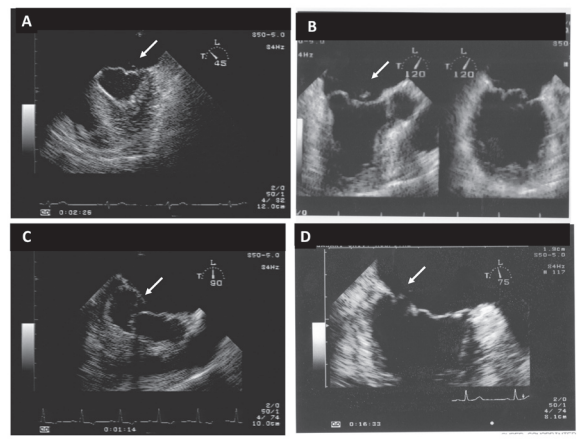

Figure 2. Photographs of cases with a false positive diagnosis of RCT by transesophageal echocardiography. **A:** Prolapse of anterolateral commissure of mitral leaflet (arrow) was misdiagnosed as RCT. **B:** Diffuse severe prolapse of P1 in mitral leaflet (arrow) was misdiagnosed as RCT. **C:** Flail healed vegetation (arrow) of P3 in mitral valve was misdiagnosed as RCT. **D:** Edge of a small hole in posteromedial commissure in mitral leaflet (arrow) was misdiagnosed as RCT.

17 patients, and RCT with infective endocarditis in 2 patients. When the patients were stratified according to the etiology of MR, the diagnostic sensitivity of TEE was significantly higher than that of TTE (TEE, 17/22 versus TTE, 8/22; $P = 0.034$) in patients with RCT without a myxomatous mitral valve. However, there was no significant difference between the two methods in patients with myxomatous mitral valves (TEE, 12/17 versus TTE, 9/17; $P = 0.48$) (Table VI). There was no significant difference in RCT presenting segment and MR grade between RCT with and without a myxomatous mitral valve (segments A1, A3, P1, P3, AC and PC; 11/19 versus 17/25; $P = 0.71$: MR grade 4; 9/17 versus 13/22; $P = 0.95$)

False positive diagnosis of RCT by TEE: There were 4 TEE studies that gave a false positive diagnosis of RCT. Subsequent surgical and/or pathological examination showed that 2 of these cases had severe prolapse of the mitral valve (anterolateral commissure (Figure 2A) and P1 segment (Figure 2B)), 1 case had mobile healed vegetation of infective endocarditis (P3 segment) (Figure 2C), and 1 case had a small hole in the posteromedial commissure (Figure 2D).

Discussion

The present study has demonstrated that the sensitivity, but not the specificity, of TEE was higher than that of TTE for the detection of RCT. The sensitivity and specificity of TEE and TTE to detect RCT in previous reports as well as the present study are summarized in Table VII. Our results are compatible with those of previous studies. These previous studies showed differences in sensitivity of TTE for the diagnosis of RCT that ranged from 0% to 90%. Among these studies, 3 using direct detection of RCT by TTE reported the sensitivity was 0% to 35%, and these data are lower than other studies that used other criteria, including the presence of abnormal coaptation of mitral leaflets in systole or flail mitral leaflets in the left atrial cavity during systole, or systolic mitral flutter, in addition to the direct detection of RCT. Thus, the difference in diagnostic criteria for RCT is one of the major reasons for the different results. In the present study, only direct detection of RCT by TTE was used, and the sensitivity of TTE was higher (44%) than in previous studies that used the same criteria, except for one study in which the criteria of RCT was not mentioned. These findings suggest that the sensitivity of TTE to detect RCT may have increased because of improvements in the resolution of TTE over the past 20 years.

Previous studies indicated two reasons for a higher sensitivity for TEE compared with TTE to detect RCT.[10-13] One reason is that the access of ultrasound to the heart from the esophagus is not restricted by lung tissue. Another reason is that the structures in the left atrium are readily assessed because of the close proximity of the esophagus and left atrium and the ability to scan this cardiac chamber freely from the esophageal transducer position.

However, there have been no previous reports on the various factors that can differentially affect the diagnostic accuracy of TTE and TEE.

The present study demonstrated that BMI, severity of MR, and lateral and medial segments of mitral valve were positive factors for the superior diagnostic sensitivity of TEE compared with TTE, and the presence of a myxomatous mitral valve was a negative factor.

Table VII. Sensitivity and Specificity of the Diagnosis of RCT by TEE and TTE in Previous Reports and Our Report

	Year	Patients (RCT)	Sensitivity		Specificity	
			TEE	TTE	TEE	TTE
Mills, *et al*	1989	16 (12)	100	25	100	100
Hozumi, *et al*	1990	28 (17)	100	35	100	100
Alam, *et al*	1991	23 (6)	100	0	100	100
Sochowski, *et al*	1991	27 (20)	100	60*	86	100
Shyu, *et al*	1992	60 (40)	100	65*	90	90
Hellemans, *et al*	1996	380 (86)	79	57*	96	96
Monin, *et al*	2005	279 (?)	97	90#	91	89
Our study	2011	61 (39)	74	44	82	100

RCT indicates ruptured chordae tendineae; TTE, transthoracic echocardiography; and TEE, transesophageal echocardiography. *; Other criteria in addition to the direct detection of RCT by TTE were included. #; Criteria of RCT by TTE were not mentioned.

BMI is an index of obesity, and it is also related to the thickness of subcutaneous tissue including soft tissue and muscle. Attenuation, ie, the loss of ultrasound when it propagates through a medium, is important for the interaction between ultrasound and tissue, and it is greater in soft tissue compared with blood and is even greater in muscle, lung, and bone.[14] Although there have been no reports on soft tissue or BMI and RCT detection, a previous report did find that the accuracy of ultrasound-based navigation systems of cup in hip arthropathy is influenced by the BMI and the thickness of the soft tissue layer.[15] Thus, our results suggest that BMI in association with subcutaneous soft tissue may be an important factor that contributes to the superior detection of RCT with TEE.

In patients with MR grade 4, the diagnostic sensitivity of TEE was significantly superior to that of TTE although there was no significant difference between TEE and TTE in patients with MR grade ≤ 3. To the best of our knowledge, there have been no reports on the relationship between the diagnostic sensitivity of RCT by echocardiography and MR grade.

We evaluated the MR grade using the area of color Doppler flow of MR. The area of the color jet signal is correlated with regurgitation volume and velocity.[16] We did not measure the MR flow velocity directly. In the present study, all patients with RCT, with the exception of one case, were treated with mitral valve repair but not replacement, and these patients had MR with eccentric jet flow. This suggested the area of the MR color jet signal may be positively related to MR jet velocity. Thus, high-speed movement of the RCT induced by high MR jet velocity in severe MR flow may make it difficult to detect RCT by TTE. This may account for the superiority of TEE for the detection of RCT in more severe MR.

In the present study, the sensitivity of TEE to detect RCT was significantly higher than that of TTE in the lateral and medial segments of the anterior and posterior mitral leaflets, but there was no difference between the diagnostic sensitivity of TTE and TEE in the middle segments of the anterior and posterior mitral leaflets. There have been no reports comparing the detection rate of RCT in different segments of mitral valve between TTE and TEE. Monin, *et al*[9] reported that single P2 prolapse or flail was identified correctly by TTE and TEE in 95% and 98% patients, respectively, although commissural prolapse was correctly identified by TTE and TEE in 93% and

87%, respectively. This indicates that lesions in the lateral and medial segments of the mitral valve were more difficult to detect by echocardiography compared to those in the middle segment of the mitral valve. Moreover, it has been reported that the incremental accuracy of TEE over TTE was significant, especially for the visualization of chordal rupture compared to other mitral valve diseases because TEE provides more excellent visualization of heart anatomy because of its high resolution compared to TTE.[9,17] Taken together, a RCT-presenting segment may account in part for the difference in accuracy between TTE and TEE to detect RCT.

In contrast, TEE was not superior to TTE at detecting RCT in patients with a myxomatous mitral valve, which is one of the most important causes of RCT. However, TEE was superior to TTE at detecting RCT in patients with RCT without a myxomatous mitral valve. In a myxomatous mitral valve, chorda is thickened by accumulation of glycosaminoglycan and/or interchordal fusion,[18] and the RCT detection rate by TTE was higher in patients with a myxomatous mitral valve (45%) compared to patients without a myxomatous mitral valve (35%), although the difference was not significant. Thus, the thickness of RCT may be the reason why TEE was not superior to TTE in patients with a myxomatous mitral valve, although unfortunately we did not measure the thickness of RCT.

Although there was no case of false positive detection of RCT by TTE in this study, there were 4 cases of false positive detection by TEE. The causes of false positive detection by TEE were as follows: severe prolapse of the anterior commissure or P1 segment of the mitral valve (2 cases), a mobile healed vegetation of infective endocarditis, and a small hole in the mitral valve of unknown etiology. Shyu, *et al*[7] reported two cases of false positive diagnosis of RCT by TEE; one patient had multiple vegetations, and the other had severe mitral valve prolapse with a markedly redundant mitral leaflet. Sochowski, *et al*[6] reported a single false positive diagnosis that was due to a mobile healed vegetation. In addition to these cases, we experienced a false positive case due to the edge of a small hole, although we were not able to confirm the etiology of the hole (ie, destruction due to infective endocarditis or congenital malformation). Moreover, the location of these lesions may also play a role in the false positive diagnosis of RCT by TEE.

Study limitations: To include several previous cases that were also discussed in our study, we used our original criteria for MR grading. These criteria were used in our laboratory for decades before the standard criteria for MR severity were released. Thus, the MR grade may not be correct in some cases.

We were not able to evaluate the direct effect of movement of the RCT induced by severe MR on the detection of RCT because MR jet velocity was not measured. We also did not measure the length and diameter of RCT to evaluate the effect of the size of RCT on its detection.

In conclusion, TEE is superior to TTE for the detection of RCT of the mitral valve in cases where the medial and lateral segments of the mitral valve are involved, and in patients with severe MR. However, care must be taken when using TEE to distinguish RCT from severe prolapse of the mitral leaflet, vegetation of infective endocarditis, and a small hole in the mitral valve.

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