Evaluation of Valvular Changes by Three-Dimensional Echocardiography in Patients With Mitral Stenosis Undergoing Percutaneous Transvenous Mitral Commissurotomy : A Preliminary Study

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Although evaluation of patients with mitral stenosis for percutaneous transvenous mitral commissurotomy (PTMC) has relied on two-dimensional Doppler echocardiographic and hemodynamic methods, recent studies have highlighted on the potential role of three-dimensional echocardiography (3-DE) as a diagnostic tool. In this study, clinical utility of 3-DE was evaluated in patients before and after PTMC. The mitral valve area (MVA) was assessed by 4 methods (two-dimensional echocardiography, Doppler pressure half-time, invasive hemodynamic method and 3-DE) in 10 patients before and after the PTMC. The valve areas assessed by 3-DE and two-dimensional echocardiography (2-DE) were compared with those derived from Doppler pressure half-time method and cardiac catheterization method, respectively. Morphologic changes of the mitral valve were also examined with the use of three-dimensional image reconstruction. The 3-DE method had the best fit with Doppler pressure half-time method in assessing MVA before and after PTMC ($r = 0.87$, $p = 0.001$ and $r = 0.94$, $p = 0.0001$, respectively). Good assessment of morphologic changes, including valvular and subvalvular changes, which cannot be well assessed by 2-DE, before and after PTMC was also achieved in some cases by means of three-dimensional image reconstruction. The 3-DE method is suggested to be a potentially useful method for assessing MVA and morphology change before and after PTMC. It affords the best correlation with pressure half-time method in determing MVA before and after intervention. In some cases, it also reliably demonstrates valvular and subvalvular changes after sucessful PTMC. **(Mid Taiwan J Med 1999;4:186-93)**

Key words

balloon mitral valvuloplasty, mitral stenosis, three-dimensional echocardiography

INTRODUCTION

Rheumatic mitral stenosis remains a major health concern in developing countries. Evaluation of stenotic mitral valves has traditionally been based on two-dimensional echocardiography (2-DE), Doppler pressure half-time and/or invasive hemodynamic methods. These methods, however, have their drawbacks. For example, 2-DE, although noninvasive and widely accessible, is limited by its ability to assess the spatial structure of the mitral valve. Although Doppler pressure half-time is considered a well-established method for mitral valve area (MVA) esti-

Received : March 12, 1999. Revised : April 1, 1999.
Accepted : April 9, 1999.

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mation, it, however, provides no structural data. On the other hand, cardiac catheterization, although considered a reference method for MVA calculation, is invasive, may be influenced by multiple factors, and yields limited information on valvular structure [1-4].

The advent of multiplane transesophageal echocardiography (TEE) in recent years has somewhat supplemented and increased the diagnostic yield of 2-DE [5-7]. The application of TEE for 3-DE is a relatively new diagnostic tool. Already, it has shown promise as a diagnostic technique. It allows straightforward objective three-dimensional reconstruction of cardiac structure, and enables detailed analysis of structural and complex pathological conditions, including morphologic evaluation, and accurate and reproducible assessment of MVA [1,5,8-11]. The use of this technique compared with other well-established methods in assessing MVA and in determining the outcome of percutaneous transvenous mitral commissurotomy (PTMC) in patients with mitral stenosis, however, has rarely been described [12]. Accordingly, the aims of the present study were to determine (1) whether 3-DE has better correlations with Doppler pressure half-time and cardiac catheterization methods in estimating MVA compared with 2-DE method around PTMC, and (2) the clinical utility of 3-DE in PTMC.

MATERIALS AND METHODS

Patients

Ten patients with mitral stenosis (eight women and two men, mean age of 46 years) who underwent 2-DE, Doppler echocardiography cardiac catheterization and 3-DE before and after PTMC from January 1997 to January 1998 were enrolled in the present study (Table 1). Majority of the patients (80%) were in sinus rhythm.

Echocardiography Study

Transthoracic 2-DE and multiplane TEE before PTMC were performed during the hospitalization or OPD before the admission for PTMC. After PTMC, the 10 patients were examined again within 24 hours. MVA was measured by planimetry based on the smallest orifice of the mitral valve obtained in the parasternal short axis view of transthoracic 2-DE. Doppler study was performed in the apical four chamber view. Transmitral flow velocity and MVA were measured using continuous-wave Doppler method and pressure half-time method, respectively.

Three-dimensional echocardiography was performed by multiplane TEE (HP sonos 2500) for data acquisition. Image reconstruction of the mitral valve was obtained using the TomTec-GmbH system. Numerical dynamic image and 3-DE reconstruction image were stored on optic discs for off-line analysis. From the three-dimensional data sets, cut planes were selected and presented in both two-dimensional format (anyplane echocaridography) and volume-rendered dynamic display. MVA was measured based on the two-dimensional image of the parallel short-axis cut plane of the mitral valve between the mitral annulus and the mitral tips of leaflets in the end diastolic phase when the valve was opened maximally (Fig. 1). The smallest MVA measured using planimetry was then obtained.

These 3-DE and 2-DE results were then compared with those derived from Doppler pressure half-time and catheterization methods. Three-dimensional image was also obtained for morphologic evaluation.

Hemodynamic Study

Hemodynamic data was obtained during PTMC. A Mullin catheter was introduced to the left atrium after transeptal puncture. An Inoue balloon was then advanced to the left atrium through the artificial interatrial septal defect. After recording the left atrial pressure, the Inoue balloon was advanced to the left ventricle. Transmitral pressure gradient between the left atrium and ventricle was then obtained. Cardiac output was derived by the Fick method. Hemodynamically-derived MVA was then calculated based on the Gorlin formula with an average of 9 beats imme-

Table 1. The clinical characteristics of patients

Case No.	Age (yr.)	Sex	Height (cm)	Body weight (kg)	Balloon size (mm)	EKG	Valvular lesions
1	52	F	158	50	26	AF	MR1+, AR1+, TR4+, PR1+
2	29	F	156	46	26	NSR, RVH	TR2+
3	70	F	148	44	24	NSR, RVH	MR1+, TR2+
4	62	M	172	82	26	AF	MR1+, AR1+, TR3+
5	52	M	156	57	24	NSR, LAH	MR2+, TR1+
6	32	F	156	53	24	NSR, LAH	AR2+, TR1+, moderate AS
7	39	F	153	52	26	NSR	AR2+
8	46	F	155	45	24	NSR	TR1+
9	28	F	159	55	26	NSR	TR1+
10	52	F	152	55	26	NSR	MR2+, AR1+, TR1+

EKG = electrocardiography; M = male; F = female; AF = atrial fibrillation; MR = mitral regurgitation; AR = aortic regurgitation; TR = Tricuspid regurgitation; PR = pulmonary regurgitation; NSR = normal sinus rhythm; RVH = right ventricular hypertrophy; LAH = left atrial hypertrophy.

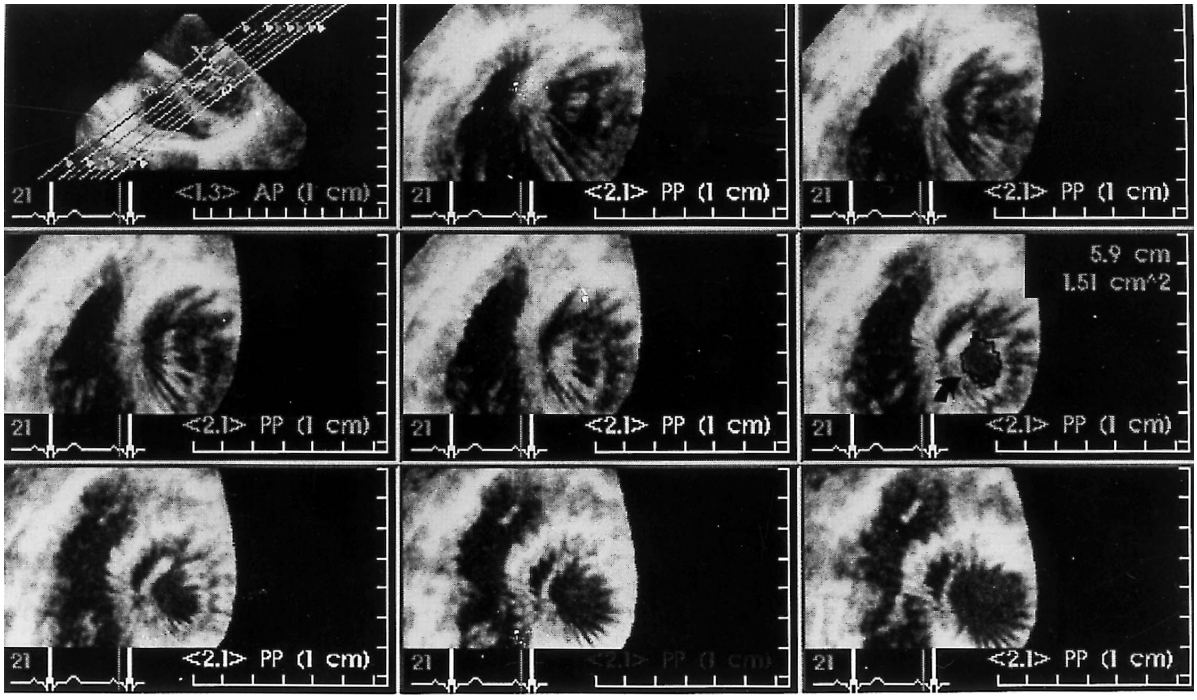

Fig.1 Two-dimensional parallel images obtained by parallel cut planes (left frame in top panel) from spatial reconstruction images. Mitral valve area is calculated by planimetry (black arrow, right frame in middle panel).

diately before and after PTMC.

Statistics

Continuous data were reported as mean ± SD. The difference between MVA before and after PTMC were tested by Student's t test. The correlation among MVA derived by these four methods were analyzed by Pearson correlation statistics analysis. Results with coefficients greater than 0.8 were considered strong correlation, between 0.6 and 0.8 were considered good correlation, between 0.4 and 0.6 were considered moderate correlation, between 0.2 and 0.4 were considered weak

Table 2. Mitral valve area before and after PTMC

Case No	Before PTMC (cm^2)				After PTMC (cm^2)			
	CATH	PHT	2-DE	3-DE	CATH	PHT	2-DE	3-DE
1	1.1	0.9	1.1	1.1	2.2	1.5	1.3	1.3
2	0.7	0.7	1.4	0.6	1.5	1.5	1.5	1.5
3	1.0	0.9	0.8	1.0	1.6	1.6	1.0	1.6
4	1.3	1.0	1.5	0.9	2.4	1.4	1.9	1.6
5	0.9	0.9	0.8	0.8	1.4	1.4	2.1	1.5
6	1.2	1.1	1.5	1.0	2.2	2.0	2.1	2.0
7	0.8	1.3	1.0	1.0	1.9	1.8	1.6	1.8
8	1.1	1.0	0.9	1.1	2.2	2.2	1.8	2.1
9	1.0	1.4	1.6	1.5	2.2	2.1	1.8	1.9
10	1.6	1.6	1.8	1.6	3.3	2.4	2.3	2.3
Mean ± SD	1.07 ± 0.25	1.08 ± 0.27	1.24 ± 0.36	1.06 ± 0.30	2.05 ± 0.54	1.79 ± 0.36	1.74 ± 0.40	1.76 ± 0.31
p value					$p=0.00001$	$p=0.000005$	$p=0.002$	$p=0.00001$

CATH = cardiac catheterization method; PHT = pressure half time method; 2-DE = two-dimensional echocardiography; 3-DE = three-dimensional echocardiography.

Table 3. Correlation analysis among MVAs measured by different methods

Methods	Before PTMC			After PTMC		
	CATH	3DE	2DE	CATH	3DE	2DE
Before PTMC						
PHT	r = 0.56 ($p=0.10$)	r = 0.87 ($p=0.001$)	r = 0.55 ($p=0.10$)			
CATH		r = 0.64 ($p=0.04$)	r = 0.55 ($p=0.10$)			
After PTMC						
PHT				r = 0.78 ($p=0.008$)	r = 0.94 ($p=0.0001$)	r = 0.46 ($p=0.19$)
CATH					r = 0.72 ($p=0.02$)	r = 0.49 ($p=0.15$)

r: Pearson correlation coefficient.

correlation and less than 0.2 was considered weakest correlation. Results with *p* value less than 0.05 was considered statistically significant.

RESULTS

The MVAs measured by cardiac catheterization and echocardiography are shown in Table 2. MVAs estimated derived by 3-DE ranged from 0.6 cm^2 to 1.6 cm^2 (mean ± SD: 1.06 ± 0.30 cm^2) before PTMC and 1.3 cm^2 to 2.3 cm^2 (mean ± SD: 1.76 ± 0.31 cm^2) after PTMC. The MVAs derived by 2-DE ranged from 0.8 cm^2 to 1.8 cm^2 (mean ± SD: 1.24 ± 0.36 cm^2) before PTMC and 1.0 cm^2 to 2.3 cm^2 (mean ± SD: 1.74 ± 0.40 cm^2) after PTMC. The result of MVAs yielded a significant improvement in MVA ($p<0.005$).

The results revealed strong correlation with statistical significance between the 3-DE method and Doppler pressure half-time method (r = 0.87, $p=0.001$ before PTMC; r = 0.94, $p=0.0001$ after PTMC). The result also revealed good correlation between the 3-DE and cadiac catheterization method (r = 0.64, $p=0.04$ before PTMC; r = 0.72, $p=0.02$ after PTMC). However, 2-DE showed a relatively weak correlation with Doppler pressure half-time method (r = 0.55, $p=0.10$ before PTMC; r = 0.46, $p=0.19$ after PTMC) and cardiac catheterization method (r = 0.55, $p=0.10$ before PTMC; r = 0.49,

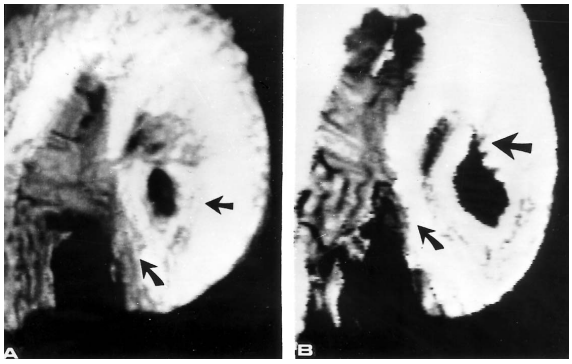

Fig.2 Short-axis view (case 2). A: Mitral valve image before PTMC showing a small mitral orifice with sclerotic change of leaflets (right straight arrow). Curved arrow indicates left ventricular outlet. B: Mitral valve image after PTMC demonstrating a larger mitral orifice. Note unilaterally commissural splitting indicated by larger black arrow. Small curved arrow also points to the left ventricular outlet.

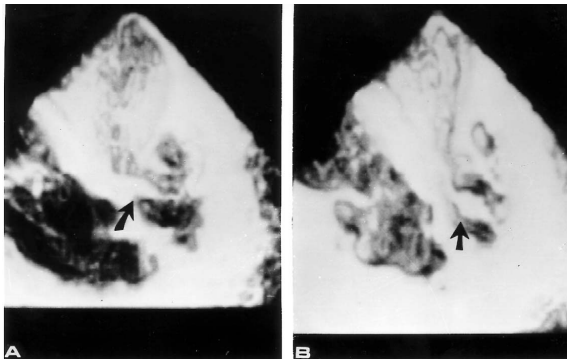

Fig.3 Four-chamber view (case 2). A: Subvalvular image before PTMC revealing thick leaflets, shortened chordae tendineae and narrow channel below mitral orifice (black arrow). B: Similar subvalvular image obtained after PTMC showing a fibrocalcified nodule (dark arrow). Subvalvular channel has become wider. More straightened and lengthened chordae tendineae were considered in comparison with Fig. 3A.

p=0.15 after PTMC).

The morphologic change before and after PTMC was also available via three-dimensional reconstruction. Valvular change with commissural splitting between mitral leaflets can be delineated in 5 patients (50%) after PTMC, including 3 patients with bilateral splitting and 2 with unilateral splitting. Subvalvular change, such as thickened leaflets and chordae tendineae and fibrocalcified nodule of chordae tendineae, was demonstrated in some cases (Figs. 2 and 3).

DISCUSSION

Three-dimensional echocardiography has been applied in the assessment of valvular structure, ventricular volume, cardiac defect, intracardiac endoprocessor and other cardiovascular lesions [1,5,9-11]. Recently, 3-DE was demonstrated to be a reliable method for mitral valve evaluation and may even be superior to traditional 2-DE method for this purpose [1,5,8,13,14]. The 2-DE method for MVA measurement may be influenced by the examination technique for detecting the mitral orifice; besides, the desired plane cannot always be obtained despite extensive probe manipulation [1,15]. In contrast, the spatially reconstructive image via multiplane echocardiography with 3-DE reconstruction provides an adequate cut-plane for MVA measurement, and by the very fact, a more accurate MVA estimation [1,8,16]. In a previous study, Chen et al [1] used the 3-DE, Doppler pressure half-time method, and 2-DE for MVA measurement and obtained a good correlation between 3-DE and other noninvasive methods. On the other hand, rare study applied 3-DE for mitral valve evluation around PTMC and compared with other methods including 2-DE [12]. In the present study, we showed the application of 3-DE for evaluation before and after PTMC. Our results demonstrated a strong correlation in MVA estimation between the 3-DE and Doppler pressure half-time method, which were consistent with that of Chen et al [1]. A good correlation was also found between 3-DE and cardiac catheterization method. However, we only obtained a moderate correlation rather than a statistically significant correlation between 2-DE and the reference methods including Doppler pressure half-time method and cardiac catheterization method. Three-dimensional echocardiography may be a superior method to 2-DE for MVA measurement around PTMC.

The application of 3-DE in the morpholgic

or quantitative assessment of mitral valve has been reported in some literature [17-20]. In contrast, our literature search found only one study [12] on the morphologic change around PTMC. In our study, valvular change, such as enlarged mitral orifice, commissural splitting between mitral leaflets after PTMC were demonstrated in some cases. Subvalvular change including wider subvalvular channel, more straightened and lengthened chordae tendineae with fibrocalcified nodule after PTMC were also illustrated. These morphologic change was considered to be the result of the expansive force of the Inoue balloon during PTMC.

Recently, real-time 3-DE has been developed for evaluation of cardiovascular status by a high speed, phased-array real-time scanner. This new method permits recording of the entire left ventricle (LV) in a single beat and also has the potential to substantially decrease the imaging time compared with standard 2-DE [21-23]. Multiplane TEE has been used as a clinical tool during intraoperative monitoring of cardiac surgery [24]. The application of real-time 3-DE during interventional procedure for monitoring may be feasible in the future. The ability to dynamically display 3-DE may play a vital role in the evaluation of cardiac diseases.

MVA based on Gorlin may be influenced by several factors, such as valvular lesion and interventricular septal defect [1-4]. In our study, valvular lesions, such as mitral regurgitation and aortic regurgitation, were present in some patients. This may explain why there was a suboptimal correlation between MVA measured by 3-DE and calculated by hemodynamic Gorlin method.

A number of limitations exist in our study. First, the findings of our study should be considered preliminary as it enrolled only 10 patients. Larger prospective studies are thus required to verify our results. Second, data acquisition and 3-DE reconstruction with current technology is still time-consuming. However, with the advances in 3-DE, we foresee that this shortcoming will be circumvented in the near future.

In conclusion, our preliminary study suggests that 3-DE provides a non-invasive assessment of MVA in mitral stenosis patients and allows a more accurate evaluation of morphological changes of the mitral valve before and after PTMC than 2-DE.

ACKNOWLEDGMENT

We greatly thank Dr. Kean-Wah Lau for reviewing the manuscript.

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三維心臟超音波對接受經皮穿靜脈二尖瓣成型術之二尖瓣狹窄病患其瓣膜變化之評估：一初步研究

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雖然對接受經皮穿靜脈二尖瓣成型術之瓣膜狹窄病患之評估主賴二維杜卜勒超音波及血流動力學之方法，但近來之研究顯示三維心臟超音波是一有潛力之診斷工具。在本研究中，經由對接受經皮穿靜脈二尖瓣成型術病人之檢查，對三維心臟超音波之臨床運用予以評估。在10個接受經皮穿靜脈二尖瓣成型術之病人，我們以四種方法（二維心臟超音波，杜卜勒壓力減半時間，血流動力學及三維心臟超音波）評估二尖瓣出口面積。由二維與三維心臟超音波測量出之二尖瓣出口面積分別與杜卜勒壓力減半時間及血流動力學方法測出之面積作比較，瓣膜形態學之變化亦經由三維影像重組後予以評估。在接受經皮穿靜脈二尖瓣成型術前後，三維心臟超音波與杜卜勒壓力減半時間之方法測量二尖瓣出口面積具有最佳之相關性（$r=0.87$, $p=0.001$ 及 $r=0.94$, $p=0.0001$）。經皮穿靜脈二尖瓣成型術前後瓣膜形態學之變化，先前並無法由二維心臟超音波作良好之評估，經由三維心臟超音波可以在一些病人得到良好之影像。故在經皮穿靜脈二尖瓣成型術前後，評估二尖瓣出口面積及瓣膜形態學變化，三維心臟超音波應可成爲一有潛力之評估方法，它在介入性處理二尖瓣狹窄前後，對二尖瓣出口面積之測量具備了與杜卜勒方法最佳之相關性，且在部份病人，亦確實呈現了瓣膜及瓣膜下之變化。（中台灣醫誌 **1999;4:186-93**）

關鍵詞

氣球二尖瓣膜成型術，二尖瓣狹窄，三維心臟超音波

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收文日期：3/12/1999　　修改日期：4/1/1999

接受日期：4/9/1999