J Cardiol 2007 Sep; 50(3): 159–166

Mitral Annulus Displacement Measured by Tissue-Tracking Method With Doppler-Tissue Images is a Useful Marker of the Severity of Heart Failure

Koji ITO, MD
Mitsuru NOMA, MD
Masahiro MOHRI, MD
Kohtaro ABE, MD
Umpei YAMAMOTO, MD
Kan KIKUCHI, MD
Kenji MIYATA, MD
Hideki ORIGUCHI, MD
Hideo YAMAMOTO, MD
Tsukasa TAJIMI, MD
Yutaka KIKUCHI, MD

Abstract

Objectives. This study investigated whether the measurement of mitral annulus displacement by the tissue-tracking method with Doppler-tissue images can provide more accurate information on the severity of heart failure compared to conventional methods, such as left ventricular ejection fraction (LVEF).

Background. Impaired left ventricular function is an important predictor of poor prognosis. Although LVEF has been used to assess left ventricular function, such indicators do not necessarily correlate well to clinical variables such as New York Heart Association (NYHA) functional class or plasma brain natriuretic peptide (BNP) concentration.

Methods. In 90 subjects with or without various heart diseases, mitral annulus displacement was measured by the tissue-tracking method with Doppler-tissue images and the correlations evaluated with NYHA functional class, plasma BNP concentration, left ventricular mass index and Tei index.

Results. Mitral annulus displacement by the tissue-tracking method with Doppler-tissue images was well correlated with NYHA functional class and plasma BNP concentration. LVEF was also correlated with these clinical variables, but significantly more weakly. Furthermore, mitral annulus displacement by the tissue-tracking method with Doppler-tissue images was correlated with left ventricular mass index and Tei index, which indicate left ventricular systolic and diastolic function.

Conclusions. The present study suggests that mitral annulus displacement measured by our technique is a useful and reliable method for assessing the severity of heart failure.

J Cardiol 2007 Sep; 50(3): 159−166

Key Words

- **Echocardiography (Doppler-tissue images, tissue-tracking)**
- **Heart failure (mitral annulus)**

九州厚生年金病院 循環器内科: 〒806−8501 北九州市八幡西区岸の浦 1−8−1
Department of Cardiology, Kyushu Kosei-Nenkin Hospital, Kitakyushu
Address for correspondence: NOMA M, MD, Department of Cardiology, Kyushu Kosei-Nenkin Hospital, Kishinoura 1−8−1, Yahatanishi-ku, Kitakyushu 806−8501; E-mail: mitsuru.noma@qkn-hosp.jp
Manuscript received March 14, 2007; revised June 14, 2007; accepted June 18, 2007

INTRODUCTION

Impaired left ventricular function is an important predictor of poor prognosis.[1-3] There is no doubt that the evaluation of left ventricular function is important in various heart diseases. Left ventricular function is commonly evaluated using the left ventricular ejection fraction (LVEF) determined by cineangiography or echocardiography. Echocardiography is noninvasive and less time-consuming compared to other diagnostic modalities, so is usually used. The modified biplane Simpson method is preferable,[4] but needs skill to reduce measurement errors. Furthermore, LVEF could represent mainly the left ventricular systolic function, and so LVEF sometimes does not correlate with the clinical factors of heart failure such as New York Heart Association (NYHA) functional class.

Echocardiographic M-mode tracing of mitral annulus motion is correlated with LVEF[5-10] and mortality.[11,12] However, whether mitral annulus motion indicates the clinical status of heart failure such as NYHA functional class or plasma BNP concentration remains unknown. Furthermore, echocardiac M-mode tracing of mitral annulus motion cannot measure the displacement at the identical point during a cardiac cycle.

The tissue-tracking method using Doppler-tissue imaging exactly reflects myocardial velocity and displacement.[9,13,14] Therefore, this tracking method can evaluate mitral annulus displacement more accurately than the M-mode method.

The present study investigated whether the measurement of mitral annulus displacement by the tissue-tracking method with Doppler-tissue images can provide more accurate information on the severity of heart failure than conventional methods such as LVEF, and assessed the correlation with NYHA functional class as an index of heart failure.

SUBJECTS AND METHODS

Study population

This study included 90 consecutive subjects referred for echocardiographic examination at the Kyushu Kosei-Nenkin Hospital between October 2005 and May 2006 (**Table 1**). Exclusion criteria included right-sided heart failure caused by primary pulmonary hypertension or severe tricuspid regurgitation. All participating subjects provided informed consent before the study.

Table 1 Patient characteristics

Men/women	55/35
Age (yr)	67 (range 16−85)
Etiology of heart failure	
Ischemic heart disease	20
Hypertensive heart disease	5
Non-ischemic dilated cardiomyopathy	13
Hypertrophic cardiomyopathy	11
Valvular heart disease	14
Lone atrial fibrillation	6
Others	5
Normal (no heart disease)	16
Rhythm	
Sinus	63
Atrial fibrillation	16
Pacemaker	11

Echocardiographic analysis

The present study used a Vivid 7 digital ultrasound system (GE Medical Systems, BT05). Scanning was performed longitudinally from the apex to acquire the apical four-chamber view and the two-chamber view, and from the left sternal border to acquire the parasternal long-axis view with a M4S transducer. Gain, filter, pulse repetitive frequency, sector size, and depth were adjusted to the optimum conditions and to reach the highest frame rate as possible (> 100 frames/sec). The Doppler-tissue imaging data with two-dimensional images were stored on hard disc and analyzed offline. The analysis software built into the Vivid 7 (Q-analysis) was used to determine the tissue displacement at several locations. Measurements were done at two differential points: the hinge of the mitral valve at the lateral wall, and the hinge of the mitral valve at the septum in the apical four-chamber view. The sampling area size was 4×4 mm, and the sampling area was maintained at the identical area of the tissue during the entire cardiac cycle by manual tracking. Positive peak values of mitral annulus displacement were determined by the tissue-tracking method with Doppler-tissue images at each point (**Fig. 1**). LVEF was calculated by the modified biplane Simpson method using the apical four- and two-chamber views. Left ventricular mass was calculated by the following equation:[15]

$$\text{Left ventricular mass (g)} = 1.04 \times 0.8\,[(\text{LVDd} + \text{PWT} + \text{IVST})^3 - \text{LVDs}^3] + 0.6$$

where LVDd = left ventricular diastolic dimension

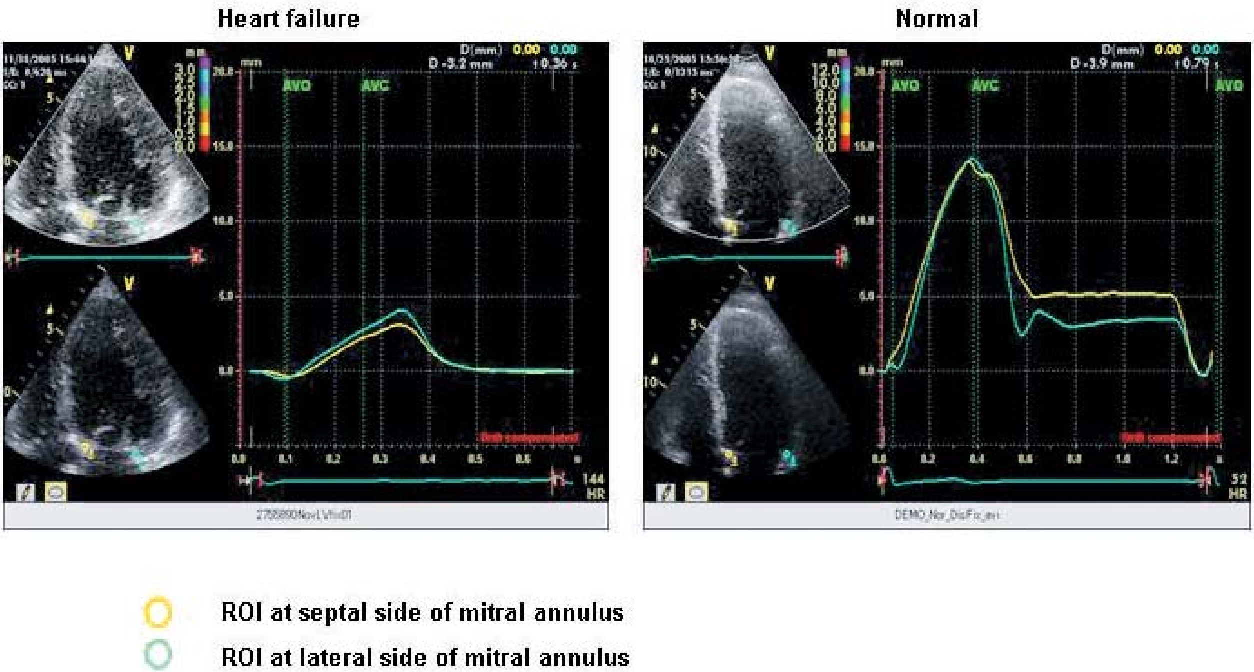

Fig. 1 Representative profiles of mitral annulus displacement measured by the tissue-tracking method with Doppler-tissue images

Left panel illustrates a patient with heart failure subject and *right panel* shows a normal subject. The circle at the mitral annulus in the apical four-chamber view is the region of interest, at the septal side (*yellow*) and the lateral side (*green*). *X*-axis is the time course in cycle lengths and *Y*-axis mitral annulus displacement. ROI = region of interest; AVO = aortic valve opening; AVC = aortic valve closing.

(cm), LVDs = left ventricular systolic dimension (cm), PWT = posterior wall thickness (cm) and IVST = interventricular septal thickness (cm) at end-diastole and systole in two-dimensional images from the parasternal long-axis view. Left ventricular mass index was also calculated from the body surface area.

The Tei index was measured as the sum of isovolumic contraction and relaxation intervals divided by ejection time as previously reported. Briefly, left ventricular inflow and outflow velocity profiles were determined in the apical four-chamber and apical three-chamber views. The time interval between the end and the onset of left ventricular inflow was designated as "*A*", and the ejection time derived from the duration of left ventricular outflow velocities as "*B*". Tei index was calculated as follows: Tei index = $(A - B)/B$.[16,17]

Three consecutive beats were analyzed for all measurements, and the values were averaged.

Meaurement of plasma brain natriuretic peptide concentration

This part of the study excluded patients with chronic renal failure (serum creatinine level > 2.0 mg/d*l*) to avoid the effects of renal dysfunction on plasma brain natriuretic peptide (BNP) clearance.[18] Blood samples for measuring plasma BNP concentrations were collected from peripheral veins within 7 days of echocardiographic examination.

Statistical analysis

Data are expressed as mean value ± standard deviation. Statistical analysis used Dr SPSSII for Windows (SPSS Inc. 2001). Analysis of variance was used to compare differences between the various values such as mitral annulus displacement measured by the tissue-tracking method with Doppler-tissue images, plasma BNP concentrations or LVEF, and NYHA functional class. Comparisons between mean values were performed with Fisher's correlation for multiple comparisons. The Pearson correlation coefficient was used for analysis of linear correlation between different variables. A p value < 0.05 was considered statistically significant.

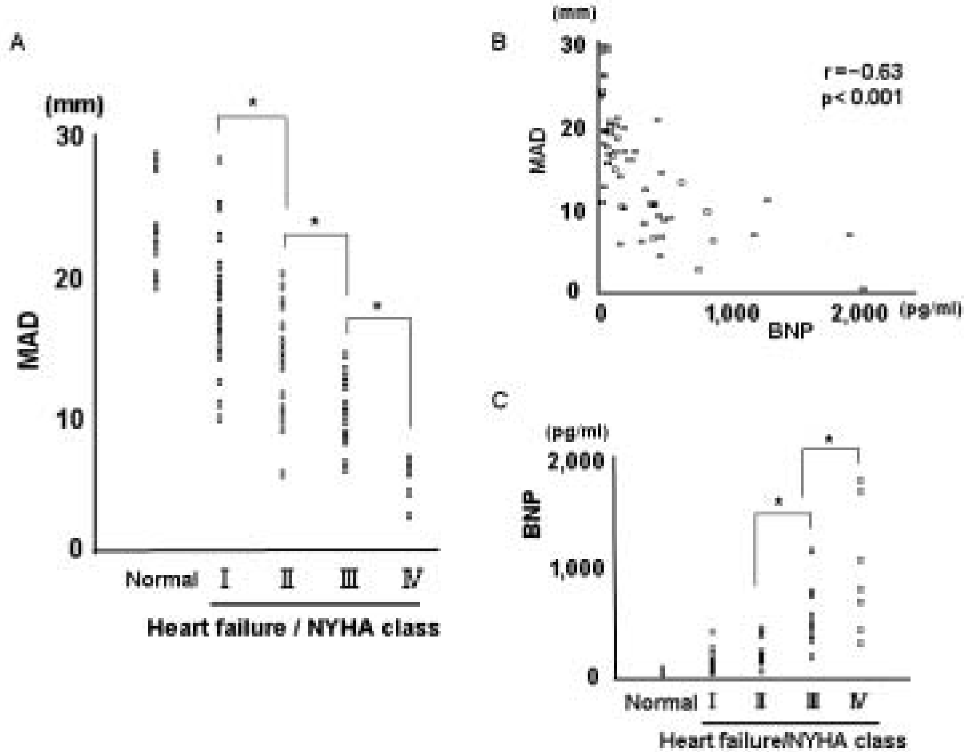

Fig. 2 Relationships between mitral annulus displacement measured by tissue-tracking method with Doppler-tissue images and other factors

A: The relationship with NYHA functional class. The value of mitral annulus displacement is significantly different between neighboring NYHA functional classes.
*$p < 0.05$ vs neighboring NYHA functional class.
B: The relationship with plasma BNP concentration. There is a statistically significant, inverse correlation between mitral annulus displacement and plasma BNP concentration.
C: The relationship between plasma BNP concentration and NYHA functional class.
*$p < 0.05$ vs neighboring NYHA functional class.
MAD = mitral annulus displacement; NYHA = New York Heart Association; BNP = brain natriuretic peptide.

RESULTS

Measurement of mitral annulus displacement by tissue-tracking method with Doppler-tissue images

Representative recordings of mitral annulus displacement by the tissue-tracking method with Doppler-tissue images in a normal subject and a patient with heart failure are shown in **Fig. 1**. The peak values of the displacement were measured at both septal and lateral sides of the mitral annulus.

Relationship between mitral annulus displacement and NYHA functional class

Fig. 2−A shows the relationship between mitral annulus displacement measured by the tissue-tracking method with Doppler-tissue images and NYHA functional class. Mitral annulus displacement was significantly inversely correlated with NYHA functional class ($n = 90$, $r = -0.85$, mean value ± SD; normal subjects ($n = 16$): 24.4 ± 3.7 mm, NYHA Ⅰ ($n = 27$): 18.9 ± 4.7 mm, NYHA Ⅱ ($n = 22$): 13.7 ± 3.8 mm, NYHA Ⅲ ($n = 18$): 10.3 ± 2.3 mm, NYHA Ⅳ ($n = 7$): 5.7±1.8 mm). Furthermore, the value of mitral annulus displacement in each NYHA functional class was significantly different from that in the neighboring classes.

Relationship between mitral annulus displacement and plasma BNP concentration

Mitral annulus displacement measured by the tissue-tracking method with Doppler-tissue images was inversely correlated with plasma BNP concentration ($n = 57$, $r = -0.63$; **Fig. 2−B**). Plasma BNP concentration was also correlated with NYHA functional class (**Fig. 2−C**).

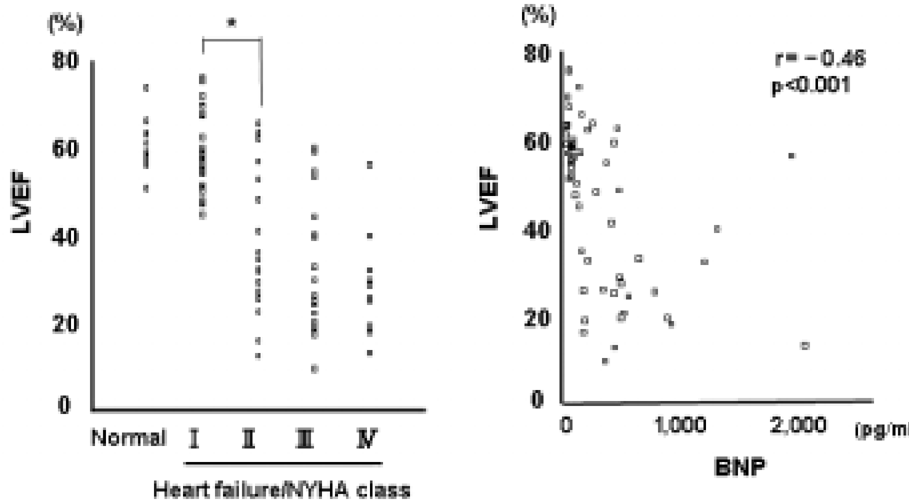

Fig. 3 Relationships between LVEF and other factors
A: The relationship with NYHA functional class. Significant difference is noted only between NYHA functional classes Ⅰ and Ⅱ.
$^*p < 0.05$ vs NYHA functional class Ⅰ.
B: The relationship with plasma BNP concentration.
LEEF = left ventricular ejection fraction. Other abbreviations as in Fig. 2.

Relationship between LVEF and severity of heart failure

Fig. 3−left shows the relationship between LVEF and NYHA functional class ($n = 90$, $r = -0.57$) and **Fig. 3−right** shows the relationship between LVEF and plasma BNP concentrations ($n = 57$, $r = -0.46$). The relationships between LVEF and these values were weaker than those with mitral annulus displacement by the tissue-tracking method with Doppler-tissue images.

Relationships between mitral annulus displacement and LVEF, left ventricular mass index, and Tei index

Mitral annulus displacement measured by the tissue-tracking method with Doppler-tissue images was correlated with LVEF in all patients ($n = 90$, $r = 0.67$; **Fig. 4**). Mitral annulus displacement was also correlated with left ventricular mass index, which indicated both left ventricular dilation and left ventricular hypertrophy ($n = 90$, $r = -0.61$; **Fig. 5−left**). Furthermore, mitral annulus displacement had a statistically significant correlation with the Tei index, a marker of global left ventricular function incorporating both left ventricular systolic and diastolic function ($n = 47$, $r = -0.47$; **Fig. 5−right**).

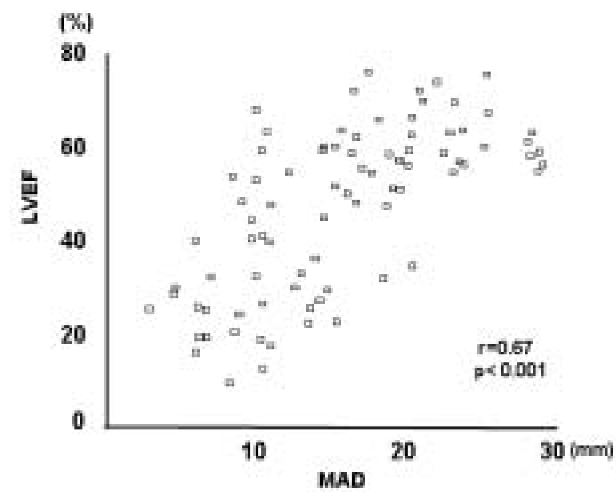

Fig. 4 Relationship between LVEF and mitral annulus displacement measured by the tissue-tracking method with Doppler-tissue images
Abbreviations as in Figs. 2, 3.

DISCUSSION

Previous studies showed mitral annulus motion is useful to evaluate left ventricular systolic function using two-dimensional image-guided M-mode echocardiography. The present study evaluated mitral annulus displacement by the tissue-tracking method with Doppler-tissue imaging, which provides accurate assessment of mitral annulus displacement. We found that mitral annulus displacement measured by the tissue-tracking method with

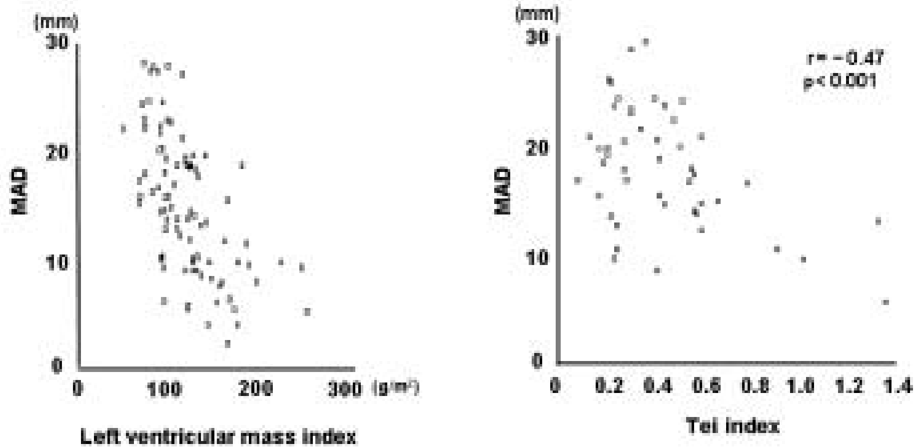

Fig. 5 Relationships between mitral annulus displacement measured by the tissue-tracking method with Doppler-tissue images and other factors
Left: There is a statistically significant, inverse correlation with left ventricular mass index.
Right: There is a statistically significant, inverse correlation with the Tei index.
Abbreviations as in Fig. 2.

Doppler-tissue images was a more powerful indicator of NYHA functional class as a subjective marker of heart failure severity compared with LVEF, was also correlated with plasma BNP concentration which is another marker of heart failure severity, and was correlated with the left ventricular mass index and Tei index. These results indicate that this method is useful and reliable to evaluate the severity of heart failure.

LVEF is commonly applied as a useful and reliable index of left ventricular systolic function.[1−3,19,20] However, we occasionally encounter patients with overt heart failure but preserved LVEF. In fact, heart failure may be caused not only by systolic dysfunction but also by diastolic dysfunction.[21,22] Furthermore, LVEF does not correlate with NYHA functional class.[12] Therefore, we aimed to investigate whether mitral annulus displacement measured by the tissue-tracking method with Doppler-tissue images can provide a reliable and objective indicator of heart failure severity and NYHA functional class.

The present study showed that mitral annulus displacement measured by the tissue-tracking method with Doppler-tissue images was correlated with both NYHA functional class and plasma BNP concentration. LVEF had weak relationships with NYHA functional class and plasma BNP concentration. These results suggest that mitral annulus displacement by tissue-tracking method with Doppler-tissue images has the potential to be a more useful and reliable indicator to assess heart failure severity rather than conventional methods such as LVEF.

In addition, the present study revealed a significant relationship between mitral annulus displacement by the tissue-tracking method with Doppler-tissue images and the Tei index, a marker of global left ventricular function including diastolic function.[16,17,23] This result suggests that mitral annulus displacement by the tissue-tracking method with Doppler-tissue images reflects both left ventricular systolic and diastolic function. The mechanisms involved are beyond the scope of the present study.

The tissue-tracking method with Doppler-tissue images detects the motion of the mitral annulus at both septal and lateral wall sides, which allows us to measure the actual displacement of the mitral annulus independent of angle. Furthermore, the values measured by this technique may reflect the displacement of the identical point in the mitral annulus during a cardiac cycle. Therefore, it is likely that such measurement of mitral annulus displacement can provide more accurate measurements of mitral annulus motion compared to M-mode tracing, thus providing better correlation with severity of heart failure.

Measurement of mitral annulus displacement by the tissue-tracking method with Doppler-tissue images was correlated well with NYHA functional class in patients with divergent etiologies of heart failure. Therefore, this method provides a simple approach to evaluate global left ventricular function in various heart diseases.

In conclusion, we suggest that mitral annulus displacement measured by the tissue-tracking method with Doppler-tissue images is a useful and reliable marker of the severity of heart failure caused by various heart diseases.

要 約

Dopper-Tissue Imageを用いた**Tissue-Tracking**法による僧帽弁輪移動距離測定は心不全重症度マーカーとして有用である

伊藤 浩司 野 間 充 毛利 正博 阿部弘太郎
山本 雲平 菊 池 幹 宮田 健二 折口 秀樹
山本 英雄 多治見 司 菊 池 裕

目 的：心機能評価では，一般に左室駆出率の測定が行われる．M-mode法による僧帽弁輪の収縮期移動距離(僧帽弁輪移動距離)は左室駆出率と相関があることが示されている．しかし，左室駆出率は必ずしも心不全の重症度とは相関しないとされており，僧帽弁輪移動距離においても心不全の重症度との相関は明らかではない．本研究では，tissue-tracking法を用いて測定した僧帽弁輪移動距離と心不全重症度(NYHA class，血清脳性ナトリウム利尿ペプチド濃度)との相関を検討した．さらに，左室駆出率やTei indexとの関連についても検討した．

方 法：さまざまな心疾患が疑われ心エコー図を行った連続90症例で，心エコー図検査時のNYHA class，左室駆出率(MOD法)，左室心筋重量，tissue-tracking法による僧帽弁輪移動距離(中隔側＋側壁側)，心エコー図検査日前後1週間以内での血清脳性ナトリウム利尿ペプチド濃度の測定を行った．

結 果：平均年齢67歳，男性55例，女性35例，洞調率63例，心房細動16例，ペースメーカー調律11例であった．基礎心疾患は，虚血性心疾患20例，拡張型心筋症13例，肥大型心筋症11例，高血圧性心疾患5例，弁膜症14例，正常(明らかな心疾患なし)16例，不整脈(心房細動)6例，その他5例であった．僧帽弁輪移動距離はNYHA class，血清脳性ナトリウム利尿ペプチド濃度と有意な負の相関を示した．その相関は左室駆出率よりも強い相関を示した．僧帽弁輪移動距離は左室心筋重量やTei indexとも有意な負の相関を示した．

結 論：Tissue-trackingによる僧帽弁輪移動距離測定は，さまざまな心疾患における心不全重症度の有用なマーカーとなりうると考えられる．

J Cardiol 2007 Sep; 50 (3): 159−166

References

1) Cohn JN, Rector TS: Prognosis of congestive heart failure and predictors of mortality. Am J Cardiol 1988; **62**: 25A−30A
2) Curtis JP, Sokol SI, Wang Y, Rathore SS, Ko DT, Jadbabaie F, Portnay EL, Marshalko SJ, Radford MJ, Krumholz HM: The association of left ventricular ejection fraction, mortality, and cause of death in stable outpatients with heart failure. J Am Coll Cardiol 2003; **42**: 736−742
3) Nelson GR, Cohn PF, Gorlin RG: Prognosis in medically-treated coronary artery disease: Influence of ejection fraction compared to other parameters. Circulation 1975; **52**: 408−412
4) Gottdiener JS, Bednarz J, Devereux R, Gardin J, Klein A, Manning WJ, Morehead A, Kitzman D, Oh J, Quinones M, Schiller NB, Stein JH, Weissmen NJ; American Society of Echocardiography: American society of echocardiography recommendations for use of echocardiography in clinical trials. J Am Soc Echocardiogr 2004; **17**: 1086−1119
5) Zaky A, Grabhorn G, Feigenbaum H: Movement of the mittral ring: A study in ultrasound cardiography. Cardiovasc Res 1967; **1**: 121−131
6) Alam M, Rosenhamer G: Atrioventricular plane displacement and left ventricular function. J Am Soc Echocardiogr 1992; **5**: 427−433
7) Alam M, Höglund C, Thorstrand C: Longitudinal systolic shortening of the left ventricule: An echocardiographic study in subjects with and without preserved global func-

tion. Clin Physiol 1992; **12**: 443−452
8) Höglund C, Alam M, Thorstrand C: Atrioventricular valve plane displacement in healthy persons: An echocardiographic study. Acta Med Scand 1988; **224**: 557−562
9) Simmonson JS, Schiller NB: Descent of the base of the left ventricule: An echocardiographic index of left ventricular function. J Am Soc Echocardiogr 1989; **2**: 25−35
10) DeCara J, Toledo E, Salgo IS, Lammertin G, Weinert L, Lang RM: Evaluation of left ventricular systolic function using automated angle-independent motion tracking of mitral annular displacement. J Am Soc Echocardiogr 2005; **18**: 1266−1269
11) Willenheimer R, Cline C, Erhardt L, Israelsson B: Left ventricular atrioventricular plane displacement: An echocardiographic technique for rapid assessment of prognosis in heart failure. Heart 1997; **78**: 230−236
12) Hedberg P, Jonason T, Lönnberg I, Nilsson G, Pehrsson K, Ringqvist I: Mitral annulus motion as a predictor of mortality in a community-based sample of 75-year-old men and women. J Am Soc Echocardiogr 2006; **19**: 88−94
13) Sohn DW, Chai IH, Lee DJ, Kim HC, Kim HS, Oh BH, Lee MM, Park YB, Choi YS, Seo JD, Lee YW: Assessment of mitral annulus velocity by Doppler tissue imaging in the evaluation of left ventricular diastolic function. J Am Coll Cardiol 1997; **30**: 474−480
14) Kang SJ, Song JK, Song JM, Kang DH, Lee EY, Kim J, Nam GB, Choi KJ, Kim JJ, Kim YH: Usefulness of ventricular longitudinal contractility assessed by Doppler tissue imaging in the prediction of reverse remodeling in patients with severe left ventricular systolic dysfunction. J Am Soc Echocardiogr 2006; **19**: 178−184
15) Naylor LH, Arnolda LF, Deague JA, Playford D, Maurogiovanni A, O'Driscoll G, Green DJ: Reduced ventricular flow propagation velocity in elite athletes is augmented with the resumption of exercise training. J Physiol 2005; **563**: 957−963
16) Tei C: New non-invasive index for combined systolic and diastolic ventricular function. J Cardiol 1995; **26**: 135−136
17) Tei C, Ling LH, Hodge DO, Bailey KR, Oh JK, Rodeheffer RJ, Tajik J, Seward JB: New index of combined systolic and diastolic myocardial performance: A simple and reproducible measure of cardiac function: A study in normals and dilated cardiomyopathy. J Cardiol 1995; **26**: 357−366
18) Tsutamoto T, Wada A, Sakai H, Ishikawa C, Tanaka T, Hayashi M, Fujii M, Yamamoto T, Dohke T, Ohnishi M, Takashima H, Kinoshita M, Horie M: Relationship between renal function and plasma brain natriuretic peptide in patients with heart failure. J Am Coll Cardiol 2006; **47**: 582−586
19) Port S, McEwan P, Cobb FR, Jones RH: Influence of resting left ventricular function on the left ventricular response to exercise in patients with coronary artery disease. Circulation 1981; **63**: 856−863
20) Specchia G, De Servi S, Sciré A, Assandri J, Berzuini C, Angoli L, La Rovere MT, Cobelli F: Interaction between exercise training and ejection fraction in predicting prognosis after a first myocardial infarction. Circulation 1996; **94**: 978−982
21) Petrie M, McMurray J: Changes in notions about heart failure. Lancet 2001; **358**: 432−434
22) Baicu CF, Zile MR, Aurigemma GP, Gaasch WH: Left ventricular systolic performance, function, and contractility in patients with diastolic heart failure. Circulation 2005; **111**: 2306−2312
23) Bruch C, Schmermund A, Marin D, Katz M, Bartel T, Schaar J, Erbel R: Tei-index in patients with mild-to-moderate congestive heart failure. Eur Heart J 2000; **21**: 1888−1895