Demographics and Clinical Characteristics of the Isolated Noncompaction of the Ventricular Myocardium

Akiko Ishige*, Hitoshi Sawada and Tokuhsa Uejima****

***Department of Cardiology, Tokyo Heart Center, Tokyo, Japan**

****Department of Cardiology, The Cardiovascular Institute Hospital, Tokyo, Japan**

Abstract

Background. Echocardiography is a reliable procedure for the diagnosis of the isolated noncompaction of the ventricular myocardium (INVM). We studied the demographics and clinical characteristics of echocardiographically diagnosed INVM.

Methods. We analyzed two-dimensional and color Doppler echocardiograms in 16,623 consecutive patients from June 2000 to February 2005.

Results. There were 99 INVM patients (68 males) with a prevalence was 0.6% (0.7% in males, 0.5% in females). Ten male patients had left ventricular dysfunction. Twenty-nine male patients and 10 female patients had mitral valve prolapse. Of 95 INVM patients, 38 male patients and 20 female patients had thoracic deformity, and 18 male patients and 7 female patients had thoracic deformity and mitral valve prolapse.

Conclusions. Echocardiographically diagnosed INVM is not an uncommon disease. Left ventricular function is almost normal in many patients (86.9%). Thoracic deformity and/or mitral valve prolapse are often associated with INVM.

(J Echocardiogr 2006; 4: 117-122)

Key words: isolated noncompaction of the ventricular myocardium, echocardiography, thoracic deformity, mitral valve prolapse

Isolated noncompaction of the ventricular myocardium (INVM) is an unclassified cardiomyopathy [1]. Reported INVM cases were with severe clinical manifestations such as congestive heart failure (CHF), critical arrhythmia, or systemic to asymptomatic embolism [2-10]. We investigated the demographics and characteristics of echocardiographically diagnosed INVM.

Methods

Study population. Between June 2000 and February 2005, 16,623 consecutive patients (10,230 males) underwent echocardiographic examination at the Cardiovascular Institute Hospital, Tokyo, Japan. No patient was previously diagnosed as INVM.

Echocardiography. Complete two-dimensional, M-

mode, and Color Doppler echocardiographic examinations were performed in all patients. The sonographers had adequate knowledge of INVM and were ordered to record the left ventricular short axis images from the base to the apex. The echocardiograms recorded on videotape were reviewed by one or two of the cardiologists in our laboratory. We used ProSound II SSD 6500 (ALOKA), SONOS 5500 (Hewlett Packard), or SYSTEM FIVE (VingMed SOUND, ALOKA). The left ventricular wall was divided into 17 segments according to the AHA recommendation [11]. Left ventricular mass was calculated with the Devereux formula [12].

Normal values were calculated from 547 normal subjects (288 males, 259 females) [13].

INVM criteria. We used the echocardiographic criteria of INVM proposed by Oechslin et al [6] and Jenni et al [7]: (1) markedly thickened left ventricular wall presenting with two layers of different structure; (2) 2:1 ratio of noncompacted versus compacted myocardium at end systole obtained in the parasternal short-axis view; (3) deep intertrabecular recesses filled with blood from the left ventricular cavity visualized by

Received August 21, 2006; revision received October 17, 2006; accepted November 1, 2006

Address for correspondence: Akiko Ishige

Department of Cardiology, Tokyo Heart Center,

Kitashinagawa 5-4-12, Shinagawa-ku, Tokyo 141-0001, Japan.

Telephone: +81-3-5789-8100

Fax: +81-3-5789-8101

E-mail: akikoishige@hotmail.com

© 2006 Japanese Society of Echocardiography

color Doppler echocardiography; (4) hypokinesis of the affected and possibly other adjoining segments; and (5) prominent trabecular meshwork in the left ventricular apex or midventricular segments of the inferior and lateral wall.

Thoracic deformity. Thoracic deformity was diagnosed by lateral chest X-ray. Sternum convex to the back was diagnosed as the funnel chest. Straight back was diagnosed by Davies' definition: the distance between Th8 and the line from Th4 to Th12 < 12 mm [14]. Four patients without lateral chest X-ray were excluded from the thoracic deformity analysis.

Results

Demographics. There were 99 INVM patients (0.6%); 68 of 10,230 male patients (0.7%) and 31 of 6,393 female patients (0.5%) had INVM. The difference of prevalence was not significant ($\chi^2=2.15$, $p=0.14$).

Characteristics. The median age was 38.3 ± 16.3 years old (15-82), 37.0 ± 16.0 in males, 41.0 ± 16.8 in females.

The body mass index was 20.0 ± 2.2 , 20.5 ± 2.2 in males and 19.1 ± 2.4 in females. Fifty nine patients had symptoms: chest pain and shortness of breath in 31 patients (17 males), palpitations in 20 (12 males), back pain in 2 females, dizziness in one male, and chest pain and loss of consciousness in one male. (Table 1)

Echocardiographic findings. The typical echocardiographic and magnetic resonance imaging (MRI) of

INVM are shown in Figure 1 and 2. The echocardiographic findings are summarized in Table 2. Left ventricular mass was less than normal in 17 patients (16 males) [13]. Ejection fraction was decreased ($\leq 52\%$) in 13 patients (12 males). One patient had been diagnosed with CHF. Mitral valve prolapse was detected in 39 patients (29 males). Localization of the noncompacted segments are summarized in Figure 3. Noncompacted segments were localized to the apical segments in 60 patients (40 males) and to the apical

Table 1. Clinical characteristics

	Number of patients
With symptoms	59 (60%)
chest pain and shortness of breath	31
palpitation	20
chest pain, palpitation and shortness of breath	4
back pain	2
dizziness	1
chest pain and loss of consciousness	1
Without symptoms	40 (40%)
ECG abnormality	12
arrhythmia	12
screening examination	8
hypertension	4
heart murmur	3
mitral valve prolapse	1

Fig. 1. Short axis echocardiograms of the left ventricle
A: Enddiastole, B: Endsystole
The ratio of the noncompacted to compacted layer was 2.4 : 1 at endsystole.

and mid ventricular segments in 39 patients (28 males). There were no patients with noncompaction of the basal segments.

Thoracic deformity. Thirty five patients (27 males) had pectus excavatum, 13 patients (6 males) had decreased thoracic kyphosis. Ten patients (5 males) had both pectus excavatum as well as decreased thoracic kyphosis. Twenty five patients (18 males) had thoracic deformity and mitral valve prolapse. (Table 3)

ECG findings. 12-lead and Holter electrocardio-

graphic findings are shown in Table 4 and 5. ECG was normal in 65 patients (42 males). Sixty patients underwent Holter electrocardiography. There were no abnormal findings in 35 patients.

Discussion

Two-dimensional and color Doppler echocardiography is regarded as the reliable method for the diagnosis of INVM. Chin et al described echocardiographic characteristics of INVM in 1990 [3]. They proposed

Fig. 2. Magnetic Resonance Imaging
Numerous trabeculations with deep recesses wereshown at the left ventricular apex.

Table 2. Echocardiographic characteristics

	mean $\pm$ SD (range)
left ventricular end-diastolic dimension (mm)	49 $\pm$ 4.4 (35~60)
fractional shortening (%)	33 $\pm$ 5.1 (16~46)
ejection fraction (%)	61 $\pm$ 7.6 (34~79)
stroke volume (ml)	70 $\pm$ 14.0 (37~110)
left ventricular mass (g)	128 $\pm$ 39 (61~237)
Number of patients	
mitral valve prolapse	39 (39.4%)

Fig. 3. Localization of noncompacted segments
N=number of patients, ()=number of male patients

quantitative echocardiographic criteria using the peak to trough ratio of the trabeculation of the noncompact layer; however, their criteria have not been widely used. Oechslin et al and Jenni et al proposed echocardiographic INVM criteria [6, 7]. They validated the criteria and confirmed that the combination of all criteria was specific [15]. In this study, we used the criteria proposed by Oechslin et al and Jenni et al.

The prevalence of INVM was 0.6% in this study. This is not the prevalence among the general population as all patients in our study had cardiac evaluations at our hospital. This was higher than the prevalence in the previous studies using the same criteria (0.01% [6] and 0.14% [8]). The reasons may be as follows. (1) In the previous studies, echocardiographic diagnosis of

INVM was retrospectively made, but we diagnosed INVM during the echocardiographic examination with the knowledge of the INVM criteria. (2) Many patients had no significant signs or symptoms, and noncompaction was observed in the apical segments in 60 patients. Thus, many of the patients in this study would not have been diagnosed as INVM had the examiners had adequate knowledge of INVM. (3) Improvement of the echocardiographic resolution may contribute to higher INVM detection rate.

The prevalence of INVM in prior reports was higher in males [3, 4, 6]. In our study, the prevalence was also higher in males, but without a significant difference.

Noncompacted segments were localized to apical segments in 60.6% of our patients but no basal distribution in any of the subjects. This distribution of noncompacted segments may be due to the embryonic development of the compacted layer from the base to the apex of the ventricles [3-8].

In several prior studies, the prevalence of significant CHF in INVM was 30-70% [3, 4, 6, 10]. In our study, 13 patients (13.1%) showed left ventricular systolic dysfunction. (Table 6) Six of these thirteen patients were symptomatic, and one patient was diagnosed with CHF. Only one patient was female, and they were compared using the χ^2 -test or Fisher exact test, but the difference in prevalence was not significant.

Table 3. Chest radiographic characteristics

	Number of patients
Thoracic deformity	58 (61.1%)
funnel chest	35 (36.8%)
straight back	13 (13.7%)
funnel chest and straight back	10 (10.5%)
Thoracic deformity and mitral valve prolapse	25 (26.3%)

Table 4. Electrocardiographic characteristics

	Number of patients
normal	65 (65.6%)
intraventricular conduction disturbances	14
LBBB	1
RBBB	8
IVCD	5
PVC	9
ST-T changes	3
axis deviation	3
LAD	1
RAD	2
PAC	2
first-degree AV block	1
R wave regression	1
second-degree AV block (Wenckebach), sinoatrial block and RBBB	1

LBBB=left bundle branch block, RBBB=right bundle branch block, IVCD=intraventricular conduction defects, PVC=premature ventricular contraction, LAD=left axis deviation, RAD=right axis deviation, PAC=premature atrial contraction, AV=atrioventricular

Table 5. Holter electrocardiographic characteristics (60 patients)

	Number of patients
Normal	35
frequent PVCs (> 3000/day) (with VT 2)	9
SVT	3
second-degree AV block (Wenckebach)	4
PAF	2
PAF and SVT	2
occasional PVCs	1
frequent PACs and SVT	1
occasional PACs	1
PSVT	1
PAF, PAFL and PSVT	1

PVC= premature ventricular contraction, VT=ventricular tachycardia, SVT=supraventricular tachycardia, AV=atrioventricular, PAF=paroxysmal atrial fibrillation, PAC=premature atrial contraction, PSVT=paroxysmal supraventricular tachycardia, PAFL= paroxysmal atrial flutter

Table 6. Characteristics of patients with left ventricular dysfunction ($EF \leq 52\%$)

case	Age/Sex (years)	BMI (kg/m ²)	symptoms and signs	LVDd (mm)	EF (%)	LVM (g)	MVP	Localization	Thoracic deformity
1	37/M	19.9	palpitation	57 ↑	34	182	+		—
2	33/M	23.5	frequent PVCs	60 ↑	42	201	+		—
3	45/M	18.8	hypertention	52	46	212	+		—
4	25/M	20.7	palpitation	60 ↑	47	218	—		—
5	16/M	18.4	chest pain	51	48	161	—		—
6	19/M	18.5	frequent PVCs	55 ↑	50	155	+		funnel chest
7	21/F	17.9	palpitation	46	50	88 ↓	—		funnel chest
8	50/M	22.3	palpitation	56 ↑	50	160	+		straight back
9	35/M	19.0	ECG abnormality (high voltage)	50	51	116	+		—
10	47/M	20.1	hypertention	51	51	134	+		funnel chest
11	20/M	21.7	ECG abnormality (ST-T depression)	52	52	182	+		funnel chest
12	29/M	18.3	chest pain, palpitation and shortness of breath	55 ↑	52	155	+		straight back
13	57/M	20.1	hypertention	46	52	110	—		funnel chest

EF=ejection fraction, BMI=body mass index, LVDd=left ventricular end-diastolic dimension, LVM= left ventricular mass, MVP=mitral valve prolapse, M=male, F=female

Though it was reported that left ventricular systolic thickening was decreased not only in noncompacted segments but in compacted segments in INVM [7], the fact that only apical segments were involved in 60 patients in our study was one of the reasons for the low frequency of congestive heart failure. Here, left ventricular function was normal in many patients by two-dimensional echocardiography. However, to detect latent left ventricular dysfunction in INVM, the assessment of left ventricular function by new methods, such as myocardial strain imaging and tissue Doppler imaging are thought to be necessary [16, 17]. In our hospital, echocardiography is one of the screening examinations and INVM is one of the cardiac diseases sonographers must know. This may be one of the reasons that many asymptomatic and/or apically localized INVM patients have been detected in our hospital.

It was reported that many INVM patients developed left ventricular dysfunction, and some patients underwent cardiac transplantation. Twenty-four INVM (25.3%) patients were followed by echocardiography from 6 months to 3 years. Aggravation of the left ventricular function was not observed in these patients.

An association between INVM and neuromuscular disorders and between INVM and facial dysmorphism have been described [3]. In this study, associations between INVM and mitral valve prolapse, between

INVM and chest deformity, and between INVM and mitral valve prolapse with thoracic deformity were observed. An association between mitral valve prolapse and thoracic deformity was thought to be due to the same intrauterine differentiation period (35th-42nd day) of both mitral valve and thoracic cage [18, 19]. Myocardial compaction occurs between weeks 5 to 8 of embryonic life [3, 4, 7]. The association between INVM and mitral valve prolapse and/or thoracic deformity might be due to the period of embryonic development. Chief complaints in INVM patients such as palpitations, chest pain, and shortness of breath, are also known to be the chief complaints of patients with thoracic deformities [14]. Therefore, the symptoms of INVM patients may be in fact those of thoracic deformities.

Limitations of this study are as follows. Only one of the 99 patients underwent myocardial biopsy and was diagnosed as INVM. However, pathologic diagnosis was not confirmed with the other 98 subjects.

Though familial INVM cases have been reported, we could not examine the families of our patients.

Patients with clinical diagnoses of dilated cardiomyopathy, myocarditis, hypertensive heart disease, or ischemic cardiomyopathy were excluded from this study, so the INVM patients with significant signs or symptoms might not have been analyzed in this study.

Conclusions

The prevalence of INVM was not so uncommon as previously reported. Many INVM patients had almost normal cardiac function. An association between INVM and mitral valve prolapse (39.4%), thoracic deformity (61.1%) or mitral valve prolapse with thoracic deformity (26.3%) was observed.

References

1. Report of the 1995 World Health Organization / International society and federation of cardiology task force on the definition and classification of cardiomyopathies.
2. Jenni R, Goebel N, Tartini R, Schneider J, Arbenz U, Oelz O. Persisting myocardial sinusoids of both ventricles as an isolated anomaly: Echocardiographic, angiographic, and pathologic anatomical findings. *Cardiovasc Internal Radiol* 1986; 9: 127-31.
3. Chin TK, Perloff JK, Williams RG, Jue K, Mohrmann R. Isolated noncompaction of left ventricular myocardium: a study of 8 cases. *Circulation* 1990; 82: 507-13.
4. Ritter M, Oechslin E, Sutsch G, Attenhofer C, Schneider J, Jenni R. Isolated noncompaction of the myocardium in adults. *Mayo Clin Proc* 1997; 72: 26-31.
5. Agmon Y, Connolly HM, Olson LJ, Khandheria BK, Seward JB. Noncompaction of the ventricular myocardium. *J Am Soc Echocardiogr* 1999; 12: 859-63.
6. Oechslin EN, Attenhofer Jost CH, Rojas JR, Kaufmann PA, Jenni R. Long-term follow-up of 34 adults with isolated left ventricular noncompaction: a distinct cardiomyopathy with poor prognosis. *J Am Coll Cardiol* 2000; 36: 493-500.
7. Jenni R, Oechslin E, Schneider J, Attenhofer Jost C, Kaufmann PA. Echocardiographic and pathoanatomical characteristics of isolated left ventricular non-compaction: a step towards classification as a distinct cardiomyopathy. *Heart* 2001; 86: 666-71.
8. Pignatelli RH, McMahon CJ, Dreyer WJ, et al. Clinical characterization of left ventricular non compaction in children: a relatively common form of cardiomyopathy. *Circulation* 2003; 108: 2672-8.
9. Weiford BC, Subbarao VD, Mulhern KM. Noncompaction of the ventricular myocardium. *Circulation* 2004; 109: 2965-71.
10. Ichida F, Hamamichi Y, Miyawaki T, et al. Clinical features of isolated noncompaction of the ventricular myocardium. *J Am Coll Cardiol* 1999; 34: 233-40.
11. AHA writing group on myocardial segmentation and registration for cardiac imaging. Standardized myocardial segmentation and nomenclature for tomographic imaging of the heart. *Circulation* 2002; 105: 539-42.
12. Devereux RB, Alonso DR, Lutas EM, et al. Echocardiographic assessment of left ventricular hypertrophy: comparison to necropsy findings. *Am J Cardiol* 1986; 57: 450-8.
13. Sawada H. Cardiology. In: Miyamoto Y, Furuhashi H, editor. *Clinical Radiology*. Medical View 2003; 19: 46-49.
14. Davies MK, Mackintosh P, Cayton RM, Page AJF, Shiu MF, Littler WA. The straight back syndrome. *Q J Med* 1980; 49: 443-60.
15. Frischknecht BS, Attenhofer Jost CH, Oechslin EN, et al. Validation of noncompaction criteria in dilated cardiomyopathy, and valvular and hypertensive heart disease. *J Am Soc Echocardiogr* 2005; 18: 865-72.
16. Nakatani S, Maruo T, Hasegawa T, Abe Y, Kanda R, Miyatake K. Lazy heart muscle demonstrated by myocardial strain imaging. *J Echocardiogr* 2003; 1: 43.
17. Oishi Y, Mizuguchi Y, Sawa Y, et al. Regional myocardial systolic function assessed by strain tissue Doppler imaging in patients with isolated noncompaction of left ventricular myocardium: a study of two cases. *J Echocardiogr* 2005; 3: 40-5.
18. Bon Tempo CP, Ronan JA Jr, Leon AC Jr, Twigg HL. Radiographic appearance of the thorax in systolic click-late systolic murmur syndrome. *Am J Cardiol* 1975; 36: 27.
19. Kumar UK, Sahasranam KV. Mitral valve prolapse syndrome and associated thoracic skeletal abnormalities. *JAPI* 1991; 39: 536-9.