J Cardiol 2007 Apr; 49(4): 187–191

Thermal Therapy Improves Left Ventricular Diastolic Function in Patients With Congestive Heart Failure: A Tissue Doppler Echocardiographic Study

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Abstract

Objectives. We previously reported that systemic thermal therapy using 60°C dry sauna improves left ventricular systolic function and clinical symptoms in patients with chronic heart failure. The aim of this study was to investigate the effects of thermal therapy on left ventricular diastolic function.

Methods. We examined transmitral inflow and mitral annular velocity before and after sauna in 10 patients with congestive heart failure using pulsed and tissue Doppler echocardiography.

Results. Left ventricular and left atrial dimensions and left ventricular percentage fractional shortening did not change after sauna. Early diastolic mitral inflow velocity (E) increased and the deceleration time of the E wave decreased significantly after sauna compared to before sauna. Early diastolic mitral annular velocity (E') significantly increased after sauna. The deceleration time of E' significantly decreased after sauna compared to before sauna. The E/E' significantly decreased 30 min after sauna.

Conclusions. Thermal therapy improves acute left ventricular diastolic function in patients with congestive heart failure.

J Cardiol 2007 Apr; 49(4): 187−191

Key Words
■ **Cardiovascular disease** ■ **Diastole** ■ **Echocardiography, transthoracic**
■ **Heart failure**

INTRODUCTION

Recently, a large number of studies have suggested that left ventricular (LV) diastolic dysfunction occurs in a high percentage of heart failure patients.[1] Therefore, not only LV systolic function but also diastolic function is considered part of the mechanism underlying heart failure.[2,3] Systemic thermal therapy, such as taking a bath or sauna, induces systemic vasodilation resulting in the reduction of cardiac pre and after-load in patients with chronic heart failure.[4] Cardiac and stroke indices and systemic vascular resistance, an invasive index, are improved after thermal therapy.[4] The Tei index,[5,6] a noninvasive index that combines systolic and diastolic myocardial function, is also improved after thermal therapy.[7] However, there have been few studies on the effects of ther-

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Manuscript received December 15, 2006; revised February 6, 2007; accepted February 6, 2007

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mal therapy on LV diastolic function.

LV diastolic function has been widely assessed using mitral inflow velocity.[8] However, mitral flow depends on multiple interrelated factors, including heart rate and the extent of ventricular relaxation, atrial and ventricular compliances, and left atrial pressure.[9] Tissue Doppler imaging of mitral annular motion has been proposed to correct for the influence of myocardial relaxation on transmitral flow, and is an excellent predictor of LV relaxation and diastolic filling in subsets of patients.[9−16] Therefore, combining tissue Doppler imaging and pulsed Doppler echocardiography may accurately assess the changes in LV diastolic function after thermal therapy.

SUBJECTS AND METHODS

The study group consisted of 10 patients, 9 men and 1 woman (mean age 62 ± 16 years), with congestive heart failure who underwent repeated sauna treatment and standard medical therapy. Five patients had dilated cardiomyopathy, 3 had prior myocardial infarction without myocardial ischemia by stress testing, 1 had myocarditis and 1 had aortic regurgitation. New York Heart Association (NYHA) functional classes were Ⅱ in 2 patients and Ⅲ in 8 patients. The mean values of B-type natriuretic peptide were 410 ± 708 pg/m*l* (range 37−2,000) on admission. All patients were in sinus rhythm. All patients gave informed consent to the study and the protocol was approved by the Ethical Committee of Kagoshima University Hospital.

Sauna treatment

Thermal therapy with a far infrared-ray dry sauna was performed to exclude the effect of hydrostatic pressure.[4,17−20] Medical therapy was not discontinued before sauna treatment. Patients were placed in a supine position on a bed in a 60℃ sauna for 15 min, and after removal, continued bed rest with a blanket to keep them warm for an additional 30 min. Patients were weighed before and after the sauna treatment. Oral hydration with water was used to compensate for lost weight. Blood pressure, heart rate, body temperature and transthoracic echocardiographic examinations were performed before and 30 min after sauna treatment.

Echocardiography

With patients in the left lateral decubitus position, standard M-mode, two-dimensional echocardiography, and pulsed and tissue Doppler echocardiography were performed using a Toshiba Aplio 80 ultrasound system. Mitral inflow and LV outflow velocity patterns were recorded by placing a sample volume between the tips of the mitral leaflets and at the LV outflow tract in apical views. Mitral annular tissue Doppler examinations were performed by placing a sample volume lateral to the mitral annulus on apical 4-chamber view.[11,12] LV end-diastolic and end-systolic dimensions, LV percentage fractional shortening and left atrial dimension were obtained.

LV stroke volume was obtained as the product of LV outflow cross-sectional area and velocity time integral. Cardiac output was derived from stroke volume multiplied by heart rate. Doppler time interval "a" from cessation to the onset of mitral inflow and interval "b" from the onset to the cessation of LV outflow velocity were obtained. The Tei index, defined as the sum of isovolumic contraction and relaxation times divided by the ejection time, was calculated as: $(a-b)/b$.[7] Early (E) and late (A) diastolic mitral flow velocities and deceleration time of the E wave were measured using the standard methods.[8] Systolic, early (E') and late diastolic mitral annular velocities and deceleration time of the E' wave were obtained.[11] Systolic annular waves were identified as beginning approximately 100 msec after the onset of the electrocardiographic QRS complex.[21] The mitral E/A and E/E' ratios were subsequently derived. All data were obtained from 6 consecutive cardiac cycles and averaged.

Statistical analysis

Values are expressed as mean ± SD. The paired *t*-test was used to examine the significance of continuous values between the two groups. Differences were considered significant at $p < 0.05$.

RESULTS

None of the sauna-treated patients experienced dyspnea, angina pectoris or palpitations. Body weight decreased slightly, but significantly, 30 min after sauna compared to before sauna. Body temperature rose significantly after sauna compared to before sauna. Heart rate and systolic blood pressure did not change significantly before and after sauna. Diastolic blood pressure decreased significantly 30 min after sauna compared to before sauna (**Table 1**).

LV diastolic and systolic dimensions, percentage

Table 1 Results of measurements before and 30 min after sauna

Indices	Before sauna	30 min after sauna
Body weight (kg)	57.0±15.2	56.7±15.0*
Temperature (℃)	36.1±0.4	36.9±0.4**
Heart rate (beats/min)	66±17	67±20
Systolic blood pressure (mmHg)	120±28	123±39
Diastolic blood pressure (mmHg)	63±10	56±14*

Values are mean±SD. *$p<0.05$, **$p<0.01$ vs before sauna.

Table 2 Changes in M-mode and pulsed Doppler echocardiography data

Indices	Before sauna	30 min after sauna
LVDd (mm)	52±13	53±9
LVDs (mm)	45±13	45±11
%FS (%)	13±6	16±10
LAD (mm)	38±7	39±7
SV (m*l*)	53±7	58±9
CO (*l*/min)	3.5±1.5	3.6±13
a (msec)	406±43	368±38**
b (msec)	268±38	262±35
Tei index	0.53±0.15	0.42±0.14**

Values are mean±SD. **$p<0.01$ vs before sauna.
LVDd=left ventricular end-diastolic dimension; LVDs=left ventricular end-systolic dimension; %FS=percentage fractional shortening; LAD=left atrial dimension; SV=stroke volume; CO=cardiac output.

fractional shortening, left atrial dimension, stroke volume and cardiac output did not change significantly after sauna (**Table 2**). Time interval "a" decreased significantly 30 min after sauna compared to before sauna. Time interval "b" did not change significantly after sauna. Thus, the LV Tei index decreased significantly 30 min after sauna compared to before sauna.

E velocity increased significantly 30 min after sauna compared to before sauna. Deceleration time of the E decreased significantly 30 min after sauna compared to before sauna. A velocity and E/A ratio did not change significantly after sauna (**Table 3**).

E' annular velocities increased significantly 30 min after sauna compared to before sauna. The deceleration time of the E' decreased significantly 30 min after sauna compared to before sauna (**Fig. 1**). Late diastolic annular velocities did not change significantly before and after sauna. The E/E' ratio

Table 3 Changes in mitral inflow velocity and mitral annular velocity data

Indices	Before sauna	30 min after sauna
E (cm/sec)	71±31	81±35***
E DcT (msec)	329±97	266±76***
A (cm/sec)	80±16	85±28
E/A	0.91±0.50	1.1±0.93
E' (cm/sec)	9.4±2.6	10.7±3.1**
E' DcT (msec)	70±15	50±8**
A' (cm/sec)	8.9±3.0	9.7±3.3
E/E'	8.1±3.9	7.7±3.6*
Sw (cm/sec)	6.3±0.8	6.5±0.9

Values are mean±SD. *$p<0.05$, **$p<0.01$, ***$p<0.001$ vs before sauna.
E= early diastolic mitral inflow velocity; DcT=deceleration time; A=atrial systolic mitral inflow velocity; E'=early diastolic mitral annular velocity; A'=atrial systolic mitral annular velocity; Sw=systolic annular velocity.

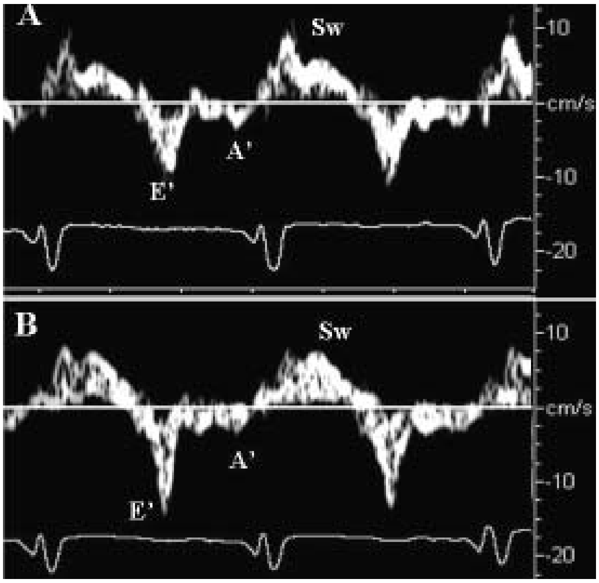

Fig. 1 Tissue Doppler imaging of the mitral annulus before (*A*) and 30 min after sauna (*B*) in a 40-year-old patient with prior myocardial infarction
Early diastolic annular velocity (E') increased from 10 cm/sec to 14 cm/sec and the deceleration slope of E' became steeper in *panel B* compared to that in *panel A*.
A' = atrial systolic velocity; E' = early diastolic velocity; Sw = systolic wave velocity.

decreased significantly 30 min after sauna compared to before sauna. Systolic annular velocity did not change significantly before and after sauna (**Table 3**).

DISCUSSION

In this study, heart rate and systolic blood pressure did not change significantly after sauna. E' annular velocity increased significantly 30 min after sauna compared to before sauna. Deceleration time of the E' also decreased significantly 30 min after sauna compared to before sauna. There is a strong correlation between E' and the time constant of LV relaxation (tau) and the first derivatives of LV pressure in diastole (−dP/dt).[13] E' has been considered as a reliable marker of the preload-independent index of LV relaxation. Deceleration time of E' may be an index of LV relaxation, because the deceleration time of E' was significantly prolonged in patients with diastolic dysfunction.[11] Therefore, our data strongly suggest that LV relaxation was improved after sauna compared to before sauna, probably due to the acute effects of thermal vasodilation.

E/E' has been accepted as a reliable estimate of LV filling pressures. E/E' shows strong correlations with pulmonary capillary wedge pressure[11,12,14] or LV mean[9] or end diastolic pressure[15,16] in patients with sinus tachycardia,[12] systolic and diastolic heart failure[16] and mitral regurgitation.[15] E/E' > 15 reliably predicts elevated LV filling pressure > 15 mmHg in patients with angina,[9] congestive heart failure[14] and other heart diseases,[15] while E/E' < 8 accurately predicted normal mean LV pressure in such patients.[9] In our data, E/E' was 8.1±3.9 before sauna, suggesting that LV filling pressure was not elevated in our patients before sauna. E/E' decreased significantly 30 min after sauna compared to before sauna, suggesting that LV filling pressure decreased significantly 30 min after sauna.

Mitral flow peak velocity before sauna was 71±31 msec in the E wave, 80±16 msec in the A wave and deceleration time was 329±97 msec, suggesting an abnormal LV relaxation pattern. E velocity increased and deceleration time decreased significantly 30 min after sauna compared to before sauna. These findings suggest that mitral flow velocity pattern changed from an abnormal relaxation pattern toward a more normal relaxation pattern, because tissue Doppler data showed that LV diastolic function was improved by sauna.[8]

Systolic indices such as percentage fractional shortening, stroke volume, cardiac output and tissue Doppler systolic annular velocity[21,22] did not change significantly before and after sauna. The Tei index improved significantly 30 min after sauna compared to before sauna as previously reported.[7]

Limitations

The number of subjects examined was small. We did not observe how long the improvement in LV diastolic function persisted. Further studies are needed to clarify the chronic effects of repeated thermal therapy on LV diastolic function in a large series of patients with congestive heart failure.

CONCLUSIONS

Thermal therapy improves acute LV diastolic function in patients with congestive heart failure.

要　約

温熱療法は心不全例の左室拡張能を改善させる：組織ドップラー法による検討

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目　的：我々は60℃の乾式サウナを用いた全身の温熱療法が慢性心不全患者の左室収縮能や臨床症状を改善することを報告してきた．本研究の目的は温熱療法の左室拡張能に及ぼす影響を研究することである．

方　法：心不全患者10例を対象にして，通常の断層心エコー図法とパルスドップラー法，組織ドップラー法による左室流入血流速度波形と僧帽弁輪運動速度波形を温熱療法前と30分後に記録した．

結　果：左室内径，左房径，左室短縮率はサウナ療法の前後で有意に変化しなかった．拡張早期の左室流入血流速度(E)はサウナ療法後に有意に増大し，その減速時間は有意に短縮した．拡張早期の僧帽弁輪運動速度(E')はサウナ後に有意に増大し，その減速時間は有意に短縮した．両者の比であるE/E'はサウナ後に有意に減少した．

結　論：温熱療法は心不全患者の左室拡張能を改善させることが示唆された．

J Cardiol 2007 Apr; 49 (4): 187−191

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