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Hemodynamic Effects of Warm Bathing in a Hubbard Tank and Exercise Loading in Patients After Myocardial Infarction

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Abstract

Hemodynamic parameters were measured during bathing and exercise testing in 43 patients with myocardial infarction (mean age : 60.2 years) to investigate the predictive parameters to determine when patients could safely resume bathing.

Patients took a fresh water bath at 42°C in the supine position for 5 min in a Hubbard tank. Group A showed an elevation of pulmonary capillary wedge pressure (PCWP) during bathing of 10 mmHg or more (23 patients, mean age : 61.7 years) and group B showed an elevation of less than 10 mmHg (20 patients, mean age : 60.5 years). Continuous multistep exercise tests were performed with a bicycle ergometer in the supine position, and hemodynamic parameters were measured at up to 50 W for 3 min on the day before the warm bathing test.

There were no significant differences in the changes of arterial pressure and heart rate between the two groups. The PCWP at 3 min with a load of 50 W was significantly higher in group A (26.9±9.0 mmHg) than in group B (16.7±9.1 mmHg, $p<0.01$). The stroke index (SI) during exercise testing was significantly lower in group A than in group B. The difference in the stroke index from baseline values (ΔSI) at 3 min with a load of 50 W was significantly lower in group A (3.5±5.5 ml/m^2/beat) than in group B (10.6±7.0 ml/m^2/beat, $p<0.01$). Similarly, ΔCI and Δ oxygen pulse during testing were significantly lower in group A than in group B. The physical work capacity and ejection fraction of the left ventricle of group A were significantly lower than those of group B, whereas the left ventricular end-diastolic pressure was higher in group A than in group B. CI, ΔCI, SI, ΔSI, METs, oxygen pulse, and Δ oxygen pulse were examined by regression analysis and multivariate analysis to predict a significant elevation of ΔPCWP during bathing. ΔSI ($p=0.0032$), ΔCI ($p=0.0094$), ΔSI+METs ($p=0.0051$), ΔCI+METs ($p=0.0061$), ΔCI+ΔSI ($p=0.0084$), and ΔCI+ΔSI+METs ($p=0.0093$) showed the highest correlations with ΔPCWP.

These findings suggest that changes in ΔCI, ΔSI, and METs are good predictive parameters for determining when patients may safely resume bathing. We suggest that patients with myocardial infarction, reduced cardiac function and a physical work capacity of approximately 4.0 METs, ΔSI : 5 ml/m^2/beat

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and ΔCI : 2.4 l/min/m^2 resume bathing only after careful consideration.

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Key Words
Myocardial infarction, Exercise (warm bathing load, exercise test), Hemodynamics

INTRODUCTION

Patients with myocardial infarction may suffer attacks of angina pectoris, recurrent myocardial infarction, and sudden death during or after bathing, so warm bathing presents an important problem for the rehabilitation and normal daily life of patients with myocardial infarction. We previously found that cardiac function is reduced in patients showing a marked increase of pulmonary arterial pressure and pulmonary capillary wedge pressure (PCWP) during warm bathing. Such patients are at high risk of cardiac events, so caution is required when these patients start bathing[1–4]. The present study compared hemodynamics during warm bathing and exercise loading, and studied various parameters to predict which patients require caution when starting warm bathing after myocardial infarction.

SUBJECTS AND METHODS

This study included 43 myocardial infarct patients with a mean age of 60.2 years (range : 36 to 74 years) who underwent rehabilitation (walking for at least 300 m on a flat surface) in the program for patients with acute myocardial infarction prepared by the Research Group of the Cardiovascular System established by the Ministry of Health and Welfare, Japan. There were 17 patients with anteroseptal infarction, 10 with extensive anterior infarction and 16 with inferior infarction. The objectives of the study were carefully explained to all subjects and their informed consent was obtained.

A Swan-Ganz catheter was inserted via the right subclavian vein before the patients bathed in the supine position in fresh water (42°C) for 5 min using a Hubbard tank. The zero point was set at the fourth intercostal space on the anterior axillary line during bathing. Patients in group A (n=23) showed an increase of PCWP by at least 10 mmHg during bathing and those in group B (n=20) showed a wedge pressure increase of less than 10 mmHg. Hemodynamics, physical work capacity, and cardiac catheterization findings were compared with data obtained by a continuous multistep exercise test on the supine position using a bicycle ergometer (starting from 25 W for 3 min and increasing by 25 W every 3 min) on the day before warm bathing. Exercise testing was symptom limited, but only the hemodynamic data obtained up to 50 W for 3 min were used for comparison. The hemodynamic parameters were the arterial pressure, heart rate, PCWP, right atrial pressure, cardiac index (CI), and stroke index (SI). The arterial pressure was measured using a mercury sphygmomanometer. The t-test, regression analysis, and multivariate analysis were used for statistical analysis, with $p<0.05$ considered significant.

Selected abbreviations and acronyms

CI=cardiac index
LVEDP=left ventricular end-diastolic pressure
LVEF=left ventricular ejection fraction
PCWP=pulmonary capillary wedge pressure
RAP=right atrial pressure
SI=stroke index

Table 1 Clinical characteristics of groups A and B

	Group A (n=23)	Group B (n=20)	Total (n=43)
Mean age (yr)	61.7±7.5	60.5±8.8	60.1±8.2
Previous MI			
(−)	18	19	37
(+)	5	1	6
Site of MI			
Anteroseptal	11	6	17
Extensive anterior	8**	2	10
Inferior	4	12	16
Number of disease coronary arteries			
Single	10	12	22
Double	5	8	13
Triple	8**	0	8
Interval from onset to exercise testing (day)	63.3±32.4*	44.5±12.4	55.0±27.3

*$p<0.05$, **$p<0.01$.
MI=myocardial infarction.

RESULTS

The reason for discontinuing the exercise testing

Table 2 Changes of hemodynamics during exercise testing and warm bathing

	Exercise testing				Warm bathing			
	Before		50 W 3 min		Before		After 1 min of bathing	
	Group A	Group B	Group A	Group B	Group A	Group B	Group A	Group B
APs (mmHg)	136±17	137±15	165±20	173±29	114±15	124±16	132±17	134±18
APd (mmHg)	72±10	77±9	89±14	94±14	68±9	72±7	76±9	78±10
HR (/min)	69±13	69±11	113±17	110±13	71±10	73±13	84±14	84±13
PCWP (mmHg)	9.0±3.9**	5.4±3.0	26.9±9.0**	16.7±9.1	4.9±2.2	3.7±2.3	17.2±2.9**	10.2±2.7
RAP (mmHg)	3.3±1.9	2.3±2.2	8.8±3.6**	5.0±3.4	1.3±1.5	0.8±1.2	8.3±2.7*	6.4±2.3
CI (l/min/m^2)	3.13±0.68	3.04±0.59	5.47±0.81	6.02±1.04	3.01±0.36	3.13±0.65	3.57±0.50*	4.07±0.74
ΔCI (l/min/m^2)			2.30±0.75**	3.00±0.73			0.75±0.58	1.01±0.66
SI (ml/m^2/beat)	45.3±7.1	44.3±6.3	47.8±10.2*	55.0±8.2	42.8±7.7	45.4±4.3	43.5±7.5*	52.0±8.1
ΔSI (ml/m^2/beat)			2.0±8.5**	10.6±7.0			0.2±4.9*	3.3±5.9
Oxygen pulse (ml/min)	3.0±0.7	3.1±0.9	7.1±2.2	7.9±1.4				
Δ oxygen pulse (ml/min)			3.9±1.5*	4.7±0.7				

$^*p<0.05$, $^{**}p<0.01$.
APs=systolic arterial pressure; APd=diastolic arterial pressure; HR=heart rate.

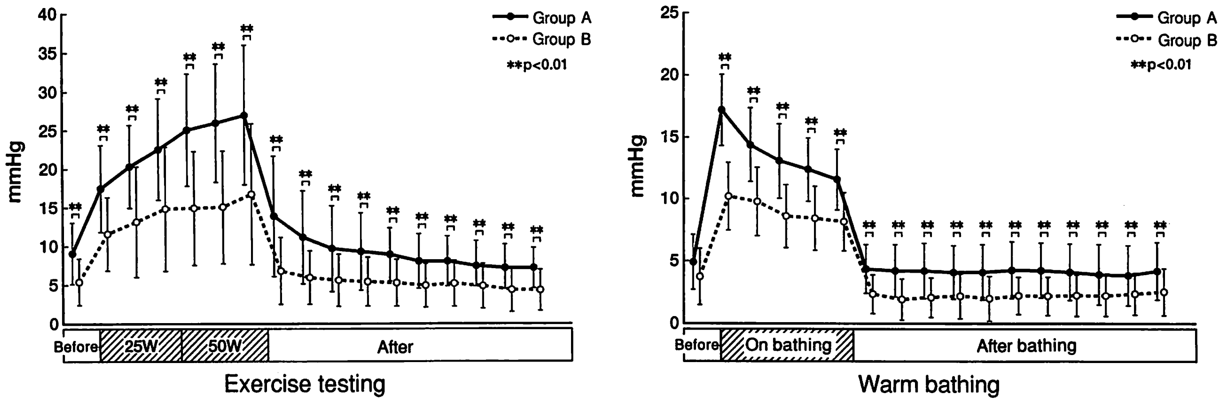

Fig. 1 Changes in pulmonary capillary wedge pressure

was fatigue of the lower limbs in 79.1%, achievement of the target heart rate in 16.3%, ischemic ST elevation in 14.0%, and ST depression in 4.7%, as well as shortness of breath, chest pain, increased arterial pressure, or supraventricular premature contraction in 2.3% each. None of the patients required any specific treatment for these symptoms. No subjective symptoms or arrhythmias requiring treatment were noted during warm bath testing.

Patient characteristics

The clinical characteristics of the two groups are shown in **Table 1**. The mean age was 61.7±7.5 years in group A and 60.5±8.8 years in group B. There were significantly more patients with extensive anterior infarction and triple-vessel disease in group A than in group B.

Comparison of hemodynamics

Table 2 and **Fig. 1** show the comparison of the hemodynamics during exercise testing and during warm bathing.

Arterial pressure and heart rate

These parameters increased after 50 W for 3 min exercise testing, compared with before exercise testing in both groups, but there was no significant difference. Similar changes also occurred during warm bathing.

Pulmonary capillary wedge pressure

Changes of PCWP with exercise testing and warm bathing are shown in **Fig. 1**. Before exercise testing, PCWP was 9.0±3.9 mmHg in group A and 5.4±3.0 mmHg in group B, with group A showing a significantly higher value than group B ($p<0.01$). Directly after the start of exercise testing, a marked

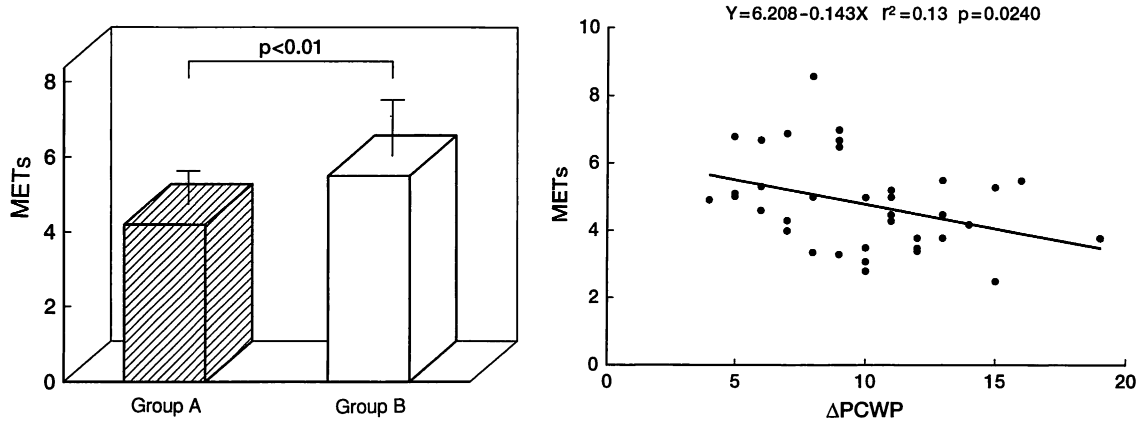

Fig. 2 Physical work capacity

Left: Comparison of physical work capacity between groups A and B.
Right: Correlation between ΔPCWP and physical work capacity.

increase was seen in group A. After exercise testing at 50 W for 3 min, PCWP increased to 26.9 ±9.0 mmHg in group A and to 16.7±9.1 mmHg in group B. The increase was greater in group A than in group B, and the difference was significant ($p<0.01$). After exercise testing was discontinued, group A still showed a significantly higher PCWP than group B ($p<0.01$) and more time was required for the return to the baseline value.

Before warm bathing, PCWP was 4.9±2.2 mmHg in group A and 3.7±2.3 mmHg in group B, with no significant difference. After 1 min of warm bathing, there was a marked increase to 17.2±2.9 mmHg in group A compared with 10.2±2.7 mmHg in group B, and group A showed significantly higher pressures than group B. After warm bathing, PCWP decreased in both groups, but remained significantly higher in group A than in group B.

Right atrial pressure

A significant increase of right atrial pressure (RAP) was seen during exercise testing in both groups, reaching 8.8±3.6 mmHg in group A and 5.0±3.4 mmHg in group B after exercise testing at 50 W for 3 min. Group A showed a significantly higher RAP than group B ($p<0.01$).

During warm bathing, a significant increase of RAP was also seen in both groups. One min after starting to bathe, RAP was 8.3±2.7 mmHg in group A and 6.4±2.3 mmHg in group B. Group A showed a significantly higher value than group B ($p<0.05$).

Cardiac index

CI increased during exercise testing in both groups. CI before exercise testing was 3.13±0.68 *l*/min/m² in group A and 3.04±0.59 *l*/min/m² in group B. After 50 W for 3 min exercise testing, CI was 5.47±0.81 *l*/min/m² in group A and 6.02±1.04 *l*/min/m² in group B. Group A showed a lower CI than group B during exercise testing, but the difference was not significant. The ΔCI from before exercise testing was calculated, and the values at 50 W for 3 min were 2.30±0.75 *l*/min/m² in group A and 3.00±0.73 *l*/min/m² in group B. ΔCI was significantly lower in group A than in group B ($p<0.01$).

Warm bathing also increased the CI in both groups, reaching 3.57±0.50 *l*/min/m² in group A and 4.07±0.74 *l*/min/m² in group B. CI was significantly lower in group A than in group B ($p<0.05$).

Stroke index

Group A showed almost no change of SI during exercise testing, but group B showed a significant increase from 44.3±6.3 m*l*/m²/beat before exercise testing to 55.0±8.2 m*l*/m²/beat afterwards ($p<0.01$). Group A showed a significantly lower SI than group B at 50 W for 3 min on exercise testing. The ΔSI from before exercise testing was calculated showing the values at 50 W for 3 min were 2.0±8.5 m*l*/m²/beat in group A and 10.6±7.0 m*l*/m²/beat in group B. The ΔSI was significantly lower in group A than in group B ($p<0.01$).

SI also did not increase during warm bathing in group A, but group B showed a significant increase from 45.4±4.3 m*l*/m²/beat before warm bathing to 52.0±8.1 m*l*/m²/beat at 1 min of warm bathing ($p<0.01$). At 1 min of warm bathing, SI was signifi-

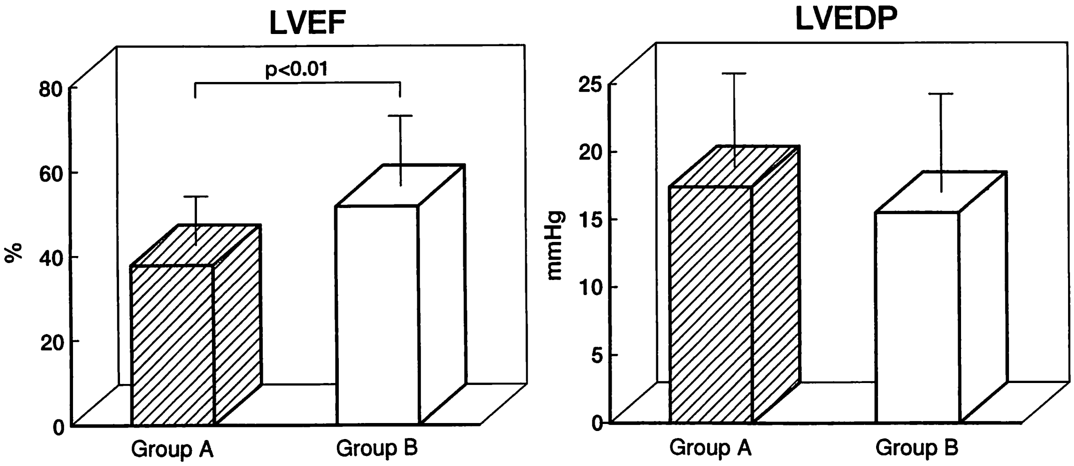

Fig. 3 Comparisons of LVEF and LVEDP between groups A and B

cantly lower in group A than in group B, and ΔSI was also significantly lower.

Oxygen pulse

Both groups showed an increase during exercise testing but the difference was not significant. However, Δ oxygen pulse was significantly lower in group A than in group B before or during exercise testing at 50 W for 3 min.

Physical work capacity

Fig. 2–left shows the comparison of physical work capacity. Physical work capacity was 4.2±0.9 METs in group A and 5.5±1.5 METs in group B, significantly lower in group A ($p<0.01$). The relationship between the difference in PCWP before and after 1 min of warm bathing (ΔPCWP) and physical work capacity is shown in **Fig. 2–right**. A significant negative correlation was seen between ΔPCWP and physical work capacity ($r^2=0.13$, $p=0.0240$).

Cardiac catheterization findings in the chronic stage

Comparison of the left ventricular ejection fraction (LVEF) and left ventricular end-diastolic pressure (LVEDP) obtained by cardiac catheterization performed at the same time as the exercise testing is shown in **Fig. 3**. The LVEF was 37.8±11.7% in group A and 51.8±16.5% in group B, so significantly lower in group A ($p<0.01$). LVEDP was 17.4±6.9 mmHg in group A and 15.5±7.3 mmHg in group B, and tending to be higher in group A.

Table 3 Correlation analysis between ΔPCWP and other indices

	p value	Relative risk
ΔSI	0.0032	0.4607
ΔCI	0.0094	0.4108
SI	0.0228	0.3639
METs	0.0243	0.3602
CI	0.0538	0.3111
Δ oxygen pulse	0.1278	0.2795
Oxygen pulse	0.1882	0.2428

Predictors of marked increase in ΔPCWP during warm bathing

We previously reported that cardiac function declines in patients with a marked increase of PCWP by at least 10 mmHg during warm bathing[1–4], and that there is a strong possibility of cardiac events occurring in such patients. Therefore, it is important to predict which patients have a ΔPCWP of at least 10 mmHg, but there are many difficulties in making such an estimate. We examined CI, ΔCI, SI, ΔSI, METs, oxygen pulse, and Δ oxygen pulse as possible parameters to predict a marked increase of ΔPCWP during warm bathing using regression analysis and multivariate analysis.

Table 3 shows the results of regression analysis comparing ΔPCWP during warm bathing and each parameter. ΔSI ($p=0.0032$) and ΔCI ($p=0.0094$) showed the best correlation with ΔPCWP, and SI ($p=0.0228$) and METs ($p=0.0243$) also showed good correlations.

To obtain a stronger correlation with ΔPCWP

Table 4 Multivariate analysis between ΔPCWP and other indices

	p value	Relative risk
ΔSI+METs	0.0051	0.5299
ΔCI+METs	0.0061	0.5221
ΔCI+ΔSI	0.0084	0.4831
ΔCI+ΔSI+METs	0.0093	0.5532
ΔSI+*Δ* oxygen pulse	0.0158	0.5062
ΔSI+METs+*Δ* oxygen pulse	0.0249	0.5372
ΔCI+METs+*Δ* oxygen pulse	0.0354	0.5178

Table 5 Reliability of various parameters for estimating that ΔPCWP is increased by at least 10 mmHg during warm bathing assuming ΔSI≦5 m*l*/m²/beat, ΔCI≦2.41 *l*/min/m², METs≦4.0

	Sensitivity (%)	Specificity (%)	Accuracy (%)
ΔSI	87.5	81.2	83.8
ΔCI	80.0	71.5	75.0
ΔSI+METs	100	86.7	91.3
ΔCI+METs	100	83.3	88.5
ΔCI+ΔSI	86.7	80.0	82.9
ΔCI+ΔSI+METs	100	81.3	87.0

during warm bathing, we performed multivariate analysis using combinations of two or more parameters. The results are shown in **Table 4**. The combinations showing the best correlations were ΔSI+METs ($p=0.0051$), ΔCI+METs ($p=0.0061$), ΔCI+ΔSI ($p=0.0084$), and ΔCI+ΔSI+METs ($p=0.0093$). Good correlations were also seen for ΔSI+*Δ* oxygen pulse ($p=0.0158$), ΔSI+METs +*Δ* oxygen pulse ($p=0.0249$) and ΔCI+METs+*Δ* oxygen pulse ($p=0.0354$).

When $p<0.01$ was required for a significant correlation, ΔSI, ΔSI+METs, ΔCI+METs, ΔCI+ΔSI, ΔCI+ΔSI+METs, and ΔCI qualified.

Based on the hemodynamic changes in the exercise testing and the results of regression and multivariate analyses, we investigated the values of parameters predicting an increase of at least 10 mmHg in ΔPCWP during warm bathing based on the mean values obtained after exercise testing at 50 W for 3 min in group A. ΔSI of 5 m*l*/m²/beat, ΔCI of 2.4 *l*/min/m², and physical work capacity of 4.0 METs were calculated as the standard values. The sensitivity, specificity, and accuracy of these predictors are shown in **Table 5**. A high reliability was obtained in all cases.

DISCUSSION

Warm bathing is a very important problem in the rehabilitation of patients with myocardial infarction, and there is still considerable controversy about the time to start the bathing, correct water temperature, and other factors in these patients. Attacks of angina pectoris, recurrent infarction, and sudden death may occur during and after warm bathing, so it is important to understand the hemodynamic effects of warm bathing. Ozawa *et al.*[1,2] and Suzuki *et al.*[3] reported that the increase of venous return with warm bathing cannot be tolerated by patients with severely reduced cardiac function, so that marked increases occur in pulmonary artery pressure and PCWP. Matsuzaki *et al.*[4] reported that the prognosis is poor in patients with myocardial infarction who show an increase of PCWP of at least 10 mmHg during warm bathing, and there is a high risk of sudden death, recurrent myocardial infarction, or congestive heart failure during hospitalization, after discharge, and during warm bathing. Therefore, we investigated parameters which can be used to predict a marked increase in PCWP during warm bathing and to evaluate cardiac function in patients after myocardial infarction.

Our patients were categorized into two groups depending on the increase of PCWP during warm bathing. The LVEF was significantly lower and LVEDP tended to be higher in group A. In group A physical work capacity was significantly lower and the PCWP increased significantly in group A during exercise testing. After exercise, the PCWP took longer to return to baseline values in group A. McCallister *et al.*[5] and Thadani *et al.*[6] also inserted a Swan-Ganz catheter into patients with old myocardial infarction and performed exercise testing using a supine position bicycle ergometer in the same way. Patients with physical work capacity, *i.e.*, reduced cardiac function, showed an increase in PCWP during exercise testing, results that agree with ours. There have been no previous studies that compared hemodynamic parameters during warm bathing and exercise testing, but our data indicated that changes in hemodynamics during bathing are very similar to those during exercise.

When the prognosis was examined over a follow-up period of 3.5±0.9 years, one patient had recurrent infarction, three suffered heart failure (one during bathing) and two suffered sudden death (one during bathing) among the 28 patients in whom follow-up was possible. All six of these patients were in group A. These results were consistent with the reports of a poor prognosis for patients with myocardial infarction when the LVEF decreases by 30 to 40%[7-10], and the reports of Davidson *et al.*[11] and Krone *et al.*[12] who found that the prognosis was poor if physical work capacity was 4 or 5 METs less, respectively, and the results of Matsuzaki *et al.* mentioned previously[4]. It appears that patients with reduced cardiac function and a marked increase of PCWP during warm bathing (as in group A) have a poor prognosis.

Therefore, it is important to predict which patients may show a marked increase of PCWP during warm bathing. However, there were no significant differences in various hemodynamic parameters (arterial pressure, heart rate, PCWP, right atrial pressure, and CI) before warm bathing, and it was often difficult to predict a marked increase of wedge pressure during warm bathing from the LVEF or LVEDP obtained by cardiac catheterization. Therefore, we investigated hemodynamic parameters during exercise testing to determine which were appropriate for predicting an increase of PCWP. CI and SI showed significantly lower values during exercise testing in group A in our study, but the changes were clearer when ΔCI and ΔSI were calculated. Grande *et al.*[13] observed hemodynamics during exercise testing on a sedentary bicycle ergometer by the impedance method in patients soon after their first myocardial infarction. The extent of the infarct and SI showed an inverse correlation and patients with large infarcts had an increase of SI during light exercise testing. In the present study, 19 out of 23 patients in group A (82.6%) and 8 out of 20 patients in group B (40%) had anteroseptal or extensive anterior infarction. More patients in group A had large infarcts, so our results agreed with those obtained in the above studies.

Changes of oxygen pulse did not show any significant difference between the two groups when absolute values were assessed, but Δ oxygen pulse was significantly lower in group A than in group B.

The oxygen pulse is defined by physiological momentum (V_{O_2}) divided by heart rate and indicates energy efficiency in the cardiovascular system, which is considered to be closely correlated with stroke volume[14]. Group A, with reduced cardiac pump function, showed a significant difference in Δ oxygen pulse, as occurred with ΔCI and ΔSI.

The most significant predictors ($p<0.01$) of a marked increase of ΔPCWP during warm bathing were ΔSI, ΔCI, ΔSI+METs, ΔCI+METs, ΔCI+ΔSI, and ΔCI+ΔSI+METs. Among these, ΔSI was especially useful. The values of these parameters predicting a marked increase in ΔPCWP during warm bathing were 5 m*l*/m^2/beat for ΔSI, 2.4 *l*/min/m^2 for ΔCI, and 4.0 METs for physical work capacity. These standard values showed the highest sensitivity, specificity, and accuracy among those tested.

Hasegawa *et al.*[15,16] reported the changes of hemodynamics according to the depth of immersion during bathing in patients with myocardial infarction. Because of differences in venous return due to the effects of static water pressure, *etc.*, the pulmonary arterial pressure and PCWP were increased at shoulder depth when compared with umbilical or chest depth, and patients with reduced cardiac function showed a marked increase of PCWP at shoulder depth when compared with before warm bathing. Changes of hemodynamic parameters such as the PCWP during warm bathing in the supine position using the Hubbard tank were intermediate between the changes while semi-sitting in the bath at chest-depth and shoulder-depth. Although hemodynamic changes are known to depend on the water temperature[1], it can be assumed that patients showing increase of at least 10 mmHg in PCWP during warm bathing in the supine position will also show the same changes when warm bathing in the ordinary seated position. Therefore, although the parameters obtained in the present study are for warm bathing in the supine position using a Hubbard tank, presumably they can also be used to predict a marked increase of PCWP during ordinary warm bathing.

Our results suggested that the ΔSI, ΔCI, and METs values obtained with exercise testing are good parameters for detecting patients requiring special supervision at the start of warm bathing and for predicting the prognosis. Caution is required when warm bathing is commenced in patients with reduced cardiac function with a physical work capacity of 4.0 METs, ΔSI of 5 m*l*/m^2/beat, and ΔCI of 2.4 *l*/min/m^2 like those in our group A.

CONCLUSION

Myocardial infarct patients showing an increase of PCWP by at least 10 mmHg during warm bathing had more reduced cardiac function than those with an increase of less than 10 mmHg. In such patients, PCWP increased significantly during exercise testing, whereas ΔSI, ΔCI, METs, and Δ oxygen pulse decreased significantly. These parameters were closely correlated with ΔPCWP during warm bathing and may be useful to determine whether warm bathing should be resumed. Considerable caution appears to be required when starting warm bathing after myocardial infarction in patients with physical work capacity of 4.0 METs, ΔSI of 5 m*l*/m²/beat, and ΔCI of 2.4 *l*/min/m².

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要　約

心筋梗塞患者に Hubbard 浴槽を用いた温浴負荷時と運動負荷時の血行動態の比較

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安藤　浩巳　長谷川雅一　松崎　明廣　片桐　敬

心筋梗塞 43 例 (平均年齢 60.2 歳) において，温浴負荷時と運動負荷時の血行動態を比較し，温浴開始時に注意を要する症例を判別出来る指標について検討した．

Hubbard 浴槽を用いた仰臥位での淡水 42°C，5 分間の温浴で，温浴中肺動脈楔入圧 (PCWP) が温浴前に比し 10 mmHg 以上上昇した 23 例 (A 群; 平均年齢 61.7 歳) と，10 mmHg 未満の 20 例 (B 群; 平均年齢 60.5 歳) とに分け，温浴負荷前日に施行した臥位自転車エルゴメーターによる連続的多段階運動負荷試験での全症例が施行しえた 50 W 3 分までの血行動態を対比検討した．

運動負荷中両群間で，血圧，心拍数には有意差が認められなかったが，肺動脈楔入圧は，負荷前で A 群は B 群に比し有意に高く，50W 3 分の負荷でも A 群 26.9±9.0，B 群 16.7 ±9.1 mmHg と，更に有意に上昇した (p<0.01)．運動負荷中の 1 回拍出係数 (SI) では，A 群は B 群に比し有意に低値で，負荷前値との差 ΔSI では 50 W 3 分で A 群 3.5±5.5，B 群 10.6±7.0 m*l*/m²/beat と，A 群が有意に低値であった (p<0.01)．Δ 心係数 (CI) と Δ 酸素脈も同様に，A 群が負荷中有意に低値を示した．運動耐容能，左室駆出率は，A 群は B 群に比し有意に低値を示し，左室拡張末期圧は A 群は B 群に比し高値を示した．温浴中 PCWP が著明に上昇することを予測しうると考えられる指標として運動負荷試験における CI，ΔCI，SI，ΔSI，METs，酸素脈，Δ 酸素脈を取り上げ，回帰分析および多変量解析を行った．ΔSI (p=0.0032)，ΔCI (p=0.0094) とΔSI±METs (p=0.0051)，ΔCI±METs (p=0.0061)，ΔCI±ΔSI (p=0.0084)，ΔCI±ΔSI±METs (p=0.0093) の組み合わせが ΔPCWP と最も良い相関を示した．

以上より，ΔCI，ΔSI，METs の変化は温浴開始時に注意を要する症例を予測するための良い指標であることが示唆された．また，運動耐容能：4.0 METs，ΔSI：5 m*l*/m²/beat，ΔCI：2.4 *l*/min/m² 前後の心筋梗塞例の温浴開始には，十分な注意が必要であると思われた．

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