Relation Between Oscillatory Ventilation at Rest Before Cardiopulmonary Exercise Testing and Prognosis in Patients With Left Ventricular Dysfunction*

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**Background:** Although nocturnal Cheyne-Stokes respiration alternating between hyperpnea and hypopnea has been considered a sign of severe heart failure, the clinical status of cardiac patients who exhibit oscillatory ventilation during wakefulness has not been clarified. This study was carried out to determine the relation between oscillatory ventilation during wakefulness and exercise capacity in patients with chronic heart disease. We also evaluated retrospectively whether the presence of oscillatory ventilation influences the long-term prognosis in these patients.

**Methods:** A total of 164 patients with left ventricular dysfunction performed a symptom-limited incremental exercise test. Respiratory gas exchange was measured on a breath-by-breath basis throughout the test. Oscillatory ventilation was defined when clear ventilatory oscillation of at least two consecutive cycles was identified at rest before exercise testing and the difference between the peak and nadir of oscillating ventilation was $>30\%$ of the mean value of ventilation.

**Results:** Oscillatory ventilation was noted in 45 of 164 cardiac patients (27%), and the magnitude (mean $\pm$ SD) of oscillation in these patients was 45.5 $\pm$ 16.9%. Patients with oscillatory ventilation had significantly lower left ventricular ejection fraction than those without it (40.7 $\pm$ 12.7% vs 44.9 $\pm$ 11.6%, $p < 0.05$). However, parameters of exercise capacity such as the peak oxygen uptake ($\dot{V}O_2$), the slope of the increase in $\dot{V}O_2$ relative to the increase in work rate ($\Delta \dot{V}O_2/\Delta WR$), and the ratio of the increase in ventilation to the increase in carbon dioxide output ($\Delta \dot{V}E/\dot{V}CO_2$) were not significantly different between the two groups. The mortality rate during 1,797 $\pm$ 599 days of follow-up did not differ between the groups ($p = 0.65$).

**Conclusions:** Oscillatory ventilation present at rest before cardiopulmonary exercise testing is not significantly related to the peak $\dot{V}O_2$, $\Delta \dot{V}O_2/\Delta WR$, $\Delta \dot{V}E/\dot{V}CO_2$, or prognosis in patients with left ventricular dysfunction.

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Key words: cardiac patient; exercise capacity; oscillatory ventilation; prognosis

Abbreviations: LVEF = left ventricular ejection fraction; $\dot{V}CO_2$ = carbon dioxide output; $\dot{V}E$ = minute ventilation; $\Delta \dot{V}E/\dot{V}CO_2$ = ratio of the increase in ventilation to the increase in carbon dioxide output; $\dot{V}O_2$ = oxygen uptake; $\Delta \dot{V}O_2/\Delta WR$ = increase in oxygen uptake relative to the increase in work rate

Oscillatory breathing alternating between hyperpnea and hypopnea during sleep has been recognized for more than a century in cardiac patients. This phenomenon is considered a marker of severe heart failure and an indication of poor outcome.\(^1-3\) Several hypotheses have been proposed as the mechanisms of the periodic breathing, such as instability of the ventilatory control system\(^4\) or fluctuations in the pulmonary blood flow.\(^5,6\) However, the mecha...
nisms of this breathing pattern are not fully understood. Although oscillatory ventilation can also be seen during wakefulness, the clinical status, etiology of cardiac disease, severity of heart failure, and prognosis of patients who exhibit this phenomenon while awake have not yet been established.

Formerly, risk stratification of heart failure was based on the functional assessment and resting hemodynamic measurements. To compensate, cardiopulmonary exercise testing has become important for stratifying patients with heart failure and identifying those with a poor prognosis. From our experience, it is not rare to see clear oscillatory ventilation at rest before cardiopulmonary exercise testing even in a patient without heart failure. Thus, we attempted to clarify the clinical status and mortality of cardiac patients who exhibited oscillatory ventilation while awake.

We compared the parameters obtained from echocardiography and cardiopulmonary exercise testing between patients with oscillatory ventilation and those without it. We also evaluated whether the presence of oscillatory breathing influences the long-term prognosis in these patients.

**Materials and Methods**

**Study Patients**

We retrospectively studied 164 consecutive patients with cardiovascular disease who performed cardiopulmonary exercise testing between 1992 and 1994 in our hospital and whose left ventricular ejection fraction (LVEF) was < 60% (Table 1). The exercise testing was performed to evaluate the exercise capacity or cause of dyspnea. No patients with unstable angina, myocardial infarctions within the last month, documented lung disease, cerebrovascular disease, symptomatic peripheral vascular disease, or orthopedic difficulty in performing exercise testing were included in this population. The protocol for the cardiopulmonary exercise testing was approved by the human subjects committee of our hospital. Its purposes and risks were explained to the patients, and informed consent was obtained from each patient prior to enrollment.

Coronary artery disease was diagnosed by the presence of significant coronary stenosis, defined as a ≥ 75% reduction in the luminal diameter of coronary vessels, or the presence of myocardial infarction diagnosed according to the World Health Organization criteria. Among 65 patients categorized as having coronary artery disease, 54 patients (20 patients with oscillatory ventilation and 34 without it) had a previous myocardial infarction.

**Exercise Protocol**

An incremental exercise test was performed using an upright, electromagnetically braked cycle ergometer (Corival 400; Lode; Groningen, the Netherlands). The exercise test began with a 4-min rest on the ergometer followed by a 4-min warm up exercise, and then the load was increased incrementally by 1 W every 6 s (10 W/min). The pedaling frequency was fixed at 60 revolutions per minute using a metronome. The work rate of warm-up exercise was selected as 10 W in eight patients whose daily activity was assumed to be very low. In the remaining 156 patients, 20 W was used. Breath-by-breath oxygen uptake (\(\dot{V}_O_2\)), carbon dioxide output (\(\dot{V}_C0_2\)), and minute ventilation (\(V_e\)) were measured from 4 min before starting exercise until the end of exercise using an AE-280 Respirimonitor (Minato Medical Science; Osaka, Japan), as previously described.

**Definition of Oscillatory Ventilation**

Oscillatory ventilation in a representative subject is shown in Figure 1, left. A. According to the report of Ben-Dov et al, we

**Table 1—Clinical Characteristics in Patients With and Without Oscillatory Ventilation**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>All Patients (n = 164)</th>
<th>Patients With Oscillatory Ventilation (n = 45)</th>
<th>Patients Without Oscillatory Ventilation (n = 119)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/female gender, No.</td>
<td>131/33</td>
<td>40/5</td>
<td>91/28</td>
<td>NS</td>
</tr>
<tr>
<td>Age, yr</td>
<td>57.3 ± 11.1</td>
<td>57.2 ± 12.0</td>
<td>57.4 ± 10.7</td>
<td>NS</td>
</tr>
<tr>
<td>Height, cm</td>
<td>163.2 ± 7.5</td>
<td>164.4 ± 6.6</td>
<td>162.8 ± 7.7</td>
<td>NS</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>58.5 ± 10.9</td>
<td>59.7 ± 9.7</td>
<td>58.0 ± 11.4</td>
<td>NS</td>
</tr>
<tr>
<td>Body mass index</td>
<td>21.9 ± 3.2</td>
<td>22.1 ± 3.2</td>
<td>21.8 ± 3.3</td>
<td>NS</td>
</tr>
<tr>
<td>Etiology</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>65 (40)</td>
<td>23 (51)</td>
<td>42 (35)</td>
<td>NS</td>
</tr>
<tr>
<td>Valvular disease</td>
<td>60 (37)</td>
<td>10 (22)</td>
<td>50 (42)</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Idiopathic dilated cardiomyopathy</td>
<td>21 (13)</td>
<td>10 (22)</td>
<td>11 (9)</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Congenital heart disease</td>
<td>7 (4)</td>
<td>1 (2)</td>
<td>6 (5)</td>
<td>NS</td>
</tr>
<tr>
<td>Other cardiovascular disease</td>
<td>11 (7)</td>
<td>1 (2)</td>
<td>10 (8)</td>
<td>NS</td>
</tr>
<tr>
<td>Medication</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrates</td>
<td>90 (55)</td>
<td>28 (62)</td>
<td>62 (52)</td>
<td>NS</td>
</tr>
<tr>
<td>Diuretics</td>
<td>88 (54)</td>
<td>26 (58)</td>
<td>62 (52)</td>
<td>NS</td>
</tr>
<tr>
<td>Calcium-channel blockers</td>
<td>72 (44)</td>
<td>23 (51)</td>
<td>49 (41)</td>
<td>NS</td>
</tr>
<tr>
<td>Digitalis</td>
<td>61 (37)</td>
<td>15 (33)</td>
<td>46 (39)</td>
<td>NS</td>
</tr>
<tr>
<td>Angiotensin-converting enzyme inhibitors</td>
<td>16 (10)</td>
<td>5 (11)</td>
<td>11 (9)</td>
<td>NS</td>
</tr>
<tr>
<td>β-Blockers</td>
<td>15 (9)</td>
<td>6 (13)</td>
<td>9 (8)</td>
<td>NS</td>
</tr>
</tbody>
</table>

*Data presented are mean value ± SD or No. (%) of patients, unless otherwise indicated. NS = not significant.*
defined oscillatory ventilation as follows: (1) at least two consecutive cycles of clear ventilatory oscillations are noted at rest before exercise testing, and (2) the mean of the differences between the peak and nadir of oscillating $V_e$ is $>30\%$ of the mean value of $V_e$.

**Data Analysis**

Prior to defining oscillatory ventilation and calculating the parameters of respiratory gas analysis, a five-point moving average of the breath-by-breath data were calculated. The gas exchange (anaerobic) threshold was determined by the $V$-slope method.$^{20-22}$ Peak $VO_2$ was defined as the highest $VO_2$ attained over a 15-s period during incremental exercise. The percentage of peak $VO_2$ was calculated by dividing the measured peak $VO_2$ by the predicted peak $VO_2$. The predicted peak $VO_2$ was determined based on a normal Japanese population.$^{12}$ The slope of the increase in $VO_2$ relative to the increase in work rate ($\Delta V O_2/\Delta WR$) was calculated by least-squares linear regression from the data recorded between 30 s after the start of incremental exercise to 30 s before the end of exercise. The ratio of the increase in $VE$ to the increase in $VCO_2$ ($\Delta VE/\Delta VCO_2$) was calculated from the start of incremental exercise to the respiratory compensation point by least-squares linear regression. The respiratory compensation point was determined by the following criteria$^{23}$: (1) the ratio of $V_E$ to $VCO_2$ starts to increase after a period of decrease or stability, and (2) the end-tidal $P_{ETCO_2}$ starts to decrease after a period of stability. When the respiratory compensation point could not be clearly identified, $V_E/VCO_2$ was calculated from the data recorded between the start of incremental exercise to the end of the exercise. Echocardiography was performed at a resting condition at an interval (mean $\pm$ SD) of 9 $\pm$ 13 days from the day of exercise testing.

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**FIGURE 1.** Respiratory gas exchange at rest and during exercise in a representative patient with oscillatory ventilation (left, A: a 56-year-old man with dilated cardiomyopathy) and a patient without it (right, B: a 48-year-old man with valvular disease). After a 4-min rest on the ergometer, exercise was started with a 4-min warm-up at 20 W, and then continued with a progressive increase in the work rate (10 W/min). Clear oscillatory ventilation was noted at rest and during warm-up exercise in the patient with dilated cardiomyopathy (left, A). The magnitude of oscillatory ventilation was 50.5% of the mean ventilation in this subject. $P_{ETO_2}$ = end-tidal $O_2; P_{ETCO_2}$ = end-tidal $CO_2; TV$ = tidal volume; $VE$ = ventilation.
Mortality Data

Data on mortality were examined in July 1999 by looking through medical records from the outpatient clinic and/or conducting telephone interviews with the patients or their families. Data on 15 patients were not available for follow-up due to changes in their place of residence. After excluding these patients, data on the remaining 149 patients (42 patients with oscillatory ventilation and 107 patients without it) were used for analysis on mortality.

Statistics

Data are presented as the mean ± SD. Statistical analysis was performed using a statistical software package (Statview; Abacus Concepts; Berkeley, CA). Intergroup differences for clinical, hemodynamic, and exercise variables were compared using the unpaired t test, or χ² analysis where appropriate. A Cox proportional hazards model was used to measure the influence of oscillatory ventilation on survival time. Differences in survival between groups were detected by the Kaplan-Meier method and compared using the log rank test. For all comparisons, p < 0.05 was considered statistically significant.

Results

Relation Between Oscillatory Ventilation and Exercise Parameters

Clinical characteristics and exercise parameters of the subjects are shown in Tables 1, 2. The mean peak VO₂ and percentage of peak VO₂ were 15.4 ± 4.3 mL/min/kg and 52.2 ± 12.5%, respectively, showing moderate impairment in exercise capacity. Oscillatory ventilation meeting our definition was noted in 45 of 164 cardiac patients. The mean of the magnitude of oscillation in the patients with oscillatory ventilation was 45.5 ± 16.9%. The duration of oscillatory ventilation (time from peak to peak) was 66.7 ± 14.3 s for the first cycle and 66.1 ± 16.4 s for the second cycle, showing no significant difference. There were no differences in gender, age, height, weight, or body mass index between patients with oscillatory ventilation and those without it (Table 1). There were no significant differences between oscillators and nonscillators in the prescribed medications. However, the etiology of heart disease slightly differed between the two groups: the proportion of idiopathic dilated cardiomyopathy was higher and that of valvular disease was lower in the oscillators than in nonscillators. Although Ve at peak exercise was slightly higher in the oscillators, there were no significant differences between the two groups in the other indexes of cardiopulmonary exercise testing, including the peak VO₂, gas exchange threshold, ΔVO₂/ΔWR, and ΔVe/ΔVO₂ (Table 2). However, oscillators had a significantly lower LVEF (40.7 ± 12.7% vs 44.9 ± 11.6%, p < 0.05) than nonscillators.

Relation Between Oscillatory Ventilation and Mortality

At 1,797 ± 599 days of follow-up, 26 patients had died. Of these, nine patients had died due to progressive heart failure, nine patients due to sudden cardiac arrest, three patients due to acute myocardial infarction, three patients due to cerebrovascular diseases, and two patients due to noncardiovascular-related diseases. No patient underwent cardiac transplantation during the follow-up period. Table 3 shows a univariate

| Table 2—Hemodynamic and Exercise Parameters in Patients With and Without Oscillatory Ventilation* |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|------------------|
| Parameters | All Patients (n = 164) | Patients With Oscillatory Ventilation (n = 45) | Patients Without Oscillatory Ventilation (n = 119) | p Value |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|------------------|
| Rest               |                                |                                |                                |         |
| LVEF, %           | 43.7 ± 12.0         | 40.7 ± 12.7                    | 44.9 ± 11.6                      | < 0.05 |
| LVDd, mm          | 53.6 ± 9.8          | 54.8 ± 10.4                    | 53.1 ± 9.5                      | NS     |
| LVDs, mm          | 42.0 ± 10.1         | 44.0 ± 11.2                    | 41.2 ± 9.6                      | NS     |
| Heart rate, beats/min | 86.4 ± 18.2      | 84.8 ± 16.4                    | 87.0 ± 18.8                      | NS     |
| Ve, L/min         | 11.4 ± 2.0          | 11.7 ± 2.6                     | 11.3 ± 1.7                      | NS     |
| Peak exercise     |                                |                                |                                |         |
| Heart rate, beats/min | 133.8 ± 27.3     | 133.3 ± 22.8                   | 134.0 ± 28.9                     | NS     |
| % maximal heart rate, % | 96.8 ± 18.6     | 96.4 ± 15.4                    | 96.9 ± 19.7                      | NS     |
| Ve, L/min         | 39.5 ± 10.6         | 42.7 ± 9.4                     | 38.2 ± 10.8                      | < 0.05 |
| Peak VO₂, mL/min/kg | 15.4 ± 4.3        | 16.1 ± 3.7                     | 15.2 ± 4.5                      | NS     |
| % peak VO₂, %     | 52.2 ± 12.5         | 54.1 ± 10.8                    | 51.5 ± 13.1                      | NS     |
| Gas exchange threshold, mL/min/kg | 11.9 ± 2.4 | 11.8 ± 2.0                     | 11.9 ± 2.6                      | NS     |
| ΔVO₂/ΔWR, mL/min/W | 8.2 ± 2.3         | 8.4 ± 2.4                      | 8.0 ± 2.3                       | NS     |
| ΔVe/ΔVO₂         | 35.3 ± 10.3         | 37.3 ± 11.7                    | 34.5 ± 9.6                      | NS     |

*Data presented are mean value ± SD. The percentage of peak VO₂ was calculated by dividing the measured peak VO₂ by the predicted peak VO₂. The percentage of maximal heart rate was calculated by dividing the maximal heart rate by the predicted maximal heart rate. The predicted maximal heart rate was calculated by (220 – age) × 0.85. LVDd = left ventricular diastolic dimension; LVDs = left ventricular systolic dimension. See Table 1 for expansion of abbreviation.
Cox proportional hazards analysis of the association between cardiopulmonary indexes and survival time. Among exercise variables, $\Delta \dot{V}O_2/\Delta WR$ and $\Delta \dot{V}e/\Delta \dot{V}co_2$ were found to be significant predictors of mortality. Among other variables, age and LVEF were found to be significant prognostic indexes. However, a univariate Cox proportional hazards analysis showed that the presence of oscillatory ventilation is not a significant prognostic index of survival ($p = 0.65$). Figure 2 shows the Kaplan-Meier survival curves in oscillators ($n = 42$) and nonoscillators ($n = 107$). The survival rate was 81.0% for oscillators and 83.2% for nonoscillators, showing no significant difference in survival between the two groups ($p = 0.65$).

### Table 3—Univariate Cox Proportional Hazard Survival Analysis of Association Between Variables Studied and Survival Time

<table>
<thead>
<tr>
<th>Variables</th>
<th>$\chi^2$</th>
<th>p Value</th>
<th>Hazard Ratio</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>8.520</td>
<td>0.004</td>
<td>1.066</td>
<td>1.021–1.113</td>
</tr>
<tr>
<td>$\Delta \dot{V}O_2/\Delta WR$</td>
<td>8.133</td>
<td>0.004</td>
<td>0.764</td>
<td>0.634–0.919</td>
</tr>
<tr>
<td>$\Delta \dot{V}e/\Delta \dot{V}co_2$</td>
<td>6.498</td>
<td>0.011</td>
<td>1.037</td>
<td>1.008–1.066</td>
</tr>
<tr>
<td>LVEF</td>
<td>4.407</td>
<td>0.036</td>
<td>0.969</td>
<td>0.941–0.998</td>
</tr>
<tr>
<td>Gas exchange threshold</td>
<td>1.164</td>
<td>0.281</td>
<td>0.890</td>
<td>0.719–1.100</td>
</tr>
<tr>
<td>Peak $\dot{V}O_2$</td>
<td>0.991</td>
<td>0.319</td>
<td>0.949</td>
<td>0.856–1.052</td>
</tr>
<tr>
<td>Presence of oscillatory ventilation</td>
<td>0.201</td>
<td>0.654</td>
<td>0.826</td>
<td>0.359–1.904</td>
</tr>
</tbody>
</table>

### Discussion

There are a number of reports on breathing disorders during sleep in patients with severe heart failure. However, there have only been a few investigations evaluating the prognosis in patients who show oscillatory ventilation while awake. To our knowledge, there has been no previous study investigating the prevalence of periodic breathing during wakefulness and long-term prognosis in a large number of cardiac patients. In order to clarify the clinical status, exercise capacity, and prognosis of patients with oscillatory ventilation during wakefulness, we retrospectively evaluated
the results of cardiopulmonary exercise testing and examined the 5-year survival in patients with left ventricular dysfunction.

Of 164 cardiac patients, 45 patients (27%) exhibited oscillatory ventilation while awake. The proportion of idiopathic dilated cardiomyopathy was significantly higher in the patients with oscillatory ventilation than those without it. Patients with oscillatory ventilation had significantly lower LVEF. However, there was no difference between the two groups in peak $\dot{V}O_2$, $\Delta V_2/\Delta WR$, or $\Delta V_e/\Delta V_{CO_2}$. Furthermore, the presence of oscillatory ventilation was unrelated to prognosis in our population.

**Cardiopulmonary Exercise Testing**

Parameters obtained from cardiopulmonary exercise testing are known to reflect activities of daily living and severity of heart failure in cardiac patients. Among the parameters, peak $V_{O_2}$ has been considered a “gold standard” for identifying patients with poor prognosis and selecting candidates for cardiac transplantation. The slope of $\Delta V_e/\Delta V_{CO_2}$ during incremental exercise is also an independent prognostic index of survival in cardiac patients. $\Delta V_e/\Delta V_{CO_2}$ has been thought to range from approximately 24 to 34 in normal subjects. This slope becomes steeper according to the severity of heart failure. The steeper slope of $\Delta V_e/\Delta V_{CO_2}$ is assumed to be related to an increase in the ratio of pulmonary dead space to tidal volume, a decrease in the regulatory set point for $Paco_2$, or the development of lactic acidosis during exercise. In healthy subjects, $\Delta V_{O_2}/\Delta WR$ is known to be approximately 10 mL/min/W. Since $\Delta V_{O_2}/\Delta WR$ is determined by the increasing cardiac output and increasing difference between arterial and mixed venous oxygen content during incremental exercise, the lower $\Delta V_{O_2}/\Delta WR$ implies an insufficient cardiac reserve and/or insufficient vasodilator capacity in the skeletal muscle in addition to the possible abnormalities in pulmonary vasculature.

Our present study corroborated the findings of our previous study by showing that the slopes of $\Delta V_{O_2}/\Delta WR$ and $\Delta V_e/\Delta V_{CO_2}$, parameters that reflect cardiopulmonary and circulatory adaptation during exercise, were both strong predictors of mortality in patients with left ventricular dysfunction (Table 3). However, the presence of oscillatory ventilation was not significantly associated with these parameters of submaximal exercise testing.

**Mechanisms of Oscillatory Ventilation**

Patients with heart failure often acquire a periodic breathing pattern during sleep. It has been noted by several investigators that approximately 50% of patients with symptomatic congestive heart failure have either sleep apnea or Cheyne-Stokes respiration. Although nocturnal Cheyne-Stokes respiration has been considered a sign of poor prognosis, this is still a question under debate. Several investigators have postulated that breathing disorders in cardiac patients may have a causal relationship with prolonged circulation time, impaired systolic and/or diastolic function, and left ventricular enlargements. Administration of oxygen or theophylline and continuous positive airway pressure therapy have been noted to attenuate periodic breathing. It has been reported that periodic breathing found at rest or at low levels of exercise disappears during moderate-to-heavy exercise. However, the origin of oscillatory breathing has not yet been clarified.

In the present study, patients with oscillatory ventilation during wakefulness had significantly lower LVEF than those without it, supporting the previous findings that oscillatory ventilation is related to left ventricular dysfunction. However, in our subjects, oscillatory ventilation was not related to indexes of cardiopulmonary exercise testing, which accurately reflect the severity of heart failure.

**Study Limitations**

Although the analysis on mortality of the present study was performed retrospectively, it was a cohort study rather than a case history study since its logic was prospective. We defined our cases as oscillatory ventilation when the mean of the differences between the peak and nadir of oscillating $V_e$ was $>30\%$ of the mean $V_e$ for the two consecutive cycles, according to the criteria of Ben-Dov et al. In their study, periodic breathing was defined when the difference was $\geq25\%$ of the mean $V_e$ in at least two consecutive cycles. The results were the same even though the criteria of Ben-Dov et al. which was a little milder than ours, was applied to the present study. Even if a cut-off value of 40% was selected, there was no difference in mortality between oscillators and nonoscillators.

Most of our subjects had mild heart failure of New York Heart Association functional class I or II, and their LVEF was 43.7% on average. The discrepancy in mortality between the previous reports showing poor prognosis in oscillatory ventilation and the present findings might be due to the less severe heart failure of our subjects. We also have to consider the situation in which oscillatory ventilation was detected. We evaluated the presence of oscillatory ventilation using the resting data before cardiopulmonary exercise testing. The study situation in the
present study might have influenced the subjects on the physiologic and psychological aspects.

The underlying mechanisms of oscillatory ventilation during wakefulness might not necessarily be the same as those seen during sleep. Since the analysis of the present study was performed retrospectively, we could not evaluate whether our subjects with oscillatory ventilation during wakefulness had nocturnal Cheyne-Stokes respiration. It has yet to be determined whether the presence of oscillatory ventilation while awake is a sign of nocturnal Cheyne-Stokes respiration coming on. Further studies will be necessary to establish the mechanisms of oscillatory ventilation both during sleep and wakefulness in cardiac patients. Whether oscillatory ventilation can be seen in normal subjects has to be determined in a future study.

CONCLUSION

Oscillatory ventilation during wakefulness was noted in 27% of cardiac patients who underwent cardiopulmonary exercise testing. Although LVEF was lower in patients with oscillatory ventilation than in those without it, there was no difference in peak exercise capacity, ΔV̇O₂/ΔWR, or ΔV̇E/ΔVCO₂ between the two groups. Our findings strongly suggest that oscillatory ventilation presenting during wakefulness is not significantly related to the prognosis in patients with mild-to-moderate left ventricular dysfunction.

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