Latent Cardiac Dysfunction as Assessed by Echocardiography in Bed-Bound Patients Following Cerebrovascular Accidents

Comparison With Nutritional Status

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SUMMARY

The aim of this study was to elucidate the cardiac function in bed-bound patients following cerebrovascular accidents. In accord with the criteria for activities of daily living (ADL) of the Japanese Ministry of Health, Labour and Welfare, 51 age-matched post-stroke patients without heart disease were classified into 3 groups: rank A (house-bound) (n = 16, age, 85 ± 6 years), rank B (chair-bound) (n = 16, age, 84 ± 8 years), and rank C (bed-bound) (n = 19, age, 85 ± 9 years). Using echocardiography, the left ventricular (LV) diastolic function was assessed by the ratio of early filling (E) and atrial contraction (A) transmitral flow velocities (E/A) of LV inflow. LV systolic function was assessed by LV ejection fraction (LVEF), and the Tei index was also measured to assess both LV systolic and diastolic function. No difference was observed in the E/A and LVEF among the 3 groups. The Tei index was higher in rank C (0.56 ± 0.17) than in rank A (0.39 ± 0.06) and rank B (0.48 ± 0.17), and a statistically significant difference was observed between rank A and rank C ($P < 0.05$). Serum albumin and blood hemoglobin were significantly lower in rank C (3.1 ± 0.4 and 10.6 ± 1.8 g/dL) than in rank A (4.1 ± 0.3 and 12.4 ± 1.2 g/dL) ($P < 0.001$ and $P < 0.05$, respectively). These results indicate that latent cardiac dysfunction and poor nutritional status may exist in bed-bound patients (rank C) following cerebrovascular accidents. The Tei index may be a useful index of cardiac dysfunction in bed-bound patients because it is independent of the cardiac loading condition. (Int Heart J 2007; 48: 505-512)

Key words: Bed-bound patients, Cardiac function, Echocardiography, Stroke

BEING bed-bound is a well-known clinical phenomenon following cerebrovas-

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cular accidents, and bed-bound patients have increased remarkably in number in association with increased cerebrovascular accidents in recent years. Although hypoalimentation and reduced bone salts have been some of the special conditions reported in association with the bed-bound state,[1-4] there have been few studies[5] of the effects of reduced activities of daily living (ADL) on cardiac function in bed-bound patients. It is important to estimate cardiac function in bed-bound patients following cerebrovascular accidents in order to determine the volume of infusion, because too much infusion may lead to lung congestion due to heart failure. The aim of this study was to assess cardiac function in bed-bound patients following cerebrovascular accidents in order to elucidate the effect of bed rest following a cerebrovascular accident on cardiac function. We also examined the relationship between cardiac function and nutritional status in patients following cerebrovascular accidents.

METHODS

Subjects: The study population consisted of 51 patients who had experienced a cerebrovascular accident (mean age, 84 ± 8 years, range, 69-99 years) and who had remained in stable condition with respect to activities of daily living (ADL) for at least 6 months. The patients were subdivided into 3 groups: rank A (house-bound) (n = 16, age, 85 ± 6 years), rank B (chair-bound) (n = 16, age, 84 ± 8 years), and rank C (bed-bound) (n = 16, age, 85 ± 9 years), according to the ADL classification established by the Japanese Ministry of Health, Labour and Welfare.[6] The selection criteria were as follows: no signs, symptoms, or history of cardiac disease, a normal electrocardiogram, body mass index < 28 kg/m^2, and fasting glucose < 110 mg/dL. The echocardiographic findings were compared among the 3 groups. The protocol of the study was approved by the Ethical Committee of Kagawa University, and all subjects gave written informed consent.

Evaluation of blood pressure and nutritional status: Blood pressure levels were measured after the echocardiographic examination with a mercury sphygmomanometer. Blood sampling was performed in the morning after a 12-hour overnight fast on the day when the echocardiographic examination was performed. Serum albumin and hemoglobin levels were measured by standard laboratory techniques to evaluate the nutritional status of the patients.

Echocardiographic examination: Two-dimensional and M-mode echocardiography were performed using an echocardiograph (PowerVision 6000; Toshiba, Tokyo) with a 2.5-MHz transducer. We first measured the following left ventricular structural parameters using M-mode echocardiography: ventricular septal thickness (VS) at the chordae tendineae level, left ventricular end-diastolic dimension (LVDd) at the chordae tendineae level, left ventricular end-systolic

dimension (LVDs) at the chordae tendineae level, and left ventricular posterior wall (PW) thickness at the chordae tendineae level. Relative wall thickness, which increases with left ventricular concentric remodeling and/or concentric hypertrophy, was calculated as (VS + PW)/LVDd. The left ventricular ejection fraction (LVEF) was estimated by Teichholz's method[7] and was used as the parameter of left ventricular systolic function.

We next measured the parameters of left ventricular diastolic function by recording the left ventricular diastolic inflow using pulsed Doppler echocardiography.[8] The left ventricular diastolic filling pattern was recorded from the apical transducer position with the sample volume situated between the mitral leaflet tips. The peak velocity of early rapid filling (E velocity) and the peak velocity of atrial filling (A velocity) were recorded, and the ratio of E to A (E/A) was calculated. Finally, we measured the Tei index, which reflects both left ventricular sys-

Table. Characteristics and Echocardiographic Findings of All 51 Poststroke Patients

	Rank A (house-bound) (n = 16)	Rank B (chair-bound) (n = 16)	Rank C (bed-bound) (n = 19)
Age (years)	85 ± 6	84 ± 8	85 ± 9
Women	10 (63%)	11 (69%)	12 (63%)
Cerebral infarction	15 (94%)	14 (88%)	18 (95%)
Body mass index (kg/m^2)	22.2 ± 3.2	19.0 ± 3.9	19.5 ± 4.6
Brunnstrom stage	4.8 ± 0.9	3.2 ± 0.9**	1.8 ± 0.6**
Duration of paralysis (months)	13.8 ± 4.3	14.4 ± 5.4	12.7 ± 3.8
SBP (mmHg)	140 ± 15	129 ± 18	125 ± 10*
DBP (mmHg)	76 ± 12	79 ± 10	71 ± 9
HR (beats/min)	72 ± 10	74 ± 12	79 ± 13
Serum albumin (g/dL)	4.1 ± 0.3	3.5 ± 0.6	3.1 ± 0.4**
Blood hemoglobin (g/dL)	12.4 ± 1.2	11.5 ± 1.5	10.6 ± 1.8*
VS (mm)	10.0 ± 2.6	10.7 ± 2.3	10.1 ± 2.9
PW (mm)	8.6 ± 1.3	9.4 ± 1.5	8.9 ± 1.4
LVDd (mm)	44.7 ± 6.7	44.1 ± 4.9	40.1 ± 6.6
LVMI (g/m^2)	100 ± 28	112 ± 31	97 ± 36
LVEF (%)	68 ± 4	67 ± 9	61 ± 8
E (cm/s)	54 ± 13	49 ± 13	44 ± 12
A (cm/s)	89 ± 16	85 ± 18	81 ± 24
E/A	0.62 ± 0.20	0.58 ± 0.12	0.60 ± 0.30
Tei index	0.39 ± 0.06	0.48 ± 0.17	0.58 ± 0.16*

SBP indicates systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; VS, ventricular septal thickness; PW, posterior wall thickness; LVDd, left ventricular diastolic dimension; LVMI, left ventricular mass index; LVEF, left ventricular ejection fraction; E, peak early diastolic transmitral flow; A, peak late diastolic transmitral flow; and E/A, the ratio of E to A. Values are expressed as the mean ± SD. *P < 0.05, **P < 0.001 versus rank A.

tolic and diastolic function.[9,10] Details of the method for measuring the myocardial performance index have been previously published.[11] The Tei index, defined as the sum of isovolumic contraction time and isovolumic relaxation time divided by ejection time, was obtained from Doppler recordings of left ventricular inflow and outflow.

Statistical analysis: Data are expressed as the mean ± SD. Statistical analysis was performed using the SPSS software package (SPSS, Chicago, IL, USA). Linear regression analysis was used to test the association between the echocardiographic parameters and the nutritional status. The differences in the echocardiographic and nutritional parameters among the 3 groups were calculated using analysis of variance (ANOVA), with Scheffé's multiple comparisons for any two groups. Values of $P < 0.05$ were considered to indicate statistical significance.

Results

The table shows the clinical characteristics and echocardiographic findings in each group. Degree of paralysis was assessed by the Brunnstrom stage.[12] The lower the Brunnstrom stage, the greater the degree of paralysis. Systolic blood pressure in bed-bound (rank C) patients (125 ± 10 mmHg) was significantly lower than that in house-bound (rank A) patients (140 ± 15 mmHg) ($P < 0.05$). Serum albumin and blood hemoglobin decreased with a decline in ADL. Serum albumin and blood hemoglobin were significantly lower in bed-bound patients (3.1 ± 0.4 and 10.6 ± 1.8 g/dL) than in house-bound patients (4.1 ± 0.3 and 12.4 ± 1.2 g/dL) ($P < 0.001$ and $P < 0.05$, respectively) (Figure 1). There were no sig-

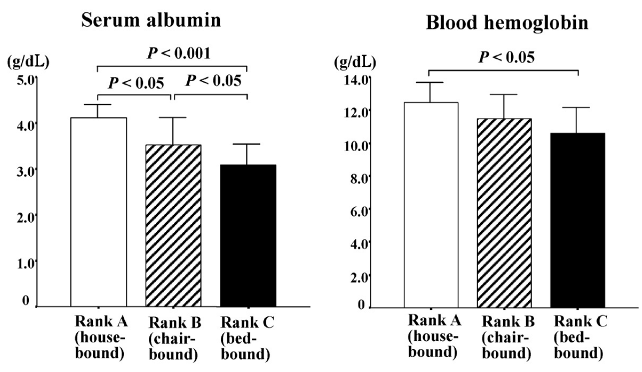

Figure 1. Comparison of parameters of nutritional status among rank A (house-bound), rank B (chair-bound), and rank C (bed-bound) patients.

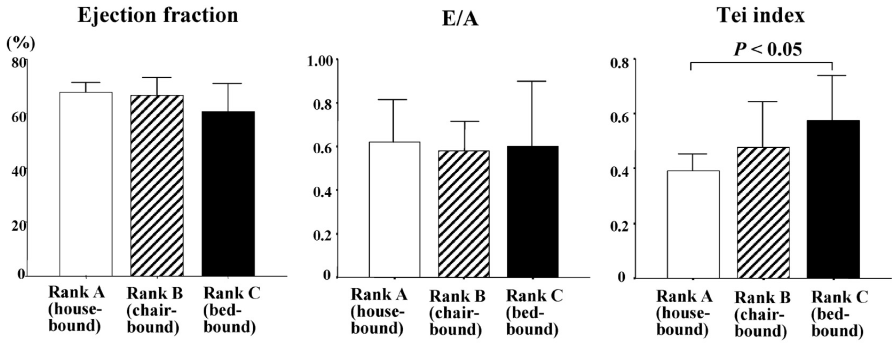

Figure 2. Comparison of parameters of cardiac function among rank A (house-bound), rank B (chair-bound), and rank C (bed-bound) patients. E indicates peak early diastolic transmitral flow; A, peak late diastolic transmitral flow; and E/A, the ratio of E to A.

nificant differences in LVEF and E/A between the groups (Table). In contrast, the Tei index increased with a decline in ADL (Figure 2). The Tei index in bed-bound patients (0.58 ± 0.16) was significantly higher than that in house-bound patients (0.39 ± 0.06) ($P < 0.05$). However, the Tei index did not demonstrate a significant correlation with either serum albumin or blood hemoglobin.

DISCUSSION

Usefulness of Tei index for assessment of cardiac function: The most striking result in our analysis was that only the Tei index of all parameters of cardiac function was able to detect the deterioration in cardiac function in bed-bound patients. Previous studies demonstrated that the Tei index, which reflects combined systolic and diastolic ventricular function, was relatively independent of heart rate[13] and cardiac preload[14] and afterload.[15] The cardiac loading condition of the bed-bound patients might be different from that of house- and chair-bound patients in the present study. Actually, the blood pressure of the bed-bound patients was significantly lower than that of house-bound patients (Table). Therefore, we believe that the Tei index is a useful parameter of cardiac function for comparing cardiac function in patients whose cardiac loading condition may vary. The Tei index identifies individuals with mild-to-moderate heart failure[15] and detects early latent cardiac dysfunction in patients without overt cardiac disease who have risk factors such as diabetes mellitus and hypertension.[16] Bed-bound patients with an abnormal Tei index value are considered to have latent cardiac dysfunction, which may result in overt heart failure. Because the Tei index is easily and reproducibly obtained by Doppler echocardiography, it is useful for detecting early

cardiac functional deterioration and assessing cardiac functional improvement as a result of drug therapy in bed-bound patients with heart failure.

Katsumata, *et al*[5] reported that left ventricular systolic function as assessed by LVEF was preserved, but left ventricular diastolic function as assessed by E/A was impaired in bedridden patients. In contrast, our results showed that the E/A in bed-bound patients was not different from that in house- and chair-bound patients. However, it is well known that E/A is affected by alterations of cardiac preload and afterload.[8,17] The E/A derived from the transmitral flow velocity pattern is influenced by loading condition, particularly preload, resulting in pseudo-normalization (E/A > 1) of the transmitral flow velocity in patients with elevated left ventricular end-diastolic pressure. Therefore, there is a limitation when left ventricular diastolic function is evaluated by the transmitral flow velocity pattern alone. The hypoalbuminemia and anemia in bed-bound patients in the present study might reduce the preload. Differences in the cardiac loading condition among the patient groups might be a cause of the failure to detect cardiac diastolic dysfunction by measuring E/A in bed-bound patients in the present study.

Mechanism of cardiac dysfunction in bed-bound patients: It is difficult to determine the mechanism of cardiac dysfunction in bed-bound patients following cerebrovascular accidents. Both parameters of cardiac function (Tei index) and nutritional status (serum albumin and blood hemoglobin) decreased with a decline in ADL in the present study. However, the Tei index did not demonstrate a significant correlation with either serum albumin or blood hemoglobin. Our results did not differ from those found in the literature, where there are no reports of a strong correlation between malnutrition level and ventricular dysfunction level in patients with chronic heart failure.[18] Although the present study did not enroll patients with chronic heart failure, cardiac dysfunction in bed-bound patients following cerebrovascular accidents is not likely to be attributed to the accompanying malnutrition. Saltin, *et al*[19] reported that stroke volume and cardiac output were reduced during supine exercise after 20 days of bed rest in healthy subjects. They attributed this phenomenon to a direct effect of bed rest on myocardial function. Cardiac dysfunction in bed-bound patients following cerebrovascular accidents in the present study may be also the direct effect of bed rest on myocardial function.

Takenaka, *et al*[20] reported that left ventricular diastolic dimension and cardiac output decreased after 20 days of bed rest in healthy young subjects. The results agreed with the results of a study conducted by other investigators who showed that prolonged bed rest produced a decrease in plasma volume which led to a decrease in cardiac output.[21] Another previous study reported that such circulatory unloading (a decrease in plasma volume) produced by bed rest may lead to cardiac atrophy.[22] In the present study, it is difficult to conclude that bed-bound

patients demonstrated circulatory unloading and cardiac atrophy because the bed-bound patients did not show statistically significant decreases in left ventricular diastolic dimension and left ventricular mass index (Table). However, the decrease in serum albumin may have led to the decrease in plasma volume in the present study. Therefore, the cardiac dysfunction in bed-bound patients following cerebrovascular accidents may also be attributed to circulatory unloading.

Study limitations: First, the data in the present study are not sufficient to evaluate whether or not the cardiac dysfunction in poststroke patients without manifest cardiovascular disease is critical in caring for these patients. Since the decrease in LVEF of the bed-bound patients was not statistically significant (Figure 2), left ventricular systolic function in bed-bound patients was thought to be preserved. It has recently been reported that at least 30% of patients with congestive heart failure have preserved systolic function and that these patients have diastolic dysfunction.[23] Furthermore, the incidence of heart failure due to left ventricular diastolic dysfunction increases with age.[24] Since the increase in the Tei index in bed-bound patients indicated left ventricular diastolic dysfunction, preventative treatment for the onset of heart failure due to diastolic dysfunction may be needed for elderly bed-bound patients following cerebrovascular accidents. Second, the data in the present study did not show whether or not the cardiac dysfunction in bed-bound patients was reversible. If some rehabilitation or treatment can improve the nutritional status, the cardiac dysfunction may disappear. A follow-up survey is needed to determine the effect of nutritional status on cardiac function in bed-bound patients following cerebrovascular accidents.

Conclusion: Latent cardiac dysfunction and poor nutritional status may exist in bed-bound patients following cerebrovascular accidents. The Tei index may be a useful index of latent cardiac dysfunction in bed-bound patients because it is independent of the cardiac loading condition.

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