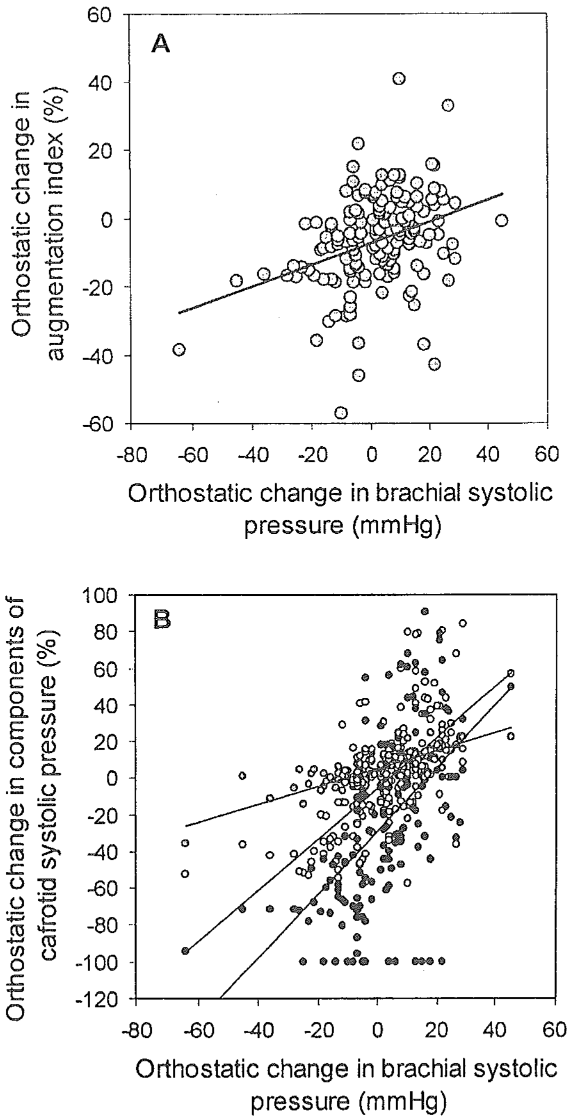

Fig. 3. *Orthostatic changes in the augmentation index and the three components of carotid pressure. A: Orthostatic change in the augmentation index (r=0.345,* p*<0.001). B: Orthostatic changes in the three components of carotid systolic pressure. Open circles: the incident component of pulse pressure (r=0.650,* p*<0.001); closed circles: the reflection component of pulse pressure (r=0.548,* p*<0.001); gray-circles: diastolic pressure (r=0.618,* p*<0.001). The analysis of co-variance indicated that the three regression lines were markedly different (F{3,455}=14.9,* p*<0.0001).*

the mean orthostatic change in carotid SBP was -41±11 mmHg, while that in brachial SBP was -32±14 mmHg (p=0.004). In the 12 OSH subjects classified by carotid BP but not by brachial BP, the mean orthostatic change in carotid SBP was -25±3 mmHg, while that in brachial SBP was -15±3 mmHg (p<0.001).

To evaluate the predisposing factors for brachial and carotid OSH, stepwise regression analysis was performed with the following parameters: age, sex, body height, and basal brachial SBP, HR, and AIx. Carotid OSH was significantly associated with AIx (β=0.19, p=0.015) in addition to basal brachial SBP (β=0.27, p<0.001) and age (β=0.18, p=0.020), while brachial OSH was only associated with basal brachial SBP (β=0.25, p=0.002) and age (β=0.20 p=0.012).

The significant association between Δbrachial SBP and ΔAIx is depicted in Fig. 3. Orthostatic changes in the three components of carotid SBP, *i.e.*, DBP and the incident and reflection component of PP, are also illustrated. The orthostatic reduction in the three components of carotid SBP were significantly associated with Δbrachial SBP. Although both the incident and the reflection components of carotid PP were markedly reduced, the decline of the reflection component (-4.0±8.4 mmHg) was much greater than that of the incident component (-1.2±9.9 mmHg, p=0.002). Representative tracings of the carotid arterial pressure waveform in one subject with OSH are shown in Fig. 1.

To assess the mechanism underlying the change in AIx in response to standing up, the association between orthostatic change in AIx and that in the arrival time of the reflection pressure wave (T_r) was evaluated. The results showed that orthostatic change in AIx was significantly related with that in T_r (r=0.21, p=0.010).

The hemodynamic characteristics of the OSH subjects are revealed in Table 2. The OSH subjects, assessed by the Δcarotid SBP as well as the Δbrachial SBP, showed significantly higher basal SBP, MBP and AIx compared with orthostatic normotension (ON) subjects. The ΔAIx was also significantly higher in the OSH group, which was partly responsible for the severe orthostatic decline of SBP. On the other hand, in the OSH subjects, the decline of MBP in response to standing up was significantly less than that of SBP. The Δcarotid SBP (-22±8%) was significantly higher than the ΔMBP (-12±8%, p<0.001). The Δbrachial SBP (-22±10%) was also significantly higher than the ΔMBP (-17±11%, p=0.002).

Discussion

In the present study we observed that carotid OSH was associated with a higher basal carotid AIx, in addition to advanced age and high brachial SBP. AIx has been associated with cardiovascular risk (*23*), and has recently been shown to independently predict coronary artery disease (*24*). Furthermore, AIx has been shown to be associated with mortality in the elderly (*7*). A background of high AIx may be responsible for the higher morbidity and mortality in OSH subjects.

The prevalence of isolated systolic hypertension, showing basal brachial SBP ≥140 mmHg and DBP <90 mmHg, was also higher in subjects with OSH (7 of 21 subjects) than in the ON group (13 of 134, p=0.008). An early returning of the

Table 2. Hemodynamic Characteristics of Orthostatic Systolic Hypotension Subjects

	Orthostatic carotid SBP change			Orthostatic brachial SBP change		
	OSH (21)	ON (134)	*p*	OSH (9)	ON (146)	*p*
Basal						
Carotid SBP (mmHg)	145±21	121±20	<0.001	151±26	123±21	<0.001
Brachial SBP (mmHg)	146±19	126±18	<0.001	151±23	127±18	<0.001
MBP (mmHg)	116±15	100±14	<0.001	120±18	101±14	<0.001
DBP (mmHg)	86±11	76±11	<0.001	87±14	77±11	0.010
Augmentation index (%)	41±15	30±15	0.001	44±12	30±15	0.012
Heart rate (beat/min)	68±11	69±11	0.761	67±11	69±11	0.594
Orthostatic changes in						
Carotid SBP (mmHg)	−32±11	4±13	<0.001	−41±11	2±15	<0.001
Brachial SBP (mmHg)	−22±13	6±11	<0.001	−32±14	5±12	<0.001
MBP (mmHg)	−14±9	6±9	<0.001	−19±11	5±10	<0.001
DBP (mmHg)	−3±7	6±6	<0.001	−5±10	5±7	<0.001
Augmentation index (%)	−17±10	−5±14	<0.001	−18±10	−6±14	0.008
Heart rate (beat/min)	15±6	10±6	0.004	16±7	11±6	0.010

Values are mean±SD. OSH, orthostatic systolic hypotension defined as more than 20 mmHg decline in SBP; ON, orthostatic normotension (except for OSH subjects); SBP, systolic blood pressure; MBP, mean blood pressure; DBP, diastolic blood pressure.

reflection pressure wave caused by an enhanced arterial stiffness was thought to be a principal reason for the enhanced AIx and isolated systolic hypertension. Recently, a significant association between carotid-brachial pulse wave velocity (PWV) and orthostatic BP response was reported in elderly subjects (*25*). In a previous study, we also demonstrated a relationship between orthostatic BP decline and carotid intima-media thickening (*26*). These reports together with the present findings indicate that enhanced arterial stiffness plays a significant role in the orthostatic BP dysregulation.

Although the present study was not designed for detailed elucidation of the mechanism responsible for the decline in AIx after standing, there seem to be several possible mechanisms. The magnitude of AIx is dependent on the distance from the reflection site, the velocity of wave conduction, as well as the reflectance (the reflection efficacy) (*27*). In the present study, we observed that orthostatic change in carotid AIx was significantly associated with that in T_r. Both the distance to the reflection point and the wave velocity influenced the timing of the return of the reflection wave. The distance to the reflection point is technically considered to be the body height. It has been shown that short stature is associated with high AIx (*28*). Since change in arterial impedance could influence the reflection point, it is conceivable that postural change from a supine to a standing position could change the reflection point through the change in impedance (*11*). It is also conceivable that OH itself could reduce AIx by reducing the wave velocity, since it is well known that PWV is highly dependent on BP. On the other hand, the changes in HR should also be considered as a confounding factor for the pressure waveform. It has been well demonstrated that an increase in HR will decrease the absolute duration of systole, effectively shifting the reflected wave into diastole, and thereby reducing AIx (*29*). The sympathetically increased HR in response to orthostatic stimuli could be another underlying mechanism of the orthostatic decline in AIx.

Neuronal dysregulation of BP plays a pivotal role in OH. In patients with autonomic dysfunction, OH results from an impaired capacity to increase vascular resistance during standing (*30*). The neuronal dysfunction leads to increased downward pooling of venous blood and a consequent reduction in stroke volume and cardiac output that exaggerates the orthostatic fall in BP (*30*). On the other hand, the enhanced arterial stiffness attenuates the baroreceptor response, since carotid and aortic baroreceptors locate in the arterial wall and are triggered by stretch. It has been reported that there is an inverse relationship between carotid distensibility and baroreceptor function (*31*).

Since none of the subjects had any orthostatic symptoms during examination, we should be cautious in extending our findings to subjects with orthostatic symptoms. However, it should be emphasized from our study that a lack of a significant orthostatic change in brachial BP does not eliminate the possibility of OSH in subjects with symptoms like light-headedness, since it could relate to cerebral hypoperfusion. In the present study, all subjects were free from any medications, including antihypertensive drugs. Since there is accumulating evidence that antihypertensive drugs have class-specific effects on central BP independent of the effect on brachial BP (*32*), it is also conceivable that the orthostatic change in carotid BP could be greatly exaggerated in subjects on antihypertensive medication. Further study is needed to clarify this very important issue.

There were several study limitations. First, we were not able to consider the hydrostatic effect when evaluating the orthostatic BP response. Since a decreased hydrostatic pressure induces a baroreceptor unloading in addition to the effect of decreased cardiac preload, excessive baroreceptor-evoked sympathoexcitation might have occurred in the study procedure. However, in the OSH subjects, the orthostatic change in HR was not larger than that of the ON group. The impaired baroreceptor function might be involved in the destabilization of BP after the postural change. Secondly, we defined the carotid OSH as a decline in carotid SBP ≥20 mmHg. However, the application of the criteria based on the changes in brachial SBP to the carotid SBP was not validated. Thirdly, we evaluated the orthostatic changes in BP and AIx by single measurement at 1 min after standing up. It has been reported that the measurement of SBP after 1 min of upright posture was twice as sensitive as a single measurement at 3 min in elderly subjects (*33*). However, the time-dependence of the alteration of orthostatic BP has been well documented (*34*). We have also reported that the time elapsed after standing up could affect the prevalence of OH (*35*). Sequential measurements could thus provide additional information that might help to clarify the association between altered AIx and OSH.

In summary, the findings of the present study indicate that evaluation of OSH from brachial BP may underestimate the prevalence of OSH as well as the magnitude of BP change, especially in elderly subjects with higher carotid AIx and individuals with high SBP. OSH was associated with a significant reduction of the reflection component of carotid PP in addition to a significant decrease in the incident component. Although further study is necessary, intervention to manipulate the reflection wave could be a therapeutic option in OSH.

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Original Article

Long-Term Compliance with Salt Restriction in Japanese Hypertensive Patients

Yuko OHTA, Takuya TSUCHIHASHI, Uran ONAKA, Kimika ETO, Mitsuhiro TOMINAGA, and Michio UENO

The purpose of the present study was to investigate the long-term compliance with salt restriction in Japanese hypertensive patients. Subjects included 389 patients, 230 women and 159 men, mean age 58±11 years, who underwent successful 24-h home urine collection more than three times over an interval of a year. Urinary salt, potassium, and creatinine were measured. Additionally, family history, habitual alcohol intake, smoking habit, physical activities, and job status were assessed by use of a questionnaire. During the follow-up period (average 3.5 years), participants underwent urine collection 4.6 times in average. Urinary salt excretion at the last visit was significantly lower than that at the first visit (8.7±3.4 *vs.* 9.6±4.1 g/day; *p*<0.01). Urinary potassium excretion also decreased significantly during this period (from 2.0±0.7 to 1.9±0.7 g/day; *p*<0.05). Among the mean 4.6 urine collections, 45.2% (men 34.6%, women 52.6%) of the patients successfully achieved <6 g (100 mmol of sodium)/day of salt excretion on at least one occasion. The rate of achievement of averaged urinary salt excretion <6 g/day dropped to 10.3% (men 4.4%, women 14.3%). Only 2.3% (men 0.6%, women 3.5%) of the patients achieved <6 g/day on all occasions. There were no significant differences in age, habitual alcohol intake, smoking habit, physical activities, or job status between patients who complied with the salt-restricted diet and those who did not. Results suggest that long-term compliance with salt restriction is poor in Japanese hypertensive patients. Since no specifically defining characteristics were found in the compliant patients, repeated measurements of urinary salt excretion seem to be important to encourage salt restriction. (*Hypertens Res* 2005; 28: 953–957)

***Key Words*: salt restriction, 24-h home urine collection, urinary salt excretion, hypertensive patients, long-term compliance**

Introduction

Lifestyle factors, including dietary salt intake, play major roles in the onset and development of hypertension (*1–3*). Many observational studies have shown a positive relationship between salt intake and blood pressure (BP) (*4–6*), and salt restriction has been suggested to be effective as a non-pharmacological treatment of hypertension (*7–11*). The seventh report of the Joint National Committee (JNC 7) recommends sodium reduction to a level of no more than 100 mmol/day in hypertensive patients (*11*). On the other hand, salt intake has been reported to be high in the Japanese population (*12*). We have previously reported that an awareness of the importance of salt restriction is not associated with actual salt restriction in hypertensive outpatients (*13*). Since the average urinary salt excretion was 9.7±3.9 g/day in that study, achieving the level of salt restriction suggested by the guidelines would seem to be difficult in the Japanese population. Based on our previous observations, we investigated the long-term compliance with salt restriction in the present study.

From the Division of Hypertension, Clinical Research Center, National Kyushu Medical Center, Fukuoka, Japan.
Address for Reprints: Yuko Ohta, M.D., Division of Hypertension, Clinical Research Center, National Kyushu Medical Center, Jigyohama 1–8–1, Chuo-ku, Fukuoka 810–8563, Japan. E-mail: yukoo@qmed.hosp.go.jp
Received June 10, 2005; Accepted in revised form October 3, 2005.

Table 1. Characteristics of the Subjects

	First visit	Last visit
Age (years)	58.2±11.0	61.7±10.9
Body weight (kg)	60.9±11.0	61.2±10.9
Systolic blood pressure (mmHg)	145±15	138±15**
Diastolic blood pressure (mmHg)	87±9	81±9**
Serum creatinine (mg/dl)	0.85±0.47	0.98±0.88**
Urinary salt excretion (g/day)	9.6±4.1	8.7±3.4**
Urinary potassium excretion (g/day)	2.0±0.7	1.9±0.7*
Urinary creatinine excretion (mg/day)	1,020±310	994±303**

Values are means±SD. *p<0.05, **p<0.01 *vs.* first visit.

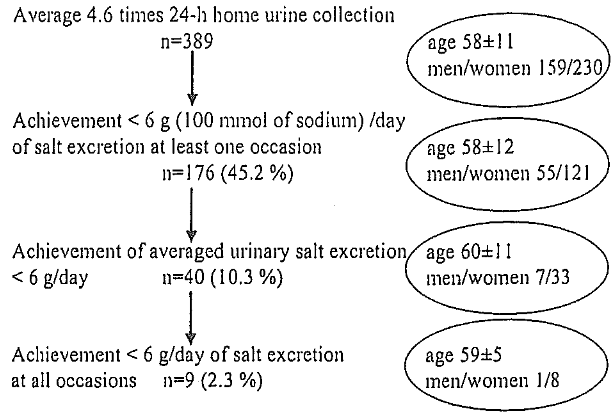

Fig. 1. *Compliance with salt restriction.*

Methods

Participants were recruited from hypertensive outpatients who visited the National Kyushu Medical Center. We undertook 24-h home urine collection in 1,567 outpatients between January 1998 and December 2004. Twenty four-hour urine samples were collected using a partition cup (proportional sampling method (*14*)), which collects a 1/50 portion of the 24-h urine. If the 24-h creatinine excretion was within ±30% of the estimated values, the urine collection was considered successful. Patients with malignant hypertension, secondary hypertension or diabetic nephropathy were excluded. Subjects included 389 patients, 230 women and 159 men, mean age 58±11 years, who underwent successful 24-h home urine collection more than three times over an interval of a year. Urinary salt, potassium, and creatinine were measured. BP was measured with a sphygmomanometer by the doctors while the patients were seated. Hypertension was considered to be present in patients with systolic BP (SBP) ≥140 mmHg and/or diastolic BP (DBP) ≥90 mmHg, or those patients on antihypertensive medication. At the first visit of the patients, family history, habitual alcohol intake, smoking habit, physical activities, and job status were assessed by use of a questionnaire. Then, the patients were advised to reduce their salt intake to the level of <7 g/day by trained dieticians. The protocol was explained in detail, and informed consent was obtained from each patient.

Statistical Analysis

Values are presented as the mean±SD. The differences in the variables were compared by one-way ANOVA. A χ^2 test was also utilized when appropriate. p values less than 0.05 were considered significant.

Results

During the average 3.5-year period of follow-up, participants underwent urine collection 4.6 times in average.

The characteristics of the subjects are shown in Table 1. The mean age was 58.2±11.0 years at the first visit and 61.7±10.9 years at the last visit. Mean BP at the last visit was significantly lower than that at the their first visit (138±15/81±9 *vs.* 145±15/87±9 mmHg; p<0.01). Serum creatinine at the last visit was significantly higher than that at the first visit (0.98±0.88 *vs.* 0.85±0.47 mg/dl; p<0.01). Urinary salt excretion at the last visit was significantly lower than that at the first visit (8.7±3.4 *vs.* 9.6±4.1 g/day; p<0.01). Urinary potassium excretion also decreased significantly during this period (from 2.0±0.7 to 1.9±0.7 g/day, p<0.05).

Figure 1 demonstrates the compliance with salt restriction. Among the mean 4.6 urine collections, 45.2% (men 34.6%, women 52.6%) of the patients successfully achieved <6 g (100 mmol of sodium)/day of salt excretion on at least one occasion. The rate of achievement of averaged urinary salt excretion <6 g/day dropped to 10.3% (men 4.4%, women 14.3%). Only 2.3% (men 0.6%, women 3.5%) of the patients achieved <6 g/day on at all occasions.

Comparisons of the characteristics between the patients who had average urinary salt excretion of less than 8 g/day (Low group, n=137) and those who had more than 8 g/day (High group, n=252) are presented in Table 2. Since urinary salt excretion was positively correlated with body weight, this analysis was conducted using urinary salt excretion values adjusted for body weight (per 60 kg body weight). Urinary salt excretion values at the last visit were significantly lower than those at the first visit in the High group (9.9±3.3 *vs.* 11.1±3.9 g/day; p<0.01), but in the Low group these values were not significantly different (6.6±2.5 *vs.* 6.8±2.8 g/day; n.s.). Mean BP at the last visit was significantly lower than that at the first visit in both groups. Urinary potassium excretions at both the first and last visits were significantly lower in the Low group, suggesting that salt restriction may be associated with low potassium intake. There were no significant differences between the two groups in any of the patient characteristics, including age, habitual alcohol intake, smoking habit, and physical activities.

In addition, the frequency of the subjects who were under

Table 2. Comparison of the Characteristics between Patients with Low and High Salt Excretions

	Urinary salt excretion	
	Low (average <8 g/day#)	High (average ≥8 g/day#)
Number of patients	137	252
Sex (men/women)	50/87	109/143
Age (years)	58.3±11.6	58.1±10.4
Body weight at the first visit (kg)	61.8±12.1	60.5±10.3
Body weight at the last visit (kg)	61.9±11.1	60.8±10.7
Systolic blood pressure at the first visit (mmHg)	146±16	145±15
Systolic blood pressure at the last visit (mmHg)	138±17**	138±13**
Diastolic blood pressure at the first visit (mmHg)	88±10	87±9
Diastolic blood pressure at the last visit (mmHg)	81±9**	81±10**
Urinary salt excretion at the first visit (g/day)	6.8±2.8	11.1±3.9††
Urinary salt excretion at the last visit (g/day)	6.6±2.5	9.9±3.3**,††
Urinary potassium excretion at the first visit (g/day)	1.9±0.7	2.0±0.7†
Urinary potassium excretion at the last visit (g/day)	1.8±0.7	1.9±0.7†
Urinary creatinine excretion at the first visit (g/day)	975±309	1,045±308†
Urinary creatinine excretion at the last visit (g/day)	967±324	1,008±290**
Habitual alcohol intake (%)	54.7	59.7
Smoking habit (%)	13.8	21.2
Physical activities (≥1–2/week,%)	57.3	49.1

Values are means±SD. ** $p<0.01$ *vs.* first visit; † $p<0.05$, †† $p<0.01$ *vs.* Low. #Urinary salt excretion was adjusted for 60 kg of body weight.

Fig. 2. *Comparison of the job status and the number of family members between patients with low and high salt excretions.*

regular employment was comparable between the groups (Fig. 2). Housewives were also similarly distributed in the two groups, and the frequency of the subjects who lived alone or with only one family member was not different between the groups (Fig. 2).

Discussion

The present study demonstrated that long-term compliance with salt restriction is poor in Japanese hypertensive patients.

JNC 7 recommends sodium reduction to a level of no more than 6 g (100 mmol of sodium)/day in hypertensive patients (*11*); however, the rate of achievement <6 g/day of salt excretion was low in the present study. The National Nutrition Survey in Japan showed that the average salt intake was 11.4 g/day in 2002 (*12*). Salt intake in the Japanese population has been decreasing in recent years, but over the last decades it has shown a more general trend of increase along with the adoption of a more Westernized lifestyle in Japan, including such phenomena as fast food and eating out (*12*, *15–17*).

Hashimoto *et al.* reported that urinary salt excretion in a group of hypertensive outpatients did not change over a 6.4-year follow-up period (*18*). In the present study, however, urinary salt excretion at the last visit was significantly lower than that at the first visit. We have previously reported that there is no obvious reduction in the actual salt intake in salt-conscious patients (*13*). Thus, repeated monitoring of urinary salt excretion, along with providing feedback to patients and follow-up counseling, seem to be the most important and practical way to achieve a reduction of salt intake in individual hypertensives (*13*, *19*).

In the present study, we had hoped to identify specific characteristics of the subjects who are able to maintain low salt consumption. However, there were no specific differences between the Low and High salt groups. Thus, although it was expected that elderly subjects might be more conscious about salt restriction than young subjects, there was no difference in age between the groups. Similarly, although subjects who are conscious about salt restriction might also be expected to be conscious about other lifestyle modifications, including alcohol restriction, smoking cessation, and regular physical activities, there were no significant differences in these factors between the Low and High salt groups. In the case of subjects with regular employment, it might be thought that they would have more opportunities to eat out, leading to an increased salt consumption, while housewives, who usually cook by themselves, would find it easier to reduce their salt consumption. Again, however, the present observations do not support the notion of a relationship between the job status and salt consumption. Finally, the frequency of the subjects who live alone or with only one family member did not differ between the Low and High salt groups. In short, the subjects with low salt consumption could not be characterized at all.

The results of a previous study underscore the importance of public health education for the control of high BP (*6*). However, there are several barriers to the promotion of salt reduction: insufficient attention to health education by health care practitioners; lack of reimbursement for health education services; lack of access to places to engage in physical activity; larger servings of food in restaurants; lack of availability of healthy food choices in many schools, worksites, and restaurants; lack of exercise programs in schools; large amounts of sodium added to foods by the food industry and restaurants; and the higher cost of food products that are lower in salt and calories (*11*). Overcoming these barriers will require an approach directed not only to high-risk populations but also to communities, schools, worksites, and the food industry, such as informing the public about the relationship between salt intake and BP, informing the public about the importance of reading food labels to determine the salt content of common foods, reducing the salt content of existing foods while maintaining flavor, and providing low-salt flavorings for home consumption (*3*, *20*).

In conclusion, long-term compliance with salt restriction is poor in Japanese hypertensive patients. Since defining characteristics could not be identified in the salt-restricted patients, repeated measurements of urinary salt excretion seem to be important to encourage salt restriction.

Acknowledgements

We greatly appreciate the technical assistance we received from the staff of the Division of Nutrition, National Kyushu Medical Center. We would also like to thank Ms. T. Shimada and Ms. Y. Ishii for their technical and secretarial assistance.

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