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Evaluation of Gastric Motor Activity in the Elderly by Electrogastrography and the ^{13}C-Acetate Breath Test

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Key Words
Gastric motility · Gastric emptying · Electrogastrography · ^{13}C-acetate breath test · Elderly

Abstract
Background: Elderly people frequently have symptoms of fullness and appetite loss due to impaired gastric motor activity. These symptoms may cause malnutrition, immunosuppression and other complications. ***Objective:*** The effects of aging and daily activity on gastric motility in the elderly were investigated by electrogastrography and the ^{13}C-acetate breath test. ***Methods:*** We enrolled seven active elderly subjects (active elderly group), seven elderly subjects staying at a geriatric facility who had reduced mental and physical capacities (inactive elderly group) and seven healthy young volunteers (young group). Electrogastrography was recorded before and after ingestion of a ^{13}C-acetate-mixed liquid meal. Expired air was sampled every 10 min after the meal to measure the $^{13}CO_2$ concentration. ***Results:*** The ratio of the incidence of the 3-cpm wave (gastric intrinsic frequency) during the postprandial period compared to the fasting state was reduced in both elderly groups compared to young subjects, and the reduction was greater in the inactive elderly than in the active elderly group. The ratio of the amplitude of the peak frequency during the postprandial period to that in the fasting state (power ratio) was also lower in the elderly groups. The time of peak $^{13}CO_2$ expiration was delayed in the active elderly and more so in the inactive elderly group. ***Conclusion:*** Postprandial peristalsis and gastric contractile force are reduced in the elderly, and gastric emptying is delayed indicating a reduction in gastric motor activity.

Introduction

Elderly people may develop reduced gastric motor activity, leading to early satiety and decreased appetite [1]. The resulting malnutrition may suppress immune function [2] and induce other complications. To maintain the quality of life in an aging society, it is important to continue healthy eating habits. Many of the current means of measuring gastric motor activity are invasive and difficult to apply to the elderly. The clinical application of noninvasive electrogastrography and the ^{13}C-acetate breath test has been initiated in recent years. These measurements of gastric motility can be applied safely

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and easily in the elderly. In electrogastrography, regular electrical activity generated by gastric smooth muscle is recorded at the abdominal surface [3]. In the ^{13}C-acetate breath test, orally ingested nonradioactive ^{13}C-labeled acetic acid is absorbed from the duodenum; its measurement in exhaled air allows the gastric emptying time to be calculated indirectly [4]. Gastric electroactivity plays an important role in the control of motor activity, and gastric myoelectrical disturbances may lead to gastric motor abnormalities and disturbed gastric emptying [5]. Using these methods simultaneously, gastric electroactivity and gastric emptying time were measured, and the effects of aging and daily activity on gastric motility were investigated.

Subjects and Methods

Subjects

Electrogastrography and ^{13}C-acetate breath testing were performed simultaneously in healthy volunteers aged 30 years or less and in elderly subjects aged 65 years or older without a past medical history of upper gastrointestinal disease or surgery. All subjects had undergone upper gastrointestinal endoscopy and none had any abnormalities. Seven elderly patients who were admitted for endoscopic colonic polypectomy and had an ordinary social life (4 men and 3 women; mean age 72.2 ± 4.3 years) were enrolled as the active elderly group. Seven elderly subjects staying at a geriatric facility for a prolonged period (2 men and 5 women; mean age 83.6 ± 4.4 years; mean duration of stay 2.9 ± 0.9 years) with reduced physical and mental daily activities were regarded as the inactive elderly group. For controls, seven healthy young volunteers (6 men and 1 woman; mean age 27.0 ± 1.6 years) were used as a young group. There was no significant difference in the height or weight of the subjects in each group. All subjects could eat and walk independently. No subject had diabetes, neurological disease or serious respiratory, liver or renal illness. This study was approved by the Ethical Committee of Osaka Medical College, and informed consent was obtained from all subjects.

Electrogastrography

Eating, drinking and smoking were prohibited for 12 h prior to the examination. The measurement was performed in the morning with the subject in the supine position. Two disposable pregelled silver/silver chloride surface electrodes were attached between the xiphoid process and the umbilicus at the left and right midclavicular lines; electrogastrographic signals were recorded by Digitrappe EGG (Synectics Medical, Stockholm, Sweden). After electrogastrography was recorded for 20 min in the fasting state, the subject ingested a liquid meal (250 ml, 250 kcal) which had been maintained at room temperature for approximately 5 min and postprandial electrogastrography was recorded for 20 min. In the active elderly group, electrogastrography was performed before premedication for polypectomy.

The frequency of electrogastrographic signals was analyzed by fast Fourier transformation using computer software (ElectroGastroGram, version 6.30, Gastrosoft, Irving, Tex., USA). Certain frequency ranges of waves of 2.40–3.70 cycles per minute (cpm), 2.40 cpm or below and 3.7–10.00 cpm were monitored as the 3-cpm wave (the dominant frequency), bradygastria and tachygastria, respectively. The percentage of 3-cpm wave, mean frequency (average of the peak frequency during fasting or the postprandial period), frequency ratio (ratio of the mean frequency during the postprandial period to that in the fasting period) and power ratio (ratio of the amplitude of the peak frequency of the postprandial period to that of the fasting period) were calculated.

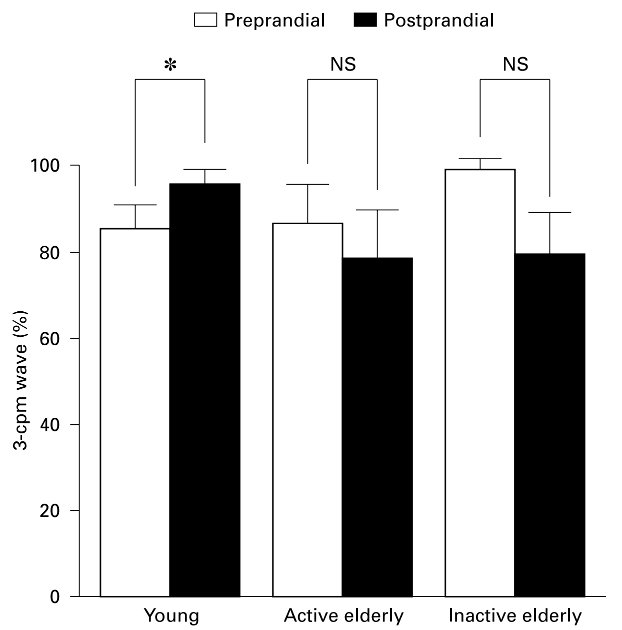

Fig. 1. The incidence of the 3-cpm wave on electrogastrography during the fasting and postprandial periods in the young, active elderly and inactive elderly groups. * $p < 0.05$. NS = Not significant.

^{13}C-Acetate Breath Test

To 250 ml of liquid meal, 100 mg of ^{13}C-acetate was added and stirred well. Expired air from the subject was collected in an aluminium bag for 10 min before ingestion of the meal. Expired air was sequentially collected 10, 20, 30, 40, 50, 60, 90 and 120 min after ingestion of the meal. The $^{13}CO_2$ concentration in the collected expired air at each time point was measured by mass spectrography (Tracer MAT, Finnigan MAT, San Jose, Calif., USA) and the time point of the peak concentration was calculated.

Statistical Analysis

The results are presented as the mean ± SD. Intragroup comparison was analyzed by the Wilcoxon signed-rank test, and intergroup comparison was analyzed by the Mann-Whitney U test. A confidence interval of 5% was regarded as significant.

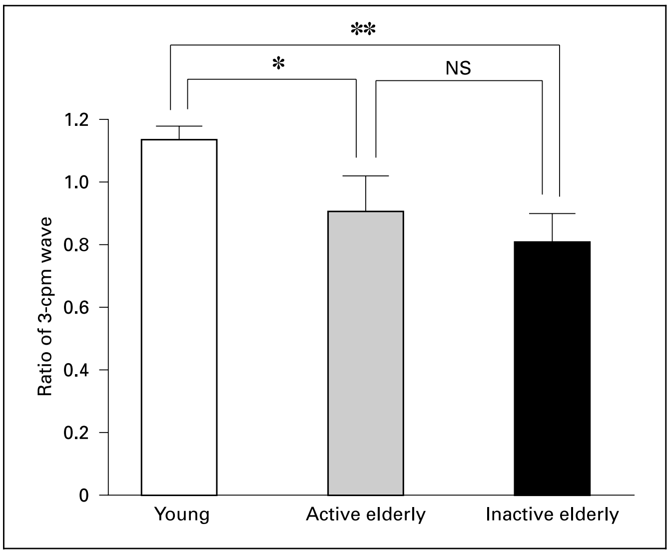

Fig. 2. The ratio of the incidence of the 3-cpm wave on electrogastrography during the fasting period to that in the postprandial period in the young, active elderly and inactive elderly groups. * $p < 0.05$, ** $p < 0.01$. NS = Not significant.

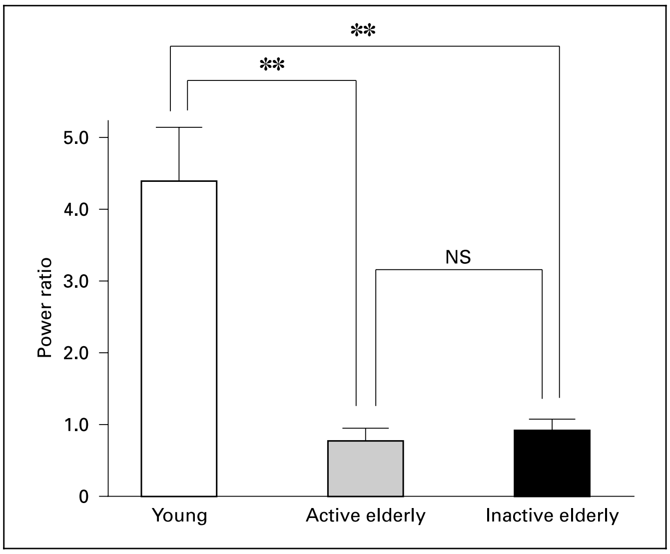

Fig. 3. The ratio of the amplitude of the peak frequency of the postprandial period to that in the fasting period (power ratio) in the young, active elderly and inactive elderly groups. ** $p < 0.01$. NS = Not significant.

Results

The 3-cpm Wave on Electrogastrography

The incidence of the 3-cpm wave during the fasting and postprandial periods in the young group were 84.4 ± 4.5 and 95.3 ± 3.7%, respectively, showing a significant increase after the meal. The incidences of the 3-cpm wave during the fasting and postprandial periods were 85.8 ± 8.7 and 78.2 ± 9.3%, respectively, in the active elderly group, and 98.8 ± 1.2 and 78.7 ± 9.3%, respectively, in the inactive elderly group (fig. 1). To compare changes among the groups in the incidence of the 3-cpm wave between the fasting and postprandial periods, the ratio of the incidence during the fasting period to that in the postprandial period was calculated. The ratios in the active elderly (0.91 ± 0.11) and inactive elderly groups (0.80 ± 0.09) were significantly lower than that in the young group (1.14 ± 0.04). There was no significant difference between the active and inactive elderly groups (fig. 2).

Mean Frequency on Electrogastrography

The mean frequencies during the fasting period were 3.01 ± 0.09, 3.05 ± 0.08 and 3.23 ± 0.04 cpm in the young, active elderly and inactive elderly groups, respectively, and those during the postprandial period were 2.98 ± 0.07, 3.05 ± 0.08 and 3.14 ± 0.16, respectively. There were no significant differences among the groups during the fasting or postprandial periods, but the mean frequency tended to increase from the young group to the active elderly group and then to the inactive elderly group.

Frequency Ratio on Electrogastrography

The ratios of the mean frequency during the postprandial period to that in the fasting period were 0.992 ± 0.03, 0.997 ± 0.03 and 0.972 ± 0.05 in the young, active elderly and inactive elderly groups, respectively; there was no significant difference between the groups.

Power Ratio on Electrogastrography

The ratios of the amplitude of the peak frequency during the postprandial period to that in the fasting period were 4.36 ± 1.5, 0.74 ± 0.21 and 0.87 ± 0.18 in the young, active elderly and inactive elderly groups, respectively. The power ratio was significantly lower in the elderly groups than in the young group, but did not differ between the active and inactive elderly groups (fig. 3).

^{13}C-Acetate Breath Test

$^{13}CO_2$ concentrations in expired air increased with time after the meal in all groups. $^{13}CO_2$ concentrations peaked 60 min (28.2 ± 6.32‰), 90 min (23.3 ± 6.08‰) and 120 min (25.9 ± 9.99‰) after the meal in the young, active elderly and inactive groups, respectively, and decreased thereafter (fig. 4).

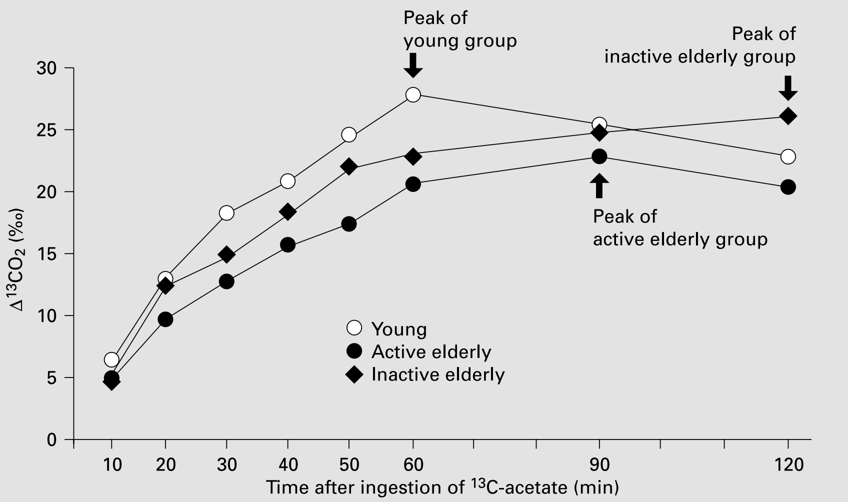

Fig. 4. The $^{13}CO_2$ concentration in the collected expired air at each time point before and after ingestion of the ^{13}C-acetate-mixed liquid meal in the young, active elderly and inactive elderly groups, measured by mass spectrography. The time of the peak concentration was calculated.

Discussion

In our aging society, the elderly experience not only physical changes, but also mental and physical stress caused by aging. Early discovery and therapy of gastric cancer and peptic ulcer diseases are possibly due to the development of endoscopy and endoscopic therapy and strong gastric acid inhibitors. However, the numbers of elderly patients with abdominal symptoms such as stomach fullness and appetite loss due to impaired gastric motor activity are increasing. Previous methods for examining gastric motility included gastrotonometry by the infused catheter method or microtransducer method, radioactive isotope methods and the acetaminophen method [6]. However, these methods are invasive and stressful and involve radiation exposure or drug-related adverse effects. In particular, these methods are generally not used for the elderly.

Recently, ^{13}C breath tests have been developed as a nonradioactive alternative by which the gastric emptying time can be indirectly measured using the $^{13}CO_2$ concentration in the expired air after a $^{13}CO_2$-labeled substance (such as acetate or octanoic acid) is ingested and absorbed from the duodenum [4, 6, 7]. The $^{13}CO_2$ method correlates well with both the radioactive isotope and acetaminophen methods, and it can be used as a noninvasive, safe measurement of gastric emptying time. The time of peak $^{13}CO_2$ concentration in expired air is the most appropriate index rather than the total amount in the expired air.

Recently, the clinical application of another noninvasive test method was initiated, in which gastric motility was estimated by transcutaneously recording the gastric electroactivity at the abdominal wall. In 1922, Alvarez [8] recorded gastric electroactivity on the human body surface. It is now possible to select, amplify and record the electric signals of gastric smooth muscle for clinical application [5, 9, 10]. Cyclic electroactivity (electrical control activity) generated by gastric smooth muscle is transmitted from the pacemaker located near the greater curvature of the upper body of the stomach to the pyloric side at a rate of 3 cpm [11].

Although it is unknown whether this electroactivity actually reflects gastric contractile motility, it is assumed to reflect emptying ability, which is the most important functional aspect of gastric motility.

Gastric myoelectrical activity plays an important role in the control of gastric motor activity [5]. Gastric myoelectrical disturbances may lead to gastric motor abnormalities and disturbed gastric emptying [5, 12]. Therefore, by simultaneously performing noninvasive electrogastrography and ^{13}C-acetate breath testing in the same patient, an investigation of the relationship between changes in gastric electroactivity and gastric emptying time becomes possible; moreover, gastric motor activity testing may be more accurate, safe and applicable in the elderly. This method may become a new clinically applicable, noninvasive gastric motility test. To evaluate this method in disease states, it is necessary to understand its changes under various conditions in healthy individuals.

Therefore, in this study, electrogastrography and ^{13}C-acetate breath testing were simultaneously performed in healthy young volunteers (young group), elderly individuals with an ordinary social life (active elderly group) and elderly individuals with reduced mental and physical activity (inactive elderly group). The effects of aging and daily activity on gastric motility were compared.

In the young group, the incidence of the 3-cpm wave was significantly increased during the postprandial period compared to the fasting period. In contrast, it tended to decrease during the postprandial period in the elderly groups. The postprandial incidence of the 3-cpm wave was significantly lower in the elderly groups than in the young group, and it was markedly decreased in the inactive elderly group compared to the active elderly group. The incidence of the 3-cpm wave increases after a meal in healthy individuals [12], perhaps due to an increase in the electroactivity generated by the pacemaker for initiating peristalsis upon food inflow to the stomach. In aged rats, reduced function of the autonomic nerve system, such as degeneration of or a decrease in activity of Auerbach's nerve plexus, has been observed [13]; the lower incidence of 3-cpm waves after a meal in the elderly may be due to a similar mechanism.

The change in the incidence differed between the active elderly and those with an inactive lifestyle. There was a difference between the average ages of the two elderly groups, which presumably might contribute to some of the differences observed. However, the daily lifestyle might also be reflected in the gastric electrical activity in our cases. Lu et al. [14] reported that postprandial gastric myoelectrical activity after moderate-intensity exercise was enhanced. The mean frequency during electrogastrography has been shown to increase with age or not change [15]. In this study, the mean frequency tended to increase with age, but the difference was not significant. Moreover, there were no significant differences among the groups in the ratio of the mean frequency during the postprandial period to that in the fasting period (frequency ratio), suggesting that the mean frequency is not affected by aging or daily activity.

In healthy individuals, the amplitude of the peak frequency increases continuously after a meal [16, 17]. This increase in amplitude is considered to be a conversion from electrical control activity, which is the electroactivity in the fasting state, to electrical response activity accompanied by strong gastric contractions [8] and reflecting the contractile motility of the antral pylorus [5, 18]. Smout et al. [3] simultaneously recorded electrogastrography and gastrotonometry and confirmed the postprandial appearance of electrical response activity in the stomach. The amplitude of electrogastrography waves reflects the gastric contractile force [3, 5] and may also correlate with gastric emptying [19]. Various factors, such as differences in electrodermal resistance on the body surface, thickness of the abdominal wall and differences in the distance from gastric smooth muscle to the electrode, are involved in the height of the amplitude; thus, it is difficult to compare amplitude among individuals. Therefore, we compared amplitude among the groups using the ratio of the amplitude of the peak wave during the postprandial period to that in the fasting period (power ratio).

The power ratio was significantly lower in the elderly groups, indicating that the postprandial gastric contractile force is reduced (hypomotility), resulting in a delay of gastric emptying in the elderly [20]. This delayed gastric emptying time was also demonstrated by the simultaneously delayed $^{13}CO_2$ expiration peak time in the elderly. In the elderly, reduced autonomic function, reduced sensitivity of smooth muscle to hormones, atrophy of the gastric wall muscular layer and fibrosis in the muscular layer are observed, suggesting that reductions in both autonomic nervous function and smooth muscle contractility are involved in the reduction of gastric motor activity [21]. The gastric motility-reducing and gastric emptying-reducing mechanism of aging may be explained by electrogastrography.

Complaints of early satiety may be considered to be caused by the postprandial reduction of gastric motor function and the accompanying delay in gastric emptying time. Based on the results of this study, these methods allow easy monitoring of gastrointestinal motor activity in order to screen elderly populations and identify patients who may benefit from treatment. Larger studies are needed to determine the validity of these findings.

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