ORIGINAL

Evaluation of the effects of mastication and swallowing on gastric motility using electrogastrography

Yoshitaka Kimura, Masahiro Nomura*, Yuki Sawada, Naoko Muraoka, Nao Kohno, and Susumu Ito

*Department of Digestive and Cardiovascular Medicine, Institute of Health Biosciences, The University of Tokushima Graduate School, and *Faculty of Integrated Art and Sciences, Department of Human and Social Sciences, The University of Tokushima, Tokushima, Japan*

Abstract : ***Objectives*** **: The influence of mastication and swallowing on gastric motor function was evaluated by electrogastrography (EGG) and abdominal ultrasonography.**
Methods**: The subjects were 30 elderly patients with tubal feeding without mastication and swallowing (T group) and 30 elderly controls who processed food by mastication and swallowing (C group). Gastric motor function was percutaneously examined before and after the ingestion of 250 ml of a liquid diet using an electrogastrograph (NIPRO EGG, A&D, Tokyo, Japan). The cross-sectional area of the gastric antrum was measured at 1 and 30 min after the start of ingestion of the liquid diet by external ultrasonography of the abdomen, and the gastric excretion function was evaluated. Furthermore, the spectral analysis of heart rate variability was performed using Holter electrocardiograms before and after ingestion. The low frequency power (LF power, 0.04-0.15 Hz), high frequency power (HF power, 0.15-0.40 Hz), and the LF/HF ratio were determined.**
Results**: The peak amplitude at 3 cycles per minute (cpm) was significantly increased after ingestion in the C and T groups ($p<0.05$), and the ratio of increase was significantly lower in the T group ($p<0.05$). The mean amplitude for the brady-gastria and tachy-gastria was significantly higher in the T group than in the C group ($p<0.05$). The gastric excretion function, as evaluated by external ultrasonography of the abdomen, was significantly lower in the T group than in the C group ($p<0.05$). An analysis of heart rate variability demonstrated that the HF power, a parameter of parasympathetic activity, after ingestion was significantly higher in the C group than in the T group ($p<0.05$). No changes in LF power or LF/HF ratio, parameters of sympathetic activity, were induced by ingestion in either the C or T groups.** ***Conclusions*****: The parasympathetic nerve dominantly controls gastric motor function, but autonomic nervous activity is reduced in patients who are unable to masticate and swallow food, resulting in adverse effects on gastric motor function and excretion function. Mastication and swallowing not only prepare food for passage from the oral cavity to the esophagus but are also important in terms of subsequent events that occur in stomach. It has been proposed that autonomic nervous activity might be involved in mastication and swallowing. J. Med. Invest. 53 : 229-237, August, 2006**

Keywords **:** *mastication, swallowing, electrogastrography, autonomic nerve, gastric motility*

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Address correspondence and reprint requests to Yoshitaka Kimura, M. D., Department of Digestive and Cardiovascular Medicine, Institute of Health Biosciences, University of Tokushima Graduate School, Kuramoto-cho, Tokushima 770-8503, Japan and Fax : +81-88-633-9235

INTRODUCTION

Oral intake and tubal feeding activate digestive functions, but, although the intake of food by these two routes is nutritionally similar, mastication and swallowing are required for oral intake (1, 2). Ingestion, mastication and swallowing are important in gastric motor function, and this function is markedly affected by manner in which food is ingested (3).

Electrical activity of the stomach caused by gastric movement can be recorded by means of electrogastrography (EGG). This percutaneous recording of electrical activity of the stomach was first reported in 1922 by Alvarez *et al* (4). However, only a few studies, involving the use of EGG, have been reported because of difficulties associated with cardiac electrical activity or electromyography caused by respiratory movement (5-7). With the recent development of computers and digital filters, non-invasive and simple percutaneous EGG recording using skin electrodes have become possible (8, 9).

Several studies have evaluated clinical application of EGG (10-14), but no studies of the importance of mastication and swallowing in gastric motility in elderly subjects have been reported. In the present study, relationships between ingestion, mastication, and swallowing on gastric motility were examined using EGG.

PATIENTS AND METHODS

1) Patients

The subjects were 30 elderly patients with tubal feeding without mastication and swallowing, consisting of 6 men and 24 women, aged 63-84 (T group ; mean age, 74.6±4.3 years) and 30 elderly control subjects who ingested food by mastication and swallowing, consisting of 12 men and 18 women, aged 60-96 years old (C group ; mean age, 77.2±6.1 years). All subjects had previously been admitted to convalescent wards in a general hospital or in a healthcare facility for the elderly, and their mental and physical activities in daily life were reduced.

The subjects had not undergone any surgical treatment of the digestive tract, nor were they being administered autonomic agents, such as H_2 blockers, proton pump inhibitors, improvers of gastric motor function, β-blockers, or sedatives. Tube nutrition was preformed in each patient in the T group for prevention of aspiration by dysphagia. Of these patients, 19 were geromarasmus, 4 Parkinson disease, 2 meningitis sequela, 5 after aspiration pneumonia, respectively. Patients with diabetes mellitus or neurological disorders that could cause abnormalities in autonomic nervous function and patients with cerebral infarction or arterial fibrillation in whom heart rate variability could not be analyzed were excluded. Tubal feeding was performed using a gastrostomy tube for 17 patients, and a transnasal gastric tube was used for the remaining 13 patients.

After fasting for more than 5 hours, the subjects were given a 250 ml liquid diet (Ensure liquid®, vanilla flavor, 250 kcal, Dainapot Inc.), which had been stored at room temperature (22-26℃) for over about 30-60 min, and data were collected on the 2 groups before and 30 min after ingestion.

2) Electrogastrography

As shown in Fig. 1, 5 electrodes including the central electrode were arranged on the upper abdomen with a fixed a silver-silver chloride electrode (Vitorode M, Nihon Koden Inc. Tokyo, Japan). Percutaneous EGG was continuously performed using a portable electrogastrograph (NIPRO EGG, A&D, Tokyo, Japan) for 30 min before and after ingestion. The EGG data were transferred to a personal computer (Windows XP) using special software for the Nipro electrogastrograph (NIPRO ESCI, A&D, Tokyo), and were converted to EGG spectra by means of fast Fourier transform (FFT). The sampling frequency for the EEG was 1 point/sec,

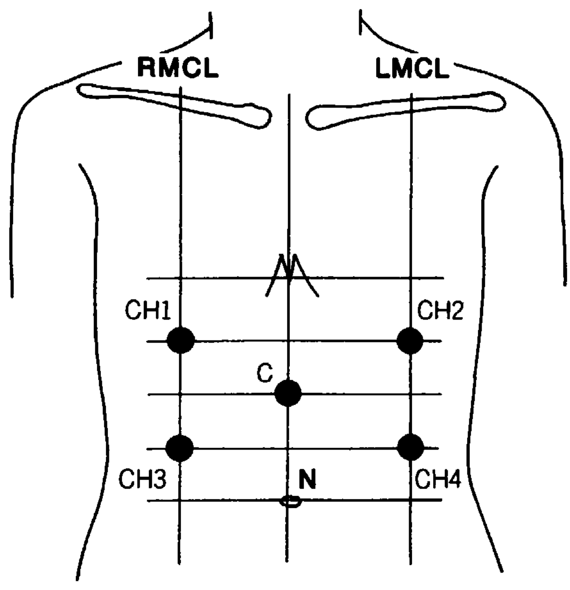

Fig. 1. **Recording positions of electrogastrogram.**

and the FFT interval was 256 points. The measurement frequency was 2.1-6.0 cpm. The normal EGG frequency is 2.4-3.6 cpm, which is defined as normo-gastria. A higher frequency range of more than 3.6 cpm is defined as tachy-gastria, and a lower frequency range of less than 2.4 cpm as brady-gastria (15). The mean amplitudes in the brady-gastria, normo-gastria, and tachy-gastria, as determined by EGG spectral analysis, were evaluated.

The increase in the ratio of the peak amplitude was calculated in the next formula :

Increase in the ratio of the peak amplitude) = [(peak amplitude after ingestion - peak amplitude at fasting)/(peak amplitude after ingestion)] $\times$100 (%)

3) External abdominal ultrasonography

The cross-sectional area of the gastric antrum was determined by placing an ultrasonic probe (5.0 MHz, SSD-2000, ALOKA, Tokyo, Japan) in a location from which the cross-sections of the abdominal aorta, superior mesenteric artery, and gastric antrum could be depicted in the same frame (16). A liquid test diet was then fed to the subjects, and gastric emptying was evaluated based on the percent area changes in the gastric antrum over a 30-minute period. A probe with a frequency of 5.0 MHz was used in the B mode. The analyses were performed using video recording data.

4) Spectral analysis of heart rate variability

Electrocardiograms were continuously recorded before and after ingestion using a Holter electrocardiograph (SM-50, Fukuda Denshi Inc, Tokyo, Japan), and heart rate variability were examined before and after ingestion. A two-channel recording of electrocardiograms (CM5 and CC5 leads) was performed (17), and magnetic tapes of the Holter electrocardiograms were analyzed using an ambulant ECG analyzer workstation specifically designed for the analysis of Holter electrocardiograms (DMW-9000 H, Fukuda Denshi, Tokyo, Japan). The R-R interval data by electrocardiography were transferred to a personal computer via an RS 232 C cable, and analyzed using the Holter data processing software program (Fukuda Denshi, Tokyo, Japan) and a time-series data analysis system (Fukuda Denshi, Tokyo, Japan). The low frequency power (LF power, 0.04-0.15 Hz), high frequency power (HF power, 0.15-0.40 Hz), and LF/HF ratio were determined by the spectral analysis of heart rate variability.

All subjects were examined in a sitting position at 45-60 degrees. The present study was approved by the directors of the hospital and institution, and informed consent was given to the patients or their family after full explanation of the purpose of this study.

5) Statistical analysis

All values were expressed as the mean ± standard deviation. Statistical analyses were performed using the Student's paired t-test (two-tail)and unpaired t-test, and values of $p<0.05$ were considered to indicate a statistical significance. Data analysis was performed using the StatView statistical software (Stat View 5.0 ; SAS Institute, Inc., Cary, NC, USA).

RESULTS

1) Electrogastrography

The dominant frequency of electrogastrography was around 3 cpm in all subjects in both tubular feeding (T) and oral intake control (C) groups, within the range of the normo-gastria (2.4 - 3.6 cpm).

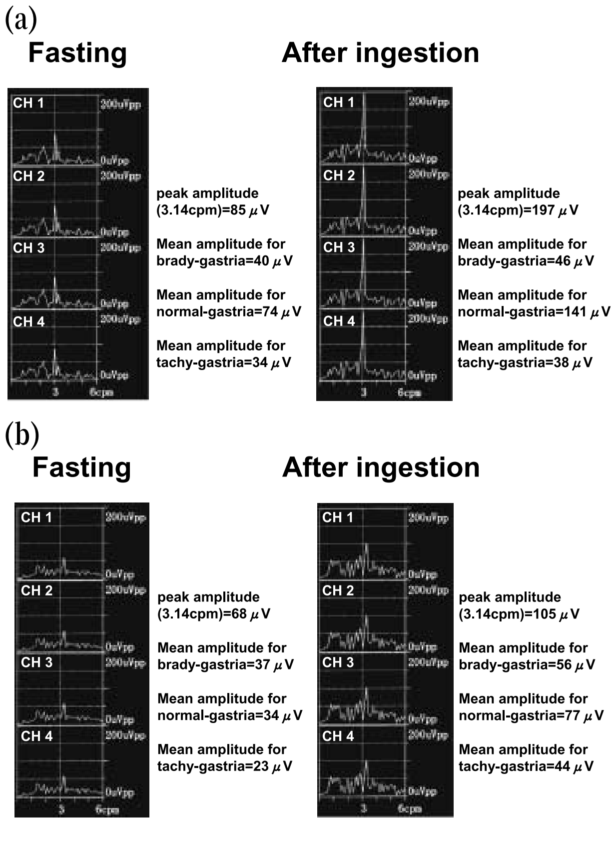

Fig. 2. epresentative examples of EGGs for the oral intake control (C) group (a) and the tubular feeding (T) group (b). CH 1, channel 1; CH 2, channel 2; CH 3, channel 3; CH 4, channel 4. The increase in the ratio of the peak amplitude followed by ingestion was 57% in the C group and 35% in the T group, respectively.

Fig. 2a and 2b show representative examples of FFT analysis of EGG, for the C group and T group. In both examples, the dominant frequency was within the range of normo-gastria (2.4-3.6 cpm), and the peak amplitude was increased as the result of ingestion in both cases. The increase in the ratio of the peak amplitude followed by ingestion was 57% in representative examples of the C group and 35% in the T group, respectively.

Fig. 3 shows the peak amplitude for normo-gastria (panel a) and the mean amplitude for both brady-gastria and tachy-gastria (panel b) in the C and T groups. In both the C and T groups, the peak amplitude was significantly higher after ingestion than before (C group : p<0.01, T group : p <0.05). The increase in the ratio of the peak amplitude following ingestion was significantly higher in the C group than in the T group (p<0.05). In the C group, the mean amplitudes for brady-gastria and tachy-gastria were not significantly changed by ingestion, while in the T group, the mean amplitudes for brady-gastria and tachy-gastria were

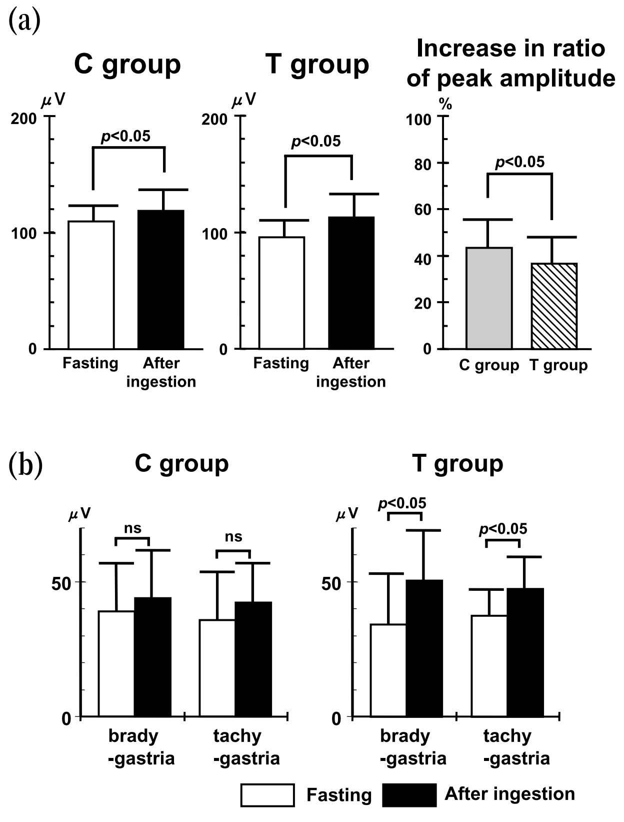

Fig. 3. Peak amplitude for normo-gastria (panel a) and mean amplitude for both brady-gastria and tachy-gastria (panel b) in the oral feeding control (C) and the tubular feeding (T) groups.

significantly increased (p<0.05).

2) Abdominal ultrasonogram

Fig. 4 shows an abdominal ultrasonogram of an elderly subject who received food orally (panel a) and for a subject who underwent tubal feeding (panel b). In both subjects, the cross-sectional area of the gastric antrum, measured 30 min after the start of ingestion, was smaller than that 1 min after the start of ingestion, and the ratio change, i.e., the gastric emptying, was 72% in the subject who took food orally and 43% in the one who underwent tubal feeding. Fig. 5 shows the ratio of gas-

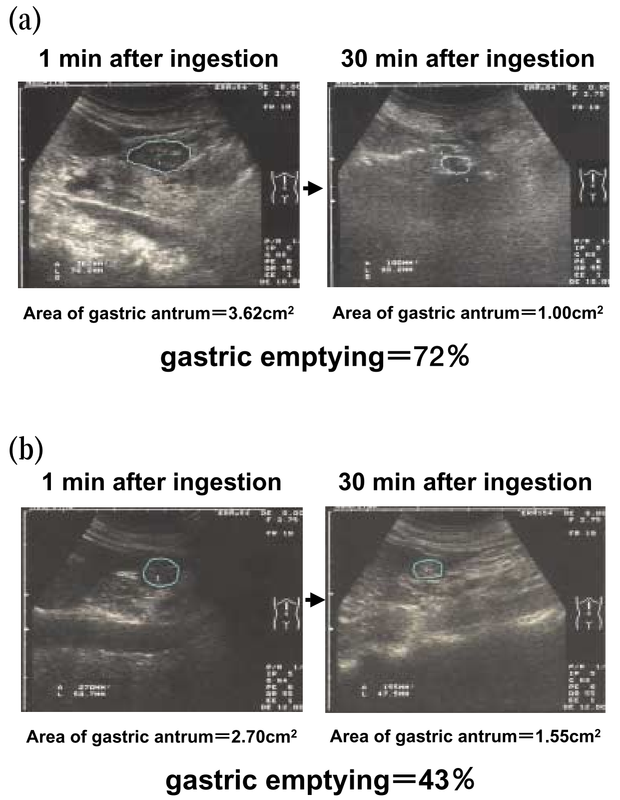

Fig. 4. Abdominal ultrasonogram of an elderly subject who received food orally (panel a) and that for a subject who underwent tubal feeding (panel b).

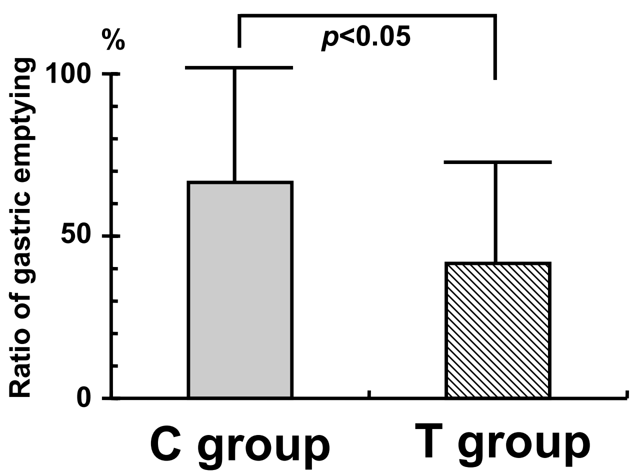

Fig. 5. Ratio of gastric emptying in the C group and T group.

tric emptying, which was significantly higher in the C group (30 cases ; 66 ± 37 %) than in the T group (30 cases ; 42 ± 31 %) (p<0.05).

3) Spectral analysis of heart rate variability

Fig. 6 shows representative changes in heart rate variability, as determined by spectral analysis in an elderly subject who took food orally (panel a) and in one who underwent tubal feeding (panel b). The increase in ratio following ingestion of HF power in the C group subject and T group subject were 140.1% and 115.8%, respectively.

Fig. 7 shows the parameters used for the spectral analysis of heart rate variability in the C and T groups. The HF power was significantly higher after ingestion than before ingestion in both groups (C group : $p<0.01$, T group : $p<0.05$). The increase in ratio following ingestion was significantly higher in the C group than in the T group ($p<0.05$). Regarding LF power, changes as the result of ingestion were not significant in the C and T groups. The LF/HF ratio was not significantly changed by ingestion in either the C or T groups.

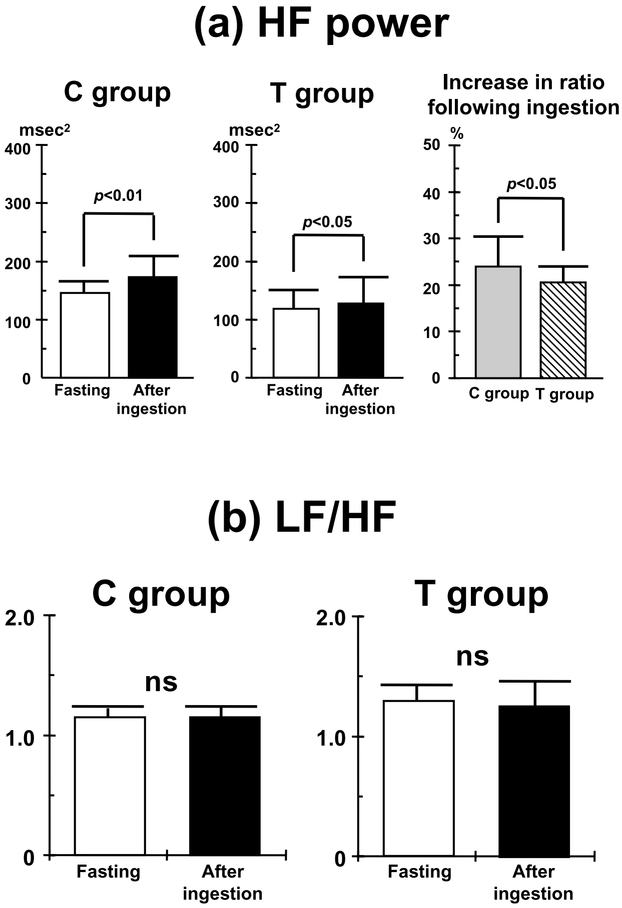

Fig. 7. Spectral analysis of heart rate variability in the C and T groups.(panel a, HF power ; panel b, LF/HF)

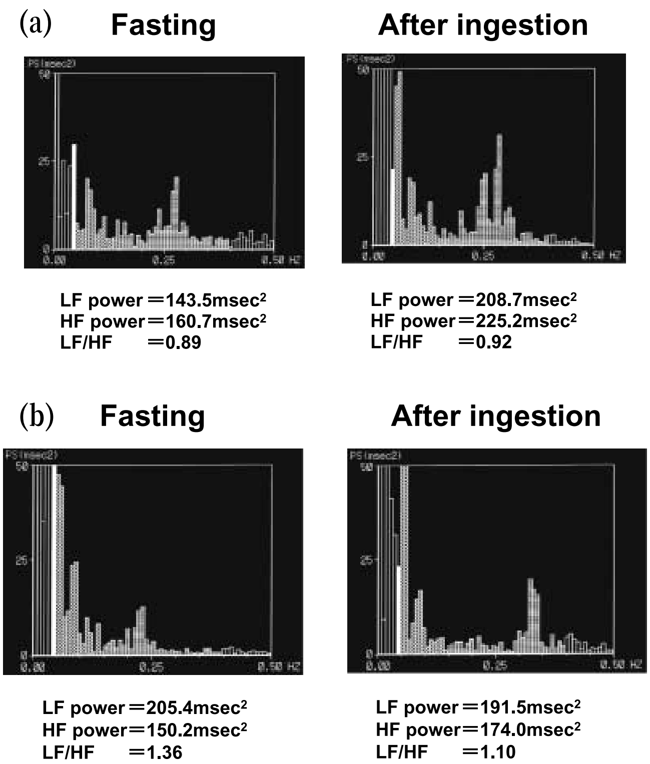

Fig. 6. Representative changes in heart rate variability, as determined by spectral analysis in an elderly subject who took food orally (panel a) and in one who underwent tubal feeding (panel b).
LF power, low frequency power (0.04-0.15 Hz, parameter of sympathetic activity modified by the parasympathetic nerve) ; HF power, high frequency power (0.15-0.40 Hz, parameter of parasympathetic activity) ; ratio of low frequency power to high frequency power, LF/HF ratio (parameter of sympathetic activity).

DISCUSSION

In the present study, the effect of mastication and swallowing on gastric motility was evaluated. The findings indicate that mastication may play a role in the maintenance of good motility in the digestive tract by enhancing physiological gastric motion.

A previous study, in which the effects of mastication on the postoperative function of the digestive tract were evaluated via the use of a contrast medium capsule indicated that compulsory mastication of chewing gum during the postoperative fasting period enhanced the movement of the intestine, and induced early gas discharge, resulting in an early start of oral intake and a reduction in the postoperative admission period (18). The relationship between stimulation by taste or touch senses and gastric motor function was previously evaluated using an EGG method (19), and it was concluded that both taste and touch senses had an affect on gastric motility.

Moreover, in an experimental study using rats, it has been reported that food is retained in the stomach by abnormal mastication because the secretion of gastric acid and the motility of the digestive tract were reduced (3). In the present study, a reduction in gastric excretion was observed in elderly subjects who underwent tubal feeding without mastication, indicating the importance of mastication on gastric motility.

With the recent concerns related to motility dysfunction in the digestive tract, such as non-ulcer dyspepsia (NUD), is particularly difficult of the diagnosis, but EGG would be useful for this disorder (20-26). The clinical usefulness of EGG for the examining of gastric motility disorders, such as gastric ulcers, gastroparesis caused by diabetic autonomic neuropathy, have been reported (27, 28). The condition unders which brady-gastria and tachygastria are mixed is called dysrhythmia, and has been shown to be related to abnormalities in gastric motor function (29). In NUD, tachy-gastria before eating is characteristic (14, 21), while in nausea during pregnancy, either brady-gastria or tachy-gastria are observed more frequently (30).

There is a close correlation between the dominant frequency and gastric motility on EGG after eating (10, 14, 29, 31-34). In the present study, normal gastric motility (normo-gastria of EGG) was increased by ingestion in the C and T groups, but the ratio of increase was higher in the C group (oral intake subjects) than in the T group (subjects with tubal feeding). Moreover, in the T group, abnormal gastric motility (brady-gastria and tachygastria of EGG) were markedly increased by ingestion.

An examination of autonomic nervous function using heart rate variability is in general and widespread use non-invasively (35-38). It has been reported that HF power disappears on the intravenous injection of atropin, is unaffected by the intravenous injection of propranolol, and is closely correlated with the degree of cardiac and parasympathetic activities measured pharmacologically (36, 39). Sympathetic activity has a rhythm corresponding to the Mayer wave of arterial pressure (40), and LF power, which reflects the rhythm of sympathetic activity, is suppressed by the intravenous injection of atropine (36). Therefore, HF power can be regarded to be a parameter of parasympathetic activity, and LF power and the LF/HF ratio are regarded as parameters of sympathetic activity that can be modified by the parasympathetic nerve (41).

In an evaluation of changes in the autonomic nervous system by stimulation of the oral cavity, HF power, a parameter of parasympathetic function, was reported to be reflexively increased by stimulation (42, 43). In the present study, the analysis of the autonomic nervous activity using heart rate variability indicated that HF power, a parameter of parasympathetic activity, was significantly increased by ingestion, and the ratio of increase was significantly higher in the C group than in the T group. In both groups, the LF/HF ratio and LF power parameters of sympathetic activity were unchanged by ingestion. It was found that the parasympathetic nerve was dominant in the movement of the digestive tract after the start of ingestion irrespective of the method of ingestion, and mastication and swallowing further might activate parasympathetic nervous activity.

In the present study, EGG revealed abnormalities in gastric motility in patients without mastication and swallowing, indicating that the inability of the oral intake of food induced abnormalities in gastric motility. Furthermore, abdominal ultrasonography and an analysis of heart rate variability demonstrated that the inability of the oral intake of food induced a reduction in gastric emptying and autonomic nervous function.

The stomach, which is the first organ for digestion and absorption, is physiologically important in the digestive motility mechanism. Mastication and swallowing in the upper digestive tract are not part of ingestion, but these functions are enhanced by contraction of gastric muscles, and are derived from the autonomic nervous function in the digestive tract (44, 45). A number of studies of relationships between mastication and activity in daily life in elderly subjects have been reported, and mastication has been found to be important in the health and nutritional state of the elder (46).

The present study, using EGG, external ultrasonography, and an analysis of heart rate variability suggest that it is possible to activate autonomic nervous activity in the digestive tract and enhance its motility by rehabilitating mastication rather than continuing tubal feeding without provisions even in elderly patients who are incapable of the oral intake of food. There is a positive correlation between masticatory movement and cerebral blood flow (47, 48). Since a reduction in mastication decrease neuronal activities in various regions of the human brain (47, 48), the present study clarify the enhancement in the motivation for oral intake of food by the synergistic effects of mastication.

In the evaluation of the gastric emptying in patients with swallowing difficulty due to cerebrovascular disorders, gastric myoelectrical activity and gastric emptying were improved after percutaneous endoscopic gastrostomy tube placement in patients with total parenteral nutrition (49). Since gastric motor and excretion functions were reduced, but were retained in these patients, if the ability of mastication is maintained, an improvement of the gastric motility in patients with swallowing disorder would be expected in this study.

In conclusion, although the parasympathetic nerve dominates gastric motor function, autonomic nervous activity might be reduced if ingestion by mastication and swallowing is impossible, which would then affect gastric motion and excretion. Mastication and swallowing are not simply motions for the transfer of food from the oral cavity to the esophagus but components of the physiological processes of digestion and absorption, which play important roles in subsequent gastric motility. The involvement of autonomic nervous activity in these motions is suggested.

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