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A Study on EGG Affected by Viscosity and Shear Rate Dependence of Fluid and Semi-solid Diets

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Abstract –**The purpose of this study is to clarify the relation among the viscosity values of semi-solid diets and the electrical mechanism of gastric motility. Firstly, a measurement procedure suitable for stomach physiology was proposed. A new measurement procedure lessened the psychological and physiological burdens of the subjects, and controlled the cycle of gastric activity of the subjects. And the dispersion of data for subjects was decreased by this new method, in which the measurements were started after 4 hours fasting. Secondly, we prepared five grades of viscosities of fluid to semi-solid diets from low to high viscosity (30 mPa･s ~ 20000 mPa･s) mixed by five different amounts of two kinds of thickening agents. The measurements were performed for 8 healthy volunteer subjects. By evaluating DPr (Dominant Power ratio: Ratio of post/pre-prandial DP values), a significant increment by ingestion of high viscosity semi-solid diets was confirmed in both kinds of thickening agents. DFD (Dominant Frequency Dispersion) was significantly decreased in both high viscosity semi-solid diets. Thus, these results suggested that gastric activity was physiologically stimulated and the cycle of gastric activity became stable by ingestion of high viscosity diets. The results showed that an electrophysiological phenomenon in the evaluation of electrogastrography (EGG) is affected by the viscosity of diets, and also suggested that the difference in the shear rate dependence of diets was not really significant to the electrical behavior of gastric motility.**

I. Introduction

Recently, the patients who are eligible for the enteral nutrition such as gastrostomy are increasing. The patients of gastrostomy are likely to develop gastroesophageal reflux disease (GERD) [1] [2]. And enteral nutrition using fluid diets may cause results in many serious complications. The semi-solid diet is one of the best candidates for preventing such complications.

There have been some reports which showed semi-solid diets reduced the complication such as GERD [3] [4]. However, the viscosity values of semi-solid diets which can exert physiological gastric motility and digestive function have not been clarified yet.

So far, we analyzed the relation among viscosity and gastric myoelectrical activity (GMA) with EGG measurement to measure GMA non-invasively [5] [6]. The results suggested that gastric emptying related to function of distal stomach may be promoted by ingestion of high viscosity semi-solid diet.

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Measurement at that time was performed with at least 9 hours fasting period. But a prolonged fasting period had heavy burdens given to subjects and preprandial EGG worsens reproducibility. And so a less burdensome measurement for subjects and the experimental procedure suitable for stomach physiology were proposed in this paper.

The influences of the viscosity and the shear rate dependence of the semi-solid diets to EGG were analyzed. Concerning test diets, we prepared the five grades of viscosities by mixing with five different amounts of two kinds of thickening agent which is different in the shear rate dependence.

II. Materials and Methods

A. Proposal of the experiment procedure suitable for stomach physiology

a. Proposal of experimental procedures

The procedure for the EGG measurement makes admissible burden to the subject including long time fasting before the test. And also well-established protocol to stabilize the stomach state is required to make clear gastric conditions.

Gastric peristalsis is caused when the foods are sent into the stomach and gastric contents are emptied from the stomach. This period is called gastric emptying time. There was a report that test meals mixed rice porridge 150 g and barium sulfate 100 g was emptied in 2~3 hours after ingesting it [7]. And interdigestive migrating contraction caused migrating motor complexes (MMC) in a cycle. MMC sweep saburra gastrica, and have work which prevent bacterial unusual breeding. It has about 90 min cycle. MMC are totally controlled during a meal and resumed after 90~120 min of ingesting [8] [9]. Following the above-mentioned literature, we propose the measuring method to start the experiment in 4 hours fasting. Thus, we performed three kinds of comparative experiments in this study. The measurement 1 (traditional model) was to start measuring after at least 9 hours fasting overnight. The measurement 2 was to start measuring in 4 hours after eating breakfast. The measurement 3 was to start measuring in 4 hours after eating lunch.

Since the fasting period is short, the second and third have few burdens given to subjects and it may be comfortable for the subject if the experiment performed at lunch.

b. Experimental setup

The experiments were performed in the silent room. All subjects were instructed not to speak, preferably not to move their body. The abdominal surface of the recording sites were cleaned by the preparatory procedure, cleaned with tissues moistened with ethanol, and then careful skin abrasion with skin pure (Nihon Kohden, Tokyo, Japan) to enhance electrical conduction, lastly cleaned with tissues moistened with

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saline solution. On all measurements, EGG was recorded for 48 minutes in the sitting position. Firstly, the subjects were measured for 13 minutes as fasting. And then subjects took the test meal for 5 minutes. After the meal, the subjects were measured for 30 minutes as postprandial. The test meal was Mei-balance Soft-Jelly (Meiji Corporation, 300 ml, 300 kcal, 10000 m･Pa). These series of measurement were performed for each subject on separate days.

Position of electrodes is shown in Figure 1. There were five Ag / Ag-Cl adhesive electrodes (Vitrode M, Nihon Kohden, Tokyo, Japan). Four of them were attached to the abdominal surface, and one of them was reference electrode, which attached to the right ankle [9] [10]. An electrode (CH3) was positioned on the midpoint between the xiphoid process and the umbilicus. The second (CH2) and forth (CH4) were positioned, 5-6 cm to the subject's left and right side in horizontal line on CH3 respectively, and the first (CH1) was positioned 4-5 cm above to the CH2 in the vertical line.

The subjects of this study were 7 healthy male volunteers (students of Akita University) without any history of significant gastrointestinal, neurological or psychiatric disease. And none had any medication for the gastrointestinal function, at the time of measurement. This EGG measurement was measured 3 times per parson (a total of 21). This study was accomplished with informed consent by all subjects.

c.Electrogastrography and Analysis

Gastric myoelectric activity in each subject was measured using a portable recording device (Nipro EG, Nipro, and Osaka, Japan). The raw EGG signal was isolated using a band-pass filter from 0.035 to 0.2 Hz, and then digitally recorded at a sampling rate of 1 Hz. Recorded EGG data were transferred to a personal computer using EGS1 software (Gram, Urawa, Japan), and EGG signal processing was performed with short-time Fourier transform (STFT) using a Hamming window, frame length and frame rate were 120 s and 20 s respectively.

Evaluation indexes of EGG which we proposed so far were shown in Table I. Since a quantitative normal/abnormal value of the EGG is not clear, this paper discusses the dominant power ratio (DPr) and the dominant power deviation (DPDr) in which we newly consider to be effective indexes.

The dominant power (DP) which was given as the peak voltage on the frequency spectrum from 0.035 to 0.2 Hz reflects the intensity of GMA. And the dominant frequency (DF) which was given as the frequency at the DP on the each frame of the frequency spectrum reflects the rhythm of GMA. And the dominant power deviation (DPD) and dominant frequency deviation (DFD) are defined the standard deviation with 10 min interval DP and DF respectively.

Since the conventional indexes (DP, DPD) were evaluation in the absolute value, dispersion among subjects was too large to evaluate. But new indexes (DPr, DPDr) are the ratio of the pre-postprandial value. Regardless of dispersion among subjects, we can evaluate relatively with these new indexes. On the contrary, the disppersions of preprandial DF (DFD) among subejects are quiet large among subjects, if DF (DFD) is evaluated relatively pre-postprandial, this rative value depends much on the preprandial value, so the dispersion of the value among subjects will be quite large. In order to evaluate the preprandial postprandial value properly, we adopted the absolute value in DF and DFD.

TABLE I. EVALUATION INDEXES OF EGG

DP	Index for the intensity of GMA
DPr	Ratio of post-/preprandial DP values
DF	Index for the frequency of GMA
DPD	Index for the irregularity of intensity of GMA
DPDr	Ratio of post-/preprandial DPD values
DFD	Index for the irregularity of frequency of GMA

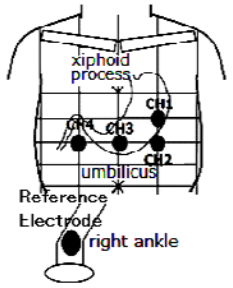


Figure 1. Position of electrodes [5][9][10]

Statistical analysis was performed by means of multiples comparisons and student's *t* test. A p value < 0.05 or a p value < 0.01 was considered statistically significant.

DP and DPr are still unable to compare as quantitative indexes. In this paper, discovering anomalies and standard gastric myoelectric activity are discussed by the rise or fall of DP and/or DPr for one of important knowledge

B. EGG evaluation affected by the viscosity and the shear rate dependence of fluid and semi-solid diets

a. Subjects

The subjects of this study covered 8 healthy male volunteers without any history of significant gastrointestinal, neurological or psychiatric disease. None had any medication for the gastrointestinal function, at the time of experimental study. The mean age was 24 ± 2.6 standard deviation (SD) years (range of age 22 - 25 years) and mean body mass index (BMI) was 21.5 ± 2.87 SD kg/m^2 (range of BMI 18.6 – 26.1 kg / m^2). This EGG measurement was measured 9 times per parson (a total of 72). This study was accomplished with informed consent by all subjects.

b. Method

We prepared a fluid diet (YH-Flore, 400ml, 30 mPa･s, MEIJI, Tokyo, Japan), and then we made semi-solid diets which different viscosity grade, in order to clarify the relationship among viscosity of fluid diets and GMA. Two sets of five kinds of a fluid diet (30mPa･s) and semi-solid diets (500 mPa･s, 5000 mPa･s, 10000 mPa･s, 20000 mPa･s) were prepared by using the same fluid diet mixed with two kinds of thichenig agent (agent-A: Toro-make-SP, MEIJI, Tokyo, Japan, agent-B: Toromi-up-A, Nisshin-Oillio, Tokyo, Japan). These viscosities were measured by a B-type rotation viscometer (TOKI SANGYO, TVB-10W, Tokyo, Japan) at 12 rpm of rotor. At same values of the shear rate as agent-B, agent-A is maximum of about 0.64 times. But since the shear rate dependence of agent-A is larger than agent-B, agent-A h-

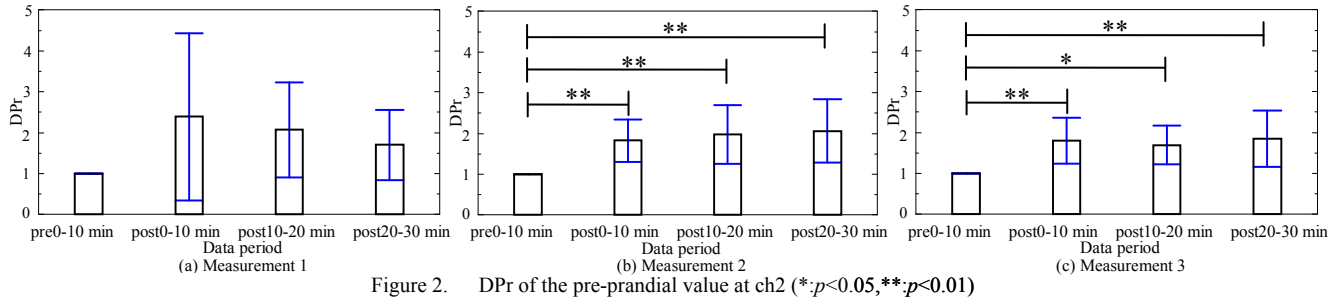


Figure 2. DPr of the pre-prandial value at ch2 (*:p<0.05,**:p<0.01)

as the characteristic which the viscosity of agent-A exceeds at lower values of the shear rate.

Position of electrodes and the system of measurement of waveform and statistical analysis were as above-mentioned.

c.Experimental procedures

On all measurements, EGG was recorded for 13 minutes in the semi-supine position, and then meals were fed to subjects with a disposable syringe (JMS syringe catheter-fit, JMS, Hiroshima, Japan) for 15 minutes. After the meal, postprandial EGG was recorded for 30 minutes. The experiments were performed in the silent room. These series of measurement were performed for each subject on separate days.

III. Results and Discussion

A. Proposed experimental procedure suitable for stomach physiology

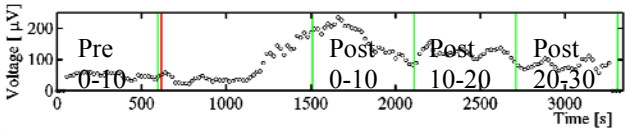
Three kinds of experimental measurements were weighed using pre-prandial evaluation indexes of EGG. Example of results (DPr) was shown in Figure 2. The bars with asterisk meant that where significant differences were confirmed. Data process is shown in Figure 3 (a). This is example of DP waveform in EGG. Using the above indexes, we compared statistically the preprandial value 0-10 min (pre 0-10) to the postprandial value 0-10 min (post 0-10), 10-20 min (post 10-20), 20-30 min (post 20-30).

The increment in GMA was confirmed in all measurements. As compared to the measurement 1, the measurement 2 and 3 had significant increments. And DF in measurement 2 and 3 was in the range of stable cycle of GMA. As fasting period of the measurement 2 and 3 became shorter than that of measurement 1 (traditional model), subjects may be suffered less burdensome fasting period. On measurement 2 and 3, MMC cycle were regulated appropriately, and dispersions of GMA before ingestion among subjects is decreased.

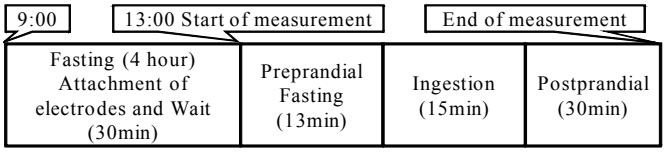
From these results, EGG evaluation was performed using this measuring method in the viscosity and the shear rate dependence of the following section. Proposed experimental procedures are shown in Figure 3 (b). There were two patterns of interdigestive migrating contraction motility and postprandial motor activities in the stomach. We decided starting the measurement in 4 hours, after the subject finished eating breakfast in order to prepare the gastric motility cycle of interdigestive migrating contraction among subjects.

B. EGG affected by the viscosity and shear rate dependence of the diets

a. Pre-postprandial EGG affected by viscosity of semi-solid diets



(a) Data process



(b) Experimental procedures

Figure 3. Experimental procedures and data process

TABLE II. DPr in the postprandial of agent-A (*:p<0.05,**:p<0.01)

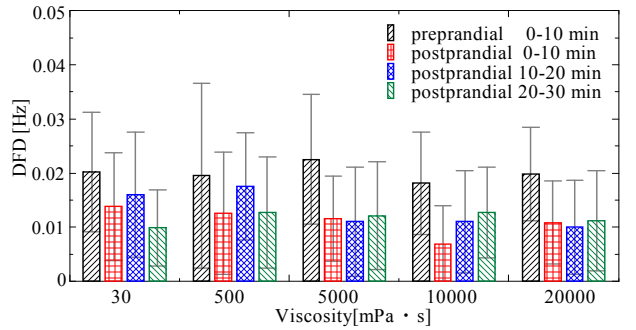
viscosity[mPa·s]	channel	pre 0-10	post 0-10	post 10-20	post 20-30
30	ch1	1.00	1.61 *	1.52	1.47
	ch2	1.00	1.59	1.47	1.43
	ch3	1.00	2.29 *	2.11	1.93
	ch4	1.00	2.20 **	2.06 **	2.03 **
500	ch1	1.00	1.90 *	1.84	2.08 *
	ch2	1.00	1.98 **	1.83 *	2.07 **
	ch3	1.00	2.84 **	2.23 *	2.44 *
	ch4	1.00	2.58 **	2.38 **	2.38 **
5,000	ch1	1.00	2.78 **	2.45 *	2.11
	ch2	1.00	2.60 **	2.27 *	1.94
	ch3	1.00	2.85 **	2.79 **	2.44 **
	ch4	1.00	3.28 **	3.32 **	2.85 **
10,000	ch1	1.00	2.38 **	2.08 *	2.00 *
	ch2	1.00	2.09 **	1.83 **	1.73 **
	ch3	1.00	3.20 **	2.86 **	2.87 **
	ch4	1.00	3.16 **	2.70 *	3.04 **
20,000	ch1	1.00	2.50 **	1.94	1.63
	ch2	1.00	2.35 **	1.83 *	1.64
	ch3	1.00	2.85 **	2.30 **	2.04 **
	ch4	1.00	3.07 **	2.43 **	2.13 **

Data process has been done as in Figure 3 (a) for each viscosity. Compared with the preprandial, it can be estimated whether GMA changes significantly.

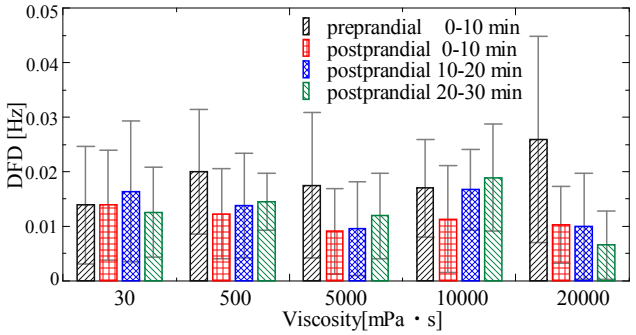
DPr in the experiment using agent-A and agent-B in each viscosity were summarized on Table II and Table III. Both of the experiment using the agent-A and agent-B, significant increments of DPr after the meal with the high viscosity food were observed in many cases. The quantitative viscosity dependence was not clear yet. But we could estimate GMA was stimulated with the high viscosity regardless of the shear rate dependence. Results on DPDr in all viscosity showed that dispersion of GMA became larger in the postprandial. The preprandial stomach contracted in the normal cycle because DF in all viscosity fell within criterion of activity frequency

TABLE III. DPr in the postprandial of agent-B (*:p<0.05,**:p<0.01)

viscosity[mPa・s]	channel	pre 0-10	post 0-10	post 10-20	post 20-30
30	ch1	1.00	1.61 *	1.52	1.47
	ch2	1.00	1.59	1.47	1.43
	ch3	1.00	2.29 *	2.11	1.93
	ch4	1.00	2.20 **	2.06 **	2.03 **
500	ch1	1.00	1.79 **	1.70 **	2.00 **
	ch2	1.00	1.77 **	1.71 *	1.91 **
	ch3	1.00	2.28 **	2.27 **	2.30 **
	ch4	1.00	2.60 **	2.30 **	2.41 **
5,000	ch1	1.00	2.19 **	2.23 **	1.97 **
	ch2	1.00	2.30 **	2.30 **	2.10 **
	ch3	1.00	2.91 **	2.93 **	2.52 **
	ch4	1.00	3.56 **	3.29 **	2.84 **
10,000	ch1	1.00	1.67 **	1.68 **	1.60 **
	ch2	1.00	1.66 **	1.63 **	1.54 **
	ch3	1.00	2.29 **	2.11 **	2.04 **
	ch4	1.00	2.28 **	2.20 **	2.23 **
20,000	ch1	1.00	2.72 **	2.55 **	2.30 **
	ch2	1.00	2.83 **	2.76 **	2.49 **
	ch3	1.00	3.34 **	3.16 **	3.01 **
	ch4	1.00	3.01 **	2.37 **	2.28 **



(a) Agent-A



(b) Agent-B

Figure 4. DFD in each viscosity at ch3

(0.034-0.067Hz) of the stomach. The DFD compared the viscosity and agent-A or B were shown in Figure 4. The DFD of both were confirmed that they were decreased by ingestion, DFD of agent-B showed significant decrement by ingestion.

b. Comparison of the shear rate dependence by the thickening agent

Using indexes (DPr. DF, DFD), we compared statistically the results of agent-A to the agent-B for each viscosity in all subjects. As results of this comparison, there were seldom significant differences in two kinds of the thickening agent. In other words, significant differences were not observed substantially. Thus, results suggested that the difference of the shear rate dependence might not affect gastric activity.

IV. Conclusion

We proposed a new experimental procedure suitable for stomach physiology, and this new measurement method was compared to traditional method. One could argue that the measurement to start after only 4 hours fasting eased the burden for the subjects. And the dispersion of MMC cycle before ingestion was diminished for subjects. In addition, clarifying the relationship among the viscosity of semi-solid diets and the shear rate dependence in the EGG was performed. As results, GMA was stimulated with the high viscosity regardless of the shear rate dependence. It could be suggested that an electrophysiological phenomenon in the evaluation of EGG is affected by the viscosity than the shear rate dependence. For the future, since gastric activity may vary according to the patient's condition, efforts to clarify quantitative relation between viscosity and EGG are required.

Acknowledgment

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