

# Backflow prevention mechanism of laparoscopic Toupet fundoplication using high-resolution manometry

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## Abstract

**Background** The use of multichannel intraluminal impedance pH (MII-pH) and high-resolution manometry (HRM), which are new devices used to examine the esophageal function, has recently become common in Europe and the USA, thus garnering much attention. There have not been enough studies as of yet, however, on the esophageal motor function and the benefits of treatment after these devices have been used in laparoscopic fundoplication.

**Objective** To use MII-pH and HRM to study the treatment effectiveness of laparoscopic fundoplication and consider a backflow prevention mechanism for laparoscopic Toupet fundoplication.

**Materials and methods** The study looked at 27 of a total of 60 patients undergoing laparoscopic fundoplication due to reasons of either gastroesophageal reflux disease or esophageal hiatal hernia between October 2012 and February 2014, who underwent a postsurgical HRM examination. Of these, 25 patients whose symptoms disappeared following surgery and who were not orally administered gastric secretion inhibitor (of whom nine were male, average age  $55.9 \pm 14.9$  years, and of whom 76 % underwent MII-pH) were taken as the subjects of the study. The postsurgical evaluation was conducted 3 months after the operation.

**Results** Using HRM, although no change was noted in the lower esophageal sphincter pressure (LESP) ( $p = 0.943$ ), an increase in lower esophageal sphincter pressure integral ( $p = 0.024$ ) and extensions in both overall length and

abdominal length were noted (both  $p < 0.001$ ), while a significant improvement was noted in the lower esophageal sphincter (LES). Furthermore, the cases subjected to MII-pH demonstrated a reduced gastroesophageal reflux time, total number of liquid reflux episodes, and total number of reflux episodes ( $p < 0.001$ ,  $p = 0.008$ ,  $p = 0.009$ ).

**Conclusions** Backflow prevention mechanism of laparoscopic Toupet fundoplication is thus considered to improve the overall LES function without elevating LESP.

**Keywords** Toupet fundoplication · High-resolution manometry · Normal values · Gastroesophageal reflux disease · Multichannel intraluminal impedance pH · Hiatal hernia

Recently, high-resolution manometry (HRM) and multichannel intraluminal impedance pH monitoring (MII-pH) have come into use, thus facilitating more detailed evaluations of the esophageal motor function and gastroesophageal reflux (GER). Many reports have already confirmed their effectiveness [1–4]. Pandolfino et al. used HRM to propose a new method of classifying the esophageal motor function, known as the Chicago classification, while Tutuian and Castell et al. detected physical reflux from changes in the esophageal internal impedance, and by further measuring the pH of the substance refluxed, reported the effectiveness of MII-pH in identifying all types of reflux, including not only acid, but also non-acid GER [5, 6].

Laparoscopic fundoplication in regard to gastroesophageal reflux disease (GERD) and esophageal hiatal hernia is reported as having a high success rate as a treatment not only in the short term but also over the long term [7–11]. Currently, laparoscopic fundoplication takes

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the form of the Nissen method and the Toupet method, with both methods offering roughly the same level of treatment effectiveness. Many reports have dealt with the evaluation, using conventional manometry, of the esophageal motor function following surgery using these methods. At the same time, the only study using HRM is that by Wilshire et al. [12] which uses the Nissen method, with none having been conducted using the Toupet method. For this reason, the authors carried out a study of a laparoscopic Toupet fundoplication gastroesophageal backflow prevention mechanism in relation to GERD-related conditions using HRM.

## Materials and methods

Between October 2012 and February 2014, 60 patients underwent laparoscopic fundoplication due to either GERD or esophageal hiatal hernia at Jikei University Hospital. Of these, the study focused on 25 cases who underwent an HRM examination, whose symptoms had disappeared following surgery, and who were not being orally administered gastric secretion inhibitors (Fig. 1). Of these patients, nine were male (36 %), with a median age of 60 years.

### High-resolution manometry

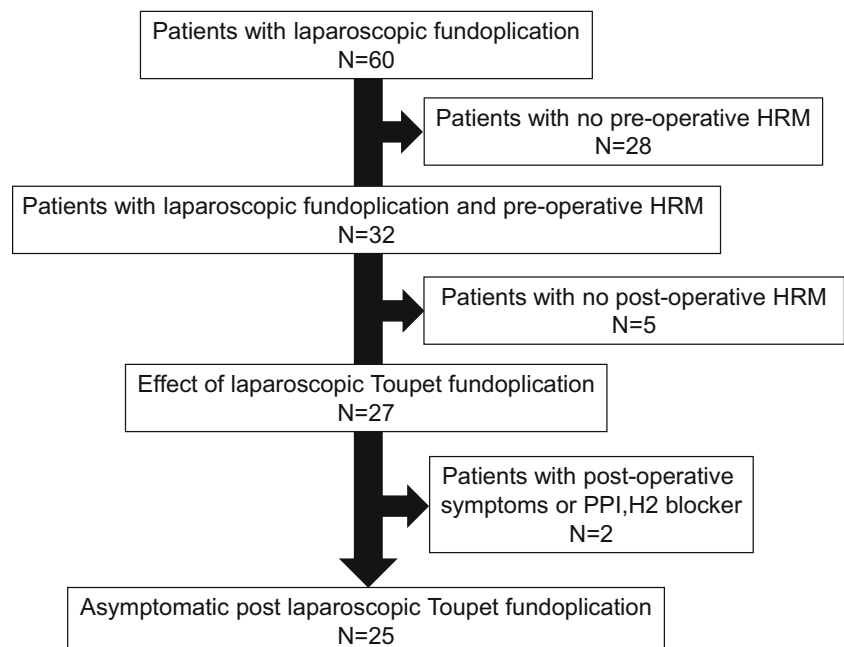
The patients were taken off the oral administration of a gastric secretion inhibitor and prokinetic drugs 1 week before the examination. HRM was conducted using a given imaging-manufactured Mano Scan, with the catheter

inserted nasally. Once confirmation was obtained that its leading end had reached the stomach, it was fixed in a position that allowed confirmation of the area between the LES and the upper esophageal sphincter (UES). After remaining still for a few minutes, the patient swallowed 10 ml of water 10 times while in the dorsal position, after which the evaluation was carried out. Data analysis was carried out using the Mano View software program version 3.0, and lower esophageal sphincter pressure (LESP), integrated relaxation pressure (IRP), overall length (OL), abdominal length (AL), contractile front velocity (CFV), distal contractile integral (DCI), distal latency (DL), and intact peristalsis were calculated based on the Chicago classification proposed by Pandolfino et al. [1, 5]. The lower esophageal sphincter pressure integral (LESPI), which is an indicator for the evaluation of overall LES function, was calculated in line with previous reports [13]. The postsurgery analysis was carried out 3 months after the operation.

### Multichannel intraluminal impedance pH monitoring

Of the 25 cases studied, 19 cases (76 %) were subjected to postsurgical MII-pH. These patients ceased using gastric secretion inhibitors 1 week before the test. MII-pH was performed using a Sandhill-manufactured Sleuth device, while the catheter, manufactured by the same company, was used in the same way. The catheter was nasally inserted with its leading end positioned 5 cm above the upper edge of the LES under fluoroscopic control. During

**Fig. 1** During the period in question, 32 patients underwent presurgical HRM followed by surgery. In five cases, no postsurgical HRM was implemented and two patients (7 %) either had ongoing symptoms or could not cease administration of gastric secretion inhibitor. In the end, 25 cases were included in the study



testing, the patients took only three hospital meals and were prohibited from snacking, although they were allowed to drink water. They were monitored 24 h per day. Data analysis was automatically conducted using BioView, which was manufactured by the same company [3, 4, 6]. The parameters used were esophageal pH < 4 holding time, number of liquid GER episodes, liquid non-acid GER episodes, total number of liquid reflux episodes, number of gaseous GER episodes, number of gaseous non-acid GER episodes, and total number of reflux episodes. Postsurgical evaluation was conducted at the same time as HRM, roughly 3 months following surgery.

### Upper gastrointestinal endoscopy

In all cases, upper gastrointestinal endoscopy was implemented pre- and postsurgery, to evaluate esophageal hiatal hernia and reflux-related esophageal inflammation. The presence or extent of esophageal hiatal hernia was used as the A factor in AFP classification, with four levels of evaluation: A0 to A3 [14, 15]. Furthermore, reflux-related esophageal inflammation was evaluated using the Los Angeles classification, with anything equal to or above grade A defined as erosive reflux-related esophageal inflammation [16].

### Statistical analysis

The statistical analysis was conducted using the SPSS software program (SPSS Inc, version 17.0, Chicago, IL, USA). All data were expressed in terms of a median value and interquartile range (IQR), with a Wilcoxon test result of  $p < 0.05$  defined as indicating statistical significance.

## Results

### Presurgical symptoms

Prior to surgery, 17 cases (68 %) reported heartburn and 15 cases (60 %) acid reflux, while 4 cases (6 %) were suffering from respiratory conditions (Table 1). Postsurgery, the symptoms had disappeared in all cases ( $p < 0.001$ ).

### Esophageal hiatal hernia and reflux-related esophageal inflammation

Prior to surgery, all cases were confirmed as having esophageal hiatal hernia. In 48 % of cases, this was a sliding hernia measuring 3 cm or longer (A2), while 12 % were mixed (A3). Presurgical reflux-related esophageal inflammation was present as non-erosive GERD in 60 % of cases

**Table 1** Demographic data

	Asymptomatic patients ( $N = 25$ )
Sex (M/F)	9:16
Age, years (IQR)	60 (46–68)
BMI, kg/m <sup>2</sup> (IQR)	22.4 (21.1–25.9)
Preheartburn (%)	17 (68)
Preregurgitation (%)	15 (60)
Prerespiratory (%)	4 (16)
Hiatal hernia (%)	25 (100)
A1 (%)	10 (40)
A2 (%)	12 (48)
A3 (%)	3 (12)
Los Angeles classification	
N or M (%)	15 (60)
A (%)	2 (8)
B (%)	2 (8)
C (%)	2 (8)
D (%)	4 (16)

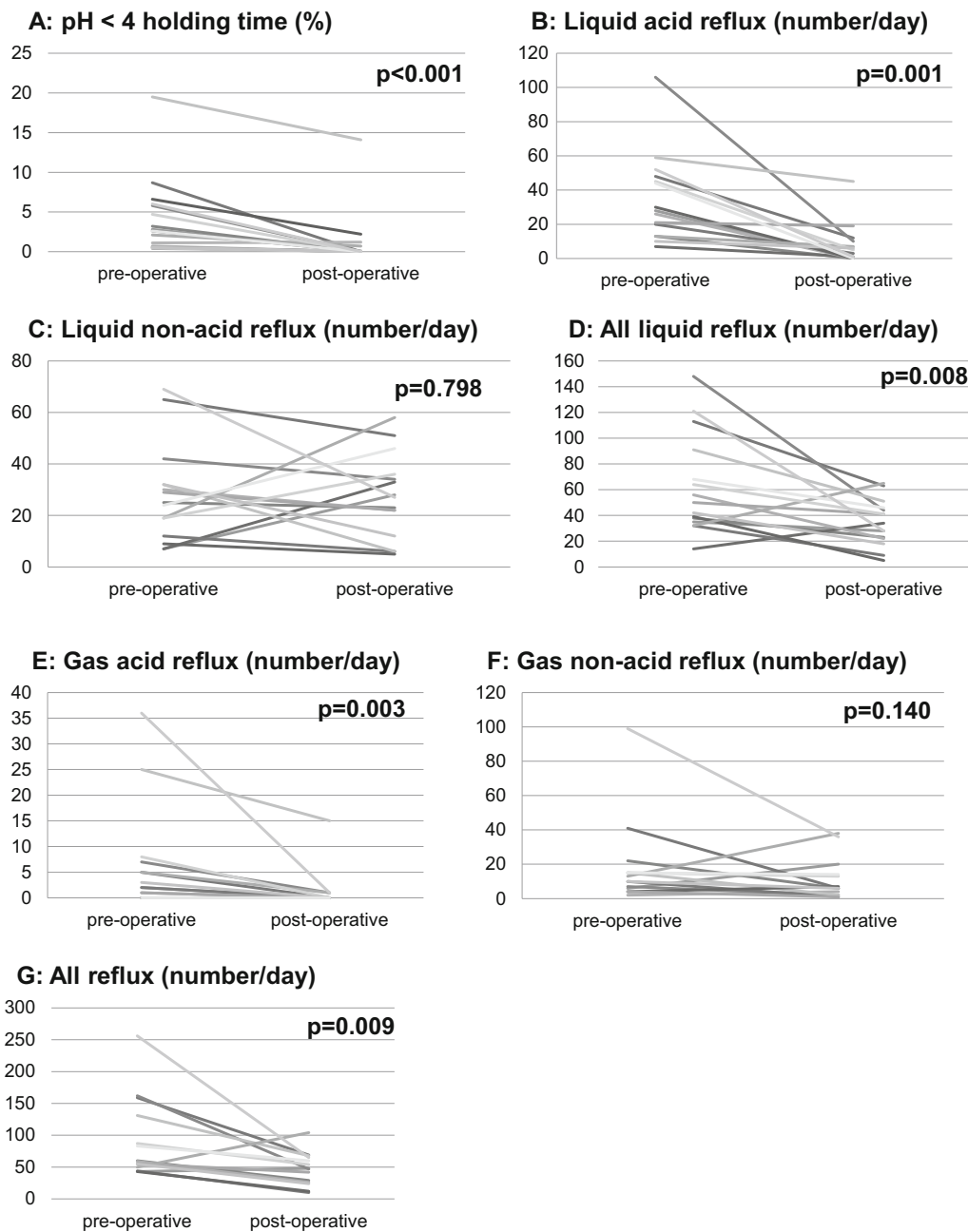
and as erosive GERD in 40 % (Table 1). Postsurgery, reflux-related esophageal inflammation was cured in all cases.

### Multichannel intraluminal impedance pH monitoring

The parameters prior to surgery were as follows. pH < 4 holding time: 2.7 (0.6–6.5) %, number of liquid GER episodes: 26 (13–47) per day, number of liquid non-GER episodes: 24 (11–32) per day, total number of liquid reflux episodes: 42 (32–80) per day, number of gaseous GER episodes: 4 (1–8) per day, number of gaseous non-acid GER episodes: 12 (5–20) per day, and total number of reflux episodes: 57 (46–120) per day. Following surgery, these improved to 0 (0–0.7) %, 3 (0–10) per day, 23 (7–34) per day, 32 (9–46) per day, 0 (0–1) per day, 9 (2–14) per day and 43 (15–61) per day (Fig. 2A–G). While significant improvements were noted in pH < 4 holding time, number of liquid GER episodes, total number of liquid reflux episodes, number of gaseous GER episodes, and total number of reflux episodes ( $p < 0.001$ ,  $p = 0.001$ ,  $p = 0.008$ ,  $p = 0.003$ ,  $p = 0.009$ ), there was no significant difference between the pre- and postsurgical results for non-acid GER of either liquid or gas.

### High-resolution manometry

Prior to surgery, a double high-pressure zone (DHPZ), which is a typical indication of esophageal hiatal hernia, was clearly



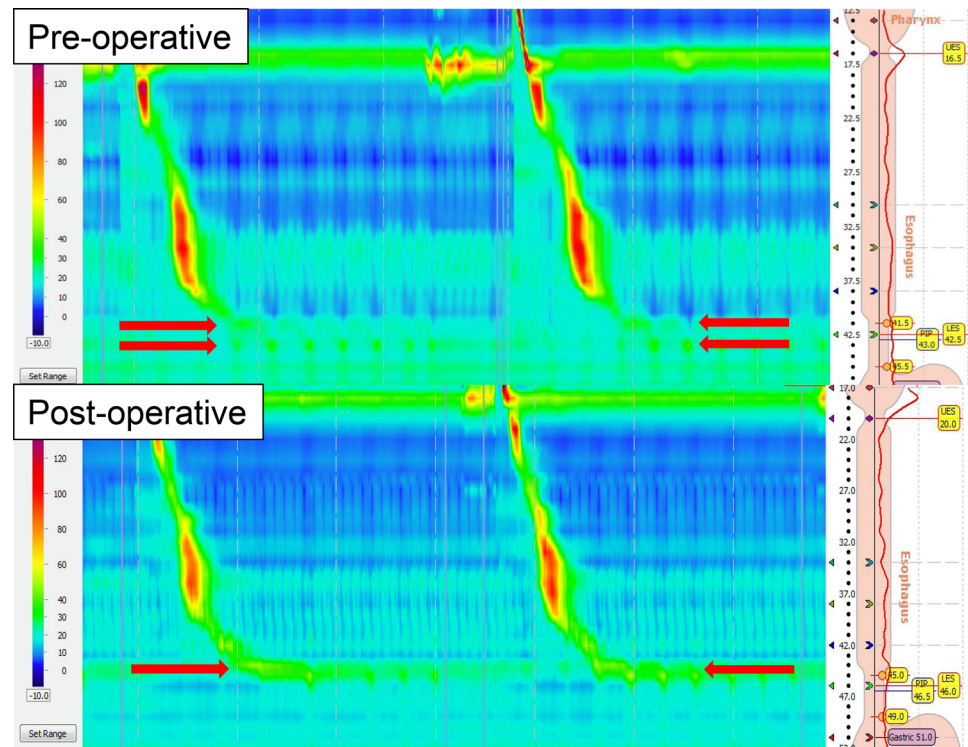
**Fig. 2** A–G Results of presurgical MII-pH implemented on 19 cases (76 %). Improvement was noted in all parameters of pH < 4 holding time, number of liquid gastroesophageal reflux episodes, total number of liquid reflux episodes, number of gaseous gastroesophageal reflux

episodes, and total number of reflux episodes ( $p < 0.001$ ,  $p = 0.001$ ,  $p = 0.008$ ,  $p = 0.003$ ,  $p = 0.009$ ). No significant difference was noted in either liquid or gaseous non-gastroesophageal reflux

observed in all 25 cases, but this had disappeared in all cases following surgery (Fig. 3). HRM parameters showed that postsurgically, LESPI had significantly increased and improved, while OL and AL had significantly lengthened ( $p = 0.024$ ,  $p < 0.001$ ,  $p < 0.001$ ); however, there was no change in the LESP value. IRP increased postsurgery, but

was below 15.0 mmHg. The frequency in the occurrence of CFV, DCI, and intact peristalsis, which are indicators of esophageal corpus movement, showed no change from pre- to postsurgery, but the DL increased in length ( $p = 0.027$ ) (Table 2). Table 3 shows mean  $\pm$  2SD (standard deviation) in asymptomatic patients.

**Fig. 3** HRM observations pre- and postsurgically for some cases. In presurgical HRM observations, the *upper arrow* indicates the LES, while the *lower one* indicates the esophageal hiatus. These two double high-pressure zones (DHPZ) indicate the presence of esophageal hiatal hernia. In postsurgical HRM observations, they have become a single high pressure, with the LES, esophageal hiatus and Toupet fundoplication overlapping one another. Postsurgery, DHPZ disappeared in all cases



**Table 2** Pre- and postoperative HRM findings

HRM findings ( $N = 25$ )	Preoperative	Postoperative	$P$ value
LESP (mmHg)	15.5 (8.6–21.7)	13.2 (10.8–21.8)	0.943
IRP (mmHg)	3.6 (1.8–6.2)	7.2 (5.3–9.8)	0.012
LESPI (mmHg s cm)	179 (63–386)	393 (230–470)	0.024
OL (cm)	2.7 (2.4–3.3)	3.4 (3.1–4.0)	<0.001
AL (cm)	0 (0–0.5)	1.6 (1.3–1.9)	<0.001
CFV (cm/s)	3.9 (2.9–4.7)	3.8 (3.1–4.5)	0.796
DCI (mmHg s cm)	1357 (688–2518)	1101 (766–1784)	0.116
DL (s)	5.2 (4.4–6.3)	6.0 (5.4–6.4)	0.027
Intact peristalsis (%)	100 (90–100)	100 (90–100)	0.472

LESP lower esophageal sphincter, IRP integrated relaxation pressure, LESPI lower esophageal sphincter pressure integral, OL overall length, AL abdominal length, CFV contractile front velocity, DCI distal contractile integral, DL distal latency

## Discussion

Many reports have been written on the effectiveness of laparoscopic surgery on GERD. The most commonly used methods at present are the Nissen method and the Toupet method. More recently, meta-analysis of long-term results has been approved, with a success rate of both methods of over 80 %. From the perspective of backflow prevention effectiveness, most reports conclude that there is no difference between the methods [17, 18]. In around 10 % of all cases, however, patients complain of a feeling of something lodged in their throats or ongoing heartburn, and

a number of patients require repeat surgery [7, 9, 11, 17], thus indicating that the postsurgical evaluation is extremely important.

To date, reports of laparoscopic fundoplication backflow prevention mechanisms have focused on conventional manometry. Peters et al. [19] implemented Nissen fundoplication on 100 cases, reporting that LES pressure, which was low presurgery at 5.1 mmHg, rose to 14.9 mmHg. Chrysos et al. [20] implemented Toupet fundoplication and found that LES pressure rose from 11 to 18 mmHg, thus indicating similar results. The main cause of GERD is a failure of backflow prevention function, with LES pressure

**Table 3** HRM reference thresholds in 25 asymptomatic post-Toupet subjects

HRM findings ( <i>N</i> = 25)	Mean (SD)	5th percentile	95th percentile
LESP (mmHg)	16.5 (± 7.7)	13.5	19.4
IRP (mmHg)	8.0 (± 3.6)	6.6	9.4
LESPI (mmHg s cm)	379 (± 188)	288	469
OL (cm)	3.5 (± 0.6)	3.3	3.8
AL (cm)	1.6 (± 0.8)	1.3	1.9
CFV (cm/s)	4.1 (± 2.0)	3.4	4.9
DCI (mmHg s cm)	1374 (± 935)	1005	1744
DL (s)	6.0 (± 1.1)	5.6	6.5
Intact peristalsis (%)	91 (± 1.3)	85	97

*LESP* lower esophageal sphincter, *IRP* integrated relaxation pressure, *LESPI* lower esophageal sphincter pressure integral, *OL* overall length, *AL* abdominal length, *CFV* contractile front velocity, *DCI* distal contractile integral, *DL* distal latency

contributing to this prevention function. Furthermore, Ayazi et al. [21] reported that gastroesophageal backflow occurs when enlargement of the gastric wall shortens the abdominal esophagus. Closely related to this, the relationship between GERD and gastric acid pockets has recently garnered attention. Herbella et al. [22] examined patients with no symptoms subsequent to Nissen fundoplication for the presence of gastric acid pockets and monitored their pH, finding almost no incidences of gastric acid pocket. They report that Nissen fundoplication successfully inhibits gastric acid pockets and that the fornix plays an important role as a factor in the onset of GERD.

The methods for the pathological evaluation and diagnosis of GERD have improved significantly in the last 10 years. The clinical applications of MII-pH and HRM are particularly worthy of note. These modalities allow a greater level of detail not only in presurgical but also in postsurgical pathological assessment. The Chicago classification, proposed by Pandolfino et al., is a categorization method now widely used around the world; however, there are very few reports on the use of Chicago classification in postfundoplication evaluation of GERD. Tatum et al. [23] first reported HRM findings subsequent to fundoplication, thus noting that the postsurgical presence of DHPZ indicates the presence of hiatal hernia, and therefore a high possibility of recurrence. Hoshino et al. [24] studied cases in which symptoms continued after fundoplication, implementing HRM and upper gastrointestinal endoscopy, and reported that the anatomical position of the LES as seen endoscopically was related to LES observations using HRM. In conventional manometry, the anatomical definition of the positional relationship of the area around the LES has always been unclear, with the result that it has not been possible to identify the mechanism for recurrence following surgery. Wilshire et al. used HRM after Nissen fundoplication to compare 25 cases with no symptoms with a further 14 cases who complained of a feeling that something was

lodged in their throats, reporting that the group complaining of the feeling of something lodged in their throats had outflow obstruction, with IRP > 15 mmHg. The analysis results for 25 cases with no symptoms postsurgery were proposed as the reference value for Nissen fundoplication [12]; however, reports referencing a postsurgical reference value using HRM have only been made in regard to the Nissen method and not for the Toupet method.

This hospital introduced laparoscopic surgery for GERD-related conditions in 1994. Initially, the Nissen method was the one mainly selected, but the frequency of cases in which patients complained of dysphagia at an early stage postsurgery, along with the fact that there is no difference between the two methods in the rate of postsurgical recurrence, means that nowadays the Toupet method is the standard method of operation. In this study, the authors looked at the Toupet method backflow prevention mechanism using HRM, to consider postsurgical reference values. Hence, the primary principles in the selection of target patients are the disappearance of postsurgical symptoms, with improvement, and non-administration of drugs, including acid secretion inhibitors. For these patients, as an objective evaluation of GER, the MII-pH method was implemented for about 80 % of the cases, and for all cases, postsurgical GER improved. From the disappearance of preoperative symptoms and the non-emergence of new postsurgical symptoms, there is a possibility that our data this time are the postsurgical HRM standard values for the Toupet method. Furthermore, no changes were made to the preoperative LESP values, and by improving LES functions, such as LESPI, the mechanism for preventing GER has become clear. LESPI is presented by the multiplication of LES pressure, LES length, and time (10 s) and represents the overall LES functions. In cases where there is acid exposure of the distal digestive tract, the LESPI values are low [13]. In this study too, compared to the preoperative values, the postsurgical values were found to have

increased. Although the IRP demonstrated slightly high postsurgical values, the value was much lower than the standard value of 15 mmHg for outflow obstruction, which is one indicator of a feeling of obstruction. The target of the present research, taking into account the absence of a feeling of obstruction subsequent to surgery, may be considered to be appropriate as a value obtained postsurgically. In the data obtained in the present research, when compared to the reports of Wilshire et al. regarding the post-Nissen procedure data, a difference between both surgical procedures was observed with respect to LES function. In other words, subsequent to the Nissen procedure, there was a tendency for the LESP values and the IRP values to be relatively higher than for the Toupet method, but on the other hand, the OL is low. With the Nissen method, the length covering the esophagus is roughly 2 cm 360°, while with the Toupet method, it is roughly 4 cm 240°. The discrepancy in the reconstruction forms of the reflux prevention mechanism is believed to be represented by HRM. On the other hand, there was no difference between CFV and DCI, and there was no difference regarding esophageal peristalsis.

In this study, it became clear that the Toupet fundoplication backflow prevention mechanism is due to an improvement in the LESPI, and the postoperative HRM parameters in the range of Table 3 suggest that surgery is success. This study dealt with only a small number of cases (25), and the fact that it did not take data from healthy subjects meant that no comparison could be implemented with postsurgical cases having no symptoms. These and other limitations mean that there are still outstanding issues that remain to be solved. Despite this, however, there are no reports to date relating to the reference values for laparoscopic Toupet fundoplication using the Chicago classification, and this study may provide one effective indicator toward establishing such values.

#### Compliance with ethical standards

**Disclosures** Drs. Masato Hoshino, Nobuo Omura, Fumiaki Yano, Kazuto Tsuboi, Se Ryung Yamamoto, Shunsuke Akimoto, Hideyuki Kashiwagi, and Katsuhiko Yanaga have no conflicts of interest or financial ties to disclose.

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