Synchronous electrogastrographic and manometric study of the stomach as an esophageal substitute

Ferenc Izbéki, Tibor Wittmann, Sándor Ódor, Balázs Botos, Áron Altorjay

Department of Medicine, Hungary. altorjay@mail.fmkorhaz.hu
Hospital, Seregélyesi u. 3., Székesfehérvár, H-8000, Hungary
Department of Surgery, Saint George University Teaching Hospital, Seregélyesi u. 3., H-8000, Hungary

Correspondence to: Áron Altorjay M.D., Ph.D., Professor of Surgery, Department of Surgery, Saint George University Teaching Hospital, Seregélyesi u. 3., Székesfehérvár, H-8000, Hungary. altorjay@mail.fmkorhaz.hu
Telephone: +36-22-504-100 Fax: +36-22-504-100
Received: 2004-07-17 Accepted: 2004-09-19

Abstract

AIM: To investigate the electric and contractile mechanisms involved in the deranged function of the transposed stomach in relation to the course of the symptoms and the changes in contractile and electrical parameters over time.

METHODS: Twenty-one patients after subtotal esophagectomy and 18 healthy volunteers were studied. Complaints were compiled by using a questionnaire, and a symptom score was formed. Synchronous electrogastrography and gastric manometry were performed in the fasting state and postprandially.

RESULTS: Eight of the operated patients were symptom-free and 13 had symptoms. The durations of the postoperative periods for the symptomatic (9.1±6.5 mo) and the asymptomatic (28.3±8.8 mo) patients were significantly different. The symptom score correlated negatively with the time that had elapsed since the operation. The percentages of the dominant frequency in the normogastric, bradygastric and tachygastric ranges differed significantly between the controls and the patients. A significant difference was detected between the power ratio of the controls and that of the patients. The occurrence of tachygastria in the symptomatic and the symptom-free patients correlated negatively both with the time that had elapsed and with the symptom score. There was a significant increase in motility index after feeding in the controls, but not in the patients. The contractile activity of the stomach increased both in the controls and in the symptom-free patients. In contrast, in the group of symptomatic patients, the contractile activity decreased postprandially as compared with the fasting state.

CONCLUSION: The patients’ post-operative complaints and symptoms change during the post-operative period and correlate with the parameters of the myoelectric and contractile activities of the stomach. Tachygastria seems to be the major pathogenetic factor involved in the contractile dysfunction.

© 2005 The WJG Press and Elsevier Inc. All rights reserved.

Key words: Transposed stomach; Electrogastrography; Gastric manometry; Post-operative complaints; Contractile dysfunction; Tachygastria

Izbéki F, Wittmann T, Ódor S, Botos B, Altorjay Á. Synchronous electrogastrographic and manometric study of the stomach as an esophageal substitute. World J Gastroenterol 2005; 11(8): 1172-1178
http://www.wjgnet.com/1007-9327/11/1172.asp

INTRODUCTION

For reconstruction of the alimentary tract, gastric interposition is the most common procedure in patients with esophageal cancer[1]. Preparation of the stomach, as an esophageal substitute, is associated with substantial alterations: vagotomy is inevitable and the blood supply is reduced. Both truncal and highly selective vagotomy have been found to disrupt the gastric electric activity[2] and to delay the gastric emptying of solids[3]. Consequently, use of the stomach as an esophageal substitute involves multiple influences on the gastric secretion and motility, resulting in post-operative symptoms in both the short and the long-term[4,5]. These motility disorder seems to be a significant problem even in 10-year survivors, who are not satisfied with the daily food intake quantity, with no resulting gain in body weight after surgery[6]. Altered motility, including a gastroesophageal and a duodenogastric reflux, has been attributed to the development of these symptoms[6,7,8]. This complaint has been found to correlate with the weekly occurrence either of reflux or of heartburn, resulting in an increasing number of non-malignancy deaths[6]. However, controversial reports have been published on the functional properties of the stomach as an esophageal substitute after esophagectomy; when pulled up into the chest, the stomach has been claimed to act as an inert organ[9,10] whereas others have reported the detection of contractions in the gastric wall on radiological examination[11] and also via manometry and the use of a barostat[12-14].
electrodes placed on the abdominal skin\textsuperscript{[15,16]}. Synchronized activity has been demonstrated between the gastric contractions and the cutaneous or electromyographic activity\textsuperscript{[16-18]}, but this was not observed following total gastrectomy\textsuperscript{[19,20]}. The ingestion of food has been associated with changes in the electromyographic activity that is reflected in both serosal and cutaneous recordings\textsuperscript{[21,22]}

The primary aim of the present study was to investigate the electric and contractile mechanisms involved in the deranged function of the transposed stomach through the synchronous application of electrogastrography and gastric manometry. Secondary objectives were to find a possible correlation between the course of the symptoms and the development of the contractile and electric parameters during time.

**MATERIALS AND METHODS**

**Subjects**

Twenty-one patients, 14 men and 7 women, aged 24-72 years (median 56.5), who had undergone subtotal esophagectomy for either cancer ($n = 15$) or benign disease ($n = 6$).

All patients were operated on by the same surgeon (AA), as described by Akiyama et al\textsuperscript{[23]}. Briefly, following a subtotal resection of the esophagus, gastric substitution was performed in one sitting. The extent of resection of the lesser curvature is determined by a line connecting the highest point in the fundus, points where the vessels of the lesser curvature enter the stomach wall, and the lesser curvature at the junction of the arterial arcades of the right and left gastric arteries. This permits the removal of all potentially-involved lymph nodes while preserving the right and left gastric arteries. This permits the removal of the test meal by the patients and the controls (16±3 and 15±2.5 min, respectively).

Manometric recordings were evaluated as described by Collard et al\textsuperscript{[33,34]}. The baseline was set by using both the manual and automatic baseline calculation systems of the software. The vertical axis was scaled up to reveal waves of $<$1.2 kPa in an amplitude that cannot be observed on the default scales. The scaled-up manometric recordings were inspected visually on screen and the ones with the most prominent microwaves were selected. As the contractile activities of the distal ports were more pronounced than those of the proximal ones, tracings recorded by one of the three distal ports were chosen. All the waves of the selected tracing were sorted into one of the different predefined classes. Waves were defined as macrowaves if the amplitude was $\geq 1.2$ kPa, and as microwaves if it was $<$1.2 kPa. Microwaves were subclassified further according to amplitude (1.2-6.6 kPa, 6.6-26.6 kPa and $>$26.6 kPa) and the frequency distribution of both micro and macrowaves was determined for each subject. The numbers of each type of contraction were determined by reading the tracings on screen and the contraction rates were determined by dividing the number of total contractions by the duration of the recording in minutes. The beginnings and ends of the time frames of the different types of waves were recorded in order to select the corresponding electrogastrographic recordings.

A motility index was calculated by dividing the sum of the areas under the macrowaves by the duration of recording time in minutes in the best antral channel during both the fasting and postprandial periods, as described by Collard et al\textsuperscript{[33,34]}.

The contraction rates were also determined in all subjects, both in the fasting state and postprandially, by counting all
pressure waves in the selected recordings.

Electrogastrography
Electrogastrography was performed as described in Refs[15,29-31]. After the manometric catheter had been positioned, the skin was cleaned and two disposable electrocardiographic electrodes were placed 5-cm apart along the gastric corpus-antrum axis, determined by ultrasonography in the control subjects and localized by the preceding fluoroscopy in the patients. A third, reference electrode was placed on the chest over the liver. Electrogastrographic recordings were started, synchronized with the manometric recordings and performed with a Digitrapper electrogastrograph (Synetics Medical AB, Stockholm, Sweden). All recordings were made at a sampling frequency of 4 Hz. The internal low- and high-pass filters were set at 0.5 and 10 cpm, respectively. The recorded data were processed by a software program (ElectroGastroGram Version 6.3, Gastrosoft Inc., Synetics Medical), using a personal computer. Before the computer-assisted analysis, the total recordings were visually inspected onscreen so as to detect artefacts and to debug the data. The parts of the electrogastrographic recordings which corresponded to the time frame of the evaluated manometric recordings were then selected and were analyzed separately by the computer. The main component of the electrogastrographic recording is the gastric signal. The frequency believed to be of gastric origin and at which the power has a peak value is called the dominant frequency.

The following parameters were evaluated: Dominant frequency (DF): the frequency with the greatest amplitude within the normal range of gastric slow waves. Dominant power (DP): the power at the DF. Power ratio (PR): the ratio of the preprandial and the postprandial DPs. Percentages of normogastria and dysrhythmia: Normogastria is the percentage of time during which normal slow waves are observed between 2 and 4 cpm. Gastric dysrhythmias are classified as bradygastria when the DF peak is in the range 0.5-2 cpm, and as tachygastria when it is in the range 4-9 cpm. Dominant frequency and dominant power instability coefficients (DFIC and DPIC): the ratio of the standard deviation and the mean of the DF or DP.

Ethical approval
The investigation received prior ethical approval from the local Ethics Committee of Saint George Teaching Hospital. All subjects gave their written informed consent to participate in this study.

Statistical analysis
Normally distributed data are expressed as means and standard deviations while non-normally distributed data are given as medians and full ranges. The Kolmogorov-Smirnov test was used to determine the normal distribution of the data. Manometric data are expressed as medians. For the statistical evaluation of the manometric data, the Wilcoxon signed-rank sum test for paired comparisons and the Mann-Whitney U-test for unpaired comparisons were used. Electrogastrographic data are expressed as means and standard deviations. Statistical evaluation of the data was performed by the Independent Samples t-test used with between-subjects designs and the Paired Samples t-test with within-subjects designs. All the statistical computations were performed with an spss 8.0 for Windows software package.

RESULTS
The median of the symptom scores was 5, with a range of 0-39. Eight patients (38%) were totally free of symptoms. On the basis of the symptoms, the operated patients were sub-classified into symptomatic and symptom-free groups. A significant difference was observed between the symptomatic and the asymptomatic patients as concerns the duration of the post-operative period (9.1±6.5 and 28.3±8.8 mo, respectively; P<0.0001). Eleven (84.6%) of the symptomatic patients, but only one of the symptom free-patients, had been operated upon within the previous year.

The symptom score correlated negatively with the time that had elapsed since the operation (Pearson’s correlation coefficient r = -0.652; P = 0.01) (Figure 1).

Seven of the symptomatic patients experienced postprandial fullness and 8 others early satiety. Mild early satiety and postprandial fullness occurred 1-3 times a week in 5 patients. The 3 most seriously symptomatic patients reported moderate early satiety and postprandial fullness daily. These symptoms were accompanied by regurgitation in 7 patients, with frequency 2-3 times a week in most cases. Nine patients had mostly mild epigastric pain 1-3 times a week. Seven patients complained of nausea, and in 2 of them it resulted in vomiting. The latter took place 2-3 times a week in the 2 most symptomatic patients. One patient

Figure 1 The correlation between the symptom score and the length of the postoperative period in patients after esophagectomy with the stomach as a substitute. A: Symptom score; B: Percentage of tachygastria.
complained of dysphagia. In general, the symptoms were mild or moderate in 85% of the symptomatic patients, and only 2 patients had serious complaints. Four patients (19%) had diarrhea, and 2 (9.5%) had the dumping syndrome; the latter was easily managed by dietary measures.

The results of electrogastrography are summarized in Table 1. The percentages of DF in the normogastria, bradygastric and tachygastric ranges were significantly different in the healthy control subjects and the operated patients. Food ingestion did not have a significant effect on the percentages of normogastria, bradygastria and tachygastria in either the healthy or the operated group. The DF did not differ significantly between the healthy controls and the patients. The significant increase observed in the DF in the healthy controls in the fed state did not occur in the operated patients. The DFIC was significantly higher in the operated patients without significant postprandial changes. In the patients, the DP did not change significantly in the postprandial period, whereas it increased significantly in the control subjects; this resulted in a significant difference between the two groups. A significant difference in PR was detected between the healthy control subjects and the operated patients. Significant change in the DPIC was not observed between the two groups or after food ingestion.

Table 1: Comparison of fasting and postprandial electrogastrographic variables in healthy control (HC) volunteers and esophagectomized patients with the stomach as a substitute

|                          | HC (n = 18) | Operated (n = 21) | P (HC vs Operated) |
|--------------------------|------------|-------------------|-------------------|
| Normogastria (%)         |            |                   |                   |
| Preprandial              | 79.1±10.5  | 45.3±20.5         | P<0.001           |
| Postprandial             | 81.8±9.8   | 42.4±23.3         | P<0.001           |
| Bradygastria (%)         |            |                   |                   |
| Preprandial              | 10.5±5.7   | 31.1±14.4         | P<0.001           |
| Postprandial             | 9.7±6.2    | 33.2±14.5         | P<0.001           |
| Tachygastria (%)         |            |                   |                   |
| Preprandial              | 8.4±5.7    | 18.5±11.4         | P<0.05            |
| Postprandial             | 6.8±4.9    | 20.8±12.1         | P<0.001           |
| DF (cpm)                 |            |                   |                   |
| Preprandial              | 2.8±1.0    | 3.0±1.8           | NS                |
| Postprandial             | 3.0±1.0    | 3.5±2.0           | NS                |
| DFIC (%)                 |            |                   |                   |
| Preprandial              | 31.2±1.8   | 53.6±25.9         | P<0.001           |
| Postprandial             | 32.3±1.9   | 55.0±27.9         | P<0.001           |
| DP (μV)                  |            |                   |                   |
| Preprandial              | 927±147    | 529±450           | P<0.01            |
| Postprandial             | 1399±727   | 603±578           | P<0.001           |
| DPIC (%)                 |            |                   |                   |
| Preprandial              | 80.1±3.0   | 82.2±36.9         | NS                |
| Postprandial             | 88.3±3.0   | 83.5±32.4         | NS                |
| Power ratio              | 1.75±1.2   | 1.09±0.18         | P<0.02            |

When the electrogastrographic parameters of the symptomatic and the symptom-free patients were analyzed separately, the percentages of tachygastria correlated negatively both with the time that had elapsed since the operation and the symptom score (Pearson’s correlation coefficients of -0.652 and -0.740, respectively; P<0.01 for both). The percentages of tachygastria for the symptomatic and the symptom-free patients differed significantly (23.9±11.7 vs 10.9±5.03, respectively; P<0.003) and similar values were observed in the fed state (24.9±11.7 vs 6.8±4.9). The tachygastric fraction in the asymptomatic patients was not significantly different from that in the healthy controls (10.9±5.03 vs 8.4±5.7; P = 0.38). A correlation could not be established between other electrogastrographic parameters and the time that had elapsed since the operation or the manometric parameters.

Table 2 presents the motility indices in the symptomatic and symptom-free groups of operated patients and in the control subjects during fasting and in the postprandial periods. The motility index increased significantly in the healthy control subjects, reflecting an increased motility after food ingestion, whereas it remained unchanged in both groups of operated patients. Although the motility indices of the symptomatic and asymptomatic groups of operated patients were significantly different, both were significantly lower than that for the healthy volunteers.

Table 2: Fasting and postprandial motility indices in healthy volunteers and in esophagectomized patients with the stomach as a substitute

|                          | Operated (n = 21) | Significance | Healthy vs control |
|--------------------------|-------------------|--------------|-------------------|
|                          | Symptomatic       | Symptom free |                  |
|                          | Fasting          | Postprandial |                  |
|                          | Preprandial       | Postprandial |                  |
|                          | P                 |              |                  |

The rates of contraction are shown in Table 3. The frequency of the contractions detected by manometry is compared with the frequency of the electric activity and expressed as a percentage. The number of contractions per minute is less than the DF in each group of subjects, in both the fasting and the fed state. On an average, only about two-thirds of the electric control activity was detected as contractions. A significant postprandial increase in the contractile rate was seen only in the healthy control subjects.

The fasting and postprandial frequency distributions of the gastric contractions in the healthy volunteers and the two groups of operated patients are depicted in Figure 2.

Significant increases in the 1.2-6.6 kPa, >6.6-26.6 kPa and >26.6 kPa waves were observed in the healthy control subjects postprandially (P<0.004 for all). Similarly, significant increases in the >26.6 kPa and >6.6-26.6 kPa waves were observed in the symptomatic and asymptomatic operated patients (P<0.02 and P<0.0001, respectively). Since the preprandial percentage of the waves of 1.2-6.6 kPa waves was significantly higher than that for the healthy controls (12.7% vs 27.1%; P<0.001), significant postprandial change was not observed. In contrast, in the symptomatic group of patients, the percentage of the waves of 1.2-6.6 kPa did not change postprandially, whereas the >6.6-26.6 kPa waves decreased significantly (P<0.002), as compared to the fasting percentage.
DISCUSSION

The origin of the complaints in patients, who have undergone oesophagectomy with the stomach substituting for the gullet, is not clearly understood. These symptoms were earlier attributed to the loss of contractility of the transposed stomach[7-9], although it has recently been demonstrated that the stomach as an oesophageal substitute maintains its contractile activity[10-13]. Notwithstanding this preserved contractile activity of the transposed stomach, the patients frequently suffer from symptoms of disordered gastric emptying[13-16] and the pathogenesis remains unresolved. Accordingly, in the present study, we investigated the relationship between the symptoms and the functional properties of the transposed stomach, and also the temporal dimensions. Previous studies had investigated the stomach as an oesophageal replacement either by manometry[13,14,16,31] or by electrogastrography[7,19,38], and proved that the transposed stomach generates measurable contractile waves and displays detectable electric activity. In order to evaluate the association between the contractile and electric activities of the transposed stomach in relation to the complaints of the patients, we applied these diagnostic modalities synchronously.

The symptoms of our patients are similar to those reported for the late results of esophagectomy with the stomach as substitute[19,31]. Postprandial fullness and vomiting have been shown to be likely consequences of delayed gastric emptying[11,24]. Half of our symptomatic patients reported postprandial fullness, which, together with the disordered contractile activity and dysrhythmias detected, implies impaired gastric emptying. The dumping syndrome and diarrhea was less frequent than reported in Ref.[24]. All of our patients with symptoms of delayed gastric emptying had been operated on within a year of the assessment. The prevalence of symptoms in our patients operated on within the previous year corresponds to or is somewhat better than the literature data[41,44]. As concerns the severity of the symptoms in our patients, which were assessed semi-quantitatively by using a scoring system, the median score proved to be less than that reported in diabetic patients with dyspepsia[21].

Our results indicate that the changes in the distribution of the gastric wall contraction waves are most pronounced in the group of symptomatic patients. The mechanical activity of the transposed stomach was affected most, both in the fasting and in the postprandial state, and resulted in the most prominent symptoms. As regards the groups of patients in whom the stomach is utilized as a substitute after esophagectomy, the motility indices of the stomach remained lower and more pronounced in the symptomatic patients. Feeding normally induces increases in the gastric motility indices, but this did not occur in either group of our operated patients. The discrimination of different types of contraction waves on the basis of their amplitudes and analysis of the frequency and distribution demonstrated a lack of postprandial modification of the gastric motor patterns; moreover, a significant decrease in the percentage of >6.6-26.6 kPa wave contractions was observed in the symptomatic patients, as another manifestation of an insufficient gastric motor activity. In contrast, Collard and Ramagnoli reported a postprandial increase in contractile activity, but we observed this only in the healthy controls in our study, and not in the patients. This controversy might be explained by the longer post-operative period in the earlier study[14]. Indeed, after feeding, the higher-amplitude contractile activities were found to be lower in our symptomatic patients, whereas an improvement was observed in the patients free of symptoms. The combined application of manometry and electrogastrography demonstrated a good correlation between the changes in slow wave activity and the mechanical performance. This is characterized by bradygastria and decreased DP; additionally, the postprandial increase in myoelectric activity that occurred in the healthy persons was not observed in the operated patients. Nonetheless, the DFs in the healthy controls and the patients did not differ significantly, which points to a preserved gastric pacemaker activity. These observations provide further evidence that the changes in both electric and motor activities are results of vagotomy[21].

The postprandial increases in DF and DP that were observed...
in our healthy control subjects are well known[16,30,31,45,46]. A postprandial increase in the DFIC did not occur either in the healthy controls or in the patients, though this instability was significantly greater in the patients in both the fasting and the postprandial states, which reveals a more unstable electric state. The postprandial change in the DP is thought to be a result of the spatial change in the position of the stomach[39]. The significant decrease in DP in the operated patients might therefore, reflect the transposition of the stomach rather than being a consequence of an altered function.

The frequency of contractions in our study was lower than that reported by Collard and Ramagnoli[40] and even the DF detected by electrogastrography. This could be a consequence of the methodological difference. We counted all the contractions in a selected tracing, while Collard and Ramagnoli counted the contractions in 3 different antral strips of 10 min each. On the other hand, a difference between the rate of the electrical control activity and contractile activity has also been detected by others in dogs by synchronous serosal electric recordings and intragastric manometry[47].

In the pathogenesis of the symptoms of esophagectomized patients, gastric vagal denervation has been shown to play a role[13,48-50]. Accordingly, a novel surgical technique was elaborated recently to spare the vagal nerves, especially in patients operated on with benign esophageal diseases[51]. After vagotomy, delayed gastric emptying of a solid meal was observed in the early postoperative period, but after a year the gastric emptying in patients with either truncal or selective vagotomy did not differ from that in controls[48].

Vagotomy has been shown to result in a disorganization of the basic electric rhythm in dogs[52], and tachygastria has been demonstrated by implanted gastric electrodes in patients with truncal vagotomy[50]. This is in accord with the relatively low prevalence and a diminishing tendency with time of the symptoms of delayed gastric emptying in our patients.

Our present data are consistent with reports on the denervated stomach as an esophageal replacement that has been shown to act as a contractile organ, this contractile activity being recovered postoperatively over time[13]. However, the recovery of the motor response is not complete, as indicated by the diminished response of the motility indices to a test meal even in the asymptomatic group of patients. A clear difference was observed in the lengths of post-operative periods of the symptomatic and the symptom-free patients: a majority of the symptomatic group of patients with truncal vagotomy had surgery more than 2 years before the symptom-free patients: a majority of the symptomatic and asymptomatic patients. A clear difference was observed in the postprandial increase of the motor response is not complete, as indicated by the diminished response of the motility indices to a test meal even in the symptomatic and asymptomatic patient groups. A clear difference was observed in the lengths of post-operative periods of the symptomatic and the symptom-free patients: a majority of the symptomatic patients had been operated on within 1 year, whereas the symptom-free patients had surgery more than 2 years previously. Collard reported recovery of the contractile activity over a 3-year period[39].

An important phenomenon is the tachygastria that occurs in the transposed stomach, which exhibits a tendency to return to normogastria in time. Tachygastria has been documented in patients with functional dyspepsia and delayed gastric emptying[16,30,31,45,46]. Tachygastria too has been shown to be accompanied by the absence of contractility in vagotomized dogs[52] and humans after vagotomy with[40] or without symptoms of altered gastric emptying. This might be a consequence of the disturbed proximal-distal coordination of pacemaker activity in the smooth muscle. The negative correlation between the symptoms of our patients and the postoperative time, together with the significant difference between the percentages of tachygastria in the asymptomatic patients suggests that tachygastria could be one of the important factors playing a role in the pathogenesis of the complaints. This is supported by the observation that significant tachygastria was not detected in the asymptomatic patients or the healthy controls. These data suggest that the complaints of patients with a transposed stomach are consequences of a decrease in the electromechanical activity of the stomach. Electrogastrography itself is a useful method with which to provide important information on the gastric motility in these patients.

The major new findings of our present study are the time dependency of the post-operative complaints and symptoms of the patients, and their correlation with the parameters of the myoelectric and contractile activities of the stomach, obtained by simultaneous electrogastrographic and manometric investigations. The processes of electromechanical adaptation in the transposed stomach result in decreases in time of the postoperative symptoms in patients after esophagectomy. Tachygastria seems to be the major pathogenetic factor involved in the contractile dysfunction.

REFERENCES

1. Skinner DB. Esophageal reconstruction. Am J Surg 1980; 139: 810-814
2. Geldof H, van der Scheer EJ, van Blankenstijn M, Smout AJ, Akkermans LM. Effects of highly selective vagotomy on gastric myoelectrical activity. An electrogastrographic study. Dig Dis Sci 1990; 35: 969-975
3. Malagelada JR, Rees WD, Mazzotta LJ, Go VL. Gastric motor abnormalities in diabetic and postvagotomy gastroparesis: effect of metoclopramide and bethanecol. Gastroenterology 1980; 78: 286-293
4. Hölscher AH, Voit H, Buttermann G, Siewert JR. Function of the intrathoracic stomach as esophageal replacement. World J Surg 1988; 12: 835-844
5. Nishihira T, Watanabe T, Ohmori N, Kitamura M, Toyoda T, Hirayama K, Kawachi S, Kuramoto J, Kanoh T, Akaishi T. Long-term evaluation of patients treated by radical operation for carcinoma of the thoracic esophagus. World J Surg 1984; 8: 778-785
6. Baba M, Aikou T, Natsugoe S, Kusano C, Shimada M, Kimura S, Fukumoto T. Appraisal of ten-year survival following esophagectomy for carcinoma of the esophagus with emphasis on quality of life. World J Surg 1997; 21: 282-285; discussion 286
7. Bonavina L, Anselmino M, Ruol A, Bardini R, Borsato N, Perachia A. Functional evaluation of the intrathoracic stomach as an esophageal substitute. Br J Surg 1992; 79: 529-532
8. Mannell A, Hinder RA, San-Garde BA. The thoracic stomach: a study of gastric emptying, bile reflux and mucosal change. Br J Surg 1984; 71: 438-441
9. Moreno-Oset E, Tomas-Ridocci M, Paris F, Mora F, Garcia-Zarza A, Molina R, Pastor J, Benages A. Motor activity of esophageal substitute (stomach, jejunal, and colon segments). Ann Thorac Surg 1986; 41: 515-519
10. Morton KA, Karwande SV, Davis RK, Datz FL, Lynch RE. Gastric emptying after gastric interposition for cancer of the esophagus or hypopharynx. Ann Thorac Surg 1991; 51: 759-765
11. Huang GJ, Wang LJ, Liu JS, Cheng GY, Zhang DW, Wang GQ, Zhang RG. Surgery of esophageal carcinoma. Semin Surg...
The effects of erythromycin given orally after esophagectomy. *Am J Surg* 2002; 183: 317-323.

34 Hill AD, Walsh TN, Hamilton D, Freyne P, O’Hare N, Byrne PJ, Hennessy TP. Erythromycin improves emptying of the denervated stomach after esophagectomy. *Br J Surg* 1993; 80: 879-881.

35 Mannell A, McKeight A, Esser JD. Role of pyloroplasty in the retrostomal stomach: results of a prospective, randomized, controlled trial. *Br J Surg* 1990; 77: 57-59.

36 Collard JM, Romagnoli R, Otte JB, Kestens PJ. Erythromycin enhances early postoperative contractility of the denervated whole stomach as an esophageal substitute. *Am J Surg* 1999; 229: 337-343.

37 Del Poli M, Mioli P, Gasparri G, Casalegno PA, Camandona M, Bronda M, Albertino B, Cassollino P. Functional study of intestinal transplants after esophagectomy. *Minerva Chir* 1991; 46: 241-245.

38 Ravelli AM, Spitz L, Milla PJ. Gastric emptying in children with gastric transposition. *J Pediatr Gastroenter Nutr* 1994; 40: 403-409.

39 Labbe F, Pradere B, Tap G, Bloom E, Gouzi JL. Late morbidity after esophagectomy for cancer: is partial esophagectomy preferred? *Chirurgie* 1998; 123: 468-473.

40 Fok M, Cheng SW, Wong J. Pyloroplasty versus no drainage in gastric replacement of the esophagus. *Am J Surg* 1991; 162: 447-452.

41 De Leys P, Coosemans W, Lerut T. Early and late functional results in patients with intrathoracic gastric replacement after oesophagectomy for carcinoma. *Eur J Cardiothor Surg* 1992; 6: 79-84; discussion 85.

42 Sarnelli G, Caenepeel P, Geypens B, Janssens J, Tack J. Symptoms associated with impaired gastric emptying of solids and liquids in functional dyspepsia. *Am J Gastroenterol* 2003; 98: 783-788.

43 Stanghellini V, Tosetti C, Paternic A, Barbara G, Morselli-Labate AM, Monetti N, Marengo M, Corinaldesi R. Risk indicators of delayed gastric emptying of solids in patients with functional dyspepsia. *Gastroenterol* 1996; 110: 1036-1042.

44 McLarty AJ, Deschamps C, Trastek VF, Allen MS, Paolero PC, Harmsen WS. Esophageal resection for cancer of the esophagus: long-term function and quality of life. *Ann Thorac Surg* 1997; 63: 1568-1572.

45 Gonlachanvit S, Chey WD, Goodman KJ, Parkman HP. Effect of meal size and test duration on gastric emptying and gastric myoelectrical activity as determined with simultaneous [13C]octanoate breath test and electrogastrography in normal subjects using a muffin meal. *Dig Dis Sci* 2001; 46: 2643-2650.

46 Geldof H, van der Schee EJ, van Blankenstein M, Grashuis JL. Electrogastrographic study of gastric myoelectrical activity in patients with unexplained nausea and vomiting. *Gut* 1986; 27: 799-808.

47 You CH, Chey WY. Study of electromechanical activity of the stomach in humans and in dogs with particular attention to tachygastria. *Gastroenterology* 1984; 86: 1460-1468.

48 Howlett PJ, Sheiner HJ, Barber DC, Ward AS, Perez-Avila CA, Duthie HL. Gastric emptying in control subjects and patients with duodenal ulcer before and after vagotomy. *Gut* 1976; 17: 542-550.

49 Aebelard P, Bedi BS. Effects of proximal gastric vagotomy (PGV) followed by total vagotomy (TV) on postprandial and fasting myoelectrical activity of the canine stomach and duodenum. *Gut* 1977; 18: 515-523.

50 Hocking MP. Postoperative gastroparesis and tachygastria: response to electric stimulation and erythromycin. *Surgery* 1993; 114: 538-542.