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Does the Stomach Remain Silent after Neonatal Loss of Its Original Pacemaker ?: Gastric Motility in Long-Term Survivors of Neonatal Gastric Rupture

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Chiba, T., Ohi, R., Kamiyama, T., Yoshida, S. and Hongo, M. *Does the Stomach Remain Silent after Neonatal Loss of Its Original Pacemaker ?: Gastric Motility in Long-Term Survivors of Neonatal Gastric Rupture.* Tohoku J. Exp. Med., 1999, **187** (2), 89-97 —— Gastric peristaltic contractions are controlled by an intrinsic electrical pacemaker located in the mid-body along the greater curve. This study was undertaken to investigate gastric motility in long-term survivors of neonatal gastric rupture who were surgically deprived of their original pacemaker. Four patients, 1 boy and 3 girls, aged between 6 and 12 years were studied. Physiological activity of the gastric remnant was assessed in terms of electrical as well as peristaltic functions by means of electrogastrography and video-recorded barium swallow study. Electrical and mechanical pacing activities were classified into normogastria or dysrhythmia (brady- or tachygastria) according to their frequencies. In these patients, ectopic pacemakers were found to be arising just distal to the site of resection along the greater curve. Electrophysiologically, one patient was diagnosed as having normogastria, and other 3 patients were found to have dysrhythmia (2, bradygastria; 1, tachygastria) on the basis of electrogastrographic analyses. In two of three patients studied further by fluoroscopy, electrical activity agreed well with peristaltic activity. In one patient, however, electrical tachygastria was associated with peristaltic bradygastria. In conclusion, an ectopic pacemaker arises in the stomach that does not remain silent after neonatal surgical loss of its own pacemaker. Noninvasive electrogastrography seems useful in assessing electrical potentials generated by the ectopic pacemaker. ——— gastric electrical activity; gastric mechanical motility; neonatal gastric rupture; ectopic pacemaker; electrogastrography

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Electrogastrography (EGG) is a means of assessing gastric electrical activities generated by an intrinsic pacemaker located at upper one third of the gastric body along the greater curve (Alvarez 1922; Kim 1988), and has been gaining a wide acceptance since technical developments have made its skin-electrode recordings feasible in daily clinical practices (You and Chey 1984; Hamilton et al. 1986). However, electrical and mechanical activities of the stomach have not been investigated well in pediatric patients following neonatal loss of the intrinsic pacemaker. Neonatal gastric rupture is an idiopathic and extensive gastric necrosis with perforation which mostly occur along the greater curve. Survivors of the disease are supposed to have undergone extensive gastric resections at the site of this lesion (Chiba et al. 1991). This study was undertaken using EGG to determine whether the stomach is electrically silent, and to investigate how its electrical activity, if any, controls mechanical activity in patients who were deprived of their own pacemakers by extensive partial gastrectomy for neonatal gastric rupture.

Patients and Methods

Patient characteristics

Four long-term survivors (1 boy and 3 girls; aged between 5 and 12 years) were investigated. These patients were diagnosed as having gastric rupture on day 0 to 6 (mean, 2.8) after birth, and surgically lost their intrinsic pacemakers by an extensive gastric resection along the greater curve where marked ischemic necrosis with resultant rupture (2-6 cm in length; mean, 4 cm) was noted intraoperatively. One girl (case 3) underwent duodeno-duodenostomy (side-to-side) for congenital duodenal stenosis associated with annular pancreas on day 49 after birth.

Evaluation of electrical pacing activities: Frequency analysis

EGG was taken according to a standardized fashion reported (Okuno et al. 1989) from these patients lying supine and sleeping in a quiet environment without any sedatives. Along with pneumograms taken by impedance method, EGG was measured by means of bipolar silver-silver chloride cutaneous electrodes that were transversely positioned on the upper abdomen. Reference electrode was placed just beneath the xiphoid process. EGG recordings were performed with high pass filters eliminating those signals greater than 0.1 Hz, time constant of 3.0 seconds, and recording paper speed of 1 mm/second. EGGs were scored visually by manual analysis to obtain an overview of the electrical control activity (ECA) and to establish its irregularities or changes. For analyzing EGGs, frequency between 2.8 and 3.2 cycles per minute (cpm) was defined as normogastria in this study (Sarna 1975). Frequency ranges slower than 2.7 cpm and faster than 3.3 cpm were termed bradygastria and tachygastria, respectively. According to Okuno (1991), the percentages (mean $\pm$ S.D.) of normogastria,

TABLE 1. *Patient characteristics*

Patient (No.)	Sex	Age at evaluation (year)	Associated anomaly	Gastric rupture	
				Site (size)	Age at surgery (procedure)
1	M	5	None	Greater curve (2 cm in length)	Day 0 (debridement)
2	F	6	Intestinal malfixation	Greater curve (5 cm in length)	Day 6 (debridement)
3	F	10	Annular pancreas	Greater curve (6 cm in length)	Day 2 (debridement, gastrostomy) Day 49 (duodenoduodenostomy)
4	F	12	None	Greater curve (3 cm in length)	Day 3 (debridement)

bradygastria, and tachygastria in normal adults were estimated to be 55.0±19.9%, 11.8±10.1%, and 23.9±15.0%, respectively. These values were used to diagnose the frequency abnormalities in our study of pediatric patients.

Evaluation of mechanical contractions

Video-recorded fluoroscopy with swallowed contrast material (30% w/v barium sulphate emulsion) was analyzed to determine the rhythm of mechanical contractions as well as to identify ectopically-formed pacemakers (the site where peristalses arise) in the gastric remnant. This study was completed in three of these four patients because one patient (case 1 in Table 1) was not cooperative. Intervals of mechanical contractions were measured, and peristaltic frequency as well as the percentages of normal rhythm, bradygastria, and tachygastria were determined based on the same criteria as that used for assessing electrical activities.

Ethical considerations

This study was approved by the Ethics Committee of our hospital. Informed, written consent was obtained from parents. EGG recordings were non-invasive, and the radiation exposure by fluoroscopic studies was carefully limited and kept minimized by video-recordings.

RESULTS

Electrophysiological evaluation based on EGG

Predominant dysrhythmia was documented in three of four patients: Bradygastria in two, and tachygastria in one. A composite pattern of brady- and tachygastria with a small percentage (13%)of normogastria was noted in case 2 (Fig. 1) unlike in case 4 (Fig. 2) that showed apparently normal electrical activity(normogastria, 51%; bradygastria 31%).

TABLE 2. *Frequency analyses based on electrogastrography (EGG)*

Patient (No.)	Bradygastria (%)	Normogastria (%)	Tachygastria (%)
1	53	34	13
2	63	13	24
3	29	24	47
4	31	51	18

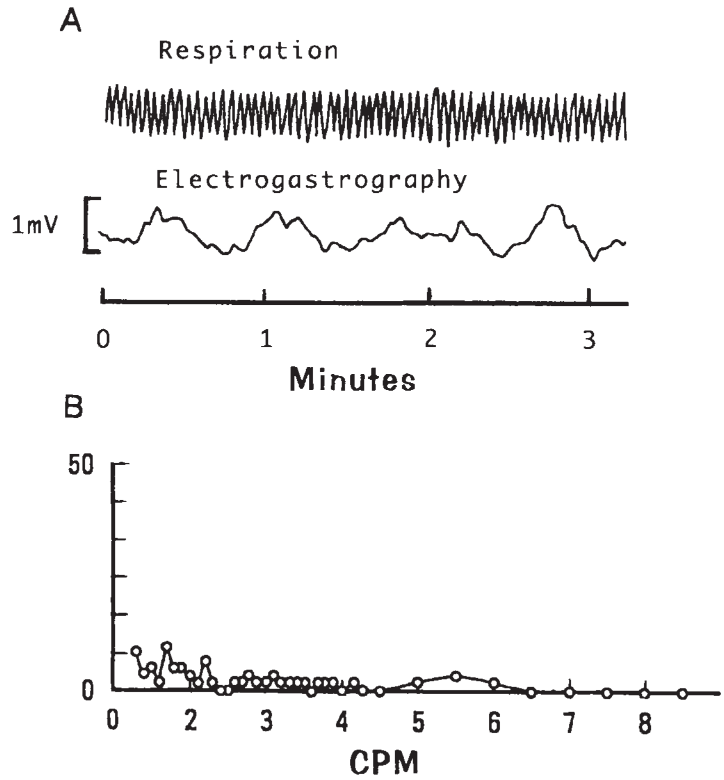

Fig. 1. Cutaneous electrogastrogram (EGG) showing gastric dysrhythmia (case 2 in Table 1). Both the original EGG recording (A) and the result of visual scoring by manual frequency analysis (B) are shown. Note that the regular gastric slow waves are not recognizable. In (B), vertical axis represents the number of recorded waves of each frequency value shown on the horizontal axis.

Evaluation of contractile activities

Propagation of gastric peristalses. On video-recorded fluoroscopy, propagating aboral peristalses were recorded (2, 8 and 8 contractions in case 2, 3 and 4, respectively). Contraction interval was 24 seconds in case 2 patient in whom only two contractions were identified due to a limited period of video-recording. The intervals were ranging from 22 to 26 seconds (23 in the average) in case 3, and were from 16 to 22 seconds (19 in the average) in case 4, respectively. Accordingly, calculated peristaltic frequencies (cpm) were 2.5 in case 2, 2.3 to 2.7 (mean; 2.6)

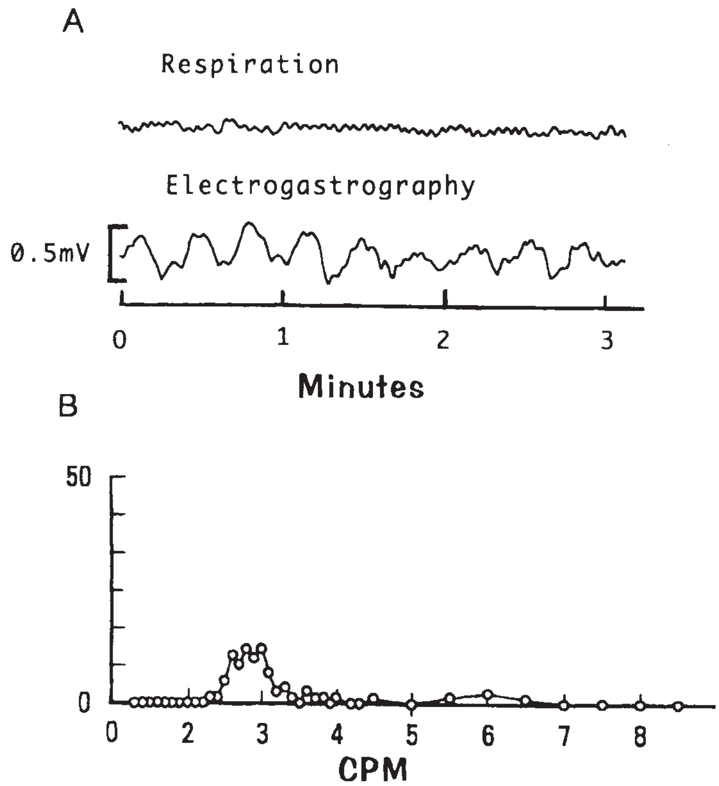

Fig. 2. Cutaneous electrogastrogram (EGG) showing predominant gastric slow waves (case 4 in Table 1) unlike that presented in Fig. 1. Likewise, both the original EGG (A) and the visual scoring by manual analysis (B) are shown.

TABLE 3. *Frequency analyses based on fluoroscopic dynamic study*

Patient (No.)	Number of contractions	Interval (seconds)	Gastric contractions	
			Frequency (cpm)	Dominant component
2	2	24	2.5	Bradygastria
3	8	24-26 (Mean; 23)	2.3-2.7 (Mean; 2.6)	Bradygastria; 63%
4	8	16-22 (Mean; 19)	2.7-3.8 (Mean; 3.2)	Normogastria; 50% Tachygastria; 38%

in case 3, and 2.7 to 3.8 (mean; 3.2) in case 4, respectively. Two peristaltic contractions in case 2 were both bradygastric. In case 3, 63% of contractions was bradygastric, and the rest was on the borderline between normogastria and bradygastria. In case 4, 50% was normogastric, 38% was tachygastric, and the rest was on the borderline between normogastria and bradygastria. It was worthy to note that this fluoroscopic study did not document any apparent delay in gastric emptying in these three patients.

Correlation between electrical and mechanical frequencies. Three (Patient No. 2, 3 and 4) of four patients were successfully investigated both electro-

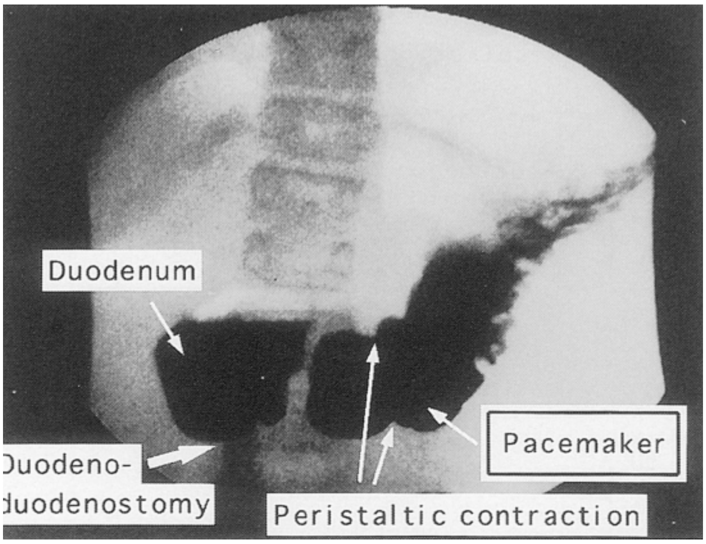

Fig. 3. Site of a possible electrical pacemaker. Radiograph (upright AP view) obtained by fluoroscopic barium swallow study in case 3 (Table 1). Peristaltic contraction is well visualized, and the location of potential pacemaker site can be identified ectopically far distal along the greater curve.

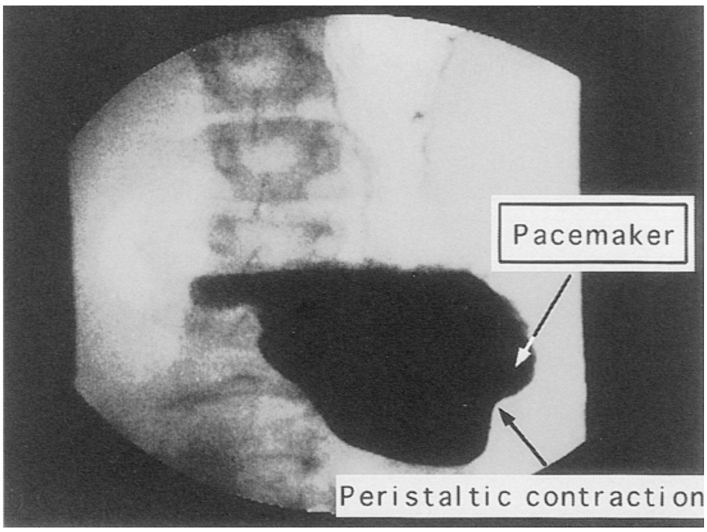

Fig. 4. Site of a possible ectopic pacemaker in case 4.

physiologically and fluoroscopically. Electrical and mechanical activities were in good agreement in two patients (cases 2 and 4). Especially in case 4, the percentage of normogastria was 51% in electrical and 50% in mechanical activities. Unlike these two patients, the outcome of case 3 showed an apparent discordance between the two assessments because tachygastria (47%) and bradygastria (29%) were electrically major components in this patient, whereas bradygastria was dominant (63%) with no tachygastric component in terms of peristalses. These results suggest that electrical tachygastria does not always lead to mechanical or peristaltic tachygastria.

Identification of ectopic pacemaker sites. As shown in Fig. 3, major proximal portion of the stomach in case 3 was mechanically aperistaltic with aborallypropagating peristalses arising just distal to the site of resection along the greater curve. This location was supposed to be an ectopic pacemaker site which developed postoperatively and is controlling motility of the distal part of gastric remnant (This patient was also associated with megaduodenum due to congenital duodenal stenosis corrected in early infancy). Likewise, a newly-arising pacemaker was found to be covering peristaltic function of the distal stomach in case 4 with the major proximal stomach left aperistaltic (Fig. 4).

Discussion

The majority of neonates with gastric rupture have characteristic extensive necrosis located most commonly along the greater curve (Chiba et al. 1991), and surgical repair which includes a combination of debridement and closure usually deprives them of the original electrical pacemakers. The goal of this report is to elucidate whether the gastric remnant holds its own electrical activities and also how it keeps physiological functions in survivors of neonatal gastric rupture. Our study based on combined analyses of EGG and video-recorded gastric fluoroscopy revealed the following three points. First, an ectopic pacemaker arises just distal to the site of resection along the greater curve as reported in adult patients with GI resection (Gustavsson and Kelly 1988), working for controlling gastric peristaltic functions without any delay in gastric emptying. Secondly, electric activity generated in the possible pacemaker site was predominantly dysrhythmic (brady-, or tachygastria), although it was normogastric in one patient (case 4). Thirdly, frequencies of electrical and mechanical activities did not always agree with each other.

Now, two questions are raised. First, why did the patient in case 4 reveal normogastria electrically. It was assumed that lower ectopic pacemaker does not show dysrhythmia clinically if the resected area along the greater curve is small, because Kelly et al. (1969) reported using canine stomach that the cycle of spontaneous electric activity in smooth muscle cells was essentially the same throughout the gastric body. The remaining question is why electrical and mechanical activities did not agree well as in a patient of case 3 whose bradygastric contractions showed an apparent discordance with her electrical tachygastria. This outcome could be explained by a well-known fact that electrical tachygastria usually fails to document a corresponding mechanical rhythm because it is mostly multifocal in origin and has too short intervals to cause corresponding peristalses (Kim et al. 1987). EGGs are expected to be helpful clinically in adults because it was reported that scintigraphic gastric emptying correlated well with the percentage of normogastria in EGG and a rise in the percentage of electrical dysrhythmia was predisposing to disordered gastric motility (Telander et al. 1978; Okuno et al. 1991). In this study, pediatric patients were assessed by EGG combined with barium swallow study which was essential to determine the frequency and the pacemaker site, although it does not always reflect physiological meal-fed conditions. Furthermore, there are two problems remaining to be solved regarding EGG study in pediatric patients. One is that available data concerning age-related development of gastrointestinal motility are still quite limited especially in those with a history of neonatal gastric resection due to ischemic necrosis. Milla (1994) reported that gastric antral ECA had a mean frequency of 3.04 cpm (range 2.4–3.6) in the fasting state and 2.1-3.4 cpm in the postprandial state in 45 control subjects aged 1 months to 14 year. Koch et al. (1993) who successfully recorded EGGs in preterm and term infants analyzed the EGG signal using the four major frequency bands: 1-2.4 cpm (bradygastria), 2.5–3.6 cpm (normal range), 3.7-9.9 cpm (tachygastria) and 10–15 cpm (duodenal and respiratory frequencies). Thus, the criteria we employed for EGG classification was essentially the same as that reported on pediatric population. The other problem is that EGGs were scored visually in our study by manual analysis, although it is a common practice lately to use the Fourier transform to compute the frequencies contained in the EGG signal with the aid of a desktop computer. It was, however, possible to obtain an excellent overview of the gastric ECA in our study and the outcome was supposed to be essentially comparable to that of Fourier transform.

In conclusion, gastric physiological functions including meal grinding and sieving are regulated well by the lower ectopic pacemakers arising in the remaining stomach in survivors of neonatal gastric rupture, and EGG study combined with radiological evaluation was considered useful for assessing these functions.

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