Pediatr Surg Int (1997) 12: 552–555

MAIN TOPIC

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Surface electrogastrography in children with esophageal atresia

Abstract Surface electrogastrography was performed in 18 patients with esophageal atresia (EA) and 10 normal controls to investigate the possible role of a congenital enteric nerve defect as a cause of gastroesophageal reflux (GER), which is common after repair of EA. The means of the dominant frequencies and ranges of the frequency distribution were compared. The dominant frequencies (0.047+/–0.007 Hz) in the EA group did not differ significantly from those of the controls (0.050+/–0.007 Hz, $P > 0.1$), although 2 patients had bradygastria and 2 had tachygastria in the EA group. The range of the frequency distribution was significantly wider in the EA group compared with normal children ($P = 0.002$). The wide frequency distribution in children with EA suggests disturbed electrical activity of the stomach, which could be associated with poor electromechanical coupling and, hence abnormal gastric contraction.

Key words Electrogastrography · Gastroesophageal reflux Esophageal atresia

Introduction

After successful repair of esophageal atresia (EA), gastroesophageal reflux (GER) is common. The symptoms include vomiting, apnea, aspiration, pneumonitis, failure to thrive, esophagitis, and esophageal anastomotic stricture. GER is present in about 70% of patients, symptomatic in about 40%, and frequently associated with poor gastric emptying [1, 2]. Reflux symptoms are more common in older children, increasing from 18% in those under 5 years of age to 52% in those over 15 years [3], with respiratory complications of GER identified as one of the main causes of late mortality of EA (6%) [4]. Fifteen percent to 45% of patients with GER fail to respond to medical therapy and require surgical intervention. It is likely that abnormal innervation of the foregut is associated with EA. In this study, we studied electrogastrography (EGG) in children with repaired EA.

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Materials and methods

Surface EGG was performed in 18 children with EA and 10 normal children without any gastrointestinal problems at Great Ormond Street Hospital for Children, London. Of the patients with EA, 16 had a distal tracheoesophageal fistula (TEF) and had undergone primary repair. EGGs were performed 1 week to 12 years following the repair. Three of these patients had symptomatic GER. The 2 patients with EA without fistula underwent staged repair with initial cervical esophagostomy and feeding gastrostomy. The mean age in the EA and control groups was 2.3 years (2 weeks to 12 years) and 2.1 years (1 month to 10 years), respectively.

The subjects were fasted for 4 h before the study. The skin over the epigastrium was cleansed with alcohol and gently abraded with electrode gel to reduce the skin-electrode impedance to less than 5 kΩ. Four pre-gelled EGG Ag/AgCl electrodes were then applied along the greater curvature of the stomach from left to right together with a reference electrode in the left lower quadrant of the abdomen and a grounding electrode. The resultant four bipolar electrodes were matched for impedance. The potential differences between the electrodes were measured after isolation amplification (Gould 11-5047-58) and passed through a low-pass analogue filter (Gould Electronics time constant 3.2 s, cut-off slope 6 dβ/octave) to remove high frequencies from potential cardiac electrical activity. The signal was digitalized at 1 Hz using an analogue to digital conversion (Data Translation DT2801A), recorded on the hard disk of an IBM personal computer for later off-line analysis, and also displayed on a polygraphic chart recorder (Gould Electronics). Running spectral analysis of the real-time signal captured on disk was performed using modular computerized algorithms for data capture, digital conditioning of the captured

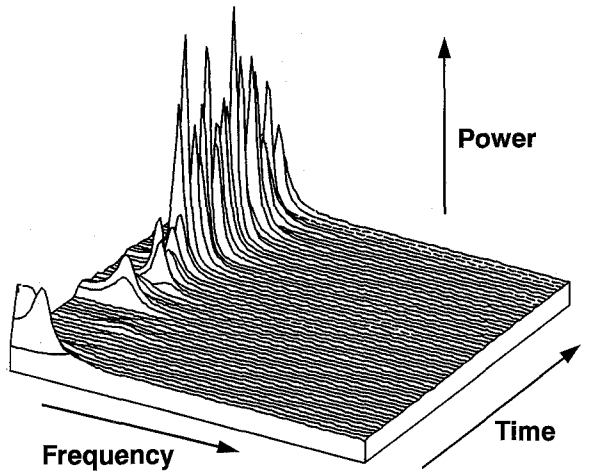

Fig. 1 Electrogastrogram (EEG) of a normal control

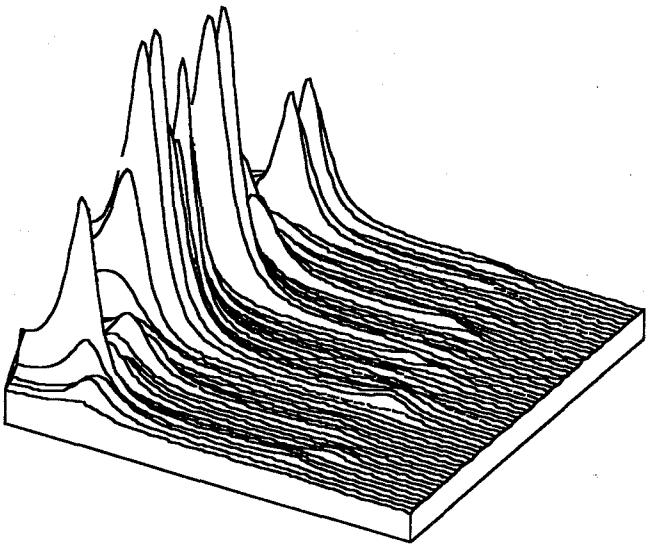

Fig. 2 Wide electrogastrographic frequency distribution in a patient with esophageal atresia

Table 1 The distribution and the range of the dominant frequencies in both the esophageal atresia and the control groups

	Esophageal atresia	Control
Distribution of frequency (Hz)	0.007 to 0.077	0.035 to 0.060
Range of the frequency (Hz)	0.070	0.025

Table 2 The p-values of Mann-Whitney-U tests comparing the range of the middle 80% of frequencies between the esophageal atresia and control groups

	Channel 1	Channel 2	Channel 3	Channel 4
Main frequency	0.090	0.002	0.002	0.139
Fasting frequency	0.240	0.014	0.055	0.640
Post-prandial frequency	0.023	0.002	0.006	0.726

Table 3 The EGG frequency ranges of the reflux and non-reflux subgroups in children with esophageal atresia and the p-values after comparing the two groups using Mann-Whitney-U test

	Channel 1	Channel 2	Channel 3	Channel 4
Reflux	1.71	1.59	1.87	2.02
Non-reflux	1.62	1.85	1.84	1.19
p-value	0.61	0.20	0.75	0.04

signal, and frequency analysis (PC-DATS, Prosig computer) as previously described [5].

The 1-h recording was divided into 55 segments. Each segment was of 128 s duration with 50% overlap with the previous segment and was subjected to Butterworth band-pass filtering with cut-offs at 0.01 Hz and 0.25 Hz to remove residual respiratory and cardiac signals. Adaptive spectral analysis based on an autoregressive moving average model by Chen was used, since it provides high-resolution power spectra. EGG frequency was determined in the fasting state for the first 20 min of recording and following a test meal for the last 40 min.

Data were presented as a pseudo-three-dimensional plot on an isometric contour plot of frequency against time and against power in the "z" axis (Fig. 1). The distribution of frequencies was plotted as a histogram for the overall recording, fasting, and post-prandial phases. To compare the distribution of EGG frequencies, each frequency in the histogram was tabulated and arranged according to its rank and percentile. The top and bottom 10% of the frequency were removed to eliminate the outlying figures. The ranges of the middle 80% of data of the EA and control groups were compared using the Mann-Whitney *U* test.

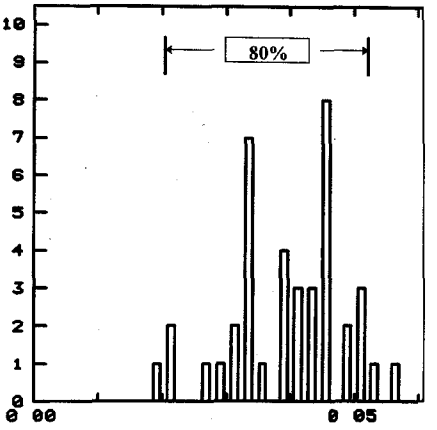

Fig. 3 Range of middle 80% of electrogastrographic frequency in a frequency distribution histogram

Results

Two patients with EA were found to have bradygastria (EGG frequency <0.04 Hz) and 2 had tachygastria (EGG frequency >0.06 Hz). These 4 patients, however, did not have any symptom of GER. The means of the dominant frequencies in the EA and control groups were 0.047+/–0.007 Hz and 0.050+/–0.007 Hz, respectively. The two groups did not differ significantly from each other ($P > 0.1$, Student *t*-test). However, the EA group had a much wider frequency distribution than the control group, the range being more than twice that of the controls (Table 1, Fig. 2).

Using the Mann-Whitney *U* test to compare the range of the middle 80% of the frequency distribution in both groups (Table 2, Fig. 3), it was found that: (1) the frequency distribution was significantly wider in the EA group over

channels 2 and 3, in which the electrodes are directly over the gastric antrum; (2) the difference in frequency distribution was close to being significant in channel 1 but was not prominent in channel 4; and (3) there was a tendency for a wider frequency distribution in the postprandial phase in channels 1 and 2. When the reflux and non-reflux patients were compared in the EA group, the former were found to have a wider EGG frequency span in three out of four channels, but only one of them was of statistical significance (Table 3).

Discussion

The high incidence of GER in patients with EA has prompted extensive investigation. It is, however, unclear whether GER is a consequence of surgical repair or a part of the congenital malformation. Gastrostomy has been implicated but no convincing evidence is available [6]. Esophageal transection in both dogs and newborn puppies does not produce any significant esophageal dysfunction [7, 8]. Extrinsic denervation of the lower esophagus has been shown to have no demonstrable effect on the lower esophageal sphincter [9]. Preoperative cinefluorographic studies have demonstrated abnormal esophageal motility in children with EA [10]. Unco-ordinated peristalsis has been found manometrically in both the proximal and distal segments of EA before any surgical intervention [11], and even occurs in infants with H-type TEF [9]. The esophageal dysmotility seems to be congenital.

The GER in patients who had undergone repair of EA with TEF was found to be associated with slow gastric emptying on barium studies [12]. Electrical activity of the stomach consists of slow waves and spike potentials. Slow waves occur at around 3 cycles/min or 0.05 Hz. They are an inherent property of smooth-muscle cells and are related to changes in permeability of the cell membrane to sodium. The frequency of the slow wave is driven by pacemaker cells high up along the greater curvature. Spike potentials are action potentials associated with muscular contractions that occur on slow waves in response to the opening of ion channels, which results in contraction. This electrical activity may be recorded from either the mucosa, serosa, or skin surface. EGG was first performed in 1921 [13], but only recently became clinically relevant following the introduction of surface EGG and spectral analysis by computers, which rendered it noninvasive and facilitated objective interpretation.

Tachygastria and bradygastria were seen in the EA group. Dysrhythmias and tachygastria are known to be associated with nausea, and delayed gastric emptying. Tachygastria is also known to occur in intrinsic neuropathic disorders of the gut [5]. Abnormalities of the myenteric plexus have been demonstrated in the esophagus and stomach in infants with EA [14], and this is consistent with the EGG changes of tachygastria seen in some of our patients [5]. Only 3 of the 18 patients had symptomatic GER. This is fewer than expected, and could be due to the fact that some of the EGGs were performed not long after the surgery. The follow-up was possibly not long enough to detect reflux.

Although the mean dominant frequency did not differ between the two groups there was a striking difference in the current study in the distribution of the frequencies, with a much wider distribution in the EA group than the control group. The difference was close to being significant in channel 1, the electrode in the vicinity of the gastric pacemaker. In this area one might suspect that the intrinsic nerves have the least effect on the muscle-cell membranes, whereas in the gastric antrum, the entrainment by the pacing cells high in the fundus is weakest and the effects of aberrant innervation might become more obvious, thus explaining the clear differences in frequency distribution between the two groups in the antrum. The fact that channel 4 failed to show any difference may be because the electrodes were not directly over the stomach, and hence the signal received was much attenuated, although other causes are possible.

A wide EGG frequency distribution implies that either the gastric pacemaker is not pacing at a regular rhythm or the activity of the actual smooth-muscle cells is varying due to an external modulating effect, probably by the intrinsic nerves. The previous findings of abnormality of the myenteric plexus are in keeping with the latter hypothesis [14]. The irregular peristalsis and unco-ordinated contraction of the stomach and esophagus may result in poor gastric emptying. We conclude that in EA there is abnormal gastric electrical activity that may lead to disturbed muscle control. This may be associated with dysmotility of the stomach in affected patients.

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