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ORIGINAL ARTICLE

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Changes in gastric myoelectrical activity in hypertrophic pyloric stenosis and after surgical correction

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Abstract The changes of gastric myoelectrical activity were investigated in 20 infants by cutaneous electrogastrography (EGG) before and after the surgical correction of infantile hypertrophic pyloric stenosis (IHPS). The dominance of 2–4 cycles per minute (CPM) "slow waves" is typical of the healthy gastric function. The shift of the dominant frequencies towards the slower frequency (0–2 CPM) is defined as bradygastria, whereas a shift towards the more frequent waves (4–10 CPM) is called tachygastria. Unlike with healthy infants, the electrogastrogram showed pathologic patterns in 85% (18 out of 20) of IHPS patients. In all except two of these infants with pathologic electrical patterns, the frequency of the waves significantly shifted towards tachygastria. The effect of feeding on the gastric myoelectrical activity could only be studied in limited (9/20) cases because of recurring vomiting during the preoperative period. In IHPS infants, a significant increase in the bradygastria group was observed in the postprandial period compared with healthy infants. Three to 5 days after surgical repair (pyloromyotomy) and the reintroduction of feeding in gradually increasing amounts, the gastric myoelectrical activity showed physiologic patterns again, showing that the pyloric function was back to normal. Cutaneous EGG is a useful, noninvasive method to obtain indirect information about the motor function of the stomach and might be further applicable to pediatric gastric motility disorders.

Keywords Infantile hypertrophic pyloric stenosis · Electrogastrography

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Introduction

Infantile hypertrophic pyloric stenosis (IHPS), characterized by the hypertrophy of the circular muscle of the pylorus, is one of the most common conditions requiring surgery in the first few months of life. The gradual development of gastric outlet obstruction is associated with marked hyperperistalsis and repeated vomiting.

Family predisposition and heredity have been implicated as important factors in the pathogenesis of this condition; however, much is still unknown about the etiology and pathomechanism of this disorder.

The motoric function of the stomach is regulated by its pacemaker activity. Cutaneous electrogastrography (EGG) is a relatively new and harmless method to study gastric myoelectrical activity and its disturbances. Although a developmental process of gastric myoelectrical activity can be observed during the first 6 months of life, [9] the dominance of 2–4 cycles per minute (CPM) "slow waves" is characteristic of healthy gastric function in infants. The shift of dominant frequencies of EGG waves towards the slower frequency (0–2 CPM) is defined as bradygastria, whereas a shift towards the more frequent waves (4–10 CPM) is called tachygastria. In healthy adults and children, the ratio of the .normal 2–4 CPM waves is $>60\%$.

The purpose of this study was to investigate changes in the myoelectrical activity of the stomach in relation to the development of IHPS symptoms before and after surgical repair.

Patients and methods

Electrogastrography was performed in 20 IHPS patients and 10 healthy controls. The age of the IHPS patients ranged between 16 and 43 days. (For detailed data on the patients and controls, see Table 1).

Moderate acid-base balance and electrolyte abnormalities were observed in all but two of the patients, without marked differences at the time of diagnosis.

Table 1 Group characteristics

	Patients with IHPS	Controls
N	20	10
Age (days)	16-43	17-39
Mean age (days)	26	30
Female/male	6/14	5/5
Gestational age at birth (weeks)	38.6 ± 3.4	39.2 ± 2.8

The highest pH value was 7.49, with the lowest serum chloride concentration being 98 mmol/l.

The diagnosis was based on clinical symptoms supported by abdominal ultrasound examination in all cases. Palpable pylorus tumor was detected in only 13 infants.

After the skin surface was prepared, electrogastrography was performed by placing two silver/silver chloride bipolar surface electrodes on the antral axis of the stomach. The reference electrode was placed on the subject's right costal margin at the level of the mid-clavicular line. The electrodes were connected to a 96-kilobyte portable battery-operated recorder (Synectics Medical, Sweden), and the recorded signals were then simultaneously digitized at an appropriate sampling rate and stored for subsequent digital processing. A low-pass filter with a corner frequency in the 0.08–0.3 Hz range ensured rejection of electrogastrographic and respiratory artifacts from the percutaneous recording.

The EGG measurements were performed over 3 h, including one feeding cycle (2 h pre- and 1 h postprandial state, after a human milk or formula meal).

The precise quantification of EGG is possible only on the computer. The whole purpose of EGG analysis is to provide a ready means for assessing the frequency content and relative powers of the recorded EGG. The raw signal is difficult to assess visually, so the frequency analysis of the EGG is an indispensable tool. The electrogastrogram analysis of the filtered signal is based on the " running spectrum analysis" or running fast Fourier transform (FFT) [4,19].To attain high accuracy, the EEG data with motion artifacts should be identified and deleted before analysis.

The following parameters were measured:

1. Dominant electrical frequency (DF), the highest frequency peaks of each FFT lines (the frequency at which the power has a peak in the range of 0.5–9.0 CPM)
2. Percentage of DF in the normal frequency range (2–4 CPM), bradygastria (< 2 CPM), tachygastria (4–10 CPM); the calculations were based on the dominant mode of the EGG analysis
3. Dominant frequency instability coefficient (DFIC), which is a measure of how much the dominant frequency changes over the course of the period. It is computed by first calculating the mean and SD of the individual dominant frequencies for the period in question. The SD of the dominant frequencies is then divided by the mean of the dominant frequencies to give the DFIC, which is reported as a percentage
4. Dominant power (DP); the power at the DF in the power spectrum of the EGG was defined as the EGG dominant power, calculated from the mean or average FFT line for the given period

The data were compared with the results obtained from 10 healthy infants who showed no gastrointestinal symptoms.

The Student's *t* -test was applied. Statistical significance was assigned for *p*-values < 0.05. All data were presented as mean ± SD.

Results

In 18 out of 20 IHPS infants, the physiologic myoelectrical activity of the stomach had changed, and pathologic patterns appeared.

In healthy infants, the distribution of gastric myoelectrical waves was similar to that observed in adults (Fig. 1). In IHPS, dysrhythmic myoelectrical activity appears. Abnormal patterns of EGG with < 60% of 2–4-CPM waves were found in 85% of IHPS patients, compared with 10% of the controls during fasting. In the IHPS patients, dysmotility consisted mostly of tachygastria during fasting (18/20, with abnormal EGG).

Because of the recurrent vomiting, the effect of feeding was successfully studied only in a limited (9/20) number of cases. Eleven infants were impossible to feed by mouth before the operation. In the postprandial period, the differences between the IHPS and the healthy groups were more pronounced. In healthy babies, an increasing ratio of physiological 2–4-CPM waves was noted after feeding,. However, in IHPS infants a significant increase in bradygastria was observed compared with healthy infants (Fig. 2).

No significant differences could be found between the IHPS and healthy groups in DP.

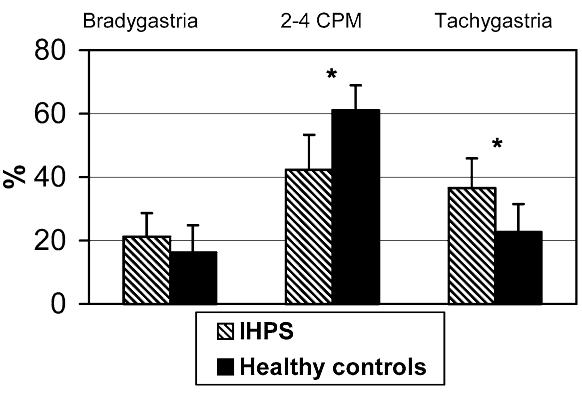

Fig. 1 Distribution of gastric myoelectrical waves in IHPS compared with healthy infants. * $p < 0.01$. No significant difference was observed in the bradygastria group

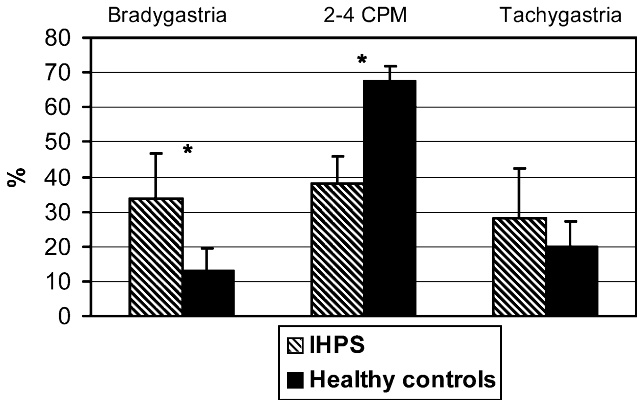

Fig. 2 Distribution of the myoelectrical waves after a meal. * $p < 0.01$. No significant difference was observed between the two groups in the frequency of the tachygastric waves

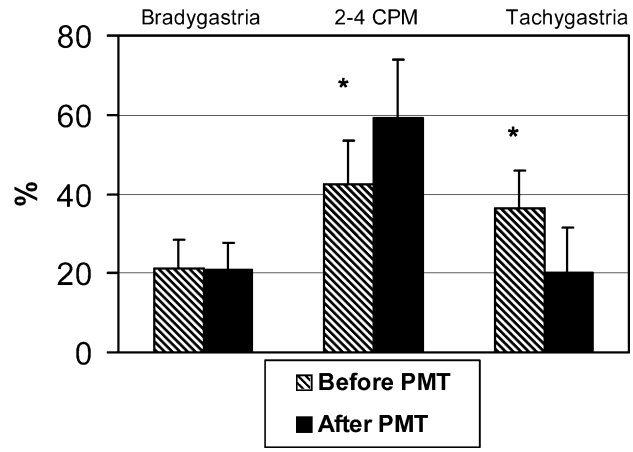

Fig. 3 Effect of pyloromyotomy (PMT) on the distribution of gastric myoelectrical waves. * $p < 0.01$. No significant difference was observed in the bradygastria group

Control electrogastrographic measurements were performed 3–5 days after pyloromyotomy, following the reintroduction of oral feeding in gradually increasing amounts according to Rickham [15]. The motility patterns were normal, with a significantly increasing ratio (more than 60% dominance) of the 2–4-CPM waves (Fig. 3).

A physiological distribution of the myoelectrical waves was considered in the postoperative period after feeding as well. A significant decrease was noted in both the bradygastria and tachygastria groups, with a simultaneous increase in 2–4-CPM waves (Fig. 4).

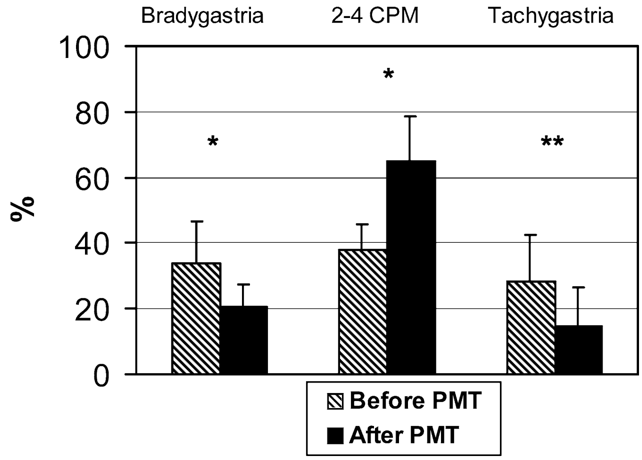

Fig. 4 Postprandial distribution of the myoelectrical waves after pyloromyotomy (PMT). Significant differences were observed in all of the groups. * $p < 0.01$, ** $p < 0.02$

Discussion

Infantile hypertrophic pyloric stenosis (IHPS) associated with pyloric obstruction is a common problem, a "classic" clinical disorder. This condition is usually treated by pyloromyotomy; the hypertrophic circular musculature is incised, via either an open or, more recently, a laparoscopic approach.

The etiology of IHPS and parts of the pathomechanism are still unknown, although some theories have appeared in the past few decades.

The genetically determined, supernormal parietal cells may lead to increased acidity in the first 4 weeks of life, and thus may play an important role in development of the disease [16].

Abnormalities of hormonal control [6,17], an increasing amount of extracellular matrix protein [1], and an active collagen synthesis of the pyloric circular smooth muscles [12] have been reported in IHPS; the latter two conditions may be responsible for the development of pyloric tumor.

Several lines of evidence suggest that a localized deficiency of pyloric autonomic innervation exists in the hypertrophied pyloric muscle [8, 20]. Presumably, the defect of nonadrenergic, noncholinergic innervation mechanisms can lead to prolonged contraction and later to hypertrophy of the pyloric circular smooth muscle [14].

Previous electron microscopic studies have mentioned the possible role of myenteric plexuses in the pathomechanism of the disease [2], but the significance of these alterations is unclear, and other experts consider them only secondary and functional [11].

On the basis of an increasing amount of clinical data seen in the literature relating to the role of the innervation disturbance of the circular smooth muscles, it is presumable that the development of pyloric stenosis also results in pathologic changes in the gastric motility.

In our present study we intended to look at alterations in the myoelectrical activity regulating the motility of the stomach in the course of IHPS development.

The stomach is a neuromuscular organ that has intrinsic electrical activities modulated by gastrointestinal hormones and the parasympathetic, sympathetic, and enteric nervous systems. Neuromuscular activities of the stomach generate electrical phenomena termed "gastric slow waves"; also described as "electrical control activity." The outer layer of the circular muscle of the stomach wall is considered to be a source of these electrical oscillations, but the interstitial cells of Cajal may also be the source of the gastric slow wave. Gastric slow waves originate in a "pacemaker region" located on the greater curvature of the stomach near the junction of the fundus and proximal gastric corpus. The slow waves are propagated distally and circumferentially and migrate towards the pylorus at a rate of one propagated wave front every 15–30 s in humans. Thus, the normal gastric slow wave frequency is 2–4 CPM. The slow wave controls the timing and propagation of gastric peristalses, which are produced by the contraction of the circular muscle layer.

Cutaneous EGG is a relatively new, noninvasive method of investigating the myoelectrical activity of the stomach [3, 5]. Because the dominant EGG frequency reflects the frequency of gastric slow waves, this dominant frequency is associated with gastric motility, and determines the maximum frequency of the gastric contractions.

Our electrogastrographic results, the dysrhythmic electrical wave activity in infants with IHPS, also support the innervation theories mentioned above. The shift of the myoelectrical activity towards more frequent waves—i.e., tachygastria—is well reflected in the clinical symptom of hyperperistalsis, as more and more hypertrophic antral wall tries to pass through the tightening pyloric channel. These observations are similar to those obtained previously by Imura et al. [7], who used manometry in five children with IHPS and found frequent 1–3-CPM (average 1.7 CPM) spastic contractions with a high amplitude.

Postprandial bradygastria can be a sign of the transient paresis of the stomach, as it was shown in cases in which the feeding's effect on electrogastrographic waves was investigable.

Three infants demonstrated some expressed short tachygastric periods before clinical vomiting, but this phenomenon was not observed in all of our cases.

Sun et al. performed antropyloroduodenal manometry and concurrent measurements of gastric emptying in six adult volunteers who had had pyloromyotomy performed in infancy because of IHPS. Abnormal patterns of pyloric motility could be registered, and the authors associated this observation with their pyloric stenosis of infancy [18]. Previously, Ludtke et al. found no relevant disturbances in gastric emptying 16–26 years after pyloromyotomy [10].

However, Nour et al., using applied potential tomography, found a significant difference in gastric emptying before as well as 2 and 4 days after pyloromyotomy in a group of 49 vomiting infants with IHPS. This abnormality then gradually normalized by the 7th postoperative day [13].

In our present study, following the surgical repair of IHPS and after the successful reintroduction and build-up of oral feeding, the gastric myoelectrical activity returned to normal levels. Our findings point to the reconstruction of the physiological function and are supported by clinical observations relating to the enhanced compensatory weight gain and the lack of any feeding disturbances in the late postoperative period.

On the basis of our results in accordance with the general observations made about the infants' compensatory postoperative weight gain, Sun et al.'s assumption about a later negative effect of pyloromyotomy is strongly doubtful.

In conclusion, we found cutaneous EGG to be useful in investigating infants. It is noninvasive, harmless, and can be used to obtain indirect information about the motoric function of the stomach. The abnormalities observed in the gastric myoelectrical activity in connection with the development of IHPS were transient, normalizing soon after surgical correction.

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