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Validation of Electrode Placement in Neonatal Electrogastrography

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Electrogastrography (EGG) is the transcutaneous measurement of gastric electrical activity. The aims of this study were to validate the electrode placement position in neonatal electrogastrography using ultrasonography to localise the stomach, and to describe the observed EGG frequency characteristics. Fifteen neonates with no known abdominal disorder were studied. Two bipolar EGG recordings were obtained from each subject, the first from electrodes placed at sites localized by ultrasound and the second from electrodes placed at the currently recommended sites. Paired sample *t* tests were used to compare electrode positioning and electrogastrographic data. There were 15 subjects with a mean age of 36 days (range 1–95). While there was a significant difference in the position of electrodes at each site, the EGG recordings did not differ. The 3-cycle/minute (2.6–3.7cpm) activity ranged from 30% to 84% of recorded time (mean at sites localized with ultrasound was 53%, and at currently recommended sites it was 50%; difference not significant, $P = 0.155$). Bradygastria (<2.6 cpm) was observed in the range of 2–29% of recorded time (mean at sites localised with ultrasound was 12.9%, and at currently recommended sites it was 11.7%; difference not significant, $P = 0.40$). Tachygastria (3.2–10 cpm) was shown to be in the range of 10–58% of recorded time (mean at sites localized with ultrasound was 33.3%, and at currently recommended sites it was 38.7%; difference not significant; $P = 0.044$). In conclusion, there was no significant difference between EGG recordings taken from electrode sites localized by ultrasound and those recommended by manufacturers of the electrogastrogram, thus confirming the validity of the manufacturer's recommended electrode positioning. The pattern of electrical control activity in the normal neonatal stomach appears to be different from that demonstrated in adults. Bradygastria and tachygastria are seen more frequently, with fewer periods of 3 cpm activity.

KEY WORDS: electrogastrography; electrode placement; stomach.

The motility of the gastrointestinal tract is presumed to be partly regulated by the electric control activity (ECA) of the stomach. This electrical activity is generated in a pacemaker area of the greater curvature of the stomach. The inherent rhythm is called a slow wave. It arises from the junction of the proximal one third and distal two thirds of the gastric corpus and propagates towards to the pylorus. Electrogastrography (EGG), first reported in 1922 (1), is now accepted as the method of transcutaneous measurement of this gastric electrical activity. A normal slow wave frequency of approximately 3 cycles per minute (cpm) has been demonstrated in adults and children (2). Abnormal EGG results have been described in patients with gastric motility disorders. *Tachygastria* is

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characterized by an increase in the frequency of slow waves and *bradygastria* by a decrease. Tachygastria has frequently been found in patients with gastric emptying disorders like gastroparesis and intestinal pseudo obstruction (3, 4, 5).

Little is known about EGG in neonates, and the recommended positioning of the electrodes is based on adult studies (6, 7). It is known that gastroduodenal motility in neonates differs from that of adults (8), and therefore it could be concluded that it is possible that the characteristics of neonatal gastric electrical activity would reflect this difference. A previous study has indicated that the characteristic pattern of neonatal EGG does vary from that of adults but suggests that this may be due to a difference in optimal electrode positions (9). Hence, it is evident that before any conclusions can be drawn from neonatal EGG, the technique currently used in adults needs to be validated in infants.

The aims of this study were to validate the electrode placement position in neonatal electrogastrography using ultrasonography to localize the stomach and to describe the observed EGG frequency characteristics.

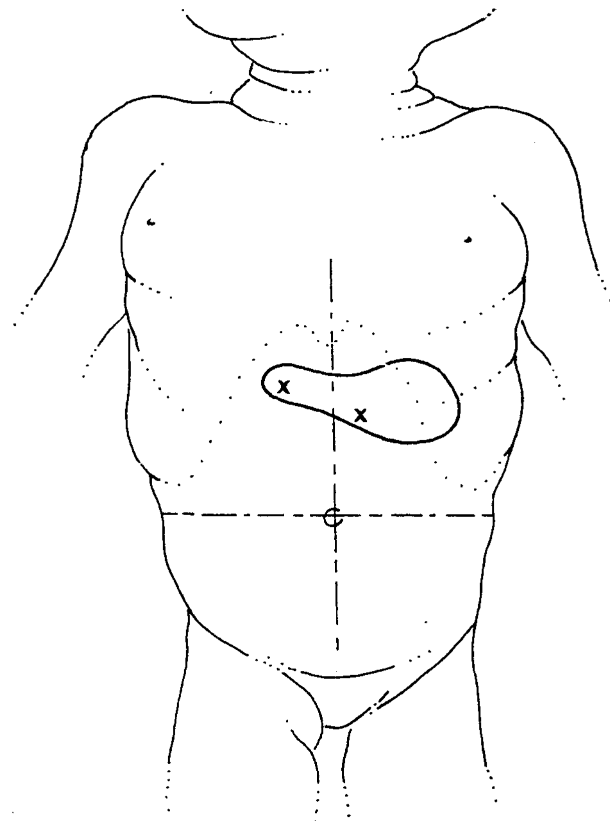

Fig 1. Electrode sites localized using ultrasound (X) were marked on abdominal skin.

MATERIALS AND METHODS

Fifteen orally fed, neurologically normal neonates with no known abdominal disorders and receiving no medication were studied. Neonates were defined as infants of postconceptional age ≤ 44 weeks.

Ultrasound Marking. The locations of the proximal and distal body of the stomach were identified using ultrasonography and their positions (×) were marked on the abdominal skin (Figure 1). The position of each mark was measured in relation to a vertical line between the umbilicus and xiphoid process (midline) and a horizontal line between the ventral midline and left/right mid-axillary lines. These positions were plotted onto a grid using fractional distance as coordinates. A further set of marks (●) was plotted onto the grid at the positions of the currently recommended electrode sites (Figure 2); these are the electrode positions recommended by Synectics Medical (Stockholm, Sweden).

Preparation for EGG Procedure. Each infant underwent two EGG recordings. Half an hour before commencement of each recording, the subjects were fed breast milk (4) or formula (10). The abdominal skin was then cleaned with an abrasive gel until impedance of <5 K Ω was achieved. This was confirmed by measurement with a skin-resistance ohmmeter.

Procedure. The EGG was performed using the Synectics Electrogastogram with bipolar sampling at 4 Hz (two active electrodes and one reference electrode). The first EGG was recorded from electrodes placed at the sites localized by ultrasound scan (US sites) with the reference electrode equidistant from these two (forming an equilateral triangle) and the second was recorded from electrodes placed at the sites recommended Synectics (SR sites).

Data. The difference in electrode positions between the US and SR sites was calculated from the grid onto which the sites were plotted. Data obtained from the EGG recordings was downloaded to Synectics Gastrosoft software. Artifact was removed before the data were analyzed using running spectral fast Fourier transformation (FFT) analysis (10).

Paired sample *t* tests at the 95% confidence interval (CI) were used to compare the results from the US and SR sites.

Ethical Considerations. Ethical approval for the study was granted by the local research ethics committee. Full written and verbal explanation was given to the parents and written consent obtained.

RESULTS

There were 8 boys and 7 girls with a mean age of 36 days (range 1–95).

Electrode Positions. There was a significant difference in the position of electrodes for the US and SR sites (Table 1). The mean fractional distances are shown in Table 2.

For *electrode 1*, the US sites were consistently located to the right laterally and above the level of the

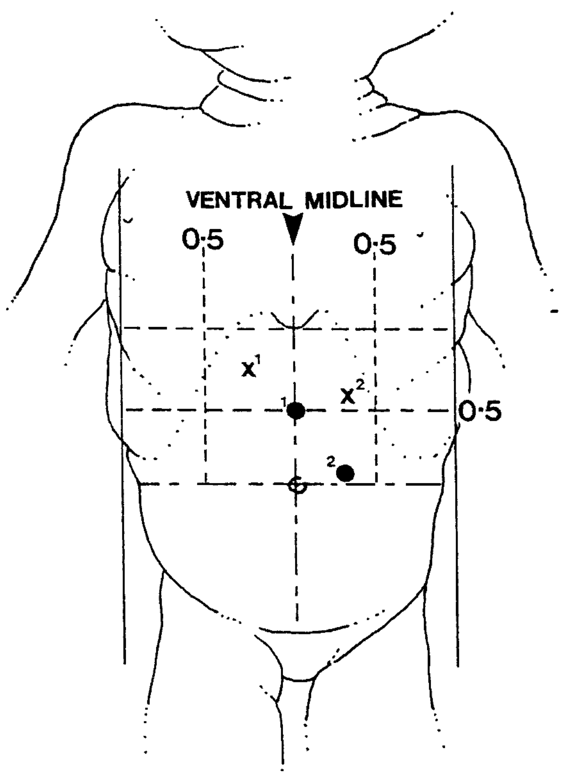

Fig 2. Electrode positions were measured in relation to the ventral midline and mid-axial lines (lateral displacement), and the umbilicus and xiphoid process (displacement above the umbilicus). 0.5 = the midpoint between these landmarks Ultrasound sites: (X^1 = electrode 1, X^2 = electrode 2; Synectic sites: ^{1}● = electrode 1, ^{2}● = electrode 2.

umbilicus. The mean fractional distance was one fourth of the distance between the midline and right mid axillary line and approximately three fourths (0.727) of the distance between the umbilicus and xiphoid process. The SR sites were not displaced laterally and were located on the midline halfway between the umbilicus and xiphoid process. The mean fractional difference between US and SR sites for electrode 1 was 0.25 (95% CI = 0.23, 0.27, P = 0.00) for the lateral displacement and 0.23 (95% CI = 0.2, 0.25; P = 0.00) for displacement above the umbilicus.

For *electrode 2*, the US sites were consistently located to the left laterally and above the level of the umbilicus. The mean fractional distance was one third of the distance between the midline and left mid-axillary line and two thirds of the distance between the umbilicus and xiphoid process. The SR sites were also placed to the left laterally one third of the length between the midline and left mid-axillary line but were located only just above the level of the umbilicus (mean fractional distance 0.09). The mean fractional difference between US and SR sites for electrode 2 was 0.05 (95% CI = 0.01, 0.09, P = 0.02) for the lateral displacement and 0.5 (95% CI = 0.44, 0.56; P = 0.00) for displacement above the umbilicus.

EGG Recordings. The mean duration of recordings was 3 hr 39 min (range 2 hr to 4 hr 52 min). There was no significant difference between the duration of recordings at US and SR sites (mean difference 0.2 min; P = 0.98).

Artifact was removed from the data before FFT analysis. There was no significant difference between the mean percentage of artifacts seen in the recordings obtained from the US sites (8.2%) and the SR sites (10.6%). (95% CI for the mean difference = −2%, 7%; P = 0.26). Bradygastria (<2.6 cpm) was observed in the range of 2–29% of recorded time for US sites (mean 12.9%) and 4–19% of recorded time for SR sites (mean 11.7%). Bradygastria observed at US and SR sites was not significantly different (95% CI for the mean difference = −4%, 2%; P = 0.40).

Three cpm (2.6–3.7 cpm) activity ranged from 30% to 84% of recorded time at US sites (mean = 53%) and from 34% to 74% of recorded time at SR sites (mean = 50%). The difference in 3 cpm activity at the US and SR sites was not significant (95% CI for the mean difference = −8.8%, 1.5%; P = 0.155).

Tachygastria (3.2–10 cpm) was seen in the range of 12–50% of recorded time at US sites (mean = 33.3%)

TABLE 1. SYNECTICS RECOMMENDED ELECTRODE POSITIONS

Electrode	*Recommended position*
Electrode 1 (active)	On the ventral midline, mid-way between the umbilicus and the xyphoid cartilage
Electrode 2 (active)	On the left side of the abdomen, 1/3 of the distance from the ventral midline to the left mid-axial line, and one centimeter below the level of the lowest rib
Reference electrode	On the abdomen, forming an equilateral triangle with the other two electrodes

TABLE 2. ELECTRODE POSITIONS: MEAN FRACTIONAL DISTANCES FOR DISPLACEMENT ABOVE UMBILICUS AND LATERAL DISPLACEMENT*

	Mean fractional distance from	
Site	*Umbilicus to xiphoid process (displacement above umbilicus)*	*Ventral midline to left/right mid axillary lines (lateral displacement)*
Electrode 1		
US	0.727	0.253 to the right
SR	0.5	0.0
Electrode 2		
US	0.594	0.35 to the left
SR	0.09	0.3 to the left

* US site: electrode site localized by ultrasound; SR site: electrode site recommended by Synectics.

and at 10–58% of recorded time at SR sites (mean = 38.7%). The difference in tachygastric activity at US and SR sites was not significant (95% CI for the mean difference = 0%, 10.6%; $P = 0.044$)

DISCUSSION

It has been suggested that failure of normal neonatal EGG to demonstrate the prominent 3 cpm slow wave activity seen in adults may be due to incorrect electrode placement. The positioning of EGG electrodes is of particular importance because, unlike other electrophysiological signals, the electrical activity in the stomach is weak and is easily impaired by cardiac and duodenal signals, respiratory disturbance and motion artifacts. The electrodes should be placed along the longitudinal axis of the stomach in order to measure the difference in electrical potential (11). It has been suggested that the optimum electrode positions will vary according to stomach size and shape (2). Therefore, it has been recommended that ultrasound be used as the gold standard in determining electrode positions (12). However, ultrasound is not always feasible and, when EGG is needed as a portable device, some estimate of optimum positioning is necessary.

The currently recommended (Synectics) cutaneous positioning of electrodes is based upon estimates of optimum positioning in adults. The position and shape of the neonatal stomach differs from that of adults. However, there appears to be no established standard for the positioning of electrodes for neonatal EGG.

This study confirms that in neonates there is a significant difference between the anatomical positioning of the currently recommended electrode sites and the sites determined using ultrasound to locate the longitudinal axis of the stomach. However, the EGG recordings taken from these sites are not significantly different, thus indicating that the currently recommended electrode positions are valid for use in neonates.

This study shows that neonatal EGG frequency differs from that of adults and that this difference cannot be attributed to incorrect electrode placement. Therefore, it is possible that the difference in gastroduodenal motility in neonates and adults is reflected in the EGG. We have confirmed that neonatal EGG is characterized by fewer periods of 3 cpm activity and more frequent periods of tachygastria and bradygastria than adult EGG. We hypothesize that neonatal ECA undergoes a maturation process.

Disorders in gastrointestinal motility, usually presenting as feeding difficulties, are common in premature infants and in neonates who have undergone gastrointestinal surgery. The basic pathophysiology of these disorders is poorly understood. We propose that a poorly developed or disordered ECA may be a significant underlying factor in these motility abnormalities. With the recommended placement of EGG electrodes validated, further studies may provide a clear EGG picture for normal neonates. This procedure may then be used to assist with clinical diagnosis of patients with motility disorders and evaluation of the effects of drugs or surgery.

We conclude that the pattern of ECA in the normal neonatal stomach appears different from that demonstrated in adults. Bradygastria and tachygastria are seen more frequently, with fewer periods of 3 cpm activity. There was no significant difference between EGG recordings taken from electrode sites localized by ultrasound and those recommended by manufacturers of the electrogastrogram, thus confirming the validity of the manufacturer's recommended electrode positioning.

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