

# Gastric myoelectrical activity in premature and term infants

K. L. KOCH<sup>1</sup>, T. N. TRAN<sup>2</sup>, R. M. STERN<sup>3</sup>, S. BINGAMAN<sup>1</sup> & N. SPERRY<sup>1</sup>

Departments of <sup>1</sup>Medicine, <sup>2</sup>Pediatrics and <sup>3</sup>Psychology, The Pennsylvania State University, The Milton S. Hershey Medical Center, Hershey, Pennsylvania, USA

**Abstract** Electrogastrography is a non-invasive method for recording gastric myoelectrical activity. The aims of this study were to record gastric myoelectrical activity in newborn infants using electrogastrographic methods and to compare frequency distributions of postprandial electrogastrograms (EGGs) recorded after gavage feedings. Nineteen infants with gestational ages ranging from 28 weeks to term were studied. Group I subjects were studied only after formula feedings ( $n = 15$ ) and were divided by age into subgroups A, B and C: A (term,  $n = 4$ ), B (33–36 weeks,  $n = 4$ ), and C (28–32 weeks,  $n = 7$ ). Group II infants (32–34 weeks,  $n = 4$ ) were studied before and after gavage feeding. The percentage of total EGG power was calculated for four frequency ranges: 1–2.4 cpm (bradygastria); 2.5–3.6 cpm (normal range); 3.7–9.9 cpm (tachygastria); and 10–15 cpm (duodenal/respiratory). Results showed no significant differences in postprandial EGG power in these frequency ranges among the Group I infants of different gestational ages. The power in these EGG frequency ranges did not change significantly after gavage feedings in the Group II infants. In conclusion: (a) EGGs may be recorded successfully from preterm and term infants, (b) postprandial gastric myoelectrical activity in all frequency bands is similar among groups of premature and term infants, and (c) gavage feedings in premature infants did not increase 3 cpm EGG activity.

**Key words** electrogastrography, feeding, gastric myoelectrical activity, premature infants, tachygastrias.

## Address for correspondence

Dr K. L. Koch, Professor of Medicine, Division of Gastroenterology, The Pennsylvania State University, College of Medicine, The Milton S. Hershey Medical Center, PO Box 850 Hershey, Pennsylvania 17033, USA.

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## INTRODUCTION

Postprandial gastric peristalses are produced by slow waves and associated plateau and spike potentials which migrate distally from the proximal corpus through the body-antrum at a rate of 3 per min.<sup>1,2</sup> Three cpm gastric myoelectrical activity may be recorded accurately from cutaneous electrodes positioned on the serosa, mucosa or abdominal surface.<sup>3–7</sup> These signals, termed electrogastrograms or EGGs, reflect the 3 cpm frequency of the normal gastric slow wave. In adults the amplitude of the 3 cpm EGG wave increases during sham feeding<sup>8</sup> and after ingestion of milk, yogurt, frankfurters and non-nutrient meals.<sup>4,7–10</sup>

Abnormal gastric myoelectrical rhythms, termed tachygastrias and bradygastrias, are associated with idiopathic gastroparesis and chronic intestinal pseudo-obstruction in children.<sup>11,12</sup> Gastric dysrhythmias also are associated with other forms of nausea and gastroparesis in adults.<sup>4,10,13–17</sup> Some newborn infants have delayed gastric emptying as reflected by large gastric residual volumes and abdominal distention.<sup>18–20</sup> In addition, 28–32 week-old infants usually require gavage feedings, whereas healthy term infants are fed by mouth. Developmental changes in gastric myoelectrical activity have not been studied in healthy infants.

We wondered if infants of different gestational age would have distinct gastric myoelectrical patterns. The goals of the present study were to record gastric myoelectrical activity in healthy premature and term infants by using non-invasive EGG recording methods and to compare postprandial gastric myoelectrical activity in neonates of varying ages to determine if differences were present. In a subset of these infants the EGG patterns before and after gavage feedings were compared.

## METHODS AND MATERIALS

### Infants

Twenty-six infants were studied in the Neonatal Intensive Care Unit, University Hospital of the Milton S.

Hershey Medical Center. Gestational ages ranged from 28 weeks to term. Gestational age at birth (Tables 1 & 2) was estimated from mother's calculated delivery date based on last menses and on physical examination of the infant at birth. All infants had EGGs performed within one week of birth.

Seven infants were excluded from the study because their EGGs contained movement artefact that prevented EGG analysis. The 19 remaining infants were divided into two groups. In the Group I infants the EGGs were recorded after feeding. These infants were divided into three subgroups by gestational age: Group A comprised four infants (term, 36–40 weeks) who were fed by mouth; Group B comprised four infants (33–36 weeks) and Group C comprised seven infants (28–32 weeks).

The latter two groups were fed by gavage. No medications were given which might affect gastric motility. In Group II infants (four infants, ages 32–34 weeks), EGG recordings were obtained before and after gavage feedings. The premature infants had no cardiac, pulmonary or neurological diseases, but because of immaturity they were observed in the Neonatal Intensive Care Unit. All infants were discharged from the hospital in good condition.

### Electrogastrography

Silver–silver chloride electrodes (miniature electrodes, SensorMedics, Anaheim, CA, USA) were used to record the EGG. Four electrodes were filled with redux paste

**Table 1** Postprandial percentage distribution of gastric myoelectrical activity (mean  $\pm$  SEM) in Group I neonates

Group I	Patient	Gestational age	Birth weight (g)	Age at time of study	Percentage of total EGG power			
					1–2.4 cpm	2.5–3.6 cpm	3.7–9.9 cpm	10–15 cpm
Group A	1	Term	4200	Day 5	40	15	32	9
	2	Term	3440	Day 7	36	20	36	8
	3	Term	3062	Day 10	80	9	9	2
	4	Term	3080	Day 5	52	18	25	5
Mean $\pm$ SEM					50 $\pm$ 10	16 $\pm$ 2	26 $\pm$ 6	6 $\pm$ 2
Group B	1	34 weeks	1721	Day 7	58	21	20	2
	2	34 weeks	1785	Day 5	59	15	25	1
	3	36 weeks	1640	Day 3	12	34	4	—
	4	34 weeks	1930	Day 9	34	13	38	16
Mean $\pm$ SEM					41 $\pm$ 6	21 $\pm$ 2	22 $\pm$ 4	6 $\pm$ 3
Group C	1	31 weeks	1729	Day 10	50	21	16	8
	2	31 weeks	1729	Day 10	39	28	29	4
	3	28 weeks	1630	Day 10	58	14	24	5
	4	31 weeks	1630	Day 10	34	32	29	5
	5	32 weeks	1572	Day 9	61	14	21	4
	6	28 weeks	883	Day 51	58	22	18	3
	7	31 weeks	1667	Day 43	77	9	13	2
Mean $\pm$ SEM					54 $\pm$ 5	20 $\pm$ 3	21 $\pm$ 2	4 $\pm$ .8

**Table 2** Pre- and postprandial percentage distribution of gastric myoelectrical activity (mean  $\pm$  SEM) in Group II neonates

Group II patient	Gestational age	Birth weight (g)	Age at time of study	Percentage of total EGG power							
				1–2.4 cpm		2.5–3.6 cpm		3.7–9.9 cpm		10–15 cpm	
				Pre*	Post*	Pre	Post	Pre	Post	Pre	Post
1	32 weeks	1150	Day 34	46	56	22	15	22	24	7	4
2	32 weeks	1600	Day 4	56	57	13	19	25	24	4	3
3	32 weeks	1274	Day 30	40	57	16	15	42	23	2	4
4	34 weeks	1930	Day 9	52	34	16	13	27	38	5	16
Mean $\pm$ SEM				49 $\pm$ 4	51 $\pm$ 6	17 $\pm$ 2	15 $\pm$ 1	29 $\pm$ 4	27 $\pm$ 4	5 $\pm$ 1	7 $\pm$ 3

and positioned on the abdominal surface over the region of the stomach.<sup>14</sup> The first electrode was located immediately below the left costal margin in the mid clavicular line. The third electrode was located between the umbilicus and the xiphoid process. The second or middle electrode was located between the first and third electrodes. The reference or fourth electrode was placed below the right costal margin in the right midclavicular line. The electrodes were connected to a SensorMedics Dynograph R511A recorder through direct nystagmus couplers (SensorMedics 9859). A low pass cutoff of 0.016 Hz and a high pass filter of 0.3 Hz were used. Sensitivities of the coupler ranged from 0.005 to 0.01 mV and the paper speed was 1 mm sec<sup>-1</sup>.

### Running spectral analysis

EKG signals were also stored on magnetic tape (Honeywell 101-B, Honeywell Instruments, Denver, CO, USA) for later computer analysis. Computer analysis of the EKG records utilized analogue to digital conversion, Fourier transformation and running spectral analysis. Details of the computer analysis have been published<sup>21</sup> and are outlined below.

The EKG signal from the magnetic tape was channeled to the A/D conversion board in the laboratory microprocessor (Sperry IT, Unysis, NY, USA) where it was digitized at 4 Hz. The digitized signal was zero-centred, a Hanning window was applied and the data were filtered to remove high frequencies ( $> 15$  cpm) and very low frequencies ( $< 1$  cpm) components that may alter the 1–15 cpm signals of interest in the raw EKG signal. The filters used were fourth order elliptical filters with a 200 milli-dB passband ripple. The low pass filter had a high frequency band edge at 2.0 Hz with an attenuation of -90 dB in the stopband. The high pass filter had a high frequency band at 0.015 Hz with required attenuation of -90 dB in the stopband.

After digital filtering the time series was Fourier transformed and the spectral density estimates were calculated. The spectral analysis provides information concerning the frequencies contained in the raw EKG signal. The spectral analysis used in these studies yielded spectra with frequency bin widths of 0.002084 Hz. The EKG spectra were calculated from a discrete period, i.e. a Fourier transformation, and graphed in a pseudo three-dimensional plot called a running spectral analysis. Running spectral analyses were constructed by performing Fourier transformations on successive segments of the digitized EKG signal, each of which was overlapped with preceding segments. In these studies, each line in the computer plots represents approximately four minutes of the digitized EKG signal, each of

which is overlapped 75% with preceding segments. Thus, each line on the plot represents 1 min of new data added to the previous 3 min of EKG data.

### Quantitative EGTG analysis

The EKG signal from one channel also was analysed quantitatively by determining the percentage of the total power present in each of four major frequency bands: 0.875–2.375 cpm (bradygastria), 2.375–3.625 cpm (normal range), 3.625–9.875 cpm (tachygastria), and 9.875–15.125 cpm (duodenal and respiratory frequencies). The percentage of total power in each of these four separate frequency bands was determined in the postprandial or preprandial periods (for example, 40% of the postprandial power is in the normal range 2.375–3.625 cpm). All calculations and running spectral analyses utilized the frequency ranges described above. For purposes of discussion and graphics these bands were simplified as follows: 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).

### Design of studies

Recordings were obtained with the infants lying supine with their heads elevated to 30°. The term infants were fed by mouth and all the premature infants had gavage feedings. The volume of the formula was 150 cc kg<sup>-1</sup> day<sup>-1</sup> divided into eight equal feedings. All infants received Enfamil Premature 24 (Mead-Johnson) formula. Individual feeding volume ranged from 30–65 cc according to weight. Calories per feeding ranged from 24 to 48 and comprised 58% carbohydrate, 26% fat and 16% protein. In Group I patients, including the term infants, the EKG recording was started 10 min after the conclusion of feeding to allow for repositioning and settling the infant after bottle or gavage feeding procedures. The duration of the postprandial recordings was 30 min. For Group II patients, a baseline EKG was recorded for 15 min before the formula was given; 10 min after the feeding concluded the EKG was recorded for 30 min. These infants had fasted approximately 3–4 h before the EKG recordings were obtained. These studies were approved by the Clinical Investigation Committee of the College of Medicine, The Pennsylvania State University. Parents of each infant signed the consent form.

Statistical methods included paired and unpaired *t*-test and analysis of variance. All values are expressed as mean  $\pm$  SE and *P* values  $< 0.05$  were considered significant.

## RESULTS

## Group I infants

Figure 1 shows a running spectral analysis and EGG trace from a term infant after feeding. Spectral analysis shows predominance of 1–2 cpm activity and several tachyarrhythmia peaks. Peaks near 3 cpm are also present. The EGG trace (insert) shows tachyarrhythmias (6–7 cpm waves) from the first 10 min of the EGG record.

Figure 2 shows mean ( $\pm$  SE) percentages of postprandial EGG power in the four major frequency bands according to gestational ages of the infants. No significant differences in EGG power in these infants of different gestational ages were found. Table 1 shows the postprandial EGG percentages in the individual subjects by different ages. Bradygastria represented 50% of the EGG power in Group A, 41% in Group B and 54% in Group C. These differences were not significant ( $P = 0.9$ ). The normal 3 cpm activity comprised 16% of the EGG power in Group A, 21% in Group B and 20% in Group C ( $P = 0.43$ ). Power in the tachygastria range was 26% in Group A, 22% in Group B and 21% in Group C ( $P = 0.34$ ). Duodenal/respiration frequencies comprised 6% of the power in Group A, 6% in Group B and 4% in Group C ( $P = 0.7$ ).

## Group II infants

Figure 3 shows a running spectral analysis and EGGs before and after gavage feeding. Clear 3 cpm peaks are

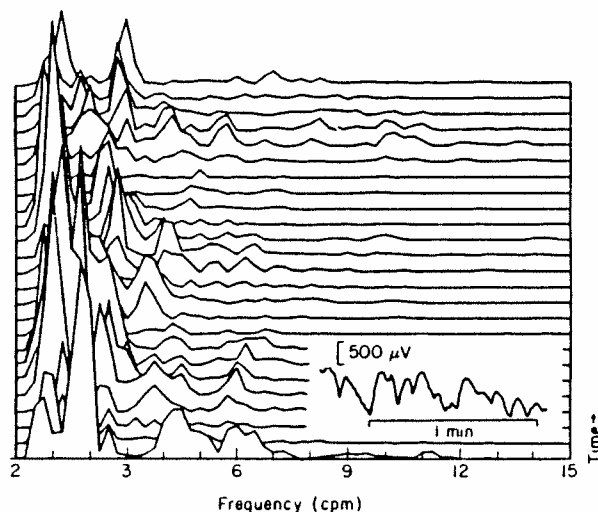


Figure 1 Running spectral analysis and EGG (insert) from full-term infant. Spectral analysis shows predominance of 1–2 cpm activity and peaks in 4 and 6 cpm (tachyarrhythmia) frequencies. Peaks near 3 cpm are also present. EGG (insert) shows 6–7 cpm tachyarrhythmias from the first 10 min of the EGG recording.

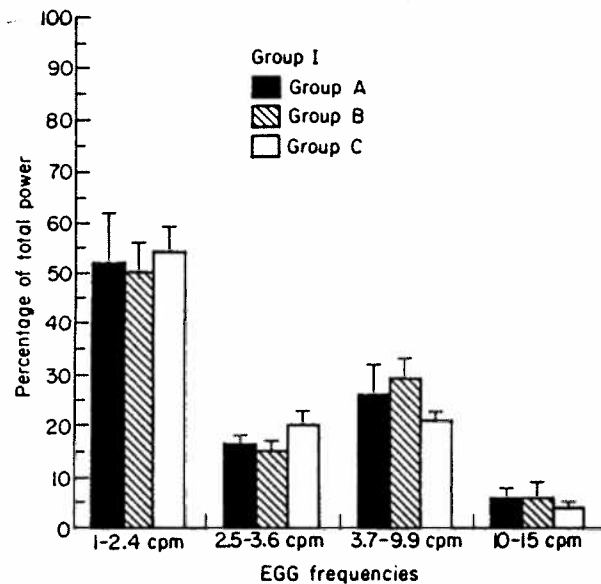


Figure 2 Percentages of postprandial EGG power (mean  $\pm$  SE) in four major frequency bands according to gestational age in infants in Groups A, B and C.

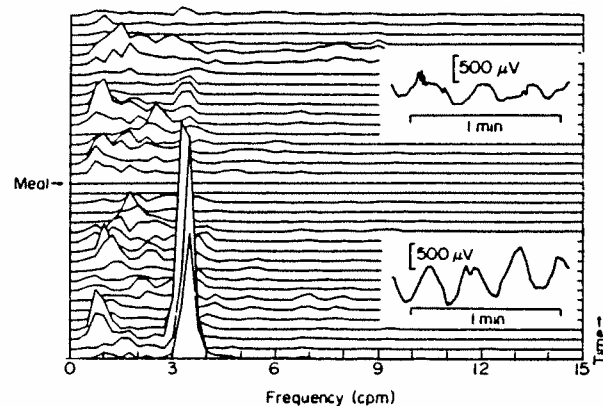


Figure 3 Running spectral analysis and EGGs (insets) from a Group II infant shows a clear 3 cpm peak before feeding; after the meal the 3 cpm peaks are present, but peaks have less power. The EGG traces (insets) also show 3 cpm waves from before and after the meal, but after Enfamil the amplitude of the 3 cpm waves decreased.

seen in the spectral analysis before feeding and the peaks are present but smaller after feeding. The EGG traces (insets) also show 3 cpm waves before and after the meal. The amplitude of the postprandial EGG waves are smaller than the preprandial waves. Figure 4 shows a running spectral analysis and EGG traces with predominance of 1 cpm peaks before and after the meal in another Group II infant. Peaks in the 4–6 cpm frequencies and a very few 3 cpm peaks are also seen in the

spectral analysis. The EGG traces (insets) show the large 1–2 cpm waves which dominated this recording.

Figure 5 shows mean ( $\pm$ SE) percentages of EGG power in the four major frequency bands comparing preprandial and postprandial EGGs from Group II infants. Table 2 shows individual and mean percentages of gastric myoelectrical activity before and after feeding. Overall, no significant differences in gastric myoelectrical activity were found after gavage feeding of the formula. Bradygastria comprised 49% of the preprandial EGG power and 51% of the postprandial EGG power ( $P = 0.75$ ). Three cpm power comprised 17% of the preprandial and 15% of the postprandial EGG power ( $P = 0.68$ ). Tachyarrhythmia comprised 29% of the preprandial and 27% of the postprandial EGG power ( $P = 0.48$ ). Because of the predominance of bradygastria and tachygastria frequencies, 3 cpm EGG waves were discernable by visual inspection approximately 15% of the time.

### DISCUSSION

EGGs were successfully recorded in 73% of our premature and term infants. EGG recording techniques are safe, may be applied repetitively, and accurately indicate the predominant slow wave frequency as recorded simultaneously by more invasive serosal or mucosal electrode recordings<sup>4-7</sup> Although movements of the body and limbs may disrupt the EGG signal, in the postprandial situation the infants were quiet and the EGGs were recorded without difficulty.

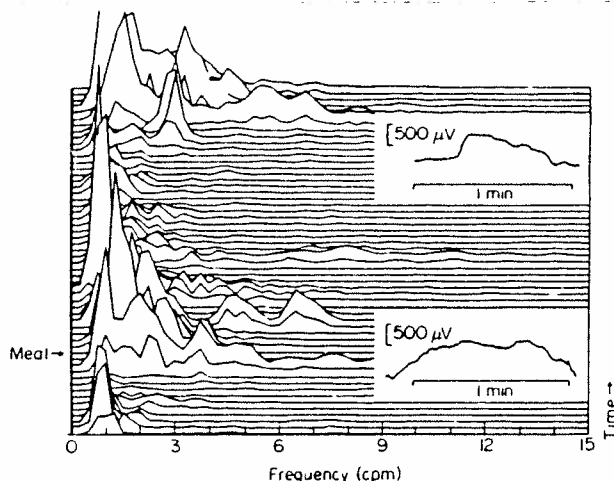


Figure 4 Running spectral analysis and EGGs (insets) from a Group II infant show predominance of 1–2 cpm peak before and after meal. Peaks in the 4–6 cpm frequencies and a few 3 cpm peaks are seen. The EGG traces (insets) show examples of large 1–2 cpm waves before and after the meal.

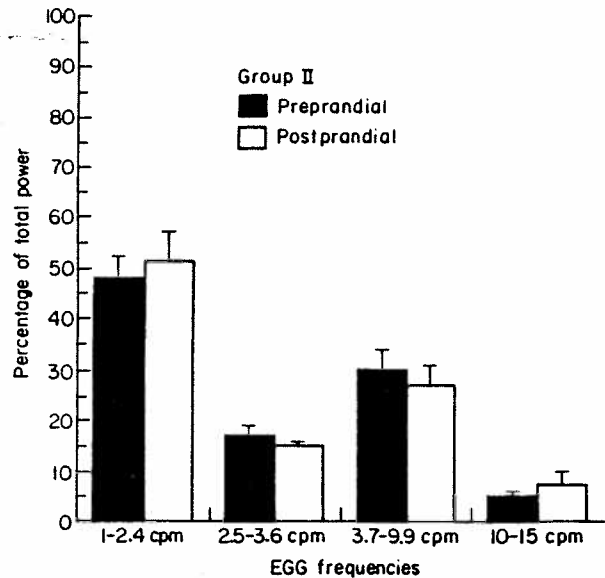


Figure 5 Percentages of EGG power (mean  $\pm$  SE) in the four major frequency bands during preprandial and postprandial periods recorded from the Group II infants.

We hypothesized that postprandial EGG patterns recorded from infants whose gestational ages spanned 28 weeks to term would differ significantly. However, the data show that 3 cpm gastric myoelectrical activity recorded after weight-adjusted formula meals are similar in these infants. These gastric myoelectrical results are consistent with gastric emptying rates which were found to be similar in premature and mature infants.<sup>22,23</sup> Manometric studies of fasting antral motility in term and preterm infants also showed no significant differences between these groups, although duodenal contractions and antroduodenal coordination were more immature in the preterm infants.<sup>24</sup> Taken together these studies indicate that gastric electrical and contractile activities do not differ across these gestational ages.

However, some infants have large post-feeding residual volumes in the stomach. These residual contents may be due to weak or poorly developed gastric musculature<sup>19,20,25</sup> in the infant. Antral muscle from newborn rabbits generates less tension than muscle strips from adult rabbits, a finding attributed to immature calcium channels and/or intracellular calcium stores.<sup>26</sup> Furthermore, and in contrast with adults, antral contractions in infants tend to occur in discrete clusters which frequently fail to migrate distally resulting in poor antroduodenal coordination.<sup>24</sup> In the present study postprandial 3 cpm gastric myoelectrical activity averaged only 19% of the total EGG power in Group I

infants. In a series of adult controls who had ingested a 200 Kcal meal, the average percentage of power in the 3 cpm range was 31% (unpublished data). Thus, the reduced 3 cpm and increased 1–2.4 cpm activity in the infants may reflect the immature response of the gastric neuromusculature to the formula meals.

Whole milk and yogurt meals increase the amplitude of the 3 cpm EGG waves in healthy adults.<sup>4,10</sup> Decreased 3 cpm EGG activity was found, however, after adults ingested a meal with 10% milk fat.<sup>28</sup> The failure to increase postprandial 3 cpm activity in the Group II neonates may reflect an appropriate response to the 26% fat content of the Enfamil gavage feedings. Although formula meals empty from the stomach much more slowly than breast milk,<sup>22</sup> breast milk and formula meals stimulate similar non-propagated, high-amplitude gastric contractions.<sup>27</sup> Whether 3 cpm EGG activity in infants would increase in response to feedings of breast milk or to other formulas remains to be studied.

The EGG recordings from these healthy term and preterm infants showed that approximately 24% of the total power was in the tachygastria range. In 31 healthy adults the percentage of total power in the tachygastria range was only 15% (unpublished observations). Tachygastrias were recorded in adults after vagotomy and were considered secondary to 'sympathetic dominance'.<sup>29</sup> Tachyarrhythmias evoked during motion sickness are associated with withdrawal of parasympathetic tone<sup>30</sup> and with increased plasma catecholamines.<sup>21</sup> Also, cold pressor tests which evoke sympathetic nervous system activity decrease the power in the normal 3 cpm range in adults.<sup>31</sup> Thus, the decreased 3 cpm power and increased tachyarrhythmia power recorded in the infants may reflect predominance of sympathetic nervous system activity at these time points in their development. Developmental changes in gastric myoelectrical activity in healthy infants have not been studied.

Finally, gastric dysrhythmias have been recorded in children with severe gastroparesis<sup>11</sup> and with chronic intestinal pseudo-obstruction.<sup>12</sup> Delayed gastric emptying also has been reported in infants with gastroesophageal reflux and failure to thrive,<sup>32</sup> but it is unknown if gastric dysrhythmias are present in these conditions. EGG recording methods may be useful in studying relationships among gastric dysrhythmias, gastric emptying and gastric residuals in healthy infants and infants with digestive disorders.

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