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Full Length Research Paper

Sonographic quantification of basal gastric antral area, gastric motility and gastric emptying time of a liquid meal in healthy subjects: A pilot study

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This study was designed to sonographically measure the basal gastric antral area, gastric motility and gastric emptying time of a standardized meal in healthy Nigerian subjects. The gastric antral area was measured pre-prandially using the antero-posterior and the longitudinal diameters in 24 healthy subjects. These measurements were repeated every 5 min after the ingestion of liquid meals for 30 min. The gastric basal antral area, gastric emptying rate (GER), gastric emptying ratio and gastric emptying time were calculated. Anthropometric variables were measured. Statistical analysis was conducted using SPSS version 16.0 with P< 0.05 as criterion of statistical significance. The mean ± standard deviation for basal gastric antral area and gastric emptying ratio were 384 ± 187 mm^2 and 1.56 ± 0.2, respectively. The stomach emptied completely between 25 and 30 min. Body surface area significantly correlated with the 15th minute gastric emptying ratio (GERA$_{15}$). A simple linear regression equation for GERA$_{15}$ was derived as 0.64BSA + 0.46. This study attempted to establish a standard model for assessing gastric emptying of a liquid meal. The normal values established in this study can be used alongside the prediction formula in the assessment of gastric motility and morbidity in patients with impaired gastric accommodation and early satiety. This small sample survey has provided a novel data which would serve as a pilot and justify the need for future research in this direction**.**

Key words: Sonographic quantification, gastric basal antral area, gastric emptying rate (GER), gastric emptying ratio, gastric emptying time

INTRODUCTION

The study of gastric motility has continued to evoke interest among medical researchers. Cross- sectional studies have shown that gastric emptying is delayed in as many as 50% of diabetic patients, causing symptoms such as postprandial early satiety, abdominal fullness, nausea, vomiting and early postprandial hypoglycemia (Vantrappen, 1994). Gastric empting is delayed in 30 to 50% of patients with functional dyspepsia (Malagelada, 1996), including liquid emptying (Kellow, 1992), solid emptying (Stanghellini et al., 1996) and non-digestible emptying (Chang et al., 1996). Upper gastrointestinal function is a critical determinant of postprandial blood glucose concentrations by influencing the absorption of ingested nutrients. Acute changes in blood glucose concentration have a major reversible effect on oesophageal, gastric, intestinal, gallbladder, and anorectal motility in both healthy subjects and diabetic patients. Interventions that reduce postprandial hyperglycemia, by modulating the rate of gastric emptying, have the potential to become mainstream therapies in the treatment of diabetes (Rayner

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et al., 2001). In 1999, Darwiche and co- authors (Darwiche et al., 1999) reported higher values of median fasting (basal) gastric antral area in diabetic patients than in healthy subjects which is most likely a correlate of antral motility. An inverse relationship between gastric motility and body surface area and between gastric motility and body weight has been reported (Lavigne et al., 1978).

Several methods have been used to assess gastric emptying in humans. Barium contrast examinations, scintigraphy, manometric technique, and intubation methods have been used to assess gastric emptying in humans (Vantrappen, 1994). Barium contrast examinations, scintigraphy, manometric techniques, and intubation methods have the disadvantages of being invasive and potentially harmful. An alternative, safe, reproducible and reliable non invasive technique would therefore be preferable. Scintigraphy is still regarded as the gold standard for clinical measurement of gastric empting (Horowitz and Akkermans, 1989). Real time ultrasonography provides another valid method for dynamic imaging of gastric peristaltic activity and its effect on gastric emptying (Darwiche et al., 2003) and has the advantage of being cheap, easily accessible and does not make use of ionizing radiation. Other non-invasive methods of assessing gastric motility include bio-impedance (Zhang-Young et al., 2011) and electrogastrogram (Parkman et al., 2003). Studies on gastric emptying rate using a standard meal in our African locality have been scarcely documented. Earlier studies using scintigraphic techniques were not done in this locality. Racial and dietary peculiarities and differences may provide additional rationale for this study among Africans of Igbo descent. This can be deduced from previous studies, which show dietary influences on gastric emptying rates in animals (Trout et al., 1977; Trout et al., 1978). This study was designed to investigate the normal values of basal gastric antral area, gastric emptying (motility) and gastric emptying time among adults of Nigerian/ African descent.

MATERIALS AND METHODS

In line with Helsinki Declaration, approval for this study was obtained from the human research ethics committee of St. Charles Borromes hospital, Onitsha, Anambra State. The procedure was explained to the participants (subjects) and each subject signed a content form before enrolling into the study. Twenty four (24) apparently healthy male subjects were recruited for this study as volunteers. Subjects had mean ages of 33.75 ± 4.12 years. The mean body mass index (BMI) was 23.12 ± 2.21 kg/m^2.

The preference for male subjects is due to the fact that majority of volunteers were males. Moreover, previous studies found no established difference between the parameters for males and females.

Potential study subjects underwent medical history, fasting blood sugar tests, occults blood tests and physical examination. Exclusion criteria included history of gastro-oesophageal reflux, peptic ulcer disease and irritable bowel syndrome. The subjects had no previous abdominal surgery (except for appendectomy). The subjects were instructed not to take drugs affecting gastrointestinal motility (Arienti et al., 1994) at least 10 days before the examination. All subjects were of Ibo (tribe) ancestry.

The fasting blood sugar was conducted using a portable blood glucose meter (companion 2 m; medisense, Waltham, MA). Subjects were advised to report to the department after an over night fast and not to drink or eat any other thing after 7.30 am and to avoid alcohol and cigarette smoking on the day of the examination. All the examinations were conducted between 9.00 and 10:00 am.

On arrival to the department, the basal (fasting) antral measurements were obtained according to established protocols (Darwiche et al., 2003). Immediately before the procedure, each subject took a tin of full cream peak brand milk [157 ml, 170 g; contents: vitamins and iodine. Carbohydrate (12.6 g), protein (8.7 g), milk fat (9.7 g), milk solids not fat 22%, milk stabilizer E 339, brand of Friesland foods, WAMCO Nig PLC] immediately before the procedures. This was immediately followed by the drinking of 30 cL of ion free water (Eva water produced by Coca Cola co, plc) (Arienti et al., 1994). 1 min was allowed for both milk and water intake. Both water and milk were stored in a large flask at room temperature.

The subjects were examined with a Siemens sonoline – SL 2 machine (Issaquah, USA), using a 3.5 MHz curve, linear probe. Gastric emptying was monitored indirectly by determining the longitudinal and antero posterior diameters of a single section of the gastric antrum using the abdominal aorta and the left lobe of the liver as internal land marks (Figure 1) to obtain the same standardized scanning level consistently according to Darwiche et al. (2003).

At this level, the scan showed the gastric antrum shape as either a circle or an ellipse, so the gastric antral cross- sectional area (GAA) was calculated with the formula for calculating the area of a circle (πr^2) with the diameter being the anteroposterior and longitudinal diameters; the area of the gastric antrum will be:

$$\pi \times d_1/2 \times d_2/2$$

Note: $d/2 = r$

The gastric emptying rate (GER) was estimated and expressed as the percent reduction in antral cross- sectional area (10) from the 5th min after ingestion of water to the 15th min after ingestion thus:

$$GER = [1 - (A\ 15\ mins / A\ 5\ mins)] \times 100$$

The subjects were studied in supine position with the ultrasound transducer applied with minimal abdominal compression.

Between examinations, the subjects were raised seated in a chair. Measurements were taken immediately before the test meal as well as at intervals of 5, 10, 15, 20, 25 and 30 min after the ingestion of the test meal. This decision for 30 min timing was based on a pilot study which showed that the test meal emptied completely from the stomach in about 25 to 30 min.

The pilot study showed maximal antral area at the 5th min and decreased, with a relative plateau at 15th to 20th min, hence the decision to use 5th and 15th min timing for calculation of GER. The subjects laid on the couch for transabdominal sonography and sat after each measurement. The methods for this procedure have been previously described and have been validated in healthy controls, correlating well with scintigraphic measurement (Darwiche et al., 1999; Darwiche et al., 2003). The gastric emptying ratio (GERA) was calculated as gastric antral area at a given observation divided by the fasting area (Holt et al., 1986). At the end of each procedure, subjects height was measured on a calibrated vertical wall and the weight measured on a weighing scale (model H 89 by Hanson Scales Coy), as well as obtaining their age. The body mass index (BMI) was measured in kg/m^2 while the body surface area (BSA) was calculated using the Du Bois and Du Bois (Arienti et al.,

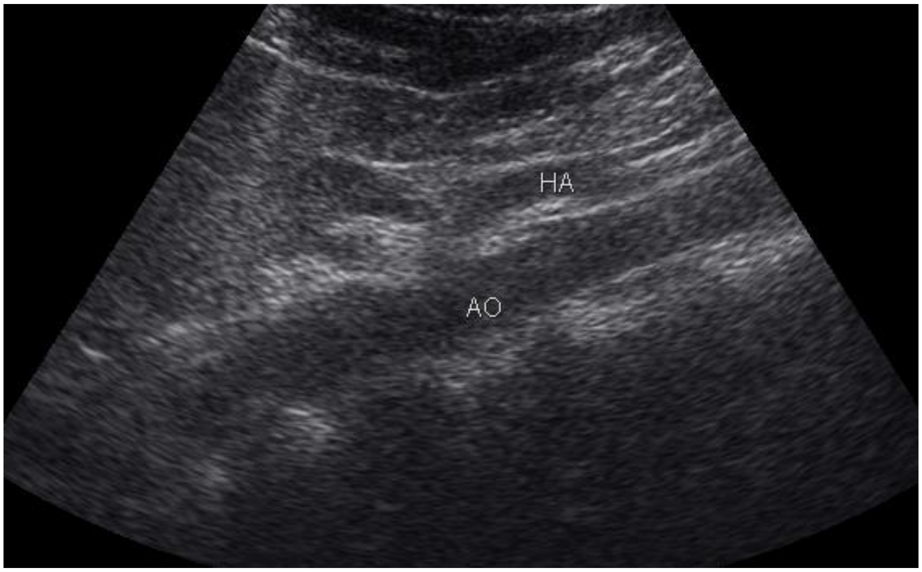

Figure 1. Ultrasonographic vertical scan through, hepatic artery (HA) and aorta (AO).

1994) equation, thus:

$$BSA= (Weight^{0.425} + Height^{0.725}) \times 0.007184$$

Statistical analysis were conducted using SPSS software version 16.0 (SPSS INC, Chicago, Illinois, USA) and graph drawn on Microsoft Excel. Both inferential (Pearson's correlation) and descriptive statistics were applied to the data namely BSA and BMI. $P<0.05$ was used as a criterion of statistical significance.

RESULTS

The mean ± 2 S.D. of fasting (basal) gastric antral area (FGAA) was 384 + 187 mm^2 with a range of 237 to 485 mm^2. The basal gastric antral area was compared with gastric antral areas (GAAs) at the 5th, 10th, 15th, 20th, 25th and 30th min using a dependent t- test. Significant differences were noted in all comparisons except for the 30 min GAA which indicates that the stomach emptied this liquid meal completely after 25 min. A significant correlation existed between FGAA and weight ($r = - 0.67$, $p = 0.00$), height ($r = - 0.50$, $p < 0.01$) and age ($r = - 0.95$, $p<0.01$). No significant relationship existed between FGAA and BMI. However, FGAA correlated with BSA as may be seen later in the results.

The gastric emptying rate (GER) was noted to be highly variable as shown by its high coefficient of variation which was 47.8%. It ranged from 23.8 to 72.5% with a mean value of 40.7%. The GERA values were also noted to be highly variable. The least variation in GERA values was obtained with the 15th minute GERA value (6.5% coefficient of variation) and hence it was adopted as the measure of gastric emptying in this study. The mean ± 2 standard deviation (SD) for $GERA_{15}$ was 1.56 ± 0.2 (range = 1.36 to 1.76) using a 2 sigma rule and a 5% false positive (type 1) error limit. The graph of GERA against time (Figure 2) gives the gastric emptying curve. Higher values of GERA indicate lower emptying rate. $GERA_{15}$ significantly correlated with age ($r= 0.61$, $r^2 = 0.224$, $P=0.02$) and BSA ($r = 0.61$, $r^2 = 0.37$, $p = 0.002$), but showed no significant correlation with height, weight and BMI. This indicates that as BSA or age increases, gastric emptying (motility) reduces as low GERA values indicates high emptying rate. A simple linear regression (predictive) equation for $GERA_{15}$ was derived as: $GERA_{15} = 0.64BSA + 0.4$. The shape of the gastric emptying curve (Figure 2) did not follow the well known 3 phase cycle: filling, lag and emptying. This could be due to the liquid nature of the test meals. Liquid meals empty faster than solid meals.

DISCUSSION

The result of the study shows a normal FGAA (mean ± 2 SD) of 384 ± 187 mm^2 and a mean ± 2 SD of 1 .56 ± 0.2 for GERA. The stomach emptied completely between the 25th and the 30th min with the standardized liquid meal used for this study. The use of mean ± 2 SD and a 5% false positive error (2 sigma rule) was adopted as these values were normally distributed. This false positive rate (type 1 error) might be lower in symptomatic subjects. This is because healthy subjects have a low pretest probability, while patients clinically referred for gut sonography have a pretest likelihood of disease. These patients have undergone extensive workup prior to referral to exclude other diseases. The Bayes theorem indicates that in healthy subjects who have a low pretest probability of diseases, a positive test result is likely to be false positive, that is, the positive predictive value is low.

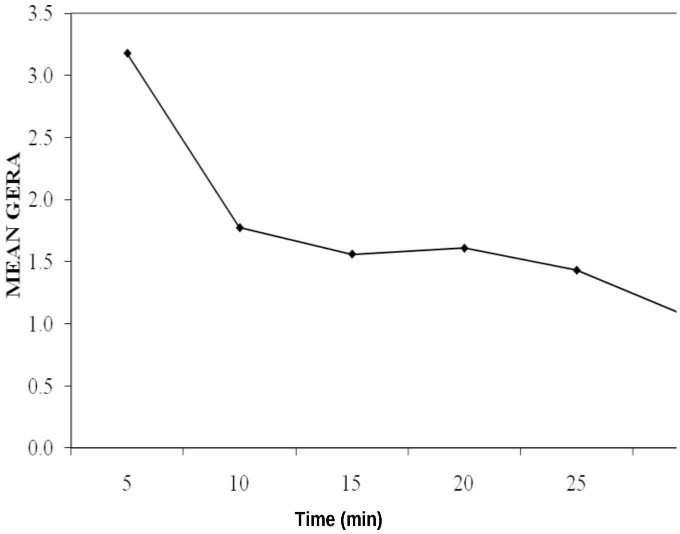

Figure 2. Gastric emptying curve

The sample size (Brown, 1995) for establishing these normal values of FGAA, GERA 15 and gastric emptying time (25 to 30 min) was small. The result can be validated on account of the normal distribution pattern of the values as proved by Lyapunov central limit theorem.

Final emptying time calculated in relation to start of meal was considered to be the time at which the antral area returned to baseline value. Reduced gastric emptying has been noted in many pathologies including diabetes (Arienti et al., 1994) and in 30 to 50% of patients with functional dyspepsia (Holt et al., 1986). A significantly higher degree of dilation of gastric antrum was found in dyspeptic patient (Xu et al., 1998) and type 1 diabetes mellitus (Malagelada, 1996). In a previous study by Darwiche et al. (1999), the basal antral area ranged from 126 to 263 mm^2 with a median value of 214 mm^2.

These Caucasian values are obviously below the range and median values established in this study among Ibos of south east Nigeria. Higher values of $GERA_{15}$ indicate reduced gastric emptying hence the positive and significant correlation between $GERA_{15}$ and age indicates that as age increases, gastric motility reduces. This fin-ding is contrary to that of a previous study by Darwiche et al. (1999) which indicated that there is no significant relationship between age and gastric emptying while still acknowledging a possible loss of autonomic function and decrease in gastric motility with increasing age (above 70 years). Darwiche et al. (1999) noted no significant difference between the gastric empting rates of males and females. Hence reports obtained from this study which recruited only male subjects can be applied widely in clinical environment. The significant positive relationship between $GERA_{15}$ and BSA indicated that subjects with higher values of BSA will have lower gastric emptying rate. This finding agrees with reports by previous researchers (Lavigne et al., 1978). Hence, variation in body size should be taken into account when measure-ments of gastric emptying of liquid meals are performed. The finding in this study which showed no significant relation-ship between $GERA_{15}$ and BMI, disagrees with a previous study (Bolondi et al., 1985) in literature. A 0.37 (37%) coefficient of determination (r^2) which translates to a 63% (100 to 37) coefficient of non determination was deduced for BSA as it affects gastric motility. The high coefficient of non determination (63%) indicates that there are other variables, cumulatively of stronger impact on gastric motility than BSA.

Scintigraphy is still the method of choice when measuring gastric emptying, although it is considerably more expensive than ultra sonography and involves exposure to ionizing radiation. In our environment, scintigraphic facilities are majorly unavailable, thus justifying a simple, cheap and available method of assessment. Until now, the sonographic technique for measuring gastric emptying has been time consuming (Vantrappen, 1994). This study has simplified the procedure and optimized time spent by using liquid meal which emptied faster than solid meal, hence saving time and resources. A variety of different test meals have been used to visualize the stomach on ultrasonography. The test meal should be appetizing, easy to ingest, and an ordinary meal since the gastric motor response could be influenced by the cephalic phase (Darwiche et al., 1999). Furthermore, it is important to choose an anechoic test meal to achieve clear images for reliable measurements of the gastric antrum (Figure 1). The volume of the meal should be limited to the quantity that can be taken with ease by both healthy and gastroparetic subjects. This is because, postprandial early satiety can occur with as little as 1.5 dL in some patients with delayed gastric emptying (Darwiche et al., 1999). Considering these points, a tin of milk, taken alongside 35 cL of ion free water provides an excellent test meal for gastric emptying assessment with ultrasonography. This method is also easy as standardized milk (peak brand) and water can easily be taken in clinical settings unlike solid meals. The use of purified and ion free water is also necessary to avoid a possible effect of ionized or carbonated water on gastric emptying (Gasbarrini et al., 1991).

Changes in meal temperature also influence gastric emptying (Sun et al., 1995). Postprandial antro-pyloro-duodenal motility in healthy subjects is retarded if the temperature is either raised or lowered from 37 to 50 and 4°C respectively (Brognaac et al., 1998). As the water and milk used as test meals in this study were stored at room temperature (21 to 23°C), a possible influence of temperature on gastric emptying was obviated and hence interpreted as insignificant in our study. Between the examinations, the subjects rested, seated in a chair since gastric emptying maybe affected by the posture and gravity as well as exercise (Brown, 1995). Each subject's usual defecation frequency was taken into consideration as a reference before evaluating presence of constipation or diarrhea (Powell, 1995). Voluntary suppression of defecation delays gastric emptying in normal subjects (Tjeerdsma et al., 1993) and this “cologastric brake” is believed to be involved in the pathogenesis of upper abdominal symptoms in constipated patients.

A fairly great range in GER (41 to 91%) was reported by Darwiche et al. (1999). Though Darwiche and co-authors (Darwiche et al., 1999) used solid meal unlike the present study which adopted the use of a liquid meal, a great congruency exists in the range established by the two studies. Whereas the study by Darwiche et al. (1999) gave a range of 41 to 91% (50%), the present study established a range of approximately 24 to 73% (49%). The lower cut off (minimum value) in this present study was obviously due to the timings (points/periods at which measurements were obtained). Normal values in this baseline study show great concordance with those of the previous study. This concordance in range indicates that liquid and solid meals could have equal diagnostic value in the assessment of GER or GERA. Furthermore, liquid meal has the advantage of easy availability, standardization and acceptability by among subjects.

Several observations indicate that feedback from gastric mucosal receptor can be influenced by prior nutrient intake (Cunningham et al., 1991) resulting in adaptive changes in gastric emptying. This could be an underlying factor that can partially explain day-to-day variability of gastric emptying within subjects.

Probably other factors exist that could affect day-to-day variability such as acute stress (Thompson, 1983). These are possible limitations to the present study as diet intake of the subjects were not moderated prior to and during the study. The stress levels in the subjects were also not considered in our study. Future studies in this area with diet moderations and predetermined stress levels should be considered. This study has provided baseline values of gastric antral area (pre-prandial), gastric emptying ratio and gastric emptying time which could guide clinicians in evaluating patients with suspected cases impaired gastric emptying, increased doudenogastric reflux and insufficient post prandial accommodation of the proximal stomach.

The mean ± 2SD for FGAA, mean ± $GERA_{15}$ the gastric emptying time, the predictive equation for $GERA_{15}$ and BSA and the predicative equation for $GERA_{15}$ and $GBCI_{35}$ (when gall bladder function is normal) should be combined in the assessment of morbidity in functional dyspepsia, diabetic gastroparesis, duodenogastric reflux and other forms of insufficient postprandial accommodation.

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