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Tolerability, gastric emptying patterns, and symptoms during the Nottingham Test Meal in 330 secondary care non-diabetic dyspeptic patients

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Abstract

Background: Scintigraphy is used for overall assessment of gastric emptying. Adherence to an international consensus protocol is recommended to ensure quality; however, this has not been widely adopted because preparation of the "egg-beater" meal is inconvenient in clinical practice. In this report, we audit the tolerability and the results of gastric emptying scintigraphy with the 400 ml Tc-99 m-labeled liquid nutrient Nottingham Test Meal (NTM).

Methods: Results from 330 consecutive adult, non-diabetic patients with dyspeptic symptoms referred for gastric scintigraphy were analyzed. Gastric half-emptying time (T50) and validated measurements of early- and late-phase gastric emptying were acquired. Postprandial sensations of fullness, bloating, heartburn, nausea, and epigastric pain were recorded using 100 mm visual analog scales (VAS) before and 0, 30, and 90 min after NTM ingestion. Results were compared with those previously obtained in healthy subjects.

Key Results: Almost all (98%) of the patients were able to consume the 400 ml NTM. Considering early- and late-phase gastric emptying, frequently observed patterns included normal early- with slow late-phase (25%) and fast early- with slow late-phase emptying (27%). Abnormal score of fullness and/ or dyspeptic symptoms were observed in 88% of dyspeptic patients. Abnormal fullness at T0 (after completed drink ingestion) was associated with slow late phase of gastric emptying, especially in women.

Conclusions: Gastric scintigraphy with the NTM is simple to perform and well tolerated. Whether the identified abnormal gastric emptying patterns could predict different treatment outcome in patients with functional dyspepsia is the subject of ongoing prospective studies.

Abbreviations: DTPA, diethylenetriaminepentaacetic acid; GI, gastrointestinal; GM, geometric mean; IQR, interquartile range; MBq, megabecquerel; PPI, proton pump inhibitor; ROI, region of interest; R[T50], late-phase emptying (rate of emptying at T50); SPECT, single photon emission computed tomography; SPSS, Statistical Product and Service Solutions; T50, 50% emptying time; VAS, visual analog scales; V0, early-phase emptying.

KEYWORDS
dyspepsia, early phase, gastric emptying, late phase, liquid meal

1 | INTRODUCTION

Dyspeptic symptoms, including postprandial fullness, early satiety, epigastric pain, or burning are common reasons for referrals to gastroenterological specialists.[1] Some individuals with these complaints will have "organic disease" (e.g., peptic ulceration); however, in most cases the cause of symptoms is a functional disorder, such as functional dyspepsia.[1,2]

The diagnosis of functional disorders of the upper GI tract is based on the presence of recurrent symptoms as recommended by Rome IV criteria.[1] The pathophysiology of these symptoms has been related to alterations in GI motility, gastric accommodation, gastric emptying (GE), and intestinal transit, as well as heightened visceral sensitivity to mechanical (e.g., distension) and chemical stimulation.[1] In most patients, these symptoms occur only after eating or are aggravated by meals.[1]

The nonspecific presentation, the absence of biological markers for definitive diagnosis on routine investigation, and the coexistence of psychosocial issues make the clinical management of these functional disorders challenging.[1,2] Scintigraphy is considered the appropriate method for assessing the overall gastric response to a meal in clinical practice. It is recommended in patients that have persistent symptoms that do not respond to first-line treatment.[2–5]

In an attempt to standardize diagnostic procedures consensus recommendations for gastric scintigraphy were produced by the American Neurogastroenterology and Motility Society and The Society of Nuclear Medicine in 2008.[6] This produced a standardized "egg-beater" meal protocol for the scintigraphic measurement of solid GE and provided normal values.[6] However, there are many disparities in the adoption of this meal since the size of eggs and composition and size of bread varies and there are differences with frying or cooking with microwave ovens. Furthermore, preparing food is problematic in many nuclear medicine departments due to food hygiene requirements.[7] As a result, this meal has not been widely used outside specialist centers, and recent surveys have reported that in the UK and the USA there is a very wide variation in radiopharmaceuticals, meals, and the methodology used for GE scintigraphy.[8,9]

Moreover, in the standard egg-beater protocol, the analysis of gastric function is focused on a single summary measurement such as GE half time (T50) or percentage retention of the meal after 2 and 4 h.[5] However, the physiological response of the stomach to a meal is complex and observations by non-invasive imaging after ingestion of liquid meals have shown that GE has distinct, early, and late phases.[10,11]

In Nottingham, we have recently published a procedure for scintigraphy gastric emptying based on the combination of a radiolabeled nutrient liquid test, the "Nottingham Test Meal", with the assessment of symptoms.[7,12] The methodology has been subjected to extensive technical validation and reference limits ("normal values") for T50, early-, and late-phase gastric emptying have been established in healthy volunteers.[12] The primary aim of the clinical audit was to evaluate the tolerability and results of the application of the Nottingham Test Meal in consecutive patients with functional dyspeptic symptoms referred for the study of gastric emptying in the Nuclear Medicine clinic at Nottingham University Hospitals (NUH).

2 | MATERIALS AND METHODS

This is a retrospective audit (Nottingham University Hospital registration number as Clinical Audit 18-365c) of GE scintigraphy investigations performed in NUH since the introduction of the Nottingham Test Meal in April 2014 to April 2019. As recommended in international guidelines,[1,2] it is standard practice in our hospital to rule out organic disease prior to referral for physiological studies. The results of dyspeptic patients referred for investigation of GE were analyzed. Results from individuals with diabetes mellitus and other disorders known to impact on GE were not included.

2.1 | Gastric emptying scintigraphy with Nottingham test meal

2.1.1 | Patient pre-test preparation

Between 1 and 3 weeks prior to the clinic appointment a letter was sent to each patient providing details of the test drink they were required to ingest. The patient received a telephone call from the clinic staff to confirm their attendance, to enquire about food allergies and current medications. A list of the medications with effects on gastric function is shown in Table S1, together with the appropriate time of withdrawal prior to the procedure. If the referring physician had not authorized withdrawal of medication in the original study request, they were contacted to provide authorization and, if appropriate, the patient was advised to stop taking medication. Patients were requested to fast for 8 h prior to the test.

2.1.2 | Patient arrival

The procedure lasted 2–2.5 h in total. On arrival the patient identity was checked, and they were asked whether they had complied with the requirement to fast prior to the test. Female patients in the age range 12–55 years were asked to confirm that they were not pregnant. Radioactive fiducial markers were prepared by adding

TABLE 1 Comparison of motor function interquartile ranges

Subject group	*n*	V0 IQ reference range (%)	T50 IQ reference range (min)	R[T50] IQ Reference range (% / min)
Healthy volunteers	61	85–92	38–56	0.75–1.10
Patients	330	80–88	43–69	0.56–0.91

approximately 0.5 MBq of either Tc-99 m or In-111 to filter paper to match the radiolabel used in the liquid test meal. These were then dried and sealed in radioactive tape and attached to the right anterior and posterior costal margins of the patients prior to imaging, to provide an anatomical reference during image analysis.

2.1.3 | Preparation of radiolabeled test meal

The Nottingham Test Meal consists of 200 ml Vanilla Fortisip (Nutricia Ltd.) mixed with 200 ml water and either 10 MBq Tc-99 m-DTPA or 5 MBq In-111-DTPA (for those patients who were also referred for colonic transit imaging). The effective dose from each of the radiolabeled drinks is 0.2 mSv and 1.6 mSv respectively. The nutritional content of the meal is 11.6 g fat, 36.8 g carbohydrate, 11.8 g protein, and 300 kcal. The 400 ml radiolabeled drink (0.75 kcaL/ml) was supplied to the patient in five disposable plastic cups, each containing 80 ml.

2.1.4 | Meal intake

Once in the imaging room the patient completed the first section of the sensation report form (T-10) and then drank one cup (80 ml) every 2 min until the full 400 ml had been ingested (total time 10 min). If a patient was unable to ingest the complete drink, and/or vomited, this was recorded and reported to the clinician.

2.1.5 | Sensation

The patients were asked to report their sensations of satiation, fullness, bloating, heartburn, nausea, and epigastric pain on visual analog scales (VAS) before the test drink was administered (T-10), directly after ingestion of the 400 ml liquid NTM (T0), after 30 minutes of imaging (T30) and after 90 minutes of imaging (T90). In our previous publication, none of the healthy subjects reported a score of more than "moderate" sensation of fullness (VAS >60/100) at T0 and none reported more than "mild" dyspeptic symptoms (VAS >30/100 for bloating, heartburn, nausea, and epigastric pain).[12]

2.1.6 | Patient imaging

Anterior and posterior imaging was carried out using a Philips Brightview gamma camera (Philips Healthcare) fitted with a low-energy general purpose collimator using an energy window centered on 140 keV ±10%. For whole gut transit studies, the camera was fitted with a medium energy general purpose collimator and energy windows of 171 keV ±10% and 245 keV ±10% were used. The patient was positioned standing erect in front of the camera and anterior and posterior images were recorded in a 256 × 256 matrix, each of 30 s duration. The nominal times for image acquisition were at 0, 5, 10, 15, 20, 30, 40, 50, 60, 75, and 90 min after ingestion. By this time, if it appeared that the stomach emptying was less than 50%, images were also acquired at 105 and 120 min after ingestion.

2.1.7 | Image processing and data analysis

The images were stored and analyzed using a dedicated Hermes nuclear medicine imaging workstation (Hermes Medical Solutions Ltd.). Geometric mean (GM) images were created from the serial anterior and posterior views. On the initial GM image, a region of interest (ROI) was drawn around the stomach and abdomen/small bowel, around the stomach alone, and a background region. In subsequent GM images, ROIs were drawn around the stomach alone and a background ROI. Calculations of GM count rates in the stomach and small bowel ROIs were corrected for background counts and for radioactive decay. The corrected count rates from the stomach and small bowel in the first image provided the 100% value for the study and allow a calculation of how much of the drink remained in the stomach in the initial image (the Y-axis intercept). This parameter, V0, is used as a measure of the early-phase gastric emptying. A plot of the percentage retention in the stomach against time was created using the Hermes Medical gastric emptying software application and an appropriate fit made to the data points using a fitting equation developed in Nottingham.[7] The gastric half-emptying time, T50, was obtained from the plot by finding the time point when the percent retained in the stomach was half V0. The rate of gastric emptying at T50, R[T50], was used as a measure of late-phase gastric emptying (the gradient of the emptying curve at T50). Reference ranges were taken from an initial analysis of gastric sensory and motor function in 61 healthy volunteers at our institution[16] (see Table 1) and expressed as interquartile range. Patients were allocated to categories comprising the combined result of their early and late-phase emptying (e.g., fast/fast and normal/slow). Reference ranges for gastric scintigraphy using the NTM have been then updated and calculated as 95% reference interval in a subsequent publication[12]; however, the results of this audit applied the interquartile range.

2.2 | Statistical analysis

Statistical analyses were carried out using SPSS version 24. Distributions of V0, T50, and R[T50] are presented as box and whisker plots. Pearson chi-squared tests were used to investigate associations between gender and gastric motility, and between gender and sensation, in the patient population. Linear-by-linear chi-squared tests were used to investigate associations between gastric dysmotility and sensation.

3 | RESULTS

A total of 521 patients were referred for GE scintigraphy studies between April 2014 and 2019. Of these patients, 191 (36.6%) were excluded from the analysis: 11 pediatric patients, 77 patients with diabetes, and 91 adults referred for a whole gut transit study (different protocol). As a result, 342 adults, dyspeptic patients without organic disease completed gastric scintigraphy with the 400 ml liquid NTM. Of this number, only 2% (eight patients) were unable to ingest the complete meal or vomited during the test. In a further four patients, the data were inadequate for analysis. Thus, results from the remaining 330 patients are presented (75% female; median 45 years [range 18.0–90.1]; see Table 2 for further detail). The study was completed within 90 minutes in most patients. Only ~10% of this cohort required additional imaging up to 120 min.

3.1 | Sensation during gastric emptying study

The fullness score after the drink at T0 was higher for patients by comparison with healthy volunteers; 65% reported an abnormal fullness score at T0 (VAS >60/100) (Figure 1). The maximum score for any of dyspeptic symptoms was also higher for patients by comparison with healthy volunteers; 84% of patients reported an abnormal score (>30/100) for at least one dyspeptic symptom: bloating, heartburn, nausea, and epigastric pain (Figure 1). The combination of abnormal fullness score (>60/100) or at least one abnormal score (>30/100) in any of the other symptoms was found in 88% of patients.

3.2 | Gastric emptying

The average T50 was higher in patients compared with healthy volunteers (Figure 2); 44% had slow ($n = 146$), 40% ($n = 131$) normal T50 and 16% ($n = 53$) fast T50.

TABLE 2 Patient demographics

Gender	*n*	Median age	Interquartile range	Range
Female	246	46.4	29.8–57.2	18.0–90.1
Male	84	40.7	30.2–61.2	18.3–83.9
Total	330	44.8	30.1–57.9	18.0–90.1

Considering early-phase GE, the patient distribution of V0 was shifted down compared with healthy volunteers indicating a higher prevalence of fast early-phase GE in patients (Figure 2); 48% of patients had fast early GE, 43% normal early GE, and 9% slow early GE. Overall, fast early-phase GE was ~5 times more common than slow early-phase GE (48% vs. 9%).

Considering the late phase of GE, the patient distribution of R[T50] was shifted down compared to healthy volunteers indicating a higher prevalence of slow late emptying in patients (Figure 2); 56% had slow late GE, 34% normal late GE and 10% of patients exhibited fast late GE. Overall, slow late-phase emptying was also ~5 times more common than fast late-phase GE (56% vs. 10%).

The interquartile ranges of the V0, T50, and R[T50] of the patients ($n = 330$) as compared to the previously published data in healthy subjects ($n = 61$) are shown in Table 1. Figure 3 shows the percentages of the different GE patterns independent of T50. The most frequent patterns were normal early-phase with slow late-phase GE (25%) and the combination of fast early-phase and slow late-phase GE (27%).

Of the group of patients with normal T50 (Figure S1), only 33.6% exhibited entirely normal function in both the early and late-phase GE, whereas 66.4% exhibited abnormal function in the early-phase only (fast/normal 24.4%, slow/normal 7.6%), late-phase only (normal/slow 10.7%, normal/fast 0.8%) or in both phases (fast/slow 22.1%, fast/fast 0.8%).

Of the group of patients with slow T50 (Figure S1), almost all patients exhibited abnormal function in the late phase (normal/slow 46.6%, fast/slow 37.0%, slow/slow 9.6%). The single patient with fast/fast emptying but a slow T50 had a very unusual pattern of emptying: rapid early emptying (V0 72%), then had virtually no emptying for 35 mins, and then very rapid emptying again (R[T50] 1.28% per min).

Of the group with fast T50 (Figure S1), patients exhibited abnormal function more often in the early-phase (fast/normal 28.3%) or in both phases (fast/fast 37.7%, fast/slow 9.4%, slow/fast 1.9%) than in the late phase only (normal/fast 18.9%).

A small number of cases with slow or fast T50 had normal early and late phases of gastric emptying when these were assessed separately. In such cases, both phases were toward the slower or faster end of normal respectively, resulting in a borderline abnormal T50.

3.3 | Association between gastric motor and sensory response with gender

There was a statistically significant difference in the prevalence of male and female patients in three categories (Figure S2). Women were more likely to fall in the normal/slow category and men were more likely to fall in the normal/fast and fast/fast categories. There was also a significant difference between male and female patients both in the prevalence of abnormal fullness (42% and 72% respectively, $p < 0.001$) and of an abnormal score in at least one dyspeptic symptom (70% and 89% respectively, $p < 0.001$). Overall, the combination of abnormal fullness score or at least one abnormal score in any of the other symptoms was present in 76% of male and 92% of female patients.

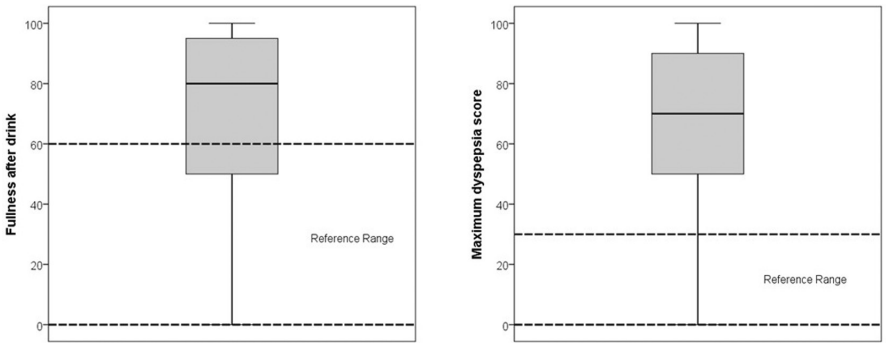

FIGURE 1 Box and whisker plot of fullness sensation score after the drink (T0) and of maximum dyspepsia score in patients ($n = 330$) as compared to reference range obtained in 61 healthy subjects.[12] The heavy black line in the box indicates the median. The upper and lower hinges indicate the 75th and 25th centile, respectively, the interquartile range (IQR). Whiskers extend to the highest or lowest data point within 1.5*IQR. Circles indicate outliers and asterisks indicate extreme values (>3*IQR)

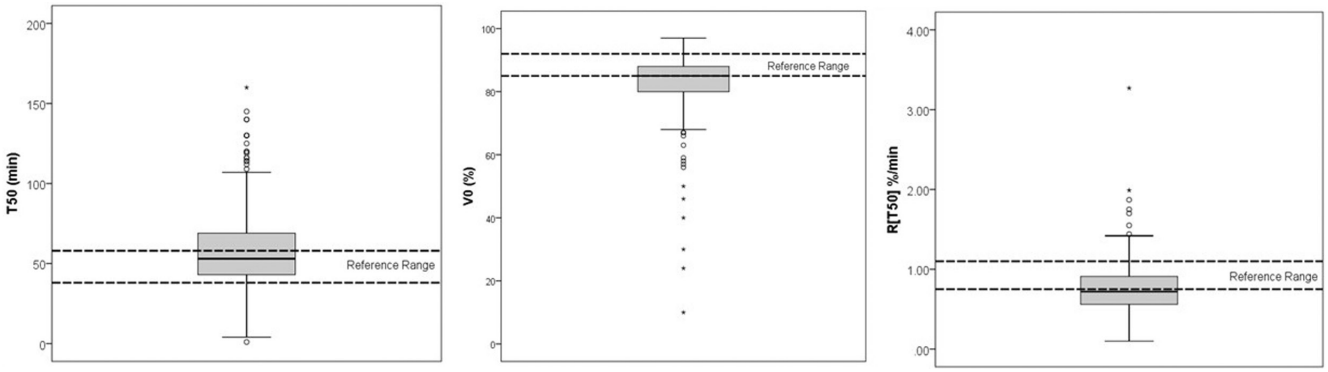

FIGURE 2 Box and whisker plot showing the distribution of T50, V0, and R[T50] in patients ($n = 330$) as compared to reference range obtained in 61 healthy subjects.[12] Outlier, * Extreme Outlier. The heavy black line in the box indicates the median. The upper and lower hinges indicate the 75th and 25th centile, respectively, the interquartile range (IQR). Whiskers extend to the highest or lowest data point within 1.5*IQR. Circles indicate outliers and asterisks indicate extreme values (>3*IQR)

3.4 | Association between sensations and gastric motor response to NTM

No significant association was found between early-phase GE and sensation of abnormal fullness (Figure S3). However, a significant linear association was found between late-phase motor dysfunction and sensation of abnormal fullness ($p < 0.001$) (Figure S4). Specifically, those patients reporting abnormal sensations of fullness exhibited a higher frequency of slow late-phase GE and a lower incidence of fast late-phase GE. No significant associations were found between early-phase or late-phase emptying and abnormal sensations in any other symptoms (Figure S5 and S6).

4 | DISCUSSION

This audit reports the tolerability and results of the assessment of gastric motor and sensory function by scintigraphy with the Nottingham Test Meal (NTM) in a large group of adults, non-diabetic patients referred for investigation of dyspeptic symptoms.

Subjects were referred for a gastric emptying study from gastroenterology and surgical clinics of Nottingham University Hospitals. The Rome IV questionnaire was not obtained; however, the symptoms, age distribution, and excess of female patients that completed the investigation is similar to cohorts with functional dyspepsia reported in previous studies, the majority of whom have the postprandial distress syndrome subtype.[1]

On a practical level, there were no barriers to implementation of the NTM protocol in the nuclear medicine department. The liquid nutrient drink on which the NTM is based is widely available and meal preparation is simple. Further, the wheat (gluten) and lactose-free liquid nutrient meal is suitable for patients with dietary restrictions based on medical concerns, religion, and lifestyle choices. The protocol was feasible, well tolerated by patients, and relatively quick to perform in routine practice. Specifically, the 400 ml NTM could be ingested by 98% patients, the protocol was often completed within 90 min (maximum 120 min if T50 prolonged), and the images were successfully acquired and analyzed in almost all cases.

The face validity of the NTM drink test was high and many patients with functional dyspepsia welcomed the chance to report their symptoms under direct observation during meal ingestion and gastric emptying. Overall, the 400 ml NTM reproduced typical dyspepsia symptoms in 88% of patients studied. Compared with thresholds established in healthy volunteers,[12] 65% of patients reported

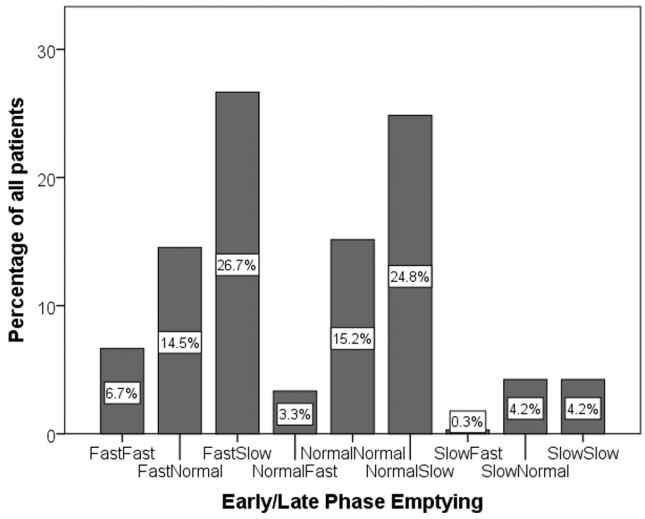

FIGURE 3 Percentage of each combined category of early and late-phase emptying in all patients ($n = 330$)

an abnormal sensation of fullness immediately after meal ingestion ("more than moderate" (VAS >60/100)) and 84% experienced dyspeptic symptoms that were never observed in healthy volunteers ("more than mild") bloating, heartburn, nausea, and epigastric pain (VAS >30/100). Female patients reported abnormal fullness and dyspeptic symptoms significantly more frequently than males.

When the results of liquid gastric emptying are represented as half-emptying time (T50), 40% of the patients present as normal, 44% slow (i.e., "gastroparesis"), and 16% fast gastric emptying (i.e., "dumping"). These percentages are similar to previous studies in this patient group using the "egg-beater" and other validated test meals.[5] However, on evaluation of the gastric response to the meal a variety of patterns were observed in our dyspeptic patients.

Fast early phase followed by either normal or slow late-phase GE was observed in approximately 40% of all patients. This included almost a half of those with normal and more than a third of those with slow GE, as identified by T50 half-emptying time. Physiological studies suggest that this fast early-phase can be caused by impaired "receptive accommodation",[13–16] a common finding in patients with functional dyspepsia.[1] If the stomach does not relax in response to a volume load, then this can lead to rapid, early-phase GE (i.e., low V0). However, this is often followed by slow late-phase gastric emptying (i.e., low R[T50]) which could be due to the neuro-hormonal response triggered by the early, rapid delivery of nutrients into the small bowel or abnormal modulation of gastric emptying from a hypersensitive/hyper-reactive duodenum.[17] Recent studies have directed attention to the role of the duodenum in functional dyspepsia and have suggested that patients with functional dyspepsia, in particular those with postprandial distress syndrome (who are defined by presence of postprandial fullness and early satiety), have an increased presence of eosinophils in the duodenum.[18,19] It will be interesting to check whether patients with the fast/slow pattern associates with this infiltration of inflammatory cells in the duodenum.

Many patients with functional dyspepsia referred for investigation had a prolonged T50 with slow late-phase gastric emptying (~56% of all patients), with a female predominance in this sub-group. Detailed analysis revealed that "fast/slow, normal/slow, or slow/slow patterns of gastric emptying were all represented in this group. All of these patients could be classified as "gastroparesis"; however, it is clear that this is a heterogeneous group. In review articles, "gastroparesis" is often considered to be caused by a reduction of tonic and phasic muscle activity in the stomach. This loss of motility would be expected to produce a slow/slow pattern of gastric emptying; however, this was present only in <5% of patients. As reported by previous studies, slow late-phase gastric emptying was associated with abnormal and prolonged sense of fullness after the meal[20–22]; however, this symptom was not specific to patients with this finding. Whether the slow late-phase of gastric emptying identifies a specific alteration to the distal gastric (antral-pyloric) motor response in a sub-group of patients with upper GI functional disorder, characterized by postprandial fullness, remains to be investigated. It would be interesting to know if this group respond to prokinetic medications better than those with other findings on gastric scintigraphy.

Less than 20% patients had rapid gastric emptying defined by a short T50. In line with previous studies, a male predominance was present in patients with gastric dumping.[13,23,24] Detailed analysis showed that this group was divided relatively equally into patients with fast/fast, fast/normal, and normal/fast patterns. Each of these groups may have a different pathophysiologic mechanism underlying "gastric dumping." Another pattern that was occasionally observed was "late-onset rapid gastric emptying" that was recently described in ~5% of patients that completed the "egg-beaters" test meal.[25] This pattern could be caused by failure to suppress, or early onset, of powerful migrating motor complex (MMC) type III contractions after the meal, an event that has been observed in patients with functional dyspepsia.[26] This finding could explain symptoms in patients with otherwise normal results on gastric scintigraphy; however, similar to previous reports,[20,27] there were no symptoms that differentiated patients with fast gastric emptying from other groups.

The present study has limitations. This is a retrospective audit of patients referred mainly from gastroenterologists without specific expertise in functional disorders and the symptoms were not prospectively characterized according to validated questionnaires. Thus, the dyspeptic patients have not been classified according to the most recent sub-classification of functional upper GI disorders. However, as noted above, the clinical characteristics of patients were similar to those with functional dyspepsia referred to tertiary care centers in previous studies. Moreover, all patients referred to gastric emptying studies had appropriate investigations to exclude organic diseases as per NICE recommendations (https://cks.nice.org.uk/topics/dyspepsia-proven-functional/). Indeed, for the same reasons, this population may be more representative of those referred for investigation in non-specialized centers. Another limitation is that we have no information about how the results affected clinical management or outcome. This is the subject of ongoing, prospective studies.

On a conceptual and methodological level, there is an ongoing debate whether liquid or solid meals should be preferred for assessment in gastric function. The protocols recommended by the

US consensus report and also the Mayo Clinic assess emptying of the labeled solid component of a mixed meal from the stomach.[5,6] Some experts believe that solid emptying is more sensitive than liquid emptying for detection of gastroparesis; although the opposite is true for the detection of gastric dumping.[13] Recent studies have investigated the use of a liquid meal with similar caloric amount of NTM as an alternative to the egg-beater meal for gastric scintigraphy. The proportion of patients with abnormal results was similar, and it was concluded that a liquid meal could serve as a convenient alternative to the conventional solid meal.[14,28] Other reports show that abnormal liquid emptying is present in about one-third of patients with a normal solid emptying, suggesting that liquid GE may be more sensitive to abnormal gastric function.[20,21,29,30] Gastric emptying of caloric liquids occurs almost linearly under the pressure gradient generated from the gastric fundus and the coordinated motility of the antrum, the pylorus, and the duodenum.[31] Gastric emptying of a solid meal requires antral breaking down until the particle size is reduced to less than 2 mm and then the food empties linearly from the stomach.[31] It is possible that gastric emptying of solids is less sensitive to disturbances of early gastric emptying while that of liquids still capture delayed late gastric emptying due to antropyloric dysfunction or other issues. When administered in combination with solid meal, the liquid component empties independently through the so-called "Magenstrasse".[32,33] The findings of the current study indicate that disturbances of early gastric emptying are common in patients with functional dyspepsia and that liquid test meals seem more sensitive than solid test meals in detecting this disorder of gastric function; however, assessment of intra-gastric distribution of gastric contents may provide another way to detect this form of gastric dysfunction.[34] Conversely, it may be that solid meals are more sensitive to other forms of gastric dysfunction in which the passage of solids is hindered more than the passage of liquids (e.g., structural outlet obstruction) and also to severe forms of gastroparesis in which contractile function has been lost. One finding that is seen for both solid or liquid test meals (including the NTM) is that the association between symptoms and abnormal gastric emptying is weak.

This study shows that the Nottingham Test Meal is a simple and practical test meal that could be easily adopted for clinical use. The liquid meal is quick and easy to prepare in the clinic, is well tolerated by patients and by combining with the analysis of early and late emptying and patient symptomatic evaluation could provide additional valuable diagnostic information. Future prospective studies will aim to confirm whether this can effectively guide patient management.

AUTHOR CONTRIBUTIONS

Peter Hay contributed to planning and conducting the study; collecting and interpreting data; drafting the manuscript; approving the final submitted manuscript. Maura Corsetti contributed to planning the study; interpreting data; drafting the manuscript; approving the final submitted manuscript. Emily Tucker contributed to planning the study; approving the final submitted manuscript. Mark Fox contributed to planning the study; drafting the manuscript; approving the final submitted manuscript. Alan Perkins contributed to planning and conducting the study; interpreting data; drafting the manuscript; approving the final submitted manuscript.

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CONFLICT OF INTEREST

None.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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