BMJ Open

# Longitudinal outcome monitoring in patients with chronic gastroduodenal symptoms investigated using the Gastric Alimetry system: study protocol

Chris Varghese ,[1] Nicky Dachs,[2] Gabriel Schamberg,[1,2] Kiel McCool,[2] Mikaela Law,[1,2] William Xu,[1] Stefan Calder,[2] Daphne Foong,[3] Vincent Ho,[3] Charlotte Daker,[4] Christopher N Andrews,[5] Armen A Gharibans,[1,2] Gregory O'Grady[1,2]

**To cite:** Varghese C, Dachs N, Schamberg G, *et al*. Longitudinal outcome monitoring in patients with chronic gastroduodenal symptoms investigated using the Gastric Alimetry system: study protocol. *BMJ Open* 2023;**13**:e074462. doi:10.1136/bmjopen-2023-074462

► Prepublication history for this paper is available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2023-074462).

Received 10 April 2023
Accepted 07 November 2023



[1]Department of Surgery, University of Auckland, Auckland, New Zealand
[2]Alimetry Ltd, Auckland, New Zealand
[3]Western Sydney University, Penrith South, New South Wales, Australia
[4]Department of Gastroenterology, North Shore Hospital, Auckland, New Zealand
[5]Department of Gastroenterology, University of Calgary, Calgary, Alberta, Canada

**Correspondence to**
Dr Chris Varghese;
cvar706@aucklanduni.ac.nz

## ABSTRACT

**Introduction** The Gastric Alimetry platform offers a multimodal assessment of gastric function through body surface gastric mapping (BSGM) and concurrent symptom-tracking via a validated App. We aim to perform a longitudinal cohort study to examine the impact of Gastric Alimetry, and changes in clinical management on patient symptoms, quality of life and psychological health.

**Methods and analysis** This is a prospective multicentre longitudinal observational cohort study of participants with chronic gastroduodenal symptoms. Consecutive participants undergoing Gastric Alimetry will be invited to participate. Quality of life will be assessed via EuroQol-5D and the Patient Assessment of Upper Gastrointestinal Disorders-Quality of Life score. Gastrointestinal symptoms will be assessed via the Patient Assessment of Upper Gastrointestinal Symptom Severity index, and the Gastroparesis Cardinal Symptom Index. Psychometrics will be assessed, including anxiety via the General Anxiety Disorder-7, perceived stress using the Perceived Stress Scale 4, and depression via the Patient Health Questionnaire 9. Clinical parameters including diagnoses, investigations and treatments (medication and procedures) will also be captured. Assessments will be made the week after the BSGM test, at 30 days, 90 days, 180 days and 360 days thereafter. The primary outcome is feasibility of longitudinal follow-up of a cohort that have undergone Gastric Alimetry testing; from which patients' continuum of care can be characterised. Secondary outcomes include changes in patient-reported symptoms, quality of life and psychometrics (anxiety, stress and depression). Inferential causal analyses will be performed at the within patient level to explore causal associations between treatment changes and clinical outcomes. The impact of Gastric Alimetry on clinical management will also be captured.

**Ethics and dissemination** The protocol has been approved in Aotearoa New Zealand by the Auckland Health Research Ethics Committee. Results will be submitted for conference presentation and peer-reviewed publication.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This is a prospective, multicentre study, which will capture a wide range of management outcomes over a 1-year period in patients with chronic gastroduodenal disorders.
⇒ Integration of a patient-facing MyCap system aims to maximise successful follow-up and data accuracy.
⇒ This study is an observational study without prespecified randomisation.
⇒ This is a protocol for a longitudinal follow-up platform and therefore dedicated studies will need to define prespecified hypotheses, and power calculations accordingly.

## INTRODUCTION

Body surface gastric mapping (BSGM) using the Gastric Alimetry System is a breakthrough diagnostic modality for the assessment of gastric function.[1–6] BSGM has found utility in defining underlying aetiologies within a diverse array of cohorts including patients with chronic gastroduodenal symptoms, type 1 diabetes, delayed gastric emptying, and postgastric surgery.[2 3 7 8] Validated metrics of gastric function and simultaneous symptom capture is also emerging as a tool to enable clinicians to make decisions based on objective and actionable biomarkers,[9–11] rather than the trial-and-error therapies pervasive in these poorly understood gastroduodenal disorders. In a recent series of patients assumed to have intestinal failure secondary to gut dysmotility, BSGM informed care in 100% of patients, offered an updated diagnosis in 60% and facilitated a cost-saving wean from parenteral nutrition in two-thirds of patients.[11]

Longitudinal data capture is required to assess the impact that Gastric Alimtery has on long-term care and clinical outcomes. A scalable data platform to rapidly accrue longitudinal data is required to track changes in symptoms, quality of life and psychological

outcomes over time. These data will form the basis of future assessments of treatment decisions at scale. Once such a data platform is established, over time a large repository of longitudinal data will be available to compare the impacts of investigations, medication changes, and procedural interventions on patient outcomes. Such causal inferences can lay the foundation for future randomised trials, with potential to open new avenues for data-driven research within current care paradigms in gastroduodenal health.

This manuscript outlines a study protocol for the establishment of a longitudinal data capture system in this context, including: (1) data and outcomes being collected, time course of collection, and rationale; (2) a detailed overview of data linkage strategies that enable multimodal and ongoing data capture; and (3) data management and infrastructure to facilitate ongoing analytics.

## METHODS

This protocol is described in accordance to the relevant items of the Standard Protocol items: Recommendations for Interventional Trials checklist.[12] The protocol has been approved in Aotearoa New Zealand by the Auckland Health Research Ethics Committee (AHREC).

### Study objectives

At the time of the initial Gastric Alimetry test, comprehensive gastrointestinal disorder, quality of life and psychometrics assessments will be completed. This study aims to follow up all consenting participants undergoing Gastric Alimetry testing over a period of 1 year to assess changes in self-reported symptoms, quality of life, anxiety, stress and depression measures, and changes in clinical care (including investigations initiated after Gastric Alimetry testing, and treatments started or changed). We aim to generate a database of patients to assess within-subject changes with regards to relevant clinical management initiated on the basis of Gastric Alimetry in patients with chronic gastroduodenal symptoms.

Specific clinical questions sought to be answered through this process include:

1. Define the natural history of chronic gastroduodenal disorders (including Rome-IV defined functional dyspepsia, chronic nausea and vomiting syndrome, and gastroparesis defined based on gastric emptying testing) by quantifying changes in symptoms, quality of life and health psychometrics over a 1-year period.
2. Define the natural history with regards to symptoms, quality of life and health psychometrics stratified by Gastric Alimetry phenotypes (as described by O'Grady *et al*),[13] initially with comparison to the current diagnostic paradigm (ie, via Rome-IV and gastric emptying testing).
3. Quantify healthcare utilisation over a 1-year period among patients with chronic gastroduodenal disorders (namely, investigations, changes in pharmacological management, referrals to other services, and procedural interventions including endoscopic and surgical).
4. Comparison of longitudinal outcomes among patients with gastroparesis treated with gastric peroral endoscopic myotomy (G-POEM) as a standalone cohort, and in comparison to matched patients with gastroparesis that do not undergo G-POEM.

Moreover, this protocol describes the development of a database platform which will enable investigation of further hypotheses relevant to chronic gastroduodenal disorders.

### Study design

This is a prospective, multicentre, longitudinal, observational cohort study that will occur via the BSGM Consortium (an international network of collaborators performing Gastric Alimetry tests). Auckland, New Zealand will be the lead site; other recruiting centres at this stage include Calgary, Canada; and Western Sydney, Australia. Further sites are eligible to enrol at any time.

### Study setting

Any site performing Gastric Alimetry tests is eligible to participate. Each site uses a standardised Gastric Alimetry App through which patient-level expressions of interest will be obtained. Thereafter, interested participants will be registered onto the Research Electronic Data Capture (REDCap) system, where informed digital consent for participation will be sought, after which standardised study questionnaires will be administered. Participants will receive surveys via MyCap, a participant-facing app linked with REDCap.

### Study procedures

#### Test procedures

The Gastric Alimetry test has been described in detail elsewhere.[1 2 5 13] However, in brief: the system comprises a stretchable array (8×8 electrodes+2 reference electrodes; 2 cm spacing; Ag/AgCl contacts with hydrogel coating), a portable data logger to enable signal capture and a symptom-logging iPad App which is time-synchronised to the data logger by Bluetooth (figure 1A). The standardised test involving 30 min of fasting baseline, consumption of a standard test meal, and 4.5-hour postprandial recording (figure 1B). During the test participants sit reclined limiting movements. Subjects fast for a minimum of 8 hours and avoid medications affecting motility 48 hours prior to testing. The array is placed over the epigastrium (capturing the stomach in>99% of subjects). The electrophysiological signal is further optimised with removal of excess hair and skin-prep (NuPrep, Weaver, Colorado) to reduce impedance, and an automated artefact rejection pipeline (figure 1C).[14] During the test, the symptoms of epigastric pain, epigastric fullness, early satiety, epigastric burning, heartburn and nausea, are assessed on 0–10 numeric rating scales at 15-min intervals, and vomiting,

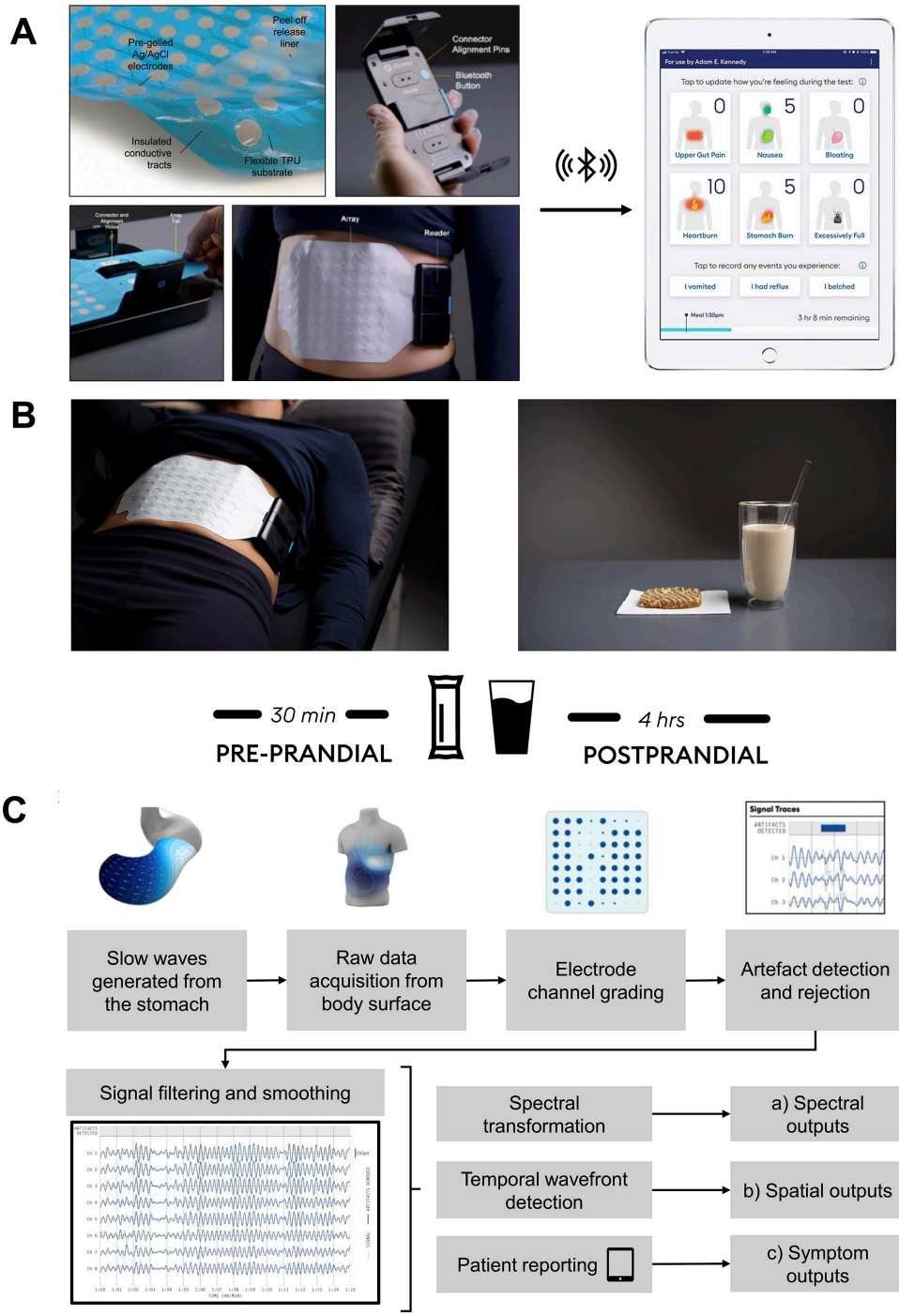


**Figure 1** Overview of the Gastric Alimetry system and analysis pipeline. (A) Gastric Alimetry system and App. (B) Gastric Alimetry test procedure. (C) Signal processing pipeline and end outputs.

reflux and belching are captured as discrete events, using a validated pictograms-based approach (figure 1A).[6]

### Test outputs

Gastric Alimetry test outputs are comprehensively overviewed in a recent technical review.[13] In brief, three main outputs are generated (figure 1C):

a. Spectral outputs: these include the body mass index-adjusted amplitude, Principle Gastric Frequency, fed:fasted amplitude ratio, and the Gastric Alimetry Rhythm Index. Further details toward the development, validation and interpretation can be found in the following references.[5 13 15]

b. Spatial outputs: these are currently under development, but preliminary work toward direction of propagation when coordinated gastric activity exists is possible.[1 7]

c. Symptom outputs: novel measures of symptom severity in relation to the gastric amplitude curve have recently been developed. In particular the correlation, or lack thereof between symptom severity curves, and gastric

amplitude curves offer insights toward their aetiological basis.[16 17]

### Sample size and power calculation

The broader aim of this study is to develop a database of participants with chronic gastroduodenal symptoms that follow a range of real-world clinical management pathways. Formal evaluations of causal links between clinical diagnoses, investigations and management to changes in patient-reported symptoms, quality of life and psychometrics will ultimately require randomised controlled trials. However, data accrued from this longitudinal follow-up will inform power calculations for subsequent prespecified research questions. Thereafter, further data collection is expected, with large-scale expansion to power further analytics. Sample size calculations will be performed prior to each specific analysis, to ensure adequate power toward specific hypothesis being investigated. Mixed models will be employed and sample size calculations will account for cluster sampling.

### Data collection and management

All data will be collected prospectively and stored online in an encrypted format through a secure REDCap web server hosted by the University of Auckland.[18] Initial and all subsequent surveys will be administered using MyCap, a participant-facing mobile application integrated with REDCap.[19]

## ELIGIBILITY CRITERIA

All adults aged 18 years and above consenting to a Gastric Alimetry test are eligible for inclusion. The primary cohort of interest are those meeting Rome-IV criteria for chronic gastroduodenal disorders (including functional dyspepsia, chronic nausea and vomiting syndromes, cannabinoid hyperemesis syndrome and cyclical vomiting syndrome) and/or gastroparesis, defined by retention of>10% of intraluminal content after 4 hours during a gastric emptying test. Given this protocol may be translatable across domains, specific cohorts including post-surgical patients (eg, after gastric surgery) may also be recruited to enable longitudinal follow-up and symptom monitoring. Exclusion criteria include age <18 years, history of skin allergies or a history of extreme sensitivity to cosmetics or lotions, and vulnerable groups such as prisoners, individuals known to have cognitive impairment or institutionalised individuals. No exclusions will be made based on the clinical management of patients as, for each intervention, a series of 'exposed' and 'controlled' participants will be required to assess causal relationships. Healthy volunteers that consent can also be included to form a comparator arm for analyses.

### Participant informed consent process

All individuals undergoing a Gastric Alimetry test will be invited to participate in the study via the Gastric Alimetry App. Those who express interest will be loaded onto the REDCap system and will receive a REDCap-initiated digital consent form. Those who provide informed consent via an e-signature will be loaded into MyCap, enrolled into the study, and issued a unique study identification number within REDCap that is linked to their MyCap and Gastric Alimetry records.

## OUTCOMES

Quality of life will be assessed via EuroQol-5D (EQ-5D) and the Patient Assessment of Upper Gastrointestinal Disorders-Quality of Life (PAGI-QOL) score. Gastrointestinal symptoms will be assessed via the Patient Assessment of Upper Gastrointestinal Symptom Severity index, and the Gastroparesis Cardinal Symptom Index (GCSI). Anxiety will be assessed through the General Anxiety Disorder-7 (GAD-7),[20] perceived stress using the Perceived Stress Scale 4 (PSS-4),[21] and depression via the Patient Health Questionnaire 9 (PHQ-9).[20] Clinical parameters including diagnoses (Gastric Alimetry phenotype, Rome-IV diagnosis),[13] investigations (gastric emptying, transit studies, manometry, endoscopy) and treatments (medications and procedures), as well as changes in the above measures, and date of change will also be captured. A comprehensive overview of the data being collected at each time point is overviewed in figure 2.

### Gastrointestinal symptoms

At each of the post-test time points (index test, 30 days, 90 days, 180 days and 365 days), participants will be asked to complete a daily symptom diary for 7 days. Each evening, they will rate the severity of seven gastrointestinal symptoms over the past 24 hours. Each symptom is rated using a 0–10 Likert scale, with anchors at 0 'none,' indicating no symptom experience, and 10 indicating the 'most severe imaginable' extent of a symptom experience. The rating is determined by the worst symptom experience in the past 24 hours for each symptom. The symptoms are stomach burn, stomach pain, nausea, bloating, postprandial fullness, early satiation, belching and number of vomiting events. An additional rating distress arising from excessive belching is included, using a 0–10 Likert scale, with anchors at 0 'none,' and 10 'worst imaginable bother.' Figure 3 shows an example of the MyCap interface for symptom ratings.

This symptom questionnaire is adapted from the basis the Functional Dyspepsia Symptom Diary and follows the recommended 24-hour recall period to minimise recall bias and account for day-to-day variation.[22] The questionnaire follows similar principles to the The American Neurogastroenterology and Motility Society GCSI Daily Diary, which recommends using 1-week blocks for baseline and follow-up symptom scoring and completion of the diary at the same time each evening, prior to bedtime, to capture the patient's experience after all of the day's meals.[23]

### Psychometric and Quality of Life Questionnaires

During the index Gastric Alimetry test, participants will complete the EQ-5D and PAGI-QOL questionnaire, and

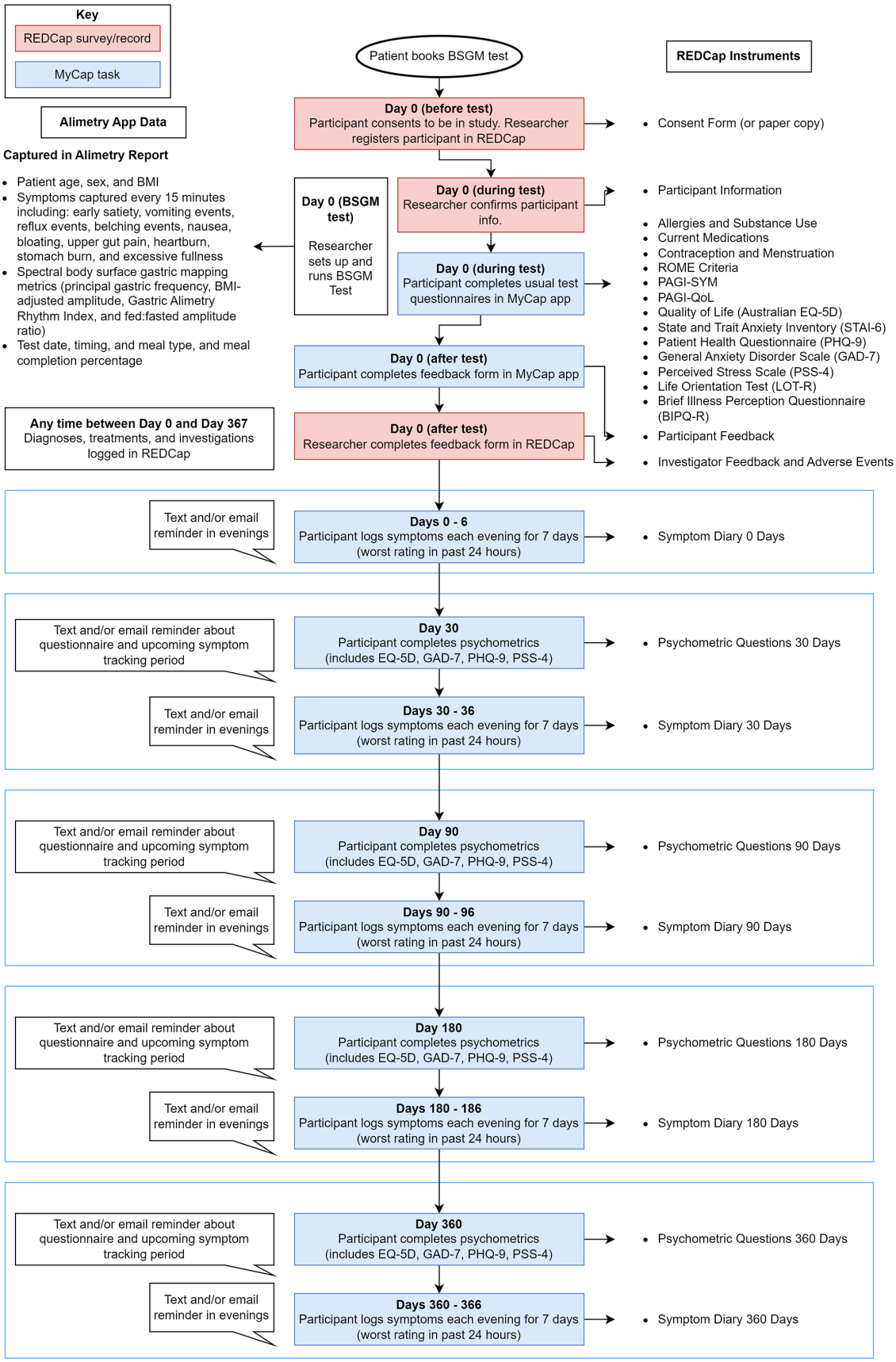


**Figure 2** Comprehensive overview of data being collected at baseline and each subsequent follow-up. BMI, body mass index; BSGM, body surface gastric mapping; PAGI-QOL, Patient Assessment of Upper Gastrointestinal Disorders-Quality of Life; PAGI-SYM, Patient Assessment of Upper Gastrointestinal Symptom Severity; REDCap, Research Electronic Data Capture.

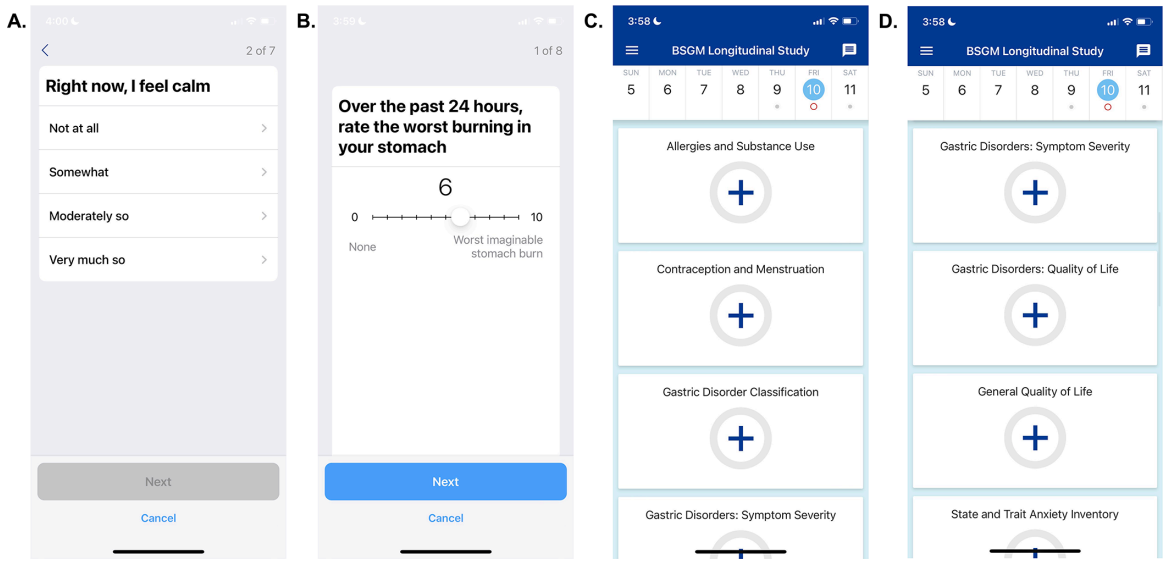


**Figure 3** MyCap mobile application interface for daily symptom ratings. 0–10 Likert scale for stomach burn shown as an example.

at each follow-up time point, the EQ-5D will be completed. The EQ-5D, a questionnaire on health-related quality of life, was chosen for its wide acceptance, brevity and advantages for cost-utility analyses.[24 25] To quantitatively assess self-reported anxiety, stress, and depression symptomatology, widely validated and accepted psychometric tools will be administered, including the GAD-7,[20] PSS-4[21] and PHQ-9, respectively.[20] These will be administered once per time point, unlike the repeating symptom diaries.

### Clinical management/interventions

The following investigations, clinical management decisions and treatments will be captured to facilitate observational analyses of causal hypotheses.

- Gastric Alimetry results (spectral metrics,[5] spatial metrics, patient phenotype—defined elsewhere).[13]
- Investigations
  - Imaging: X-ray, ultrasound, CT scans, MRI, vascular imaging, BSGM, scintigraphy, antro-duodenal manometry.
  - Specialised blood tests: coeliac serology, *H. pylori* stool PCR, alpha-1-antitrypsin, ceruloplasmin, liver function tests, IgA, lactose tolerance test, thyroid function tests.
  - Endoscopy: esophagogastroduodenoscopy±biopsy.
- Referrals
  - Specialist or referral to another service (eg, psychiatry, surgery, endocrinology, etc).
- Treatments
  - Non-pharmacological: lifestyle modifications (eg, initiating an exercise programme), change in diet, counselling (in-person, virtual, app-based), psychotherapy (eg, cognitive–behavioural therapy, acceptance commitment therapy, mindfulness, hypnosis, relaxation therapy; in-person, virtual, app-based).
  - Medications: neuromodulator, prokinetic, antiemetic, anxiolytic, proton pump inhibitor (PPI), H2-receptor antagonist, other.
  - Endoscopic procedures: G-POEM, pyloric botox.
  - Surgery: antireflux surgery, gastrointestinal resection, small intestinal diversion.

## FOLLOW-UP

Immediately following the Gastric Alimetry test, participants will complete a daily symptom diary each evening for 7 days. At 30 days post test, participants will complete a combined psychometric and quality of life questionnaire, followed by 7 days of daily symptom diaries. This combination of psychometrics, quality of life and symptom questionnaires will repeat at 90 days, 180 days and 360 days (figure 4). The MyCap system will remain open for patients to enter changes in diagnosis or management in consultation with their clinical care team (including the research team at the discretion of the recruiting sites).

To encourage engagement, participants will be able to use their own mobile phones to access MyCap's patient-centred interface. To facilitate successful follow-up and data completeness participants will be sent scheduled text message or email reminders to complete questionnaires using Twilio, a third-party REDCap add-on. Twilio is a messaging platform that allows SMS messages to be programmatically scheduled and sent worldwide.[26] Questionnaire timing will be scheduled based on individual patient timelines, customised using the date of initial Gastric Alimetry test.

## STATISTICAL ANALYSIS

This protocol describes the development of a standardised and scalable data platform for tracking changes in symptoms, quality of life and psychological

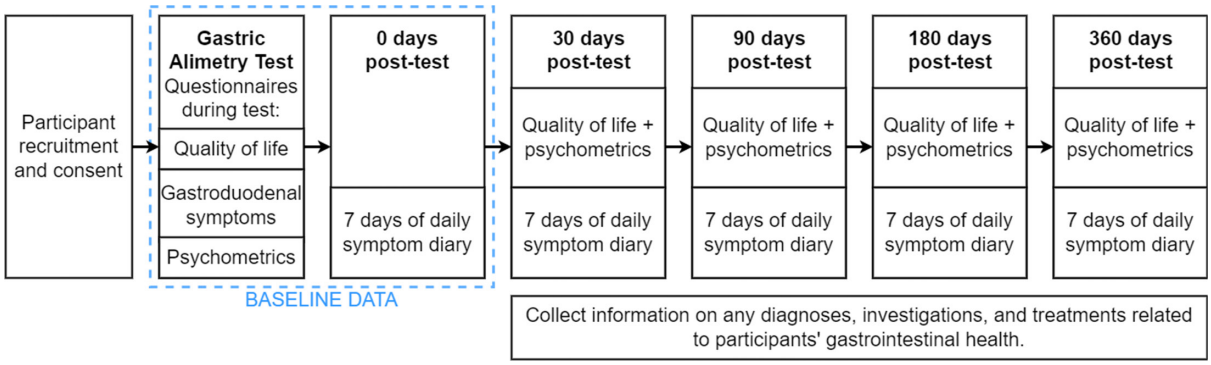


**Figure 4** Overview of data collection and follow-up.

outcomes over time. Exploratory and pilot analyses will be performed within acknowledged limitations of a non-randomised study design. Longitudinal assessments allow for the evaluation of the efficacy and utility of diagnostic assessments and treatments offered to patients. Monitoring within-subject changes has been shown to offer advantages in establishing causal relationships.[27] As data accrue over time, a large repository of longitudinal data will be available to compare the impacts of investigations, medication changes and procedural interventions on patient-reported outcomes. Such causal inferences can lay the foundation for future randomised trials, informing power calculations, and identifying research priorities.

Preliminary analyses will include descriptive comparative statistics, such as univariate between-group comparisons and also before–after testing (using individuals as their own control), where preintervention and postintervention paired statistics will be employed. Normally distributed data will be reported as mean (SD), and non-normally distributed data as median (IQR). Statistical comparisons will be performed using independent samples t-tests, analysis of variance (ANOVA), paired-samples t tests, or repeated measures ANOVA for normally distributed variables; Mann-Whitney U, Kruskal-Wallis tests, Wilcoxon signed-rank test, or Friedman's test for non-normally distributed continuous or ordinal variables; and $\chi 2$ tests or McNemar's test for categorical variables. Regression models will be used as appropriate for relevant outcomes including multivariable linear regression with adjustment for relevant demographic confounders. If sample sizes allow, mixed effects hierarchical models will be employed to account for natural clustering structures, for example, at the centre level. Interclass correlations will be assessed via the interclass correlation coefficient. Model selection will be guided by parsimony, clinically plausible relationships between predictors and outcomes, and minimisation of the Akaike information criterion.[28] Missing data will be interrogated to assess if they are missing at random, and multiple imputation by chained equations or pairwise deletion will be employed as appropriate.

### Study delivery and quality assurance

This longitudinal cohort study will be centrally managed by a steering group consisting of expert statisticians, data managers and clinician scientists with oversight and guidance from key opinion leaders in the field of gastroenterology and gastrointestinal surgery. Regular data auditing will be performed with communication between the steering group and individual sites. Training resources are available to ensure standardised use of the Gastric Alimetry system for all device users.[29]

### Patient and public involvement

Several rounds of patient interviews were completed during the development stage of the Gastric Alimetry platform,[6 30] which informed the design and delivery of the app. Patient feedback will be actively sought at the time of each test and will contribute to ongoing development and data applications. Interviews with a range of patients, and gastric disorder patient advocacy group leaders have informed relevant study designs and key clinical questions; most relevant to this protocol being the impact on individual patient's continuum of care to reduce investigations, offer more actionable diagnoses, relationships to psychological health variables and to direct more efficacious therapies.

## ETHICS AND DISSEMINATION

Ethics approvals have been sought according to the requirements of each participating centre. At the lead site, the protocol has been approved in AHREC (ref AH1130). Results will be submitted for conference presentations and peer-reviewed publication.

## DISCUSSION

Gastric Alimetry is emerging as a significant new clinical test of gastric function combining gastric electrophysiology and concurrent symptom tracking.[1 6] This diagnostic tool offers a new paradigm for the investigation and management of patients with chronic gastroduodenal disorders,[2] but longitudinal data on outcomes are now required to define its impact on clinical workflows, diagnoses and outcomes. Here, we present a longitudinal

cohort study protocol to assess the impact of Gastric Alimetry on patients' continuum of care; this will offer robust data for assessing relationships between clinical diagnoses, and management decisions on patients' symptoms, psychological symptomatology and quality of life. These observational data will guide hypothesis testing, facilitating prioritisation and powering of future trials to advance the field.

This study also aims to generate evidence in support of putative mechanisms for poorly understood gastroduodenal symptoms in line with Tack et al's plausibility criteria for disease mechanisms in functional gastrointestinal disorders.[31] The longitudinal study design in particular is essential to generate evidence for the fifth putative criterion within this framework: 'Therapeutic response'/'Congruent natural history', which states that treatment aimed at correcting an underlying disorder improves symptoms, or, changes in symptom severity parallel changes in the severity of the disturbance.[31] This evaluations are also in-line with innovation frameworks which recommend large-scale longitudinal surveillance of outcomes when novel medical innovations such as the Gastric Alimetry system are employed in routine clinical use.[32 33]

We developed an integrated digital platform for robust data-linkage, accurate and secure storage of longitudinal, repeated measures data. REDCap serves as the secure data storage infrastructure with the mobile MyCap app being the patient-facing platform for collecting patient-reported outcomes. Data completeness is encouraged through the use of Twilio, enabling automated, scheduled reminders. Scheduled tasks personalised to each individual patients' timelines facilitate scalability to a large volume of patients.[34] These data are then linked to gastric electrophysiological signal data after refined artefact rejection and algorithmic postprocessing,[14] and the Gastric Alimetry App data which are stored on a HIPAA-compliant cloud platform.[35]

## STRENGTHS AND LIMITATIONS

This study uses validated, widely used instruments to measure self-reported gastrointestinal symptoms, quality of life and psychological factors. Validated questionnaires were chosen for their external validity, brevity so as to be pragmatic with data collection, and reduced burden on patients. The use of self-administered questionnaires and diaries have also been shown to demonstrate increased reliability compared with interviews.[36] Despite these design elements, important limitations remain. We anticipate it will take time for sufficiently large cohorts to accrue prior to adequately powered inferential analyses can be performed. Also, despite efforts to rationalise questionnaire volumes, it is important to capture the multifaceted contributors and sequelae of gastroduodenal symptoms on patients' lives. Given several different scales are being used, there is a risk of non-response.[34] To mitigate against incomplete data we employ timed reminders, use a patient-friendly app, and have rationalised the questionnaires to minimise questions being asked and maximise relevant outcome data collection. A 1-year follow-up was determined to be the most pragmatic for the majority of hypotheses aimed to be addressed using this protocol; however, in specific cases, longer follow-up than 1 year may be desirable, and as such the system described here remains flexible to such alterations. This protocol does not prespecify all elements of future analyses planned through the described methodology.

In conclusion, we present a study protocol for a longitudinal cohort study of patients being investigated with BSGM using the Gastric Alimetry system. These data will offer insight into the clinical utility and impact of Gastric Alimetry, a new test to gastroenterology practice, and offer data to explore hypotheses in relation to impact on clinical decisions, treatment responses and natural histories of disease.

**Contributors** CV, ND, AAG and GOG drafted the manuscript. GS, KM, SC, AAG and GOG supervised the protocol design and final manuscript. All authors contributed to the final drafting and review of the manuscript. All authors made substantial contributions to the conception or design of the work; drafting of the work and provided final approval of the version to be published and agreement to be accountable for all aspects of the work.

**Funding** This work was supported by the New Zealand Health Research Council, the National Institutes of Health (R56 DK126935).

**Competing interests** AG and GO hold grants and intellectual property in the field of GI electrophysiology and are members of University of Auckland spin-out companies: The Insides Company (GO), and Alimetry (ND, AG, GS, ML, SC, KM CD, AG, CNA, and GO). All other authors have no relevant conflicts to declare.

**Patient and public involvement** Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

**Patient consent for publication** Not applicable.

**Provenance and peer review** Not commissioned; externally peer reviewed.



**ORCID iD**

Chris Varghese http://orcid.org/0000-0001-7369-8639

## REFERENCES

1 Gharibans AA, Hayes TCL, Carson DA, *et al*. A novel Scalable electrode array and system for non-Invasively assessing gastric function using flexible electronics. *Neurogastroenterol Motil* 2023;35:e14418.
2 Gharibans AA, Calder S, Varghese C, *et al*. Gastric dysfunction in patients with chronic nausea and vomiting syndromes defined by a noninvasive gastric mapping device. *Sci Transl Med* 2022;14:eabq3544.
3 Xu W, Gharibans AA, Calder S, *et al*. Defining and Phenotyping gastric abnormalities in long-term type 1 diabetes using body surface gastric mapping. *Gastroenterology* 2022.
4 Carson DA, O'Grady G, Du P, *et al*. Body surface mapping of the stomach: new directions for clinically evaluating gastric electrical activity. *Neurogastroenterol Motil* 2021;33:e14048.
5 Varghese C, Schamberg G, Calder S, *et al*. Normative values for body surface gastric mapping evaluations of gastric motility using gastric Alimetry: spectral analysis. *Am J Gastroenterol* 2023;118:1047–57.

6 Sebaratnam G, Karulkar N, Calder S, *et al*. Standardized system and App for continuous patient symptom logging in Gastroduodenal disorders: design, implementation, and validation. *Neurogastroenterol Motil* 2022;34:e14331.
7 Gharibans AA, Coleman TP, Mousa H, *et al*. Spatial patterns from high-resolution Electrogastrography correlate with severity of symptoms in patients with functional dyspepsia and Gastroparesis. *Clin Gastroenterol Hepatol* 2019;17:2668–77.
8 Wang T-H, Tokhi A, Gharibans A, *et al*. Non-invasive Thoracoabdominal mapping of post-Oesophagectomy Conduit function. *Surgery* 2023.
9 Camilleri M, Chedid V. Actionable biomarkers: the key to resolving disorders of gastrointestinal function. *Gut* 2020;69:1730–7.
10 Daker C, Varghese C, Xu W, *et al*. P267 the impact of gastric Alimetry on the management pathway of chronic Gastroduodenal disorders. BSG LIVE'23, 19–22 June, ACC Liverpool; June 2023
11 Varghese C, Xu W, Daker C, *et al*. Clinical utility of gastric Alimetry® in the management of intestinal failure patients with possible underlying gut motility disorders. 2023. Available: https://papers.ssrn.com/abstract=4360266 [Accessed 20 Mar 2023].
12 Chan A-W, Tetzlaff JM, Altman DG, *et al*. SPIRIT 2013 statement: defining standard protocol items for clinical trials. *Ann Intern Med* 2013;158:200–7.
13 O'Grady G, Varghese C, Schamberg G, *et al*. Principles and clinical methods of body surface gastric mapping: technical review. *Neurogastroenterol Motil* 2023;35:e14556.
14 Calder S, Schamberg G, Varghese C, *et al*. An automated Artifact detection and rejection system for body surface gastric mapping. *Neurogastroenterol Motil* 2022;34:e14421.
15 Schamberg G, Varghese C, Calder S, *et al*. Revised spectral Metrics for body surface measurements of gastric electrophysiology. *Neurogastroenterol Motil* 2023;35:e14491.
16 Varghese C, Schamberg G, Uren E, *et al*. Standardized mechanism-based Digital profiling of Gastroduodenal symptoms. *SSRN* 2023.
17 Schamberg G, Varghese C, Uren E, *et al*. Physiology-guided quantitative symptom analysis for Gastroduodenal disorders. *Gastroenterology* 2023.
18 Harris PA, Taylor R, Minor BL, *et al*. The Redcap consortium: building an international community of software platform partners. *J Biomed Inform* 2019;95:103208.
19 Harris PA, Swafford J, Serdoz ES, *et al*. Mycap: a flexible and Configurable platform for mobilizing the participant voice. *JAMIA Open* 2022;5:ooac047.
20 Tamburrino MB, Lynch DJ, Nagel RW, *et al*. Primary care evaluation of mental disorders (PRIME-MD) screening for minor depressive disorder in primary care. *Prim Care Companion J Clin Psychiatry* 2009;11:339–43.
21 Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. *J Health Soc Behav* 1983;24:385–96.
22 FDA. Clinical outcome assessments (COA) qualification program DDTCOA #000013: functional dyspepsia symptom diary (FDSD). *FDA* 2017. Available: https://www.fda.gov/media/125024/download [Accessed 19 Mar 2023].
23 Parkman H, Camilleri M, Revicki D. User Manuel for the ANMS GCSI-DD. *ANMS* 2019. Available: https://www.fda.gov/media/125038/download
24 Stolk E, Ludwig K, Rand K, *et al*. Overview, update, and lessons learned from the International EQ-5D-5L valuation work: version 2 of the EQ-5D-5L valuation protocol. *Value Health* 2019;22:23–30.
25 Wisløff T, Hagen G, Hamidi V, *et al*. Estimating QALY gains in applied studies: a review of cost-utility analyses published in 2010. *Pharmacoeconomics* 2014;32:367–75.
26 Communication Apis for SMS, voice, video & authentication. Available: https://www.twilio.com/ [Accessed 21 Mar 2023].
27 Rahmadi R, Groot P, van Rijn MH, *et al*. Causality on longitudinal data: stable specification search in constrained structural equation modeling. *Stat Methods Med Res* 2018;27:3814–34.
28 Harrison E, Riinu P. R for health data science. CRC Press, 2020.
29 Alimetry Education. Alimetry. Available: https://alimetry.talentlms.com/index [Accessed 21 Mar 2023].
30 Sebaratnam G, Law M, Broadbent E, *et al*. It's A helluva journey": a qualitative study of patient and clinician experiences of nausea and vomiting syndromes and functional dyspepsia. *Gastroenterology* 2022.
31 Tack J, Corsetti M, Camilleri M, *et al*. Plausibility criteria for putative pathophysiological mechanisms in functional gastrointestinal disorders: a consensus of experts. *Gut* 2018;67:1425–33.
32 McCulloch P, Altman DG, Campbell WB, *et al*. No surgical innovation without evaluation: the IDEAL recommendations. *Lancet* 2009;374:1105–12.
33 Težak Ž, Kondratovich MV, Mansfield E. US FDA and personalized medicine: in vitro diagnostic regulatory perspective. *Per Med* 2010;7:517–30.
34 Edwards P. Questionnaires in clinical trials: guidelines for optimal design and administration. *Trials* 2010;11:2.
35 Galendata - #1 cloud platform for medical devices. Galen Data; 2021. Available: https://galendata.com/ [Accessed 23 Mar 2023].
36 Garber MC, Nau DP, Erickson SR, *et al*. The Concordance of self-report with other measures of medication adherence: a summary of the literature. *Med Care* 2004;42:649–52.