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Review

Measurement of gastric emptying in the critically ill

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SUMMARY

Background & aims: Enteral nutrition is important in critically ill patients and is usually administered via a nasogastric tube. As gastric emptying is frequently delayed, and this compromises the delivery of nutrient, it is important that the emptying rate can be quantified.
Methods: A comprehensive search of MEDLINE/PubMed, of English articles, from inception to 1 July 2014. References of included manuscripts were also examined for additional studies.
Results: A number of methods are available to measure gastric emptying and these broadly can be categorised as direct- or indirect-test and surrogate assessments. Direct tests necessitate visualisation of the stomach contents during emptying and are unaffected by liver or kidney metabolism. The most frequently used direct modality is scintigraphy, which remains the 'gold standard'. Indirect tests use a marker that is absorbed in the proximal small intestine, so that measurements of the marker, or its metabolite measured in plasma or breath, correlates with gastric emptying. These tests include drug and carbohydrate absorption and isotope breath tests. Gastric residual volumes (GRVs) are used frequently to quantify gastric emptying during nasogastric feeding, but these measurements may be inaccurate and should be regarded as a surrogate measurement. While the inherent limitations of GRVs make them less suitable for research purposes they are often the only technique that is available for clinicians at the bedside.
Conclusions: Each of the available techniques has its strength and limitations. Accordingly, the choice of gastric emptying test is dictated by the particular requirement(s) and expertise of the investigator or clinician.

1. Introduction

Enteral nutrition is part of standard care for critically ill patients and is most commonly delivered via the gastric route [1]. Frequently, however, nutritional targets are not achieved via the gastric route, particularly because of critical illness induced gastrointestinal dysmotility, which leads to slow gastric emptying [2]. While the prevalence and magnitude of delayed gastric emptying in the critically ill are inconsistently reported [3–5], possibly because these variables are dependent on the precision of the methodology used to measure gastric emptying, as well as the definitions of critical illness and/or delayed gastric emptying, there is no doubt that markedly delayed gastric emptying occurs frequently [4].

It is now also recognised that the impact of delayed emptying, and hence the potential indications for its measurement, are broader then had been appreciated. For example, in the critically ill patient, markedly slow gastric emptying may be associated with increased risk of gastro-oesophageal reflux and pulmonary aspiration [6]. The rate of gastric emptying is a major determinant of postprandial glycaemia and, in patients treated with insulin, major changes in gastric emptying rate may impair the coordination between nutrient absorption and insulin availability predisposing to glycaemic variability [7].

Gastroparesis is a relatively frequent condition in ambulant populations with epidemiological data estimating the incidence between 2.4 and 9.8 per 100,000 person-years [8]. Delayed gastric

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emptying is particularly prevalent in the critically ill and has been reported to occur in up to one-half of all mechanically ventilated patients, which is similar to the prevalence reported in ambulant patients with long-standing type 1 or type 2 diabetes [9,10].

In the research setting, the measurement technique must be precise, whereas in routine clinical situations clinicians may be willing to trade off accuracy for other factors, such as cost, convenience, and invasiveness, so that they can have a 'point-of-care' test. Comprehensive evaluation of gastric motility requires the measurement of multiple parameters. These include intraluminal volume, flow and pressure, wall motion, and electrical activity. No single technique can measure all of these concurrently. Consequently, in research studies a complete assessment of gastric function can only be obtained by the simultaneous use of different techniques. Additional information specific to measurement of gastric emptying in the ambulant setting is covered elsewhere [11–14].

Gastric emptying is determined by a number of intraluminal and extraluminal factors, which can be endogenous or exogenous, and mediate their effects via neural and/or hormonal pathways. The intraluminal factors that modulate gastric emptying include meal composition – caloric load, volume, temperature and nutrient type, the osmolarity of small intestinal contents and length and region of small intestine exposed to nutrient – and systemic (or extraluminal factors) such as glycaemia, posture, pain, gender and age [14].

The Intensive Care Unit presents some unique challenges when measuring physiological derangements. Patients are often sedated and attached to multiple lines, tubes and monitoring devices. Perhaps paradoxically, this may facilitate measurement, as these allow ready access to body fluids such as blood, urine, faeces, and expired gases. However, as patients are non-ambulatory, it is preferable that measurements are performed at the bedside, particularly due to the logistical difficulties in transportation of these patients [15]. There is also limited space around the patient due to the frequent presence of essential but bulky equipment, such as a ventilator and dialysis machines. Techniques must be adaptable, as studies may be terminated prematurely due to unexpected clinical requirements. Of particular concern is that the reliability of a test may be impaired in the critically ill patient when compared to a 'more controlled' research setting. This may reflect technical difficulties exclusive to the intensive care environment, or physiological derangements in the patient caused by their clinical condition or treatment. Ideally, all measurement techniques should be validated in critically ill patients before their widespread use. The primary aim of this narrative review is to provide an overview of the measurement of gastric emptying in the critically ill, the evidence for each method that may be used to quantify emptying and recommendations for use in the critical are setting.

2. Methods

We performed a comprehensive search of English language manuscripts, on MEDLINE/PubMed, from inception to 1 July 2014. We used both the following MeSH words and combination of terms: gastric emptying, scintigraphy, absorption method, 3-O-methylglucose, isotope breath tests, octanoic acid, ultrasound, magnetic resonance imaging, gastric residual volumes, critical illness and intensive care. Additionally, references of extracted manuscripts were examined for additional studies that had not been identified during the initial search. Only studies of human cohorts were included. The methodology of each study was evaluated and studies that were of greater methodological quality and/or data published more recently were preferred. However data was sourced from older studies when appropriate (due to insufficient recent data).

2.1. Measurement of gastric emptying in the critically ill

Formal measurement of gastric emptying is rarely performed in the critically ill other than for research purposes. A number of techniques are available, but all have potential limitations and particular difficulties for use in this population. Comparison of different methods of measurement of gastric emptying is limited by the practical inability to perform some measurements concurrently and differences in parameters acquired.

Changes in gastric volume over time can be quantified by techniques such as scintigraphy, fluoroscopy, ultrasound and MRI. Techniques such as labelled carbon breath tests and paracetamol or synthetic glucose absorption, require small intestinal absorption, as well as gastric emptying of the substrate. In the case of breath tests, metabolism of the substrate must also occur before excretion into expired air (Table 1).

Assessment of gastric emptying also requires careful definition of the variable to be measured. When ambulatory patients are being investigated for gastrointestinal symptoms, solid meals are generally considered to be a more reliable indicator of abnormal gastric emptying than nutrient liquids. However these are less applicable to the critically ill patient where liquid formulae are used for feeding. Because gastric emptying is frequently delayed in the critically ill and is dependent on the composition of the nutrient (i.e. proportion of carbohydrate, lipid or protein), we favour the use of lower volumes of liquid nutrient that is representative of feeds that are clinically used (e.g. 100 ml of 1 kcal/ml containing between 50 and 65% carbohydrate, 20–40% lipid, 15–30% protein) [16].

In general, measurements of gastric emptying involve an ingested marker (in the mechanically-ventilated patient, the marker is infused via a nasogastric tube) that is monitored directly, via imaging, or indirectly, using blood or breath analysis. The 'ideal' technique for measurement of gastric emptying varies depending on the circumstances and priorities facing clinicians or researchers at any particular time. In addition, these patients frequently have delayed gastric emptying and, in some cases it is profoundly slow [2]. For this reason techniques that can measure gastric emptying over several hours are preferred. Finally, the function of other organs (e.g. liver and kidneys) may be impaired, and volume of distribution, metabolism and excretion of a marker may be altered in these patients [17]. This may influence the outcome of measurements obtained from indirect tests [18]. The advantages and disadvantages of the various measurements of gastric emptying are detailed below.

2.2. Direct tests of gastric emptying

Direct tests require that the nutrient is 'visualised' during emptying and therefore the technique is unaffected by liver or kidney metabolism/excretion. Accordingly direct tests are generally more precise than indirect measurements.

Table 1
Methods of gastric emptying measurement in the critically ill.

Type	Method
Direct	Scintigraphy
Indirect	Drug absorption
	Carbohydrate absorption (3-O-Methylglucose; 3-OMG)
	Isotope breath test
Other	Ultrasound
	MRI
Surrogate	Gastric residual volumes (GRVs)