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Title

Technology to inform delivery of enteral nutrition in the intensive care unit

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TEXT

One of the defining features of an Intensive Care Unit (ICU) is the capacity to provide continuous monitoring of organ function. While methodologies to quantify cardiorespiratory function have become increasingly sophisticated, monitoring of gastrointestinal function remains relatively crude [1, 2].

To monitor gastrointestinal function in the ICU, clinicians frequently rely on clinical assessment, complemented by intermittent measurement of the ‘gastric residual volume’, to identify patients with slow gastric emptying and ‘enteral feed intolerance’ [2, 3]. However, despite the presence of very large volumes (> 250 ml) identifying patients at risk of delayed gastric emptying, the gastric residual volume is an imprecise surrogate for the gastric emptying rate [4-6]. Moreover, the volume aspirated may not identify patients at risk of pulmonary aspiration and pneumonia [7, 8]. Finally, the presence of a small gastric residual volume when fasted is not a strong predictor that a patient will tolerate enteral nutrition when it is commenced [9, 10]. Given the limitations inherent with its use, many clinicians have either abandoned the use of gastric residual volumes or only persist with them due to a lack of any suitable alternative [11].

The contraction of gastrointestinal smooth muscle causes volume and pressure effects within the gastrointestinal lumen. These smooth muscle changes are referred to as gastrointestinal motility [12]. Postprandial contractions need to coordinated in an antegrade fashion to result in forward propulsion of nutrient [13]. It is important to note that not all increases in motility act to accelerate gastric emptying [4, 14].

By convention gastrointestinal motility patterns are normally considered in two phases - fasting and fed, with the latter including the so-called postprandial phase. In health, during feeding, gastric emptying is regulated to match small intestine absorptive capacity [15]. Critical illness markedly affects both fasting and fed motility with a reduction in the number and coordination of pressure waves that are essential for luminal flow and gastric emptying [16]. Gastric motility also differs in the proximal and distal stomach. The antrum (distal stomach) is relatively more active, with antegrade conduction of coordinated waves to move nutrient through the pylorus [13]. During critical illness, the antrum has increasing periods of inactivity – i.e., a reduction in antegrade antral waves is observed - alongside a closed pylorus, which is occurs when pressure waves are isolated to the pylorus [14, 17].

Despite the crude monitoring techniques available it may be important to identify and treat gastrointestinal dysfunction during critical illness. Enteral feed intolerance occurs in about 45% of patients and is associated with increased morbidity and mortality [18-20]. Clearly, unmeasured confounders will increase the strength of such associations but, nonetheless, the rationale to provide enteral nutrition is that nutrient reaches and is absorbed from the small intestine [21], whereas nutrient that remains in the stomach cannot have benefit and may cause harm [22]. For these reasons, a methodology that provides clinicians with accurate, precise and real time measurement of gastric motility has considerable appeal; however, no such device or technique is available [6].

The Leuven group has developed a novel double lumen catheter that has been named the VIPUN Gastric Monitoring System [23]. The smaller lumen connects to an intragastric balloon that is inflated with 180 ml of air. The larger lumen of the catheter allows liquid nutrient to be delivered distal to the balloon. The proximal end of the smaller lumen is attached to a pressure sensor that allows recording of balloon pressure via a custom made data acquisition and recording system [23]. When gastric smooth muscle contracts the generated changes in luminal pressure are recorded, with data cleaned using an established algorithm to identify gastric contractile waves [24]. Accordingly, the technology can measure gastrointestinal motility in real time.

In a series of studies in healthy volunteers, the Leuven group initially validated this new technique against motility patterns measured using manometric catheters [23-25]. The comparison against manometric catheters are important as these can transmit smooth muscle contractions that obliterate the gastrointestinal lumen via solid-state pressure transducers and remain the gold-standard to quantify motility [23-25]. Manometric catheters, however, are only available in specialized research centers, and even at these centers they are only used for research purposes [14, 26, 27].

In the current study, Goelen and colleagues used this VIPUN Gastric Monitoring System to continuously monitor gastric pressure changes for 10 hours [28]. The first 4 hours the investigators measured fasting motility, which was followed by 2 hours of continuous feeding and then a further 4 hours monitoring 'postprandial' motility. The 'feeding' comprised infusion of 150 ml of a polymeric 1 kcal/ml liquid formula that was labelled with ^{13}C-octanoate. This protocol provided the researchers with a simultaneous measure of gastric emptying. The ^{13}C-octanoate breath test is an indirect measure of gastric emptying as the test relies on the labelled carbon (^{13}C) being absorbed from the small intestine with the free fatty acid (octanoate). Once absorbed, the ^{13}C is metabolised in the liver to $^{13}CO_2$ with the labelled carbon excreted during exhalation. Regular sampling of exhaled breath (CO_2) from the limb of the ventilator allows a researcher to measure the percentage of ^{13}C recovered per hour, which is then plotted over time [29]. Because the rate limiting step for ^{13}C recovery is gastric emptying the area under the recovery curve can then be used to calculate two variables; the gastric emptying coefficient – a global index for the gastric emptying rate which accounts for the rate of appearance and disappearance of tracer in the breath – and gastric half-emptying time ($t_{1/2}$), which is the time to 50% of the total ^{13}C recovered [29].

The authors should be congratulated on completing a technically demanding study of a novel device, which, at least intuitively, has considerable appeal. The investigators did not demonstrate a relationship between the measured motility index and calculated rate of gastric emptying (gastric half-emptying time, $t_{1/2}$). Despite this, the device may still have a role in the monitoring of gastric motility in the critically ill. There are a number of potential limitations of both measurement techniques used in this study which should be considered when interpreting the results.

A limitation of the current iteration of the VIPUN Gastric Monitoring System is the gastric balloon motility index appears to use an algorithm that does not identify isolated pyloric pressure waves or retrograde or disorganised pressure waves [24]. This may be relevant as these motility patterns occur frequently during critical illness but act to impede trans-pyloric flow and slow gastric emptying [14, 15, 30]. Indeed, only pyloric contraction was (negatively) associated with the rate of gastric emptying in a previous study in critically ill using manometry [4, 30]. It may also be that the balloon is detecting motility from both the fundus and the antrum, and antral activity may be a greater determinant of the gastric emptying rate than fundal activity during critical illness.

Readers should also be aware of the limitations of the ^{13}C-octanoate breath test in the critically ill population. Indirect isotope breath tests, like ^{13}C-octanoate, rely on near total absorption of substrate, in this case lipid, from the small intestine [6]. We have previously reported that small intestinal lipid absorption is impaired during critical illness [31] and that $t_{1/2}$ using the ^{13}C-octanoate breath test is only modestly associated with gastric emptying rate when compared to a direct, gold-standard, technique like scintigraphy [5]. For these reasons, when using the ^{13}C-octanoate breath test to quantify gastric emptying, we have favoured taking breath samples at more frequent intervals (5 min for the first hour) and reported the gastric emptying coefficient rather than the $t_{1/2}$ [32]. It is, therefore, entirely plausible that the novel balloon catheter technique was more sensitive at identifying impaired gastrointestinal motility than the precision of gastric emptying rate estimated from the ^{13}C-octanoate breath test and calculated $t_{1/2}$.

Mindful of these limitations, it is clear that further evaluation of iterations of the VIPUN Gastric Monitoring System and similar technology is warranted. Further iterations may allow quantification of the organizational patterns and assessment of pyloric contraction. Ideally, such technology would also assist clinicians in deciding when to initiate enteral nutrition for an individual patient and, once feeding was commenced, clinicians could titrate the rate of enteral delivery to fed/postprandial gastric motility patterns and inform the use pro-motility drugs.

Given the limitations with our current clinical approach, further research into novel technology that facilitates a nuanced and dynamic approach to enteral nutrition in the critically ill is required. This study represents an important step on this journey.

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