lence. This would allow a comprehensive understanding into factors that interfere with surgical training of the trainee. Such a process may actually unearth certain aspects of the training programme that may either aid the trainee or deter his / her progress. The advantage of Process excellence is that it allows an objective comparison following the intervention to the outcomes before the change. This could thus result in further changes in the training system that could lead to further improvements.

Another possible application is in the imparting of training in complex surgical procedures by breaking up the procedures into step-wise processes that would help identify key steps.[6] Special training could then be imparted in these key steps. Six Sigma can also be used to objectively quantify the competence and efficiency of procedures, clinicians and trainees.[6] The surgical fraternity needs to explore and adopt suitable 'tools' from other non-medical disciplines and apply them in order to create best practice standards in clinical practice and surgical training. This would go a long way in improving standards across the board and also make a major difference in surgical training, ongoing training of practicing surgeons, as well as, up-gradation of the 'skill sets'.

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A window into the belly: lessons from a pioneering surgeon

The Latin words 'abdere' and 'abdomen' mean 'to hide' and 'belly', respectively. 'Intestinus', from which 'intestine' derives, simply means internal. The intestine and abdominal contents are indeed hidden, but they are much more accessible than the brain, the heart and the lungs. Modern physicians seem unwittingly to have taken the origins of these words to heart. The abdomen, and, more particularly, the intestine, are still monitored even in the critically ill using indirect measures, which are often qualitative and imprecise – auscultation, abdominal girth, nasogastric aspirate volumes, and the texture and volume (although not usually the energy content) of the stool. Respiratory and cardiac function, by contrast, is monitored with exquisite accuracy in real time with the use of highly invasive transcutaneous catheters and imaging devices. Accurate determination of cardiac output, rhythm and stroke volume, oxygen exchange and lung compliance can be acquired within seconds. Even the brain, protected by a thick layer of bone, is often monitored postoperatively and after severe head injuries using pressure devices that give instantaneous measures to guide management. MRI can also be used to show cerebral metabolism in real time.[1]

This dearth of information with respect to the gut is particularly relevant to the difficulties inherent in the provision of enteral nutritional support for post-operative and critically ill patients. Three steps are needed for enterally administered substrate to be therapeutically useful. First, the nutritionally useful component of the feed must be propelled into and down the small intestine; second, it must be absorbed by the intestine and third, absorbed substrate must be metabolized in such a way as to be metabolically useful.

With respect to gut motility in the critically ill, both gastric emptying and intestinal motility are altered substantially. The mechanisms involved are complex, with a raft of mediators, including corticotrophin-releasing factor, catecholamines, serotonin, ghrelin, nitric oxide and motilin being implicated.[2] The enterochromaffin cells of the mucosa itself have now been shown to secrete serotonin.[3] Therapies have included a variety of promotility agents, including erythromycin, neostigmine and metoclopramide, but the results are mixed. The complexity of factors governing motility has also led to a large variety of other pharmacological approaches, many of which have had to be abandoned due to unacceptable side – effects.[2]

Absorptive capacity of the intestine in the critically ill is also poorly understood. A recent Dutch study[4] showed that 30% of critically ill patients with loose stools have malabsorption of enteral nutrition (EN) (defined as at least 15% of administered feed not being absorbed). To what extent this failure to absorb nutrients was attributable to mucosal enzyme dysfunction, mural oedema or impaired intestinal function secondary to ischaemia is unknown. This groundbreaking study shows that collecting stool in the critically ill, while being logistically difficult and aesthetically unpleasant, provides valuable insights into perturbations of intestinal function.

With respect to the metabolic fate of substrate entering the portal or systemic circulation, even less, it would seem, is known. Critically ill patients have ongoing negative nitrogen balances despite nutritional supplementation.[5] This implies sub-optimal substrate utilization and raises concerns as to how much is used in the repair of tissues and for other metabolically important functions. A significant amount of the nutrition may be sequestered as fat or finish up being renally excreted as glucose. It is remarkable that less is known about the metabolism of nutritional supplements than that of most drugs.

Notwithstanding our ignorance of gastrointestinal physiology in the context of enteral nutritional support, intolerance to EN is a clinically significant problem particularly in the most critically ill[6], who ironically need it the most. Administration of EN into a poorly functioning gut may lead to diarrhoea, raised gastric aspirates/vomiting and rarely non-occlusive mesenteric ischaemia.[7] Importantly, EN per se may also improve intestinal tolerance to its presence, and, interestingly, recent studies have shown that EN supplemented with fibre can slow intestinal transit and ameliorate EN associated diarrhoea in the critically ill.[8,9] The delay required to establish a diagnosis of intolerance to EN not only exposes patients to the risks of enteral feeding in the face of a poorly functioning gut, but also can lead to a delay in the institution of alternative feeding strategies (the placement of nasojejunal feeding tubes/the administration of parenteral nutrition). A dramatic example of the morbidity and mortality stemming from this delay was shown in the recent Dutch multi-centre trial of enteral feeding in predicted severe acute pancreatitis, in which 9 out of 152 probiotic supplemented enterally fed patients suffered intestinal ischaemia (eight with fatal outcome).[10] Interestingly, none of the EN fed control group, who were not given probiotics, developed intestinal ischaemia.

In view of the variable and unpredictable tolerance to EN, accurate and objective determination of intestinal function in real time would be advantageous if significant advances are to be made in optimizing both the route and regimen of non-volitional nutritional delivery. Indirect measures, such as paracetamol absorption testing have yielded mixed results.[11] Radiological markers[12] and triolein breath testing[13] have also been used, but are time consuming and not contemporaneous. Small bowel manometry has been developed, but the data are limited,[13] and the logistics are considerable. Transcutaneous ultrasound of the small intestine has been used in the evaluation of Crohn's disease,[14] and there may be potential to widen its use. Intravesical pressure monitoring as a marker of intra-abdominal pressure is used quite widely, but is mainly of clinical use in the evaluation of abdominal compartment syndrome.[15] Finally, the placement of intra-peritoneal cameras, preferably manoeuvrable, next to or through surgical drainage tubes or even transcutaneously in non-surgical patients may be possible, particularly as such devices have already been placed into bile ducts at endoscopic retrograde cholangio-pancreatography with excellent diagnostic and therapeutic results[16].

William Beaumont, a 19th-century American surgeon, was fortunate enough to be privy to a window into the belly when he hired one of his former patients with a non-healing gastrocutaneous fistula as an assistant and began experiments on the digestive capacity of his gastric juices.[17] Beaumont, by placing bread attached to a string through his patient's fistula, was able to show that gastric juices could break the bread down. He also showed by aspirating the juice that this process could be mimicked *ex vivo*. By today's standards, the experiments were crude and of dubious ethics (it is worth noting that notwithstanding Beaumont's experiments, he predeceased his patient by several years), but the physiological approach to assessing gastrointestinal function was exemplary.

Dr Beaumont's work was serendipitous – a gunshot provided a window into the belly. Perhaps it is time to create our own more controlled window, lifting the lid on the abdomen to explore the intestine in real time? Now that we can prolong the lives of the critically ill, in whom intestinal function is often impaired, it is incumbent on us to make a misnomer of the word 'abdomen' and take full advantage of recent technological innovations to optimize nutritional support and aid timing and planning of surgical interventions. Imagine if cardiac function were still being assessed without the aid of electrocardiography and echocardiography. Undiagnosed malignant arrhythmias would give rise to ventricular fibrillation and premature death with minimal warning. Admittedly, acute abnormalities of intestinal function are not as rapidly life threatening as those of the heart. The recent Dutch pancreatitis study[10] showed nonetheless that the current difficulty in the early diagnosis of even gradually evolving intestinal catastrophes leads to major morbidity and mortality, much of which should be avoidable by earlier and more accurate assessment of intestinal function.

One cannot help wondering what Dr Beaumont (he may have in fact been called 'Mr Beaumont' as he was a surgeon) would think of today's medicine if he were still alive. His experiments on Alexis St Martin (his patient) were done before Robert Koch was born. Virchow and Pasteur were children. Bloodletting was rife, and the medicinal administration of mercury was common. The first electrocardiogram would not be performed for about 100 years, and anaesthesia and surgery were remarkably crude with spectacularly high morbidity and mortality. Even the cellular theory of disease was yet to be enunciated, with Galen's 'four humours' holding sway in many quarters. No doubt he would have been impressed by advances in abdominal imaging, gastrointestinal physiology and gastroenterology. In a world where cardiovascular and respiratory function can be monitored with digital technology in real time, he would almost certainly have been surprised at how hidden the abdominal contents remain to the bedside clinician. He would also have been surprised at how intently intensivists pump nutritional supplementation into the proximal gut of the post-operative and critically ill patient without any contemporaneous means of determining either how well it is tolerated or how it is metabolized.

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