Review Article

Pre-operative fasting in adults and children: clinical practice and guidelines

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Summary

It is widely recognised that prolonged fasting for elective surgery in both children and adults serves no purpose, adversely affects patient well-being and can be detrimental. Although advised fasting times for solids remain unchanged, there is good evidence to support a 1-h fast for children, with no increase in risk of pulmonary aspiration. In adults, a major focus has been the introduction of carbohydrate loading before anaesthesia, so that patients arrive for surgery not only hydrated but also in a more normal metabolic state. The latter attenuates some of the physiological responses to surgery, such as insulin resistance. As in children, there is no increase in risk of pulmonary aspiration. Further data are required to guide best practice in patients with diabetes.

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Introduction

The requirement for adult surgical patients undergoing elective general anaesthesia to be in the fasted state has been considered one of the fundamental cornerstones for safe peri-operative care for over a century, appreciated by both doctors and patients. The first death usually attributed to pulmonary aspiration following anaesthesia was recorded in a young girl in 1848, and apparently occurred when brandy was poured in her mouth to 'resuscitate' her at the end of chloroform anaesthesia [1]. Mendelson's classic paper introduced the concept of acid aspiration syndrome, that is, aspiration of liquid stomach contents with subsequent pulmonary damage [2]. He reviewed the notes of 44,016 pregnancies in which 66 patients developed pneumonitis, but interestingly, even in an era lacking intensive care, none died from this. The only two deaths followed upper airway obstruction from solid food pieces [2].

The incidence of pulmonary aspiration is low (≈1 in 7000) with morbidity and deaths very much lower (≈1 in 1700 and ≈1 in 100,000, respectively [3]). Unfortunately, the fear of aspiration, and the concept that the longer the fast the safer it is for the patient, has led to excessive pre-operative food and fluid restriction. In the 1980s, there developed an appreciation that excessive fasting is not only unnecessary but also detrimental. Gastric pH, as well as volume of contents, is important in determining the severity of any pneumonitis, but acid secretion continues during fasting.

Patients would often arrive in the anaesthetic room in a state of dehydration, exacerbated by other factors such as bowel preparation. The measurement of cardiac output and oxygen delivery allowed recognition of the detrimental effects of dehydration [4, 5]. From this concept arose modern individualised fluid therapy and stroke volume optimisation leading to improved outcomes, particularly in critically ill patients undergoing surgery. However, it also prompted clinicians to extrapolate that a patient arriving for surgery in a dehydrated state was not only detrimental to their comfort and well-being but also had undesirable physiological consequences even if they were healthy. This led to numerous studies demonstrating that free clear fluids could be safely administered until 2 h before surgery in adults [6, 7].

The final concept to be addressed is that even if fluids are administered appropriately and the patient arrives in the operating theatre in a state of euvolaemia, the lack of calorie intake is deleterious for patients undergoing surgery. It is nearly 90 years since Cuthbertson's landmark studies describing the catabolic state that accompanied bed-rest [8] and major surgery [9], with later work characterising the stress response and resultant catabolism and hyperglycaemia [10]. Parallels have been drawn between the energy requirements for postoperative patients and for athletes undergoing a major sporting endeavour [11]. Both require increased oxygen utilisation. If this process fails, there is a switch to anaerobic metabolism and accumulation of lactate, with the outcomes for both patients and athletes significantly impaired. It was therefore understandable that high carbohydrate diets, well known to athletes, should be tried in patients undergoing major surgery.

Thus, the scene was set for major change. We have thus have come a long way from prolonged 'nil by mouth' periods, varying widely in application, to modern protocolised pathways such as 'enhanced recovery', in which oral carbohydrate drinks are administered up to 2 h before surgery.

The various elements of practice will now be examined in detail.

Adult patients

For clinically significant pulmonary damage to occur, a critical volume and acidity of gastric acid must be aspirated. These were set at 25 ml (> 0.4 $ml.kg^{-1}$) and pH 2.5 by Roberts and Shirley [12]. It is worthy of note that these figures were derived from results that only report findings in a single rhesus monkey [13]. Further systematic animal experiments suggested a higher critical volume of 50 ml (0.8 $ml.kg^{-1}$) [14]. These experiments are impossible to perform in the human setting, but recently a 1.5 $ml.kg^{-1}$ limit has been promoted [15]. This is based on a pragmatic evaluation of the prevalence of comparable gastric volumes in nil-by-mouth patients and the very low incidence of gastric aspiration [15].

It is not possible to increase gastric pH by dilution of gastric contents with ingested water. However, highly effective and reliable increases are possible by reducing gastric acid secretion pharmacologically, for example, with the addition of H_2 antagonists [16].

A more complex area is the reduction of gastric volume. Gastric emptying shows an inverse relationship with the calorific content of the drinks consumed, with 330 kcal emptying slower than 220 kcal drinks, and water emptying the fastest [17]. There is an approximate exponential decline of stomach content volume with time, with water having a half-life of about 15 min, beef extract 20 min [18] and 25 min for tea with milk [19]. This suggests that a 1-h fasting time for water is entirely reasonable [20].

Many methods have been used to assess gastric volume including nasogastric aspiration, isotope labelling, co-absorption of paracetamol [19], magnetic resonance imaging (MRI) and ultrasound. Of these, only ultrasound is of clinical utility. A good correlation with isotope scintigraphy is well established [18].

The advent of high-quality ultrasound machines, and their widespread use among anaesthetists, has led to the possibility of an individualised and practical approach to assessment of gastric volume, recently the subject of an editorial in this journal [15]. It helps us to provide a logical approach to safely managing patients in whom there may be doubt about their gastric volumes, either due to the timing of nil-by-mouth, or the clinical situation that might prolong gastric emptying beyond normal. It allows visualisation of solid matter, which needs to be treated as a high-risk 'full stomach' even if there is a low content volume. The antral cross-sectional area (CSA) is measured in the lateral decubitus position, and the gastric fluid volume read from a validated table, using the formula: Volume (ml) = $27.0 + 14.6 \times CSA - 1.28 \times age$ [21].

Even if nothing else is to be administered by mouth, water is a good start, preventing not only dehydration but improving patient satisfaction and well-being. Maltby et al.'s classic study [6], replicated by others [7], showed no increase in volume or pH with a drink of 150 ml water given between 120 min and 180 min before anaesthesia.

Carbohydrate loading

A different area of peri-operative physiology was revolutionised with our appreciation of the stress response to major surgery and its sequelae. Major surgery elicits a characteristic response of pituitary and sympathetic nervous system activation, leading to a myriad of predictable metabolic changes including hyperglycaemia, protein (muscle) loss and insulin resistance [10]. Of all the changes, insulin resistance is often viewed as pivotal, as it will result not only in poor glucose uptake and hyperglycaemia but also reduced storage of glycogen, particularly in muscle and liver, thus leading to muscle breakdown and postoperative weakness. Moreover, insulin resistance itself is associated with an increase in morbidity, mortality and hospital stay [22, 23].

For nearly 60 years, the concept of carbohydrate loading has been studied in endurance athletes, in whom it increases muscle glycogen stores and causes a corresponding increase in performance times during endurance exercise at 75%–85% of maximum oxygen consumption [24–26]. The logical realisation that some of the key metabolic derangements in surgical patients could be ameliorated with pre-operative glucose loading was an exciting concept. In the 1980s, Ljungqvist et al. showed the beneficial effects of carbohydrates on insulin resistance, firstly using overnight intravenous (i.v.) glucose infusions and then drinks [27, 28]. Carbohydrate loading altered metabolism from the fasting to the fed state, increased liver glycogen by about 65% and blunted postoperative insulin resistance. The latter is usually described by its inverse – insulin sensitivity – of which the gold standard of measurement is the hyperinsulinaemic-euglycaemic clamp, rather than other simpler methods, such as homeostatic model assessment. Insulin sensitivity in patients receiving i.v. carbohydrate preload was restored somewhat, only falling by about 45% in a glucose group compared with 68% in a control group [27]. Intravenous glucose loading studies were the harbinger of oral carbohydrate loading, conveniently timed around the relaxation of oral intake before anaesthesia.

Although other methods have been well described to blunt the neuro-endocrine response (including insulin resistance) to surgery, such as high dose opioids or prolonged postoperative thoracic epidurals with local anaesthetics [10], the understanding that carbohydrates can achieve significant reductions in insulin resistance is recognised as one of the key areas in enhanced recovery programmes.

Although the changes in insulin resistance from carbohydrate loading are accepted, the observed clinical benefits are not so marked. Moreover, when compared with fasted controls, carbohydrate loading had more marked effects than when the controls were receiving either placebo or water. A meta-analysis showed only a small reduction in length of stay for major abdominal surgery of 1.08 days, with no benefit for orthopaedic surgery, or minor surgery that had an expected length of stay of less than 2 days [29]. In a more recent Cochrane meta-analysis, there was only a 0.3 day reduction in length of stay overall. However, for major abdominal surgery this benefit was increased to 1.7 days, with a shorter time to passage of flatus [30]. Both of these meta-analyses, however, have included studies of varying quality and openness to potential bias. A third meta-analysis compared normal dose (> 45 g) or lower dose (10–44 g) carbohydrate load. There was a small reduction in length of stay of 0.4 days for normal dose and 0.2 days for lower dose loading when compared with fasting, but no difference when carbohydrate loading was compared with water or placebo [31]. Overall, the clinical significance of carbohydrate loading on length of stay has been questioned. Moreover, these reductions in length of stay may not necessarily be attributable to carbohydrate loading alone, as other improvements in patient care, such as strategies to reduce fasting times and the surgical stress response [32], may also contribute to reduced length of stay.

Within enhanced recovery programmes, others have found advantages for carbohydrate loading, albeit in retrospective analyses. As the measured adherence to enhanced recovery protocols increased from 43.3% to 70.6%, carbohydrate loading was a major independent predictor for both reducing adverse symptoms (nausea, vomiting, pain, diarrhoea and dizziness) and complications (wound dehiscence) [33].

The standard definition of a carbohydrate load is at least 45 g administered < 4 h before surgery. A commonly used formulation is a 50 g sachet, diluted to 400 ml to make a 12.5% drink with an osmolality of 135 $mOsm.kg^{-1}$, containing 200 cal. Two 400-ml sachets are taken the night before surgery, and one 400-ml sachet 2–4 h before surgery. Although many combinations are clearly possible, the key composition of oral carbohydrates is maltodextrin polysaccharides that are emptied reliably from the stomach after 2 h; however, other formulations or additions may ultimately prove to give superior results [11].

Given the frequency with which carbohydrate loading is used worldwide, the risk of pulmonary aspiration of gastric contents following its use in elective surgical patients appears negligible. For those patients with delayed gastric emptying, such as gastro-intestinal obstruction or pregnancy, a careful case analysis, supported by gastric ultrasound where available, is recommended.

Perhaps the most unclear area is the use of carbohydrate loading in diabetic patients, who are at risk of both disturbances in plasma glucose control as well as pulmonary aspiration if they have co-existing autonomic neuropathy. The paradox is that the surgical stress response and insulin resistance will increase plasma glucose – so called 'diabetes of injury' – and should be reduced by carbohydrate loading, yet the same carbohydrate loading may substantially elevate plasma glucose levels. This is a key marker of peri-operative outcome; hyperglycaemia causes an increase in rates of infection, re-operation and death, yet when plasma glucose is controlled with insulin, there is no increase in incidence of these adverse effects [34].

There is very little data in this area, consisting of one study performed in 25 patients with type-2 diabetes mellitus with no evidence of autonomic neuropathy. Although the peak plasma glucose was higher in the diabetic patients than the non-diabetic controls (13.4 vs. 7.6 $mmol.l^{-1}$, respectively; $p < 0.01$), this was short-lived. Nevertheless, currently many clinicians choose to avoid carbohydrate loading in diabetic patients. The alternatives are to administer carbohydrates as well as normal medication and/or insulin, or consider the use of alternative drinks, such as Glycaemic Endothelial Drink. This contains less maltodextrin, as well as citrulline (a precursor of arginine) which may lead to reduced gluconeogenesis [35].

Children

As for adults, there are many methods described for measuring gastric emptying and residual gastric volumes; however, ultrasound and MRI are the most practical and best tolerated in children. Magnetic resonance imaging studies show that gastric emptying in children is rapid for clear fluids, with the majority having left the stomach within 30 min [36]; 7 $ml.kg^{-1}$ of syrup is almost all emptied from the stomach in children within an hour as shown by serial MRI; 3 $ml.kg^{-1}$ empties with a half time of approximately 20 min on MRI, returning to baseline values by 1 h [37].

Ultrasound assessment in children confirms that 10–15 $ml.kg^{-1}$ clear fluids given 2 h pre-operatively results in a reduction rather than an increase in antral volume by the time of induction [38].

There is understandable anxiety among anaesthetists that a decreased fasting time will increase the aspiration risk, but this is not the case as shown in several large studies [39–41]. The rate of aspiration is approximately 3 per 10,000 cases irrespective of whether a 2 h, 1 h or 'ad lib' clear fluid fasting time is followed [42]. Furthermore, the consequences of clear fluid aspiration in children are not severe [43].

One of the most distressing aspects for children awaiting elective anaesthesia is the need to fast [44]. Although hunger is an issue for many, it is thirst that predominates. Excessively fasted children are more irritable as judged by their anaesthetist and carers [45]. Longer fasting can also lead to hypotension on induction of anaesthesia, and evidence of a catabolic state [46]. Prolonged fasting is associated with an increased incidence of postoperative nausea and vomiting [47].

In paediatric anaesthesia, practice in terms of reducing fasting times for clear fluids has advanced more rapidly than in adults. In recent years it has become increasingly evident that it is unnecessary to keep children fasted for clear fluid for ≥ 2 h [40, 41].

If a '2-h' rule resulted in a 2-h fast, the pre-operative period would be more tolerable and less potentially detrimental; however, several studies confirm that this is not the case. A 2-h clear fluid fasting rule translates into measured fasting durations of 6–13 h [48]. This is due to many factors, such as the understandable reluctance of carers to wake children for a drink, their anxiety about breaking fasting rules and the unpredictability of timing of anaesthetic induction.

It has been shown that an ad lib policy results in a mean fasting time of 1.7 h, with no children receiving a drink within 30 min of induction [41]. A 1-h policy in another large institution resulted in a mean fasting time of 3 h [40]. Neither of these regimens increased the aspiration rate, which remains at 1–4 per 10,000 general anaesthetics in children [39–43]. Crucially, a 1-h rule allows the offer of a drink on arrival, since patients are unlikely to have anaesthesia induced in < 1 h from admission [40]. This apparently small practical issue takes the decision process and responsibility away from the parents, and allows a positive episode of the offer of a sweet drink to occur on arrival in the hospital.

According to a 2016 UK Association of Paediatric Anaesthetists of Great Britain and Ireland (APAGBI) linkman survey, a number of paediatric anaesthetic services have recently moved to a 1-h rule for clear fluids [49]. We suggest that a change to a 1-h clear fluid fasting time is a major but overdue change in anaesthetic practice [42, 48].

Up until 2012, all existing guidelines advocated a 2-h clear fluid policy [50], although none of them has been updated since the more recent evidence supporting liberal regimens. Consensus statements have been shown to have a positive impact on national fasting times in the past [51], and hence a joint consensus statement was issued by the APAGBI, the European Society of Pediatric Anesthetists and the French-Language Society of Paediatric Anaesthesiologists, not only sanctioning but also encouraging clear fluids to be given up to 1 h before elective general anaesthesia [52].

Clear fluids in this context are defined as water, pulp-free juice, ready diluted drinks, non-fizzy sports drinks and non-thickened fluids with a recommended maximum volume of 3 $ml.kg^{-1}$.

Relative contraindications to 1-h fluids include gastro-oesophageal reflux (either being treated or under investigation), renal failure, some enteropathies, oesophageal strictures, achalasia, diabetes mellitus with gastroparesis and/or surgical contraindications.

As with all clinical decisions, the theoretical risk should be weighed against the benefits on an individual basis.

There is some disparity between European countries as to what the allowable interval is for fasting after breast milk feeding. Since the above statement only addresses clear fluids, no international consensus changes have been proposed for milk feeds. There are large variations in the whey and casein contents of different formula feeds, and since these translate into variations in fat and protein content they will also differ in their speed of gastric emptying. Thus, formula feeds tend to be regarded as similar to solids in terms of their gastric transit time, and so a recommended fasting interval of 6 h is maintained [53].

Given the abundance of adult work on the optimal carbohydrate drinks that can or should be administered pre-operatively, there is clearly a lot of work still to be done in the paediatric population to arrive at a reasoned conclusion. There is currently no convincing evidence to recommend one type of carbohydrate drink over another in paediatric practice.

Promising emerging areas of study in paediatrics are the use of a bed-side ultrasound to ascertain residual gastric contents [38], perhaps as a potential tool in modifying the induction technique in the emergency setting [54]. We have come a long way since the nil-from-midnight days, but there is still much more refinement to the pre-operative fasting process to be done.

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