

# Preoperative Fasting in Children

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Children undergo a preoperative fast in an attempt to minimize the fluid and solid food component of gastric contents. The importance of a preoperative fast was acknowledged early in the evolution of anesthesia as a discipline of medicine. In response to concerns about the aspiration of gastric contents, a prolonged fast presumably came into vogue. With this practice, it was not unusual to have hungry, irritable children who were prone to hypoglycemia after fasts of 8–12 h or even longer.

The purpose of this article is to provide the reader with a narrative review of the literature pertaining to preoperative fasting in children. This article is primarily focused on randomized controlled trials (RCTs), but when not available, literature of lesser intensity was used. We present the physiology of gastric emptying with an emphasis on studies focusing on children in the perioperative period. These studies of gastric emptying were, when possible, divided into studies involving solid food and those involving clear fluids. We then present preoperative fasting of children, which was subdivided by age (neonates, infants, toddlers, and adolescents) and by health (elective versus emergent surgery and healthy versus medically compromised patients). In the concluding portions of this review, we present recommendations for the management of perioperative fasting and recommendations with respect to the need for more research, as more questions remain unanswered than those that have been answered.

During preparation of this article, we accepted several links. The linkage between gastric fluid volume and aspiration pneumonia for healthy patients has recently been examined by an ASA taskforce, which concluded that the available data were insufficient to confirm or deny a relationship. Although this means that gastric fluid volume is a surrogate end point for aspiration pneumonia, virtually all studies examining preoperative feeding practices have gastric residual

volume as their primary end point. For the purpose of this review, we focus on the end point of gastric residual volume, which is the almost exclusive choice of numerous peer-reviewed investigations. Furthermore, in the practice of anesthesia, patients undergoing emergency surgery have increased gastric contents and are at increased risk of aspiration pneumonia. This is an established link, and if we were to refute it, we would deny the need for rapid-sequence induction plus appropriate airway management during general anesthesia for emergency surgery. Although increased gastric contents increase the risk of aspiration pneumonia, there is no known gastric fluid volume that places a particular patient at clinically relevant risk or eliminates all risk.

## Selection of Articles

The articles reviewed during the preparation of this article were obtained after review of the literature using a MEDLINE search. Any article in English or French using the key word "children" and one or more of "fasting," "preoperative fluids," "gastric emptying," "gastric fluid volume," "aspiration," and "gastric pH" were reviewed. Any of these articles that may be relevant to this review were assessed in detail. In addition, 10 key articles (1–10) were identified, and all articles citing these articles in the past 5 yr were perused, and significant articles were reviewed in detail. After the detailed review, the articles and, at times, abstracts and case reports, were then assessed for methodologic quality. Those that were RCTs were ranked highest, whereas case reports and abstracts tended to be ranked lowest.

## Physiology

The importance of the stomach from an anesthesiologist's perspective has been reviewed by Davies et al. (11). After the ingestion of a meal, the stomach digests and empties solids and liquids independently (12–14). Emptying of solids follow zero-order kinetics and thus empty from the stomach in a linear manner, whereas

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the emptying of liquids follows first-order kinetics and empty from the stomach in an exponential manner. Unfortunately, many studies in the literature report gastric emptying half-life, which only has implication on the portion of the meal that follows first-order kinetics, which is the liquid phase.

Numerous factors, including gastric emptying, recent ingestion of solid and liquid food, saliva, and gastric secretions, may affect gastric contents during the induction of anesthesia (15). Salivary secretions of approximately  $1 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$  and gastric secretions of approximately  $0.6 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$  are major contributors to gastric contents in the fasting state (16).

Another factor that affects gastric contents is gastric emptying, which is primarily forward. Pathologic states, such as when one is suffering from a viral gastroenteritis or gastroesophageal reflux, will impair forward emptying of gastric contents into the duodenum via the pylorus. During vomiting and gastroenteritis, there may be retrograde giant contractions that empty duodenal and jejunal contents into the stomach. Gastric emptying varies directly with intragastric pressure and inversely with duodenal pressure and the resistance at the pylorus (17,18). The increase in gastric emptying associated with increasing intragastric pressure is noted for both solid and liquid meals, but this increased emptying is primarily associated with the liquid phase of the meal (17). As early as 1833, Beaumont (18a) observed that liquids emptied from the stomach in  $<1 \text{ h}$ , whereas solids took markedly longer. Gastric emptying of liquids occurs in the absence of gastric motor activity, but the emptying of the solid phase of a meal is dependent on gastric motility (19). Intragastric pressure will increase in response to increased intragastric volume, whereas resistance at the pylorus is altered by food types (e.g., solid versus liquid, isoosmolar versus hyper- or hypoosmolar), medication, and disease states (e.g., pyloric stenosis). Among the food types ingested, the gastric emptying of lipids is the slowest, that of protein-rich food is fastest, and that of carbohydrate-rich foods is intermediate (20). Duodenal pressure may be increased mechanically (e.g., bowel obstruction, pancreatic cancer) or alternatively due to duodenal osmolar receptors. Gastric emptying in children is also altered by patient position (21). Other factors that may alter gastric emptying are temperature of the meal, prior surgery, medication, and infections (22,23). Of these factors, it is food type—specifically solid versus liquid—that controls gastric emptying in most clinical situations.

There is no absolute definition of what is a solid food. In practical terms, solids are foods that are in a solid state within stomach. Gelatin is solid before ingestion, but it promptly liquifies in the stomach and is rapidly emptied. In contrast, cow's milk is a liquid that separates into a liquid phase plus solid phase (curds) after ingestion. This solid component of milk can take

hours to empty from the stomach, which has great clinical significance in pediatric anesthetic practice.

The digestion of solids is slow and likely involves two stages. The superior portion of the stomach stores solids, whereas the inferior portion of the stomach breaks down the solid meal into a thick fluid-like chyme containing particles approximately 2 mm in size by means of peristaltic waves and acid plus peptic digestion. The pylorus selectively restricts the passage of small particles into the duodenum. Solids that are easily broken down rapidly empty from the stomach, whereas complex meals take many hours to leave the stomach. The rate of gastric emptying of food from the stomach is dependent on a variety of factors, such as the proportion of fat, carbohydrates, and protein, but through a complex set of interrelated mechanisms, the energy content of a meal controls its emptying (24). Hunt (24) has reported that approximately 200 kcal/h of food energy is emptied from the adult stomach.

Several investigators have assessed the emptying of specific meals, and most of these studies have involved adults. Marzio et al. (25) studied the gastric emptying of 500 mL of partially skimmed cow's milk (1.8% fat) in healthy adult volunteers. By 3 h, the average gastric residual volume, which was measured by ultrasound and radionucleotides, was  $<10\%$  of the original volume ingested. Schiller et al. (26) evaluated the gastric emptying by adults of a homogenized meal consisting of a 5-oz cooked ground sirloin steak, one piece of toasted white bread with one pat of butter, plus water to a total volume of 600 mL. After 2 h,  $>90\%$  of the liquid component of this 484-kcal meal was emptied out of the stomach, and the gastric residual volume was approximately 225 mL. Moore et al. (27) studied the gastric emptying of a 900-g meal (50% solid) of beef stew, apple sauce, whole wheat bread, orange juice, and milk in adults. The solid food emptying followed zero-order kinetics, and after approximately 95 min, half of the solid component of the meal (total 644 kcal) was emptied.

The aforementioned and similar studies using this methodology must be interpreted with caution because different solids have different gastric emptying times, whereas only one food is radiolabeled, and only that particular food's gastric emptying is followed. For example, the mean  $t_{1/2}$  values of noodles and liver in adults are 52 and 82 min, respectively (28). Weiner et al. (28) demonstrated that different sizes of liver particles have different gastric emptying times. More specifically, the mean  $t_{1/2}$  values of 0.25-mm and 10-mm liver particles were 70 and 117 min, respectively.

Most investigations of gastric emptying of solids have involved small and regular meals. Moore et al. (6) compared the gastric emptying of three meals of different sizes in 10 adult volunteers. After a filling meal (mean 1692 g, 1945 kcal), a 900-g (641 kcal) meal, or a 300-g (196 kcal) meal, gastric emptying of the

solid and liquid components of the meal was followed. The solid meal component had mean  $t_{1/2}$  emptying times of 277, 146, and 77 min, respectively, whereas the liquid component mean  $t_{1/2}$  was 178, 81, and 40 min, respectively. The most clinically important observation is that, after a filling meal, average adults require >9 h to empty their stomachs. Also of importance is that a small 300-g meal of beef stew and orange juice should, on average, empty from the stomach in 154 min. These two observations are relevant to the day-to-day practice of anesthesia. First, an 8-h fast after a filling meal is inadequate. Second, a light breakfast early in the morning should have emptied from the stomach by the afternoon.

### *Infant Formula and Human Milk*

The gastric emptying of a meal ingested by neonates and infants has been studied, but not in the depth or scope needed or involving patients with disease processes that may alter gastric emptying, such as gastroesophageal reflux (29–32). The contents of the ingested meal is usually the factor that has the greatest impact on gastric emptying. Foods studied include human milk, formula, cereal, and clear fluids. Human breast milk can be considered a simple food. Its pH (6.7–7.4) and osmolarity (approximately 286) are similar to physiologic values, although its fat content is not consistent (33–36).

Cavell (37,38) investigated gastric emptying of infant formula and human breast milk in full-term and premature infants using a marker-dilution technique and observed a biphasic emptying pattern typical of adult digestion patterns. There was an initial rapid phase consistent with the rapid gastric emptying of the liquid component of the meal, followed by a slow, constant, zero-order phase that presumably represents gastric emptying of the solid phase. Most of the infants Cavell studied had little to no residual meal in their stomachs after 2 h, but a few did have large residuals. Cavell concluded that a 2-h fast after a regular meal of milk or formula is not adequate for complete gastric emptying in premature and term infants.

Siegel et al. (39) studied the gastric emptying of two formulas in premature infants. The gastric emptying of the 22-mL/kg meal was independent of meal osmolarity and was biphasic. The initial rapid phase was consistent with a rapid emptying of the liquid part of the meal. After 30 min, Siegel et al. only detected half of the original meal, but all infants required at least 100 min to empty their stomachs.

Signer and Fridrich (40) studied gastric emptying of 50 mL of formula based on cow's milk in infants aged  $\leq 10$  wk. Interestingly, they observed a first-order, exponential, monophasic manner with half-lives ranging from 45 to 141 min in all but 4 of their 28 patients. Four patients had a biphasic pattern with no emptying

in the first half hour, followed by a pattern similar to the other 24 patients. Signer and Fridrich (40) concluded that gastric emptying of formula based on cow's milk is slow in newborns and early infancy based on their study, which used radiolabeling. Gastric emptying in premature infants and newborns is not influenced by osmolality, but small meals do empty at a faster rate (39,41).

Seibert et al. (42) evaluated gastric emptying of cow's milk formula (90–150 mL) in infants and children. They reported that normal gastric emptying values over 1 h was  $48\% \pm 16\%$  in infants and  $51\% \pm 7\%$  in children. Subsequently, Gelfand and Wagner (43) reported that an accurate prediction of the 2-h gastric emptying time can only be obtained by monitoring infants with gastrointestinal reflux for a full 2 h, as the value at 1 h is not an acceptable predictor of the 2-h value.

Billeaud et al. (29) investigated the gastric emptying of several varieties of milk types in term neonates and infants  $\leq 1$  yr of age without gastroesophageal reflux. After 2 h, the gastric emptying of the 110- to 200-mL meal was  $82\% \pm 11\%$  after human milk,  $84\% \pm 21\%$  after whey-hydrolyzed formula,  $74\% \pm 19\%$  after whey-predominant formula,  $61\% \pm 17\%$  after casein-predominant formula, and  $45\% \pm 19\%$  after cow's milk. Human milk and whey-predominant formula emptied faster than casein-predominant formula and cow's milk (29). The increased gastric emptying was attributed to a lower protein content in human and whey-predominant milk.

While investigating variable clear fluid fasts in infants, Splinter et al.<sup>1</sup> noted that 5 of the 35 children who ingested formula on the day of surgery had curd-like substances in their gastric aspirate, whereas none of the 8 breastfed infants had solid material in their gastric aspirate. Andres et al. (45) reported that, in healthy infants, the gastric residual 1 and 2 h after 30 mL of rice cereal is 26% and 7%, respectively. In summary, breast milk empties slightly faster than formula in infants, but both require <2 h to empty completely. The stomach is mostly empty of small volumes of cereal by 2 h.

A few investigators have assessed feeding milk products to neonates and infants immediately before anesthesia. van der Walt et al. (46) studied 62 healthy infants aged <3 mo who ingested breast milk ( $n = 30$ ) or infant formula 3–4 h before scheduled surgery. Only 11 patients had any aspirate: 3 had gastric aspirates >0.4 mL/kg, and of these 3, 2 had the shortest fasting times—160 and 162 min, respectively.

Litman et al. (47) assessed the effect of breast milk ingestion 2 h before anesthesia. They compared 24

<sup>1</sup> Splinter WM, Schaefer JD, Bonn GE. Unlimited clear fluid ingestion by infants up to 2 hours before surgery is safe [abstract]. *Can J Anaesth* 1990;37:S95.

breastfed infants with 46 infants who ingested clear fluids approximately 2 h before surgery. They ceased their study prematurely because a greater than expected number of their breastfed infants had large ( $>1$  mL/kg) gastric residual volumes.

In summary, breast milk empties from the stomach faster than most formulas in infants and both require  $>2$  h to assure complete gastric emptying. The results from van der Walt et al. (46) and Litman et al. (47) would suggest that at least a 3-h fast after breast milk ingestion is indicated. Caution needs to be exercised when applying studies of gastric emptying of formula to one's practice. They can only be applied if the formula studied is similar to that used in one's own practice.

### *Preoperative Solids*

Investigations of the effects of solid food ingested preoperatively by children on gastric contents are unfortunately quite limited. Meakin et al. (48) studied 224 healthy children undergoing elective anesthesia. They studied six groups of patients—55 were in a control group and had a prolonged fast, 34 children ingested 10 mL/kg orange squash 2.1–3.8 h before anesthesia, and another 32 children ingested the orange squash plus two plain biscuits (size not reported) 2.1–3.9 h before anesthesia. The authors reported that the gastric volume was increased in both groups of children who received food 2–4 h before surgery compared with the control group. These results likely occurred because the gastric volume in the control group was unusually low (only 0.25 mL/kg), not because of the ingestion of food. The study patients who ingested clear fluid should have had a nadir gastric fluid volumes by 2 h after ingestion based on normal physiologic emptying plus numerous studies. The authors did assess the presence of solid food in the gastric aspirate, and 13 of the 32 patients who had eaten a biscuit 2–4 h before surgery had identifiable food residue in the gastric aspirate. This study rebukes the argument that a small meal, i.e. two biscuits, 2–4 h before elective anesthesia is acceptable.

There are few investigations pertaining to preoperative ingestion of solids in adult patients. Miller et al. (49) studied 45 adults, 23 of whom ate a light meal on the morning of surgery. They concluded that a mean 3.8-h fast was adequate. Because the chance of a type II error is great in such a small study, their conclusion is questionable. Soreide et al. (50) evaluated the gastric emptying of a light hospital breakfast (one slice of toast, one cup of coffee, and one cup of pulp-free orange juice) by ultrasonography in eight patients. By 210 min, six of eight patients did not have solid particles in their stomach, and by 240 min, all eight patients had emptied the solid particles from their stomach. To allow for a safety buffer, the authors suggested that a 6-h fast after a light breakfast is adequate.

Despite the evidence refuting the safety of brief fasts after the ingestion of solids, the ingestion of a light breakfast on the day of elective surgery that is scheduled in the afternoon is still common practice (51). We agree with Fasting et al.'s (51) speculation that the popularity of this practice occurs because pulmonary aspiration is rare, and if it occurs, it is unlikely to have been altered by the ingestion of small breakfast (50–57).

There are no investigations of the effect of a preoperative regular or large meal on gastric contents in adults or children.

### *Chewing Gum*

Gum chewing and its effect on preoperative residual gastric volume is controversial. There are two conflicting reports on gum chewing by adults. Dubin et al. (58) studied adults who chewed or did not chew sugarless gum up to immediately before the induction of anesthesia and observed no difference in gastric contents. In contrast, Soreide et al. (59) noted that healthy adults who had sugarless chewing gum on the day of surgery and who were nonsmokers had a slight increase in gastric fluid volume:  $30 \pm 19$  vs  $20 \pm 15$  mL. The clinical importance of a mean absolute difference of 10 mL is likely negligible.

### *Clear Liquids*

Liquids empty briskly from the stomach (7). This rate of emptying varies directly with gastric volume and the pressure gradient from the stomach to the duodenum and is altered by the physical properties of the liquid ingested. Liquids empty optimally if the pH is neutral, the solution is isoosmolar, and it does not contain calories (60). For example, 500–700 mL of saline is emptied by the stomach in  $<30$  min (25,26).

*Newborns and Infants.* Several investigators have studied gastric emptying of clear fluids by newborns. Gupta and Brans (61) studied the gastric emptying of 5% glucose water in neonates and reported that gastric emptying improved markedly over the first 24 h and then stabilized. Yu (62) studied gastric emptying of 7 mL/kg 10% dextrose feeds in healthy term and preterm infants and infants with respiratory distress syndrome. Yu noted that infants with respiratory distress syndrome had delayed gastric emptying and that infants in the prone or right lateral position optimally emptied their meal.

The emptying of 22 mL/kg clear fluids in newborns has been studied by Husband et al. (63) and Husband and Husband (64). They reported that the gastric residual 30 min after ingestion of water or a 10% starch solution was similar, i.e., approximately 3–3.5 mL/kg, but remained quite increased at 8–11 mL/kg after a 5%–10% glucose solution. These results are in contrast to reports in adults in which the caloric content of a

food primarily controls gastric emptying. Presumably, the marked increase in serum glucose noted in the newborns who ingested 10% glucose markedly altered gastric emptying. [It is surprising that Husband et al. (63) observed a rapid increase in serum glucose after glucose water ingestion because the infants' capacity for glucose absorption is quite limited compared with adults (65).] From a practical point of view, the studies of Husband et al. (63) and Husband and Husband (64) suggest that, if the last meal offered to a newborn is clear fluid, 10% starch is superior to glucose water.

There are only a few studies of preoperative fluid ingestion by neonates and infants. Litman et al. (47) compared the ingestion of clear fluids or breast milk in infants 2 h before anesthesia. Only 3 of the 46 infants who ingested clear fluids had a gastric residual volume >1 mL/kg. They concluded the ingestion of clear fluids up to 2 h before surgery was safe, although they did not have a control group who underwent a more prolonged fast for comparison.

Splinter et al.<sup>1</sup> studied the ingestion of clear fluids by infants preoperatively. In their study of 150 infants, they did not observe a difference in gastric fluid contents if the infants fasted from clear fluid for 2, 2.5, or 3 h. Based on the above, it is reasonable to conclude that the ingestion of clear fluids by healthy infants up to 2 h before surgery is acceptable.

*Older Children and Adolescents.* Of all the food types ingested preoperatively by children, clear fluids containing carbohydrates are the most common. Moukarzel and Sabri (20) evaluated the effect of such meals on gastric emptying and noted that gastric emptying rates in children are altered by the volume ingested, caloric content, osmolality of the fluid, and the actual sugar (e.g., fructose empties faster than isocaloric glucose or galactose, and maltodextrin or sucrose solutions empty faster than glucose solutions). Increased caloric content and increased osmolality both decrease gastric emptying. In adults, glucose also empties relatively slowly, at approximately one-third the rate, compared with a trisodium citrate solution (66). Clinically, these differences are rarely of relevance.

A substantial number of studies have investigated the ingestion of clear fluids by healthy children before elective surgery. These studies are summarized in Table 1. From these studies that involved approximately a thousand children, a variety of clear fluids, variable ingested volumes (as much as 65 mL/kg), and numerous centers, it can be safely concluded that the ingestion of unlimited clear fluids up to 2 h before surgery is both safe and beneficial (67).

Only one study has specifically addressed the ingestion of clear fluids by adolescents (68). This investigation of 152 adolescents plus numerous investigations of the ingestion of clear fluids before elective adult surgery supports the premise that a 2-h clear fluid fast in adolescents is adequate (69-71).

There are numerous benefits when children ingest fluids before anesthesia, including improved patient and parental satisfaction, increased gastric pH, ingestion of calories, decreased risk of hypoglycemia, decreased lipolysis, and improved fluid homeostasis (1,2,72-74).

## Pathophysiology

### Trauma

Several investigations have assessed the gastric contents of children undergoing emergency surgery after trauma. In a double-blinded study of 58 children undergoing surgery after trauma, Olsson and Hallen (75) noted that preoperative metoclopramide decreased gastric contents, whereas gastric contents were increased by the severity of the injury. More specifically, a fractured femur had greater gastric contents than a fractured wrist ( $P < 0.001$ ). They reported that age did not affect gastric contents and that no time interval between the last meal and time of commencement of anesthesia could be deemed safe. In 1986, Schurizek et al. (76) reported their assessment of the gastric contents of 101 children undergoing emergency surgery. Like Olsson and Hallen (75), they observed greater gastric contents in patients with more severe injuries/illnesses, whereas children with superficial wounds had lesser gastric contents. They reported that patient age altered gastric contents, with children aged 6-10 at greater risk, and there was an inverse relationship between length of preoperative fasting and volume of gastric contents.

Bricker et al. (10) obtained gastric aspirates from 110 children undergoing surgery for trauma. Although they could not find a safe interval to fast patients, aspirates were larger if the fast was brief (4-6 h) or if the patient was injured within 2 h of eating. This study also concurred with two other trauma studies and reported that children with minor injuries had smaller gastric aspirates. Finally, Bricker et al. (10) reported that 5 of the 41 children who claimed to be hungry on arrival in the operating room had solids in their gastric aspirate, and of those 5, 1 had a massive gastric aspirate of 6.8 mL/kg. The results of these studies support the following: after trauma, children's gastric contents will gradually decrease to a nadir, but the length of time required is unknown. The length of time for fast should, if reasonable, also be increased if the injury is severe or if the time from ingestion of food is close to the time of injury.

Lim-Dunham et al. (77) assessed the presence of aspiration pneumonia after the ingestion of 3% oral contrast material in children with trauma undergoing abdominal computed tomographic scans. One patient in their series of 50 consecutive children had demonstrable radiologic evidence of aspiration of the oral

**Table 1.** Clear Fluid Ingestion by Children

Reference	n	Fluid ingested	Length of fast (h)	Gastric volume (mL/kg)
Splinter et al. (108)	80	3 mL/kg apple juice	3	0.24 ± 0.31
Sandhar et al. (109)	88	5 mL/kg	2-3	0.25
Splinter et al. (110)	93	6 and 10 mL/kg apple juice	3	0.66 ± 0.79 & 0.71 ± 767
Splinter et al. (111)	121	Unlimited clear fluids	3	0.34 ± 0.28
Splinter and Schaefer (2)	228	Unlimited clear fluids	2, 2.5 & 3	0.33 ± 0.49
Schreiner et al. (1)	121	Unlimited clear fluids	2	0.44 ± 0.51
Crawford et al. (112)	100	2 mL/kg water	2-6	0.56 ± 0.39
Miller et al. (113)	44	5% dextrose ≤120 mL	3	0.57 ± 0.38

contrast material. The authors did not report any special risk factor for pulmonary aspiration, such as decreased Glasgow Coma Scale score or general anesthesia being present in the patient that aspirated.

### Gastrointestinal Reflux

Infants with gastrointestinal disorders typically have decreased gastric emptying, and pediatric radiologists often assess gastric emptying of children with suspected gastrointestinal disease. Unfortunately, the results of the radiologic investigations of children with gastroesophageal (GE) reflux have been quite variable because of the lack of standardization of test meal and quantitative analyses (78). For example, the value of an assessment of gastric emptying of a meal with radionucleotides will depend on the binding of the nucleotide to the solid and/or liquid component of a meal (79). In some studies, the study meal is the liver from chickens fed radionucleotides, and in another study, the technicium was mixed manually with a meal and was primarily dissolved in the liquid phase.

Heyman (78) concluded that patients with GE reflux have normal gastric emptying of liquids but delayed emptying of solids; this abnormal emptying was not related to severity of reflux symptoms. Jolley et al. (80) agreed with Heyman when they observed normal gastric emptying of clear fluids (apple juice) in 109 children aged 2 wk to 16 yr with GE reflux. Similar results were observed by Euler and Byrne (81), who studied the gastric emptying of water (up to 700 mL) in infants and children.

Andres et al. (19) investigated the gastric emptying of 30 mL of rice cereal plus a 30-mL water meal (120 kcal) in infants with GE reflux. Infants with cholestasis had what could be considered normal residuals (3%–17%) at 120 min, whereas the infants with failure to thrive had 20%–69% residuals at 120 min. Hillmeier et al. (82) observed only a 21% gastric emptying in infants with severe GE reflux 1 h after a meal of 120 mL of cow's milk formula. Lorenzo et al. (83) studied the gastric emptying of milk or a pudding meal by 477 infants and children (age <1 yr) with GE reflux. In the children <3 yr of age, GE reflux did not alter gastric emptying, whereas in children >3 yr of

age, GE reflux was associated with decreased gastric emptying. It seems that GE reflux does not alter gastric emptying of liquids but may alter gastric emptying of solids.

### Other Gastrointestinal Disorders

Relatively few studies address the effect of gastrointestinal disease on gastric emptying. Grill et al. (84) studied children with Crohn's disease and observed normal gastric emptying of fluids, but emptying of solids was prolonged in five of the seven patients who were also malnourished. Ingebo et al. (85) recently reported their investigation of gastric residual volume in children with gastrointestinal disease, such as persistent vomiting, abdominal pain, diarrhea, dysphagia, and poor growth. Unfortunately, this study is rather limited because of design flaws, such as lack of randomization and blinding, and it was nonprospective. The duration of fasting from clear fluids ranged from 0.5 to 24 h and averaged  $6.7 \pm 5.3$  h. The liquid gastric volume ranged from 0 mL/kg to an immense 15 mL/kg, and the large gastric volume was  $0.68 \pm 1.31$  mL/kg. The large SD reflects the propensity toward larger than usual gastric fluid volumes. A few patients were noted to have solid food in the stomach. We cannot agree with their conclusions nor with the accompanying editorial (86) about the safety of fasting recommendations in children with gastrointestinal disease because the residual gastric volumes were relatively large compared with that of fasting elective surgical patients (1,2), but the presence of solid food is generally unacceptable, and the patient's underlying conditions may predispose him or her to active and/or passive regurgitation.

Subsequent to Ingebo et al.'s (85) article, Schwartz et al. (87) evaluated the gastric contents in children presenting for upper endoscopy after a fast of at least 6 h (age <6 mo) or 8 h (age >6 mo) for liquids and solids. Their gastric residual volume was similar to healthy patients for elective surgery, and the authors did not report the presence of solid food in the gastric aspirates. Thus, a 6- to 8-h fast from solids and liquids

seems adequate in children with gastrointestinal disease. The exact duration of fasting will depend on the patient's underlying condition.

### *Co-Morbid Conditions*

There are few investigations of the ingestion of fluids by children with medical illnesses. Nicolson et al. (89) studied 91 children (ASA physical status II-IV) who underwent elective cardiac surgery. Forty-four patients requested and were permitted to ingest unrestricted clear fluids up to 2-3 h before anesthesia. The gastric aspirate was  $0.4 \pm 0.6$  mL/kg in the control group and  $0.6 \pm 0.9$  mL/kg in the study group ( $P = 0.13$ ). This study was designed to detect a 50% change in gastric fluid volume. Had the SD of the results been as predicted, the observed 50% difference between the groups would have been statistically significant. The presence of increased gastric residuals after a brief fast in cardiac patients is not surprising, as children with symptomatic cardiac disease are known to have decreased gastric emptying (90). The implications for risk of aspiration are, however, unknown.

There has been little study of gastric emptying of solids in diseased states. Ishihara et al. (88) investigated the gastric contents of adults with diabetes mellitus and noted that, although none of their control subjects had abnormal gastric contents after at least an 8-h fast (mean 15 h), 6 of 35 diabetics had solid food particles in their gastric aspirate (mean fast 13 h). The presence of food particles was associated with diabetic autonomic neuropathy ( $P < 0.05$ ).

### *Effect of Preoperative Medications*

Preoperative medication may alter gastric contents. Salem et al. (91) compared the effect of no premedication with the combination of glycopyrrolate, pentobarbital, and morphine on gastric contents in children undergoing elective surgery. They noted that the premedicated children had similar or reduced gastric volume and increased gastric pH compared with controls. When diazepam premedication was compared with the combination of pethidine, promethazine, and chlorpromazine, the combination group had reduced gastric contents and increased pH (92).

Gastric contents can be minimized by several type 2 histamine receptor antagonists and gastrokinetic drugs in children (93-95). Manchikanti et al. (93) evaluated the effect of preoperative oral cimetidine and glycopyrrolate in 96 children undergoing elective surgery. They observed that cimetidine and glycopyrrolate each reduced gastric volume and increase gastric pH. Similarly, Goudzoulian et al. (94) observed that preoperative oral cimetidine decreased gastric pH and volume. Of the type 2 histamine receptor antagonists, famotidine seems to be most effective at decreasing

liquid gastric residual volume and increasing gastric pH (95).

When Riva et al. (96) studied the effect of preoperative oral midazolam on gastric contents, they did not observe any alteration in gastric volume and pH. Unlike midazolam, trimeprazine syrup was noted to increase gastric pH of children undergoing anesthesia for elective surgery (48); in contrast, temazepam elixir increased gastric volume (48). Stanley et al. (97) assessed 55 children with an emphasis on the sedative effect of oral transmucosal fentanyl lollipops and a placebo lollipop 30-60 min before anesthesia. They observed that, independent of its fentanyl concentration, the lollipop nearly doubled the volume of the gastric aspirate. This increased gastric residual volume may be due to the physiologic increase in gastric and salivary secretions in response to the ingestion of hyperosmolar candies.

Salbutamol, a commonly used  $\beta$ -adrenoreceptor agonist, is known to decrease gastric emptying, whereas  $\beta$ -antagonists, such as propranolol, are known to increase gastric emptying (98). The clinical relevance of this to pediatric anesthesia is unknown.

There are several reports of the effects of premedication on gastric contents in adults. Diazepam has been shown to increase gastric emptying rate and to enhance gastric motility (99). Maltby et al. (100) reported that premedication with oral diazepam or with IM morphine/atropine did not effect the gastric emptying of 150 mL of water ingested 2 h before surgery. These results were confirmed by Agarwal et al. (101).

### *Effects of New Guidelines*

Several investigators have evaluated the implementation of new fasting guidelines which replaced older guidelines such as NPO after midnight (102). Weaver (103) reported that children scheduled on the morning operating room lists had their median fasting interval decrease from 13.1 h to 4.1 h after they were permitted clear fluids up to 2 h before surgery. Fasting et al. (51) recently reported the impact of a Norwegian national consensus on preoperative fasting. Three interesting results came out of their survey. First, 69% of the departments altered their fasting guidelines in response to the national consensus. Second, in 1996, 7% were noncompliant with the consensus because they reported that they did not permit the ingestion of clear fluids <6 h before anesthesia. Third, and more interesting, 31% of the departments were noncompliant because they allowed <6 h fasting after a light breakfast on the morning of surgery. The Norwegian fasting national consensus guidelines are summarized in Table 2.

In 1998, Emerson et al. (104) reported the results of their survey of pediatric anesthesiologists residing in the

**Table 2.** Norwegian National Consensus Guidelines for Preoperative Fasting in Elective Surgery

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Clear fluids may be taken up to 2 h before the induction of anesthesia.
The mandatory fasting period after solid foods should be 6 h.
Breast milk can be taken up to 4 h before anesthesia.
Oral premedication can be taken with 150 mL of water in adults up to 1 h before anesthesia.
Oral premedication can be taken with 75 mL of water in children up to 1 h before anesthesia.
Chewing gum, candies, and tobacco should be avoided for the last 2 h before anesthesia.

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Elective cesarean section and children are included.  
 Clear fluids are defined as nonparticulate fluids without fat. Non-human milk is defined as solid.  
 The guidelines apply to patients without known delay of gastric emptying.  
 Data taken from Reference 50.

United Kingdom and Ireland. Most of their respondents recommended the following duration of fast for healthy children undergoing elective surgery—neonates: 2 h for clear fluids, 4 h for breast and formula milk; infants: 2 h for clear fluids, 6 h for milk and solids; children: 2 h for clear fluids, 6 h for milk and solids.

Green et al. (105) reported their results of a national survey performed in the United States from 1992 to 1993 on the effect of recent changes in preoperative fasting times. They noted that none of the respondents reported any medical adverse event associated with the institution of more flexible fasting policies.

In 1998, Haas et al. (106) surveyed pediatric anesthesiologists in Germany and observed that, in children <1 yr of age, the clear fluid fast was 2 h for 63% of the respondents, whereas the milk fast was 4 h for 64%. For older children, the clear fluid fast was most commonly 2 h (34%) and the solid fast was most commonly 6 h (68%). The fasting guidelines in several countries as of 1996 have been summarized by Eriksson and Sandin (107).

## Conclusion

Despite our current knowledge, it is not possible to absolutely predict gastric contents. Each patient is different, and healthy patients who have abstained from solid food overnight may, on the day of surgery, vomit gastric contents containing yesterday's dinner. Other patients will become hypoglycemic, dehydrated, and irritable after a prolonged fast.

Future investigations are needed. Most of what needs to be known about clear fluid ingestion has been investigated. Based on numerous investigations of infants, children, adolescents and adults, it is reasonable to conclude that unrestricted clear fluid ingestion by healthy patients up to 2 h before surgery has a more than acceptable risk to benefit ratio. The optimal time to fast after human breast milk and similar foods is

still debatable. A 2-h fast is inadequate, but whether 3, 4, 5 h or more is more appropriate is unknown and warrants investigation. Ideally, these investigations would initially occur in healthy, nonsurgical patients.

Formulas based on cow's milk or similar foods with a high protein content require more time to empty from the stomach than human milk and formulas with whey predominance. How much more they need is not known, but it is likely  $\geq 2$  h a full feeding. Unfortunately, formulas vary from region to region, and the studies that must be performed may have results with limited, territorial applicability.

Studies involving solid food are quite limited. Adult investigations in the non-perioperative setting suggest that full meals require  $>8$  h to empty from the stomach. Alternatively, studies by gastroenterologists and radiologists, plus the experience in many European centers, suggest that a light breakfast is safe if one is undergoing anesthesia in the afternoon. Although this practice is endorsed by the recent ASA taskforce (114), formal evaluation with a generic light meal in children is needed.

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