Queen's UNIVERSITY

DEPARTMENT OF ANESTHESIOLOGY

JOURNAL CLUB

Tuesday March 27, 2018
1800 HOURS

LOCATION:
Pan Chancho Restaurant
44 Princess Street

PRESENTING ARTICLES:
Dr. Gopa Nair & Dr. Matthew Bilbily

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SUGGESTED GUIDELINES FOR CRITICAL APPRAISAL OF PAPERS
ANESTHESIOLOGY JOURNAL CLUB
QUEEN'S UNIVERSITY

Two presenters will be assigned to choose and present summaries of their papers. Ideally the two papers will represent similar topics but contrasting research methodologies. The focus remains on critical appraisal of the research and manuscript, more than on the actual contents of the article. Each presenter will then lead an open discussion about the article, based around the guidelines below. The object is to open up the appraisal to wide discussion involving all participants, who will be expected to contribute pending suspension of bar privileges.

GENERAL

1. Title of paper: Does it seem like an important problem? Does it reflect the purpose/results?
2. Authors, institution and country of origin

INTRODUCTION

1. What is the problem being addressed?
2. What is the current state of knowledge of the problem studied?
3. What is the hypothesis being tested?
4. How does testing the hypothesis help solve the stated problem?

METHODOLOGY

1. Study design:
    a) Clinical trial vs. systematic review/meta-analysis
    b) Prospective vs. retrospective
    c) Observational vs. Experimental
    d) Randomized or not
    e) Blinded or not

2. Population studied:
    a) Human, animal, other
    b) Justification
    c) Control groups: experimental vs. historical
    d) Is the sample size/power calculated, and how?
    e) Is the population similar to your own practice?
    f) Single vs. multi-centre

3. Is the study ethically sound?
    a) Clinical equipoise
    b) Does treatment meet standard of care (esp controls)?
    c) Appropriate consent and institutional ethics approval

4. Exclusions: what groups are excluded and why?

5. Experimental protocol
    a) Is it designed to test the hypothesis?

b) Is it detailed enough to be reproducible?
c) Is the methodology validated?
d) Are the drugs/equipment used detailed?
e) How does the randomization take place?

6. What are the primary endpoints?
7. Is power sufficient to justify secondary endpoints?
8. Is the protocol clinically relevant?
9. Data collection and analysis
10. Statistical analysis: Is it appropriate? Are results

RESULTS

1. Are the groups comparable?
2. Were any subjects/data eliminated?
3. Analyzed by intent to treat?
4. Are adequate details of results provided? - data, graphs, tables

DISCUSSION

1. What is the main conclusion of the study?
2. Do the results support this conclusion?
3. Do the results address the stated purpose/hypothesis of the study?
4. How do the authors explain the results obtained?
5. Are there any alternative interpretations to the data?
6. Are the results clinically as well statistically relevant?
7. How do the results compare with those of previous studies?
8. What do the results add to the existing literature?
9. What are the limitations of the methods or analysis used?
10. What are the unanswered questions for future work?

APPLICABILITY OF THE PAPER

1. Have you learned something important from reading this paper?
2. Will the results of this study alter your clinical practice?
3. Was the food and wine up to the high standards expected by self-respecting anesthesiologists?

Anaesthesia 2018, 73, 304–312 doi:10.1111/anae.14179

Original Article

The effect of pre-operative gastric ultrasound examination on the choice of general anaesthetic induction technique for non-elective paediatric surgery. A prospective cohort study*

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Summary

Ultrasound examination of the gastric antrum is a non-invasive tool that allows reliable estimation of gastric contents. We performed this prospective cohort study in non-elective paediatric surgery to assess whether gastric ultrasound may help to determine the best anaesthetic induction technique, whether rapid sequence or routine. The primary outcome was the reduction of inappropriate induction technique. A pre-operative clinical assessment was performed by the attending anaesthetist who made a provisional plan for induction. Gastric ultrasound was performed in the semirecumbent and right lateral decubitus positions for a qualitative assessment of gastric contents, using a 0–2 grading scale. A final induction plan was made based on this assessment. Immediately after tracheal intubation, gastric contents were suctioned through a multi-orifice nasogastric tube; these were defined as above risk threshold for regurgitation and aspiration if there was clear fluid > 0.8 $ml.kg^{-1}$, and/or the presence of thick fluid and/or solid particles. Gastric ultrasound was feasible in 130 out of 143 (90%) of children, and led to a change in the planned induction technique in 67 patients: 30 from routine to rapid sequence, and 37 from rapid sequence to routine. An appropriate induction technique was therefore performed in 85% of children, vs. 49% planned after pre-operative clinical assessment alone ($p < 0.00001$). Our results suggest that gastric ultrasound is a useful guide to the general anaesthetic induction technique with respect to the risk of pulmonary aspiration, in comparison with pre-operative clinical assessment alone.

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Accepted: 7 November 2017
Keywords: anaesthesia; anaesthesia complications; aspiration; emergency surgery; gastric ultrasound; paediatric; stomach contents
**Presented in part at the annual meeting of the Société Française d'Anesthésie et de Réanimation, Paris, September 2015.*
This article is accompanied by an editorial by Van de Putte and Perlas, Anaesthesia 2018; 73: 274–9, and an article by Arzola et al., Anaesthesia 2018; 73: 295–303.

Introduction

Pulmonary aspiration of gastric contents is one of the most feared complications of general anaesthesia, especially in emergency surgery [1, 2]. This is because there may not have been sufficient fasting time according to standard guidelines, complicated by the possibility of pathophysiological delay in stomach emptying [3, 4].

Identification of patients at risk of aspiration is required in order to choose the most appropriate induction sequence for general anaesthesia [5], classified as either 'classical' rapid sequence induction (preoxygenation, no facemask ventilation, cricoid pressure and neuromuscular blockade using succinylcholine), 'modified' rapid sequence induction (gentle facemask ventilation through cricoid pressure), 'controlled' rapid sequence induction (gentle facemask ventilation, no cricoid pressure and use of non-depolarising neuromuscular blocking agent) [6, 7] or routine induction (no neuromuscular blockade) [4]. The factors that the anaesthetist may consider in order to make the decision include time of the last solid and liquid oral intake, the interval between oral intake and trauma, type of surgery, medications and previous medical history [4].

Ultrasound examination of the antrum is a non-invasive and reliable tool that allows quantitative and qualitative estimates of gastric contents in both adults and children [8–13]. Studies conducted in healthy volunteer children, and in elective fasted children, found that ultrasound examination of the gastric antrum provided useful information on gastric content and volume, and that the Perlas qualitative 0–2 grading scale may be a reliable tool to assess gastric contents [11, 14–16]. We recently used this scale to guide the most appropriate induction technique in infants undergoing pyloromyotomy, avoiding rapid sequence induction in more than 85% of infants with hypertrophic pyloric stenosis when the stomach was totally emptied after suction with a gastric tube [17].

We speculated that pre-operative gastric ultrasound could also be used to choose the most appropriate induction technique in the wider paediatric population admitted for emergency or urgent surgery. To investigate this, we conducted a prospective cohort study in this group that aimed to assess whether the qualitative ultrasound assessment of gastric contents led to appropriate change in the management of general anaesthesia planned according to clinical assessment. A further aim of the study was to assess the performance of the ultrasound qualitative assessment of gastric contents for the diagnosis of gastric fluid content > 0.8 ml.kg^{-1}.

Methods

This prospective observational cohort study received approval from the local ethics committee and was registered in the French database for clinical trials. It was performed in Hôpital Femme Mère Enfant, Bron between November 2014 and May 2015. All children aged between 2 months and 16 years undergoing urgent (operation performed as soon as possible after resuscitation, usually within 24 h) or emergency (operation performed simultaneously with resuscitation, usually within 1 h) surgery [18] under general anaesthesia during the study period were eligible for inclusion, unless there was parental refusal of consent or any contraindication to insertion of a nasogastric tube.

A routine pre-operative consultation was performed by the attending anaesthetist. The anaesthetist determined the presumed status of gastric contents ('no contents'; 'contents present'; 'cannot conclude with confidence') on the basis of the consultation, and made a provisional plan for general anaesthetic induction using either rapid sequence or routine inhalational or intravenous induction. After the consultation, parents were given both verbal and written information about the research study.

The study was carried out when one of the ultrasound operators (ACG, MDQS BC), who all had experience of performing ≥ 50 gastric ultrasounds, was available. On arrival in the anaesthetic room, the child was screened for eligibility for the study, and written consent was obtained from the parent by the attending anaesthetist. The operator, blinded to the results of the clinical assessment, performed the ultrasound using a SonoSite S-Nerve™ (FUJIFILM SonoSite Inc., Bothell, WA, USA) fitted with either a linear high-frequency transducer (probe HFL38, 10–13 MHz) or an abdominal probe (C60 2–5 MHz). A sagittal cross-section of

the antrum was obtained in a plane including the left lobe of the liver and either the aorta or inferior vena cava [11, 16, 19]. All examinations were performed with the patient placed in the 45° semirecumbent and then the right lateral decubitus positions. An 'empty stomach', corresponding to Perlas grade 0, was defined as the absence of any content in both positions (originally supine and right lateral [14]), and 'contents present' was defined by seeing clear fluid in the right lateral decubitus position only (grade 1; Fig. 1), in both positions (grade 2) [14, 20], or by seeing any solid contents or thick fluid, regardless of position.

The attending anaesthetist was then presented with the results of the ultrasound assessment, and was given the opportunity to revise the plan for induction. However, if the ultrasound examination could not be performed or the result was inconclusive, the induction plan remained unchanged.

After induction of anaesthesia and tracheal intubation, a multi-orifice PVC gastric tube (Salem Sump; Covidien, Mansfield, MA, USA) 10–18 Fr, depending on the patient's size, was inserted. Intragastric position was confirmed by stomach auscultation during injection of 30–40 ml air, and by suction of gastric contents. Gastric contents were gently suctioned into a 60-ml syringe by a blinded nurse, while moving the tube backward and forward and massaging the patient's epigastrium. The volume and consistency of the gastric contents were recorded. Stomach contents from gastric tube suction were defined as 'above risk threshold' if there was clear fluid > 0.8 ml.kg^{-1}, thick fluid (fluid with floating macroscopic solid particles) or solid contents [21]. Otherwise, the contents were 'below risk threshold'.

Patient characteristics, duration of fasting duration, pain level assessed using either the FLACC (face, legs, activity, cry, consolability) scale [22] or a visual analogue pain scale (as appropriate), type of surgery, opioid administration, vomiting and gastro-intestinal obstruction were recorded in order to analyse any relationship with the presence of stomach contents.

Statistical analysis was performed using MedCalc® version 12.1.4.0 for Windows (MedCalc Software, Ostend, Belgium). Data were tested for normality of distribution using Shapiro–Wilk's W-test. Incidence data were compared using Fisher's exact test or χ^2 test, as appropriate. For each test, $p < 0.05$ was considered as statistically significant.

Sensitivity, specificity, negative and positive predictive values of conclusive ultrasound examinations to identify stomach contents above the risk threshold were calculated with 95%CI, using the Wilson method with continuity correction. These were also calculated including the results from inconclusive ultrasound examinations [23].

We assumed that the anaesthetic technique chosen after the pre-operative assessment would be inappropriate, taking into account the actual gastric contents, in 30% of children, and that the qualitative ultrasound assessment of gastric contents would reduce the risk of inappropriate induction technique to 15%. According to this hypothesis, the inclusion of 120 children was required, with a significance level of < 0.01 and a power of 0.9. Because of the possibility of some

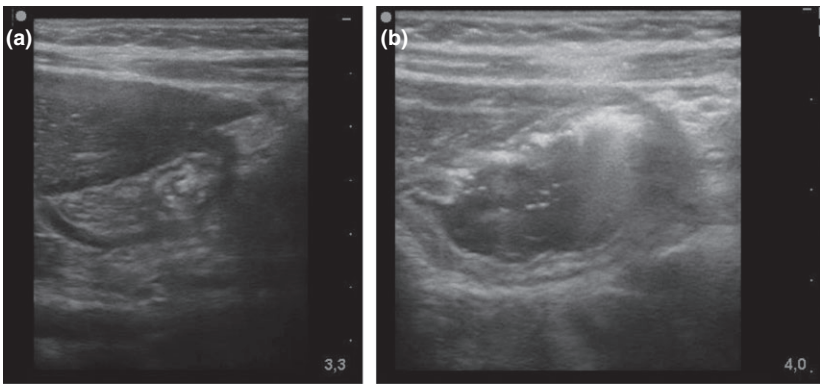

Figure 1 Ultrasound images of a child with Perlas grade 1 stomach contents. (a) empty antrum in the semirecumbent position (b) dilated antrum with anechogenic fluid content in the right lateral decubitus position.

inconclusive ultrasound examinations, we decided to include at least 140 patients.

Results

We recruited 144 patients to the study (Fig. 2). Baseline characteristics are presented in Table 1. The surgery was urgent in 116 (81%) and emergency in 28 (19%) children. The most common gastro-intestinal surgical procedures were appendicectomy (73 (79%)), peritonitis (10 (11%)) and intussusception/volvulus (5 (5%)). Orthopaedic and trauma surgery mainly consisted of fractures of the lower or upper limb (26 (81%)), and urogenital surgery related to ovarian or testicular torsion (12 (86%)).

There was a failure to insert the nasogastric tube in one patient, who was excluded post hoc. Figure 3 shows the study sequence in the remaining 143 children.

Table 3 summarises the anaesthetists' induction plans after clinical examination and then after the ultrasound examination, together with the presence of stomach contents after nasogastric suction. Rapid sequence induction was initially planned for 87 (61%) children.

Qualitative ultrasound assessment of gastric contents was not conclusive in 13 (9%) children, because of inadequate images (seven), gas in the stomach (four) and anxiety and agitation (two). Out of the 73 children with stomach contents present on ultrasound, 26 were grade 1, 38 were grade 2 and nine had thick fluid or solid antral contents seen in both the supine and right lateral decubitus positions.

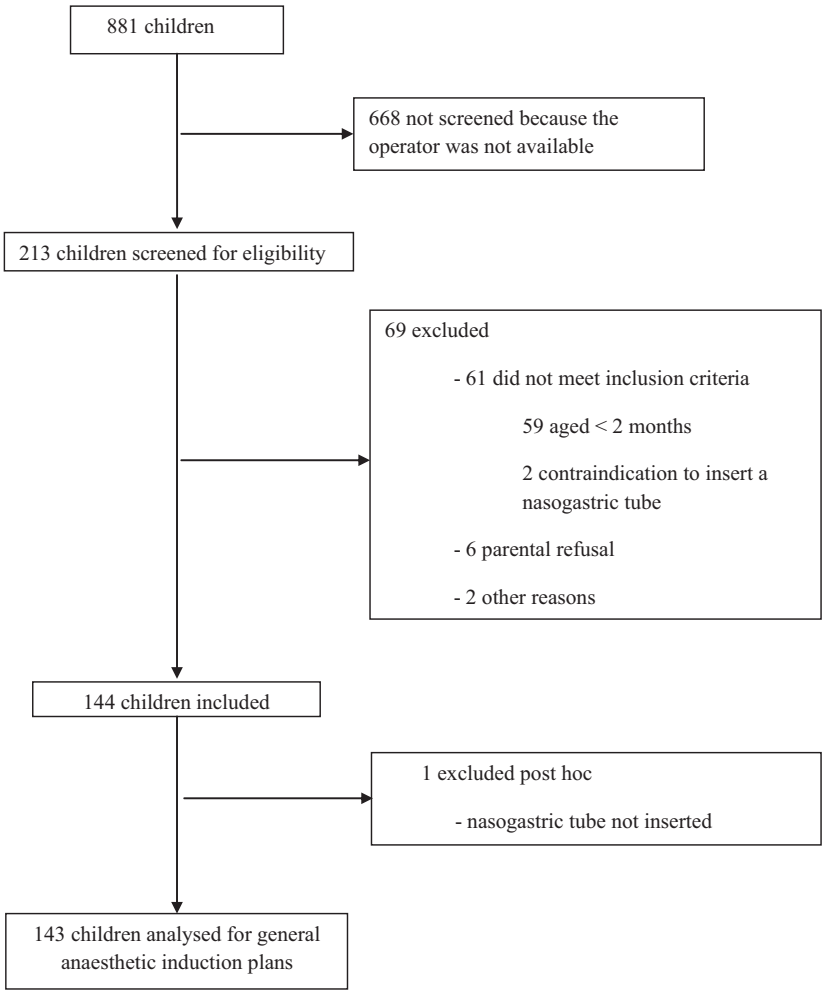

Figure 2 Diagram of recruitment flow to the study.

Table 1 Baseline characteristics of 144 children included in the study. Values are number (proportion), mean (SD) or median (IQR [range]).

Sex; male	89 (62%)
Age; years	10 (5)
Weight; kg	37 (19)
Height; cm	150 (25)
Body mass index; $kg.m^{-2}$	20 (4)
ASA physical status 1	136 (94%)
Fasting duration for solids; h	13 (8–24 [1–96])
Fasting duration for clear fluids; h	12 (5–20 [1–96])
Pre-operative vomiting	67 (47%)
Gastro-intestinal obstruction	9 (6%)
Pre-operative opioid administration	33 (23%)
Types of surgery	
Gastro-intestinal	92 (64%)
Orthopaedic or trauma	32 (22%)
Urogenital	14 (10%)
Other	6 (4%)

The median (IQR [range]) volume suctioned through the nasogastric was 0.55 (0.24–1.10 [0–10.30]) $ml.kg^{-1}$. Seventy-seven (54%) children were below the risk threshold and 66 (46%) were above. Among the 57 children with a grade 0 antrum, 53 (93%) had stomach contents below the risk threshold, whereas 17 out of 26 (65%) children with grade 1, 36 out of 38 (95%) children with grade 2, and 9 out of 9 (100%) children with solid content had stomach contents above the risk threshold.

Definitive ultrasound examination of the antrum allowed diagnosis of stomach contents above the risk threshold with a sensitivity (95%CI) of 94% (84–98%), a specificity of 83% (71–91%), a negative predictive value of 93% (82–98%) and a positive predictive value of 85% (74–92%). This did not change much when we included 13 inconclusive examinations in the calculation; seven who were below the risk threshold had routine induction (true negatives) and six who were below the risk threshold had rapid sequence induction (false positives), giving sensitivity 94% (84–98%), specificity 78% (67–86%), negative predictive value 94% (84–98%) and positive predictive value 78% (68–87%).

Rapid sequence induction was actually performed in 80 (56%) patients. The anaesthetic induction plan changed in 67 (47%) children after ultrasound examination of the antrum was performed: from rapid sequence induction to routine induction in 37 children, and from routine induction to rapid sequence induction in 30 children. Twenty-two (73%) changes in the anaesthetic induction technique from routine to rapid sequence induction were appropriate, whereas 35 (95%) changes from rapid sequence induction to routine induction were appropriate ($p = 0.03$ between both changes).

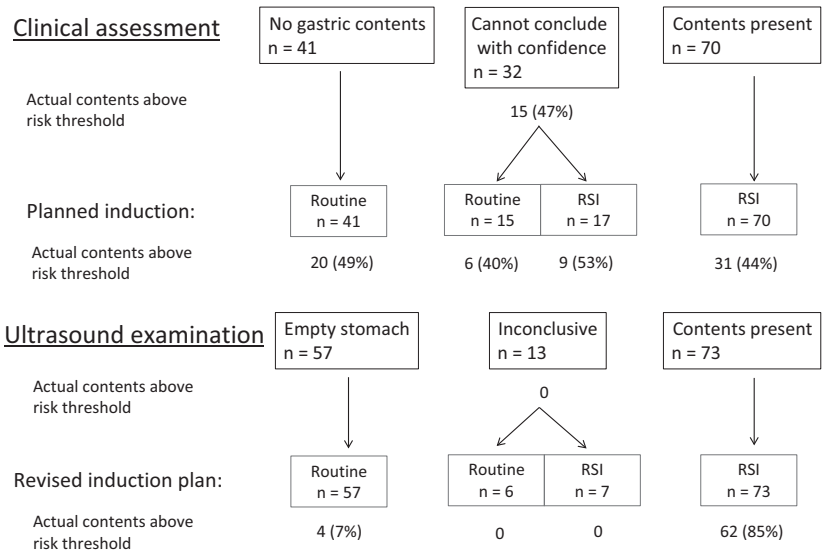

Figure 3 Flow diagram showing the allocation of 143 children to induction type after clinical assessment and after gastric ultrasound, according to gastric contents measured after anaesthetic induction.

Consequently, the rate of appropriate anaesthetic induction technique according to actual gastric contents was significantly improved after ultrasound examination of the antrum vs. after clinical assessment, 121 of 143 (85%) vs. 70 of 143 (49%; $p < 0.00001$; Fig. 3). A similar finding was found using intention-to-treat analysis, 121 of 144 (84%) vs. 71 of 144 (49%; $p < 0.00001$).

Fasting interval for solids < 6 h, acute pre-operative pain, pre-operative vomiting and gastro-intestinal obstruction were significantly associated with the clinical diagnosis of stomach contents present (Table 2). Fasting duration for solids < 6 h, shorter fasting durations for solids as well as liquids, and orthopaedic surgery were more frequent, whereas pre-operative vomiting was less frequent, in patients with stomach contents above the risk threshold (Table 3).

No children in the cohort regurgitated or aspirated gastric contents after induction of anaesthesia.

Discussion

In this prospective cohort study, ultrasound examination of gastric contents was achieved in 90% of patients; this significantly increased the rate of appropriate induction technique, confirmed by subsequent analysis of actual stomach contents, in comparison with pre-operative clinical assessment alone.

Our results demonstrate that pre-operative clinical assessment for the risk of pulmonary aspiration of gastric contents is inaccurate, since this led to an inappropriate anaesthetic induction plan in more than half of patients. Pre-operative vomiting and acute pain were significantly associated with the decision to plan rapid sequence induction by the attending anaesthetist, although these criteria were not significantly associated with the presence of confirmed stomach contents above the risk threshold. A fasting duration for solids below 6 h was the sole criterion for appropriate use of rapid sequence induction after clinical assessment. This result is not surprising, since short fasting duration for solid food is prohibited before both elective and emergency surgery in adults and children [3, 4, 24]. However, this criterion is insufficient to discriminate between the presence or absence of stomach contents above the risk threshold, since fasting duration was more than 6 h in more than two-thirds of children with stomach contents above the risk threshold. Furthermore, the median fasting durations for solids and fluids were long in the present study, compared with those commonly applied before elective surgery. Despite this, around half of children had stomach contents above the risk threshold, as has been reported previously in adult patients undergoing emergency

Table 2 Characteristics of 111 children who had a definitive clinical assessment of the absence or presence of gastric contents. Values are mean (SD), number (proportion) or median (IQR [range]).

	No contents n = 41	Contents present n = 70	p value
Age; years	10.3 (3.8)	9.4 (4.9)	0.33
Body mass index; $kg.m^{-2}$	19 (4.2)	19.6 (4.1)	0.20
ASA physical status			
1	41 (100%)	64 (91.4%)	0.14
2	0 (0%)	6 (8.6%)	
Fasting duration for solids; h	15 (10–23 [6– 72])	12 (6–24 [1–96])	0.29
Fasting duration for solids < 6 h	3 (7.3%)	20 (28.6%)	0.02
Fasting duration for liquids; h	14 (8–21 [2–24])	10 (5–18 [1–96])	0.28
Fasting duration for liquids < 2 h	1 (2.4%)	3 (4.3%)	0.97
Pre-operative vomiting	8 (19.5%)	48 (68.6%)	< 0.0001
Types of surgery			
Gastro-intestinal	28 (68.3%)	47 (67.1%)	0.93
Orthopaedic	9 (22%)	13 (18.6%)	0.83
Urogenital	3 (7.3%)	9 (12.8%)	0.57
Other	1 (2.4%)	1 (1.4%)	0.73
Gastro-intestinal obstruction	0 (0%)	9 (12.8%)	0.04
Acute pain	13 (31.7%)	43 (61.4%)	0.005
Pre-operative opioid administration	8 (19.5%)	16 (22.9%)	0.86

Table 3 Characteristics of 143 children who had gastric contents below or above risk threshold based on nasogastric aspiration. Values are mean (SD), number (proportion) or median (IQR [range]).

	Below risk threshold n = 77	Above risk threshold n = 66	p value
Age; years	8.8 (4.6)	10.8 (4.4)	0.06
Body mass index; $kg.m^{-2}$	18.5 (3.2)	20 (4.3)	0.15
ASA physical status			
1	73 (94.8%)	62 (93.9%)	0.88
2	4 (5.2%)	4 (6.1%)	
Fasting duration for solids; h	16 (12–24 [4–96])	11 (6–19 [1–72])	0.001
Fasting duration for solids < 6 h	8 (10.4%)	19 (28.8%)	0.01
Fasting duration for liquids; h	15 (8–24 [2–96])	7 (5–15 [1–48])	0.0004
Fasting duration for liquids < 2 h	2 (2.6%)	3 (4.5%)	0.86
Pre-operative vomiting	46 (59.7%)	21 (31.8%)	0.0015
Types of surgery			
Gastro-intestinal	64 (83.1%)	28 (42.4%)	<0.0001
Orthopaedic	7 (9.1%)	24 (36.4%)	0.0002
Urogenital surgery	5 (6.5%)	9 (13.6%)	0.25
Other	1 (1.3%)	5 (7.6%)	0.15
Gastro-intestinal obstruction	4 (5.2%)	5 (7.6%)	0.81
Acute pain	37 (48.1%)	33 (50%)	0.95
Pre-operative opioid administration	15 (19.5%)	18 (27.3%)	0.37

surgery [25]. Many factors may affect gastric emptying in the emergency or urgent setting, such as acute pain or stress [26], trauma or bowel obstruction [27], in addition to medical conditions and pre-operative medication.

Conversely, the performance of pre-operative gastric ultrasound for the identification of stomach contents above the risk threshold was high, with a sensitivity of 94% and a specificity of 83%. Including the 13 cases where the ultrasound was inconclusive changes these figures only a little, due to the low rate of such failure. Only the specificity was reduced, as all of these cases were below the risk threshold. This might suggest that an inconclusive ultrasound result is more likely to indicate an empty stomach, but it is outside the scope of the present study to comment further on this aspect. However, there was a roughly equal distribution of false positive and true negative results within these cases of inconclusive ultrasound, which is in line with what might be expected from clinical examination.

The anaesthetist changed their planned induction technique after gastric ultrasound in almost half of the patients studied, both from routine induction to rapid sequence induction and vice-versa. The twin benefits were increasing the number of children who were not exposed to the risk of pulmonary aspiration of gastric contents, a leading cause of mortality related to general anaesthesia [28] and simplifying anaesthesia for those without such risk. In our study, the changes in anaesthetic management were correct in 95% of the 37 changes from rapid sequence induction to routine induction, with only four cases having inappropriate routine induction with stomach contents above the risk threshold.

In our study, ultrasound assessment of gastric contents was based on qualitative analysis, without measurement of the antral cross-sectional area. A risk threshold cut-off value for antral cross-sectional area has been described in adults [9], and mathematical models have been published to predict gastric fluid volume according to antral area in the supine and right lateral decubitus positions in both adults and children [9–11, 17, 20, 29]. However, these models apply only to clear fluid contents and not to thick fluid or to solid gastric contents, they have variable accuracy with R^2 values ranging from 0.57 to 0.73, and they may even contradict each other [30]. More generally, the qualitative assessment of gastric content is particularly appropriate in children, since its interpretation does not depend on patient size and habitus. Learning to perform qualitative ultrasound assessment in adults

is straightforward, requiring 33 examinations to achieve 95% of correct diagnosis between empty, clear fluid and solid gastric content [31], and should be considered by paediatric anaesthetists.

We defined the presence of gastric contents on ultrasound assessment as viewing any solid gastric content, clear fluid content either in the right lateral decubitus only (grade 1) or clear fluid in both right lateral and semirecumbent positions (grade 2) [14]. This allowed significant discrimination between stomach contents below and above the risk threshold, although there were significant differences with regard to the distribution of patients with grade 1 and grade 2 according to their suctioned gastric content. In adults, Perlas et al. reported that grade 2 corresponded to significantly increased gastric fluid volume compared with grade 1 [14, 20], and Spencer et al. also reported that suctioned gastric fluid volumes in children significantly increased along with antral grades [11]. In our study, 95% of children with grade 2 and nearly two-thirds of children with grade 1 had stomach contents above the risk threshold, that is, a fluid volume > 0.8 $ml.kg^{-1}$ on nasogastric suction. Children with a grade-1 examination therefore should not be considered as low-risk patients [9, 32]. Nevertheless, a grade-1 examination did not allow clear discrimination between patients with low or high gastric volume, leading to a probable overestimate of the number of patients at risk. Further studies should be conducted to assess whether it is possible to improve the reliability of the qualitative assessment of gastric contents in children.

One limitation of this study was the use of nasogastric tube suction to estimate gastric contents. Cook-Sather et al. previously reported that suction of gastric contents through a multi-orifice tube removed > 90% of the gastric fluid content in fasting children, and that this technique correlated highly to the volume of clear fluids in the stomach [33]. In our study, gastric suction was performed gently in one position, while moving the tube backward and forward and massaging the epigastrium, using a multi-orifice Salem tube matched to the child's size. Hence, quantification of gastric fluid volume was probably not as precise as in their study. Furthermore, our results are dependent on the definition of a risk threshold for the volume of stomach contents. As there is no clear data as to the critical gastric content that leads to a risk of pulmonary aspiration, we used the same definition that we previously employed in adults [9]; our results would change if another definition was to be used. In this study, children were lying in the semirecumbent position during ultrasound examination of the antrum, as opposed to the supine position as originally described by Perlas et al. [14]. This may have changed our results, as the semirecumbent position tends to cause gastric contents to flow towards the antrum as compared with the supine position.

In conclusion, pre-operative qualitative ultrasound assessment of gastric contents significantly increased the rate of appropriate induction sequence of general anaesthesia in children. This point-of-care tool should be used before general anaesthesia in children admitted for emergency surgery in order to guide the anaesthetist in the choice of the most appropriate induction technique. Further studies are required to assess the impact of this ultrasound-guided strategy on the rate of complications related to pulmonary aspiration in children admitted for emergency surgery.

Acknowledgements

Local Ethics Committee (Comité pour la Protection des Personnes Sud Est III, Groupement Hospitalier Est, Lyon) approval no. 2012-043. Registered in the Agence Nationale de Sécurité du Médicament et des Produits de Santé database for clinical trials, 2012-004206-97. No external funding or competing interests declared.

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Pediatric Anesthesia

Pediatric Anesthesia ISSN 1155-5645

ORIGINAL ARTICLE

Low incidence of pulmonary aspiration in children allowed intake of clear fluids until called to the operating suite

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What is already known

- Today most departments apply the 6-4-2 fasting regime. Previous studies have shown incidence of pulmonary aspiration in pediatric anesthesia to be 1–10 in 10 000.

What this article adds

- With a regimen allowing free clear fluids until called to the operating suite the incidence of pulmonary aspiration was 3 in 10 000.

Implications for translation

- Shortened fasting times may improve the perioperative experience for parents and children and reduce dehydration and hypoglycemia.

Keywords
anesthesia general; pediatrics; fasting; intraoperative complications; respiratory aspiration of gastric contents; incidence

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Section Editor: Britta von Ungern-Sternberg

Accepted 16 March 2015

doi:10.1111/pan.12667

Summary

Background: International guidelines recommend 2 h of clear fluid fasting prior to general anesthesia. The pediatric anesthesia unit of Uppsala University Hospital has been implementing a more liberal fasting regime for more than a decade; thus, children scheduled for elective procedures are allowed to drink clear fluids until called to the operating suite.
Aim: To determine the incidence of perioperative pulmonary aspiration in pediatric patients allowed unlimited intake of clear fluids prior to general anesthesia.
Method: Elective pediatric procedures between January 2008 and December 2013 were examined retrospectively by reviewing anesthesia charts and discharge notes in the electronic medical record system. All notes from the care event and available chest x-rays were examined for cases showing vomiting, regurgitation, and/or aspiration. Pulmonary aspiration was defined as radiological findings consistent with aspiration and/or postoperative symptoms of respiratory distress after vomiting during anesthesia.
Results: Of the 10 015 pediatric anesthetics included, aspiration occurred in three (0.03% or 3 in 10 000) cases. No case required cancellation of the surgical procedure, intensive care or ventilation support, and no deaths attributable to aspiration were found. Pulmonary aspiration was suspected, but not confirmed by radiology or continuing symptoms, in an additional 14 cases.
Conclusion: Shortened fasting times may improve the perioperative experience for parents and children with a low risk of aspiration.

Introduction

Most current guidelines recommend fasting for 6 h for solids, 4 h for breast milk, and 2 h for clear fluids prior to anesthesia (6-4-2 regime) (1,2). At the pediatric anesthesia unit of Uppsala University Hospital, a more liberal fasting regime has been implemented for more than a decade. Thus, children scheduled for elective procedures requiring anesthesia are allowed to drink clear fluids until they are called to the operating room (6-4-0 regime). Otherwise, the hospital follows Scandinavian guidelines with 4 h fasting for breast milk and infant formula and 6 h fasting for nonhuman milk and solids (3). The introduction of this local routine was motivated by the need for diminishing prolonged fasting when rearrangements in the surgical schedule occurred, and the lack of evidence for any benefits of clear fluid fasting. Previously, we had observed several children who were brought to the operating room with signs of dehydration in spite of the 6-4-2 regime.

Aim

The objective of this study was to determine the incidence of pulmonary aspiration associated with general anesthesia in elective procedures, in pediatric patients subjected to a 6-4-0 fasting regime.

Material and methods

After obtaining approval from the local Ethics Committee, a list of all patients undergoing surgery at the pediatric anesthesia unit of Uppsala University Hospital between January 2008 and December 2013 was extracted from the patient data management system (PDMS). All anesthesia charts in the electronic medical record system were reviewed retrospectively. In case of vomiting, regurgitation, and/or aspiration, the discharge note and any available chest x-rays were also examined. In case of suspected aspiration, the anesthesia chart and discharge note were examined by two researchers to decide if an event had occurred. All chest x-rays performed to confirm or exclude pulmonary aspiration were re-examined by a radiologist. Descriptive statistics with mean values, standard deviations, and ranges were used to describe incidences of events.

Definitions

A perioperative pulmonary aspiration event was defined as aspiration of gastric contents occurring during induction of anesthesia, during the procedure, or after extubation in the operating room. In the present study, the aspiration events were subdivided into two groups:

1 Pulmonary aspiration – children vomiting during anesthesia with observations of gastric contents in the airway and/or showing radiological findings consistent with aspiration and/or symptoms of respiratory distress (i.e., reduced saturation, increased respiratory rate, coughing, or wheezing) after surgery.
2 Suspected pulmonary aspiration – children vomiting during anesthesia and showing transient respiratory symptoms such as desaturation or signs as crackles, rales, or obstructive breathing, but without symptoms of respiratory distress (i.e., reduced saturation, increased respiratory rate, coughing, or wheezing), or x-ray findings after surgery.

Anesthesia methods

The anesthesia methods have been fairly uniform at our department during the last decade. We prefer i.v. induction with propofol and fentanyl if a laryngeal mask airway with spontaneous ventilation is planned (the majority of elective cases), alternatively with thiopentone, fentanyl, and atracurium for intubation. Mask induction is used in cases of difficult i.v. access. Intubated children receive an oro-gastric tube, but the stomach is not routinely suctioned in elective cases. Maintenance of anesthesia is with sevoflurane except for oncology procedures, in which a propofol infusion is used (often together with low-dose sevoflurane). Classic deep extubation is not practiced, but laryngeal mask airways are occasionally removed when the patient is still in a deep plane of anesthesia.

Study population

From January 2008 to December 2013, 11 535 elective procedures were identified in the PDMS. Children anesthetized for other procedures than surgery such as radiation therapy or radiological examinations were not included, nor were children scheduled for procedures in the operating rooms (at different locations) serving Ear, Nose, and Throat, Ophthalmology, or Neurosurgery, as these departments still applied the 6-4-2 fasting routine and slightly different anesthesia methods. Exclusion criteria were emergency surgery, and neonates cared for in the neonatal intensive care unit (NICU), as these patients also follow other fasting regimes.

Results

Study population

Fifteen patients were excluded as no anesthesia charts could be found, 105 had had local or regional anesthesia, 526 were NICU patients, and 874 underwent emergency surgery. In all, 10 015 procedures on 9 889 patients were included. Age ranged from 0 to 16 years (mean ± SD; 6.5 ± 5.2). Anesthesia induction was usually intravenous. Inhalational induction was used only when peripheral access was difficult to obtain or when the patient requested it. Patient characteristics are shown in Table 1.

Incidence of pulmonary aspiration

There were three cases of patients aspirating during procedure and showing radiological findings consistent with aspiration postoperatively. In two of these, the child also showed signs of respiratory distress. The three cases were classified as pulmonary aspiration, giving an incidence of 0.03%. All cases of pulmonary aspiration are shown in Table 2.

The first case was a 16-year-old girl admitted for investigation of stomach ache, weight loss, and vomiting. The patient vomited shortly after initiation of the gastroscopy. A gastrointestinal transit time exam later showed a duodenal stenosis, probably due to Crohn's disease. The second case was a 6-year-old girl admitted for urological surgery. At induction, the child vomited and desaturated for a few minutes. The patient did not develop any postoperative symptoms and was discharged the next day. The third case was a healthy 5-year-old boy admitted for ambulatory surgery of a hydrocele. During the procedure, the boy vomited and was intubated. He was observed in the surgical ward for one night and was discharged the next day.

Table 1 Characteristics of patients included in the study

Characteristics	*n*	%
Age		
<1 year	822	8
1–5 years	4314	43
6–12 years	2932	29
13–16 years	1947	19
ASA physical status score		
I	5851	58
II	3016	30
III	734	7
IV	23	0
Unknown	392	4
Induction method		
Intravenous	8707	87
Inhalation	1288	13
Unknown	20	0
Airway management		
Laryngeal mask	5449	54
Intubation	3823	38
Other*	723	7
Unknown	20	0

*Other methods of airway management are, for example, spontaneous breathing via mask, nasal canula, or tracheostoma.

Incidence of suspected pulmonary aspiration

Fourteen patients showed transient symptoms of respiratory distress such as desaturation or rales immediately after vomiting and were hence classified as suspected pulmonary aspiration, giving an incidence of suspected pulmonary aspiration of 0.14%. In these cases, no gastric contents were observed in the trachea, endotracheal tube, or laryngeal mask, and the patients did not show any signs of respiratory distress postoperatively. In the two cases where chest x-ray was performed, no signs of pulmonary aspiration could be seen. In one of the cases, the event led to unanticipated hospital admission in spite of rapid attenuation of the respiratory symptoms. This patient was originally planned as an outpatient but spent one night in hospital for observation. All cases of suspected pulmonary aspiration are shown in Table 3.

Outcome of pulmonary aspiration

None of the cases required intensive care or respiratory support. In the two patients who developed postoperative symptoms, these were limited to 24 h with no subsequent sequelae. No procedures were cancelled due to aspirational events. No mortality was found. No patient had more than one aspirational event. In several cases, when a patient with previously suspected or confirmed pulmonary aspiration was admitted for additional surgery, the anesthetist used cricoid pressure and tracheal intubation to prevent additional events.

Incidence of vomiting

Ninety-eight patients vomited or regurgitated during anesthesia, resulting in an incidence of intraoperative vomiting or regurgitation of 0.98%.

Risk factors for pulmonary aspiration

Neither patient age nor ASA class had significant influence on the incidence of aspiration.

Table 2 Description of aspiration events showing patients characteristics, airway management technique, postoperative symptoms, and radiological findings

Event	Age	ASA class	Time of event	Airway management	Symptoms at event	Postoperative symptoms	Radiological examination	Prolonged stay in hospital (y/n)	Type of surgery
2	16	2	Maintenance	Laryngeal mask	None	Chest pain, subdued breathing, desaturation to 91%	Findings consistent with aspiration	n	Gastroscopy & colonoscopy
6	6	2	Induction		Desaturates to 85%, rales, and rhonchi	None	Findings consistent with aspiration	y	Urological
14	5	1	Induction	Laryngeal mask	None	Fever and rales	Findings consistent with aspiration	y	Urological

All three patients were intubated for the procedure and subsequently treated with antibiotics, but no one needed postoperative ventilatory support or intensive care. All symptoms had diminished the day after surgery without sequelae.

Table 3 Description of suspected aspirational events showing patients characteristics, airway management technique, and symptoms at event

Event	Age	ASA class	Time of event	Airway management	Symptoms at event	Prolonged stay in hospital (y/n)	Type of surgery
1	8	2	Maintenance	Laryngeal mask	Desaturates to 80%, crackles	n	Gastroskopi
3	2	3	Induction			n	Hematological
4	3	2	Maintenance	Laryngeal mask	Desaturates to 80%, obstructive	n	Hematological
5	3	2	Induction		Rales	n	Orthopedic
7	9	1	Maintenance	Intubated	Red fluid in the tube, rales	n	Urological
8	1	1	Induction		Desaturates to 71%, rales	n	Urological
9	2	2	Maintenance	Intubated	Rales	n	Urological
10	3	2	Extubation	Intubated	Rales	n	Gastroscopy
11	4	2	Induction	Laryngeal mask	Desaturation and bilateral rales	n	Hematological
12	1	2	Maintenance	Intubated	Rales	n	Gastroscopy &colonoscopy
13	3	3	Induction	Laryngeal mask	Rales, sat 92–99%	n	Hematological
15	12	1	Maintenance	Laryngeal mask	Desaturates, rales	y	Urological
16	1	1	Induction		Desaturates to 60%, rales dx	n	Urological
17	11	1	Maintenance	Laryngeal mask	Desaturates to 75%.	n	Gastroscopy

None of these patients showed postoperative symptoms from the respiratory system or radiological findings. All events occurring during induction resulted in subsequent intubation.

Discussion

There is an acute, life threatening danger linked to the aspiration of solid matter during anesthesia. Hence, patients need to be fasted long enough for the ventricle to be empty from solids. However, we are not aware of studies providing unequivocal evidence for an optimal fasting time in which the negative effects of fasting are attenuated, while the risk of perioperative pulmonary aspiration is minimized. Gastric emptying of clear fluids in children occurs quickly and previous studies have not been able to detect differences in residual volume when

Table 4 Incidence of pediatric pulmonary aspiration and complications after aspiration

Authors	Time period	Study design	Study size	Aspirational events (incidence)	Need for ventilation support
Olsson *et al.* 1986 (11)	1967–1970, 1975–1983	Retrospective	NR	34 (0.06–0.09%)	NR
Tiret *et al.* 1988 (12)	1978–1982	Prospective	40 240	4 (0.01%)	NR
Borland *et al* 1998 (9)	1988–1993	Retrospective	50 880	52 (0.10%)	4 (7.7%)
Warner *et al.* 1999 (10)	1985–1997	Prospective	56 138	24 (0.04%)	6 (25%)
Murat *et al.* 2004 (8)	2000–2002	Prospective	24 165	10 (0.04%)	NR
Walker (2013) (13)	2010–2011	Prospective	118 371	24 (0.02%)	5 (20.8%)
Present study	2008–2013	Retrospective	10 015	3 (0.03%)	0 (0%)

Summary of five studies of pediatric pulmonary aspiration associated with general anesthesia performed the past decades. NR, not reported.

comparing fasting times (4–7). At the pediatric anesthesia unit of Uppsala University Hospital, the fasting regime is more lenient regarding clear fluids, while the practical rules of no solid food after midnight and 4 h fasting for breast milk and formula are strictly applied (1–3). The main finding of the present study is that this practice did not result in a higher incidence of pulmonary aspiration compared with other published studies.

Incidence and outcome of pulmonary aspiration

Several studies performed in the past years have reported incidences of perioperative pulmonary aspiration in pediatric patients ranging from 1 to 10 in 10 000 (Table 4) (8–13). The reported range is likely secondary to different criteria for the diagnosis of pulmonary aspiration and different definitions for the inclusion of an event as perioperative pulmonary aspiration. In our study, we chose to also include cases where pulmonary aspiration was not proved, but could have taken place, as suspected pulmonary aspiration. In some of the earlier studies, the criteria for diagnosis are not reported (8,11,12). In other studies, patients with only transient symptoms were not included in the analysis. Borland *et al*. (9) defined pulmonary aspiration as visualization of nonpulmonary material in the larynx or trachea by laryngoscopy or bronchoscopy, or the patient had respiratory symptoms and radiographic signs of pulmonary aspiration. Warner *et al*. identified pulmonary aspiration as the presence of bilious secretions or particulate matter in the tracheobronchial tree when examined, or by postoperative chest roentgenogram with signs of aspiration (9,10). This definition was subsequently applied in a recent multicenter survey, in which the overall incidence was 2 in 10 000 (13). Borland found an incidence of aspiration of gastric contents of 4.9 in 10 000. Of these, patients that required intubation for up to 24 h or required bronchial lavage to remove solid pieces (2.9 in 10 000) were considered clinically significant cases of significant aspiration (9). Warner *et al*. found an overall frequency of pulmonary aspiration of gastric contents at 4 in 10 000. Of the 24 children that aspirated, nine developed clinical symptoms, giving an incidence of clinically significant pulmonary aspiration of 1.6 in 10 000 (10).

As pulmonary aspiration is rare, the associated morbidity and mortality is hard to study. When aspiration does occur the consequences are often not as serious as expected. None of the previous studies reported any mortality in the children that aspirated (8–13). In the studies of Warner *et al*. and Borland *et al.,* six patients and four patients required mechanical ventilation, respectively (9,10,13), while Murat *et al*. (8) found one patient that needed postoperative intensive care. Walker (13) found five patients with severe deterioration, all of which needed postoperative ventilation or intensive care. In the present study, we found two clinically significant cases in 10 000 patients, albeit neither of them needed mechanical ventilation or intensive care. Both patients were free from symptoms the day after surgery. The results of several studies thus indicate that clinically significant pulmonary aspiration is a rare event.

Notwithstanding, while differing criteria for pulmonary aspiration make direct comparisons difficult, the lack of severe complications in the present study implies that our reported incidence is at least not underestimated.

Risk factors for pulmonary aspiration

The physiology of fasting and risk factors for perioperative pulmonary aspiration have recently been reviewed by Kelly and Walker (14). Several conditions are associated with a higher risk of pulmonary aspiration, the majority due to delayed gastric emptying. Only a few studies of risk factors for perioperative pulmonary aspiration have been performed in

the pediatric population. A recent prospective multicenter survey reported the presence of at least one risk factor for pulmonary aspiration in 16 of the 24 patients who aspirated (13). Borland *et al.* (9) found no association between fasting duration and risk for pulmonary aspiration. Some earlier studies have shown a statistically significant relationship between ASA physical status and aspiration (9,11). Previous studies have also reported a range in the incidence of pulmonary aspiration in different pediatric age groups, although the results were not conclusive (8,9,11). The current study was not powered to detect differences due to age or ASA physical status, and thus no statistically significant differences could be identified. Of the three cases in the present study, the first did have known risk factors for pulmonary aspiration such as ASA II and gastrointestinal motility disorder. Regardless of fasting regime, it is important to identify patients with risk factors, and adapt the procedure to minimize the risk of pulmonary aspiration.

Incidence of intraoperative vomiting

There is a paucity of studies on the incidence of vomiting *during* general anesthesia (as opposed to postoperative nausea and vomiting) and there is a risk of underestimating the risk due to omitted reporting in retrospective studies. An earlier study reported an incidence of 28–136 in 10 000 (15), which however is in accordance with our results.

Adverse effects of fasting in pediatric patients

Fasting induces catabolism that may increase the harmful effects of surgery. Maekawa *et al.* (16) found higher plasma levels of ketone bodies in children fasting for 4 h compared to the 2-h fasting regime. This indicates that a more lenient fasting regime may lead to a reduced catabolic response. Fasting increases the risk of preoperative dehydration and hypoglycemia, and increases postoperative insulin resistance which may result in hyperglycemia (17). Shortened fasting time for clear liquids is likely to preserve intravascular volume and thus improve hemodynamic conditions and facilitate vascular access. Several studies have shown that children allowed to drink closer to surgery experience less thirst, hunger, and anxiety, show better behavior, and are more comfortable (4,5,18–22). Further research is needed concerning the effect of a free fluid regime on gastric volume and pH. Schmidt *et al.* (23) have recently reported no difference in gastric volume or pH when comparing 1–2 h of fasting for clear fluids.

Benefits from allowing children to drink clear fluids before anesthesia

The risk for prolonged fasting due to rearrangement of the surgical schedule is probably reduced with a 6-4-0 fasting regime, although this remains to be shown in future studies. For practical purposes, the 6-4-2 regime is in reality only possible to apply to the first patients of the morning lists, as subsequent cases can only be given an approximate time point for when to stop drinking clear fluids. In contrast, when the child is allowed to drink right up until he or she is called to the operating room, the estimated time for induction does not have to be set in advance to communicate to ward staff and parents when the absolute fasting period must begin. When changes in the surgical schedule do occur, it is even more important to allow the child to drink clear liquids. Furthermore, when children are permitted to drink clear fluids freely, we feel that it is easier to be rigid in enforcing strict rules for other food and drink, especially solid food (the aspiration of which may lead to serious morbidity and mortality). In our current practice, we actually enforce strict fasting from solid foods from midnight. For instance, we have cancelled the odd teenager who happily admitted staying up until 2 in the morning to prepare for fasting by consuming a teenage-sized hamburger with fries. In spite of the latter case, we believe that compliance to these rules may increase when children and their parents are given something in return, that is, to be able to drink clear fluids while fasting for food.

Limitations

Although the existing recommendations in our hospital have been available for over a decade, one cannot assume that they are strictly adhered to by patients and ward staff. Compliance to the applied fasting routines could not be measured in our study. Some children will inevitably have fasted for 2 h or more for various reasons as indicated by a preliminary survey in our own recovery room showing that many of the children still starve longer times than recommended. In this small subgroup of 52 patients, we found that children allowed free clear fluids fasted 1.7 h in average, compared to 6.2 h in a few children incorrectly instructed to fast for at least 2 h. These results are in concordance with previous studies (24). There is a need for repeated educational programs for ward staff on current fasting routines and it is important that ward staff and anesthesia services convey the same information to patients and parents, to avoid prolonged fasting, regardless of which fasting regime is implemented.

Another limitation of the present study is the difficulty to accurately diagnose aspiration retrospectively. Most aspirations occurring during general anesthesia are silent aspirations with neither symptoms nor sequelae (25). This makes the incidence of perioperative pulmonary aspiration difficult to measure even in prospective studies. Furthermore, it may occasionally be difficult to distinguish symptoms due to aspiration from, for example, coughing and bucking that have other causes.

Pulmonary aspiration is fortunately a rare event in modern anesthesia practice. We performed a power analysis that yielded at least 60 000 subjects to prove equal risks between different fasting routines, although we had sufficient power to be able to detect increased risk in the present study. To detect an increase in incidence from 0.04% to 0.09%, with a 5% significance level and 80% power, a sample size of 9100 patients was required. Moreover, comparing our findings to others has inherent difficulties. Although we used the similar definitions of pulmonary aspiration as Walker (13) and Warner *et al.* (10), we could still identify three cases from Walker's study that we may have classified as suspected pulmonary aspiration, that is, case 4, 15, and 19 (13). Not only do we use slightly different definitions of pulmonary aspiration, but except for one, the former studies were published from 10 up to almost 30 years ago (8–13), with the risk of changing practice influencing the results. For instance, in the last decades, the laryngeal mask airway is commonly used instead of either mask ventilation or endotracheal intubation for a majority of procedures. There are other factors than fasting time that are likely to have an impact on the risk of pulmonary aspiration, such as induction method, airway management technique, and level of experience of the providing anesthetist. The influence of these factors could not be ascertained in the present study due to lack of power.

Finally, the present study was performed in a single institution, in an operating room (OR) setting with trained pediatric anesthesiologists and nurse anesthetists always present. Patients that regurgitated or vomited gastric fluid were immediately suctioned, usually after being turned to the lateral position to minimize the risk of aspiration. The results cannot be extrapolated to a non-OR setting, that is, for sedation in the radiology suite or in the emergency room. In addition, the term 6-4-0 fasting regime may be slightly misleading, as anesthesia induction in our department usually occurs at least 30 min after the child is called to the operating room. With this practice, only a negligible amount of fluid is actually ingested during the last half-hour before induction. Furthermore, the children are allowed to drink clear fluids freely, but not encouraged to drink excessive amounts without being thirsty. Other departments that would like to consider implementing a 6-4-0 fasting regime must take this into account when interpreting our results, and in how the regime is implemented and communicated to patients, parents, and ward staff.

Future perspectives

The lack of observed clinically significant morbidity in the present study and the many advantages associated with avoiding dehydration prior to anesthesia suggests a need for further studies to corroborate our findings in a large prospective trial, and to investigate the distribution of real fasting times and gastric fluid content with very short fasting regimes and the association of dehydration and metabolic derangements with long vs short fasting times.

Conclusion

Allowing children to drink fluids freely until called to the operating room has a low risk of pulmonary aspiration in this single-center retrospective analysis. We found no mortality, and the morbidity was even less than in earlier studies, which suggests that there may be reasons to question the commonly adopted rule of at least 2 h of fasting for clear fluids prior to anesthesia.

Ethical approval

Ethical approval was obtained by the local ethics committee in Uppsala 2013-12-04, registration number 2013/450.

Funding

The study was funded by departmental resources.

Disclosure

The authors report no conflict of interest.

Acknowledgments

The authors gratefully acknowledge Nermin Hadziosmanovic at the Uppsala Clinical Research center for valuable help with statistical analysis and Dragan Bajic of the pediatric radiological department, Uppsala University Hospital for reviewing radiological images.

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