

PAEDIATRICS

Effect of different quantities of a sugared clear fluid on gastric emptying and residual volume in children: a crossover study using magnetic resonance imaging

A. Schmitz^{1*}, C. J. Kellenberger², N. Lochbuehler², M. Fruehauf¹, R. Klaghofer³, H. Fruehauf⁴ and M. Weiss¹

¹ Department of Anaesthesia and ² Department of Diagnostic Imaging, University Children's Hospital, Steinwiesstrasse 75, CH 8032 Zurich, Switzerland

³ Statistics, Division of Psychiatry and Psychotherapy, University Hospital, Zurich, Switzerland

⁴ Division of Gastroenterology and Hepatology, Department of Internal Medicine, Triemli Hospital, Zurich, Switzerland

* Corresponding author. E-mail: achim.schmitz@kispi.uzh.ch

Editor's key points

- Using MRI, this study compares gastric volume and emptying half-life during 1 h after 3 or 7 ml kg⁻¹ sugared clear fluid intake.
- Gastric content volume 1 h after intake of 3 ml kg⁻¹ syrup is significantly smaller than after 7 ml kg⁻¹ and within the range of baseline.
- Emptying half-life is similar for different volumes of ingested liquid with identical caloric density.
- The findings underline the impact of the volumes of ingested liquid on residual gastric volumes in children.

Background. Gastric emptying in the first 2 h after 7 ml kg⁻¹ of sugared clear fluid has recently been investigated in healthy children using magnetic resonance imaging (MRI). This study aims to compare gastric volume and emptying half-life during 1 h after 3 or 7 ml kg⁻¹ sugared clear fluid intake.

Methods. Fourteen healthy volunteer children aged 11.1 (8.2–12.5) yr were investigated prospectively after administration of 3 and 7 ml kg⁻¹ diluted raspberry syrup in a randomized order, after overnight fasting (baseline). Gastric content volume (GCV_w) was assessed with a 1.5 Tesla MRI scanner in a blinded fashion. Data are presented as median (range) and compared using the Wilcoxon test.

Results. Baseline GCV_w was 0.39 (0.04–1.00) and 0.34 (0.07–0.75) before intake of 3 and 7 ml kg⁻¹ syrup, respectively (*P*=0.93). GCV_w was 0.45 (0.04–1.55)/1.33 (0.30–2.60) ml kg⁻¹ 60 min after ingestion of 3/7 ml kg⁻¹ syrup (*P*=0.002). Thus GCV_w had declined to baseline after 3 ml kg⁻¹ (*P*=0.39) but not after 7 ml kg⁻¹ (*P*=0.001) within 60 min. *T*_{1/2} was 20 (10–62)/27 (13–43) min (*P*=0.73) after 3/7 ml kg⁻¹.

Conclusion. In healthy volunteer children, residual GCV_w 1 h after intake of 3 ml kg⁻¹ syrup is significantly smaller than that after 7 ml kg⁻¹ and within the range of baseline.

Keywords: children; fluids, oral; gastric emptying; preoperative fasting

Accepted for publication: 29 November 2011

Existing guidelines recommend 2 h of preoperative fasting for clear fluids, which is a compromise between patient comfort, cooperation, and hydration on the one hand and safety with regard to the risk of pulmonary aspiration of gastric contents on the other hand.^{1–3} Published data indicate that recommended fasting times are often exceeded.^{4–5} This may be because of several reasons, one of which is organizational delay during routine operating programmes. For practical reasons, a 1 h period of fasting or stop of fluid on demand would be desirable.

The rapid emptying of gastric contents after ingestion of sugared clear fluid has recently been shown in healthy children using magnetic resonance imaging (MRI).⁶ Residual gastric content volumes (GCV_w) at the hypothetical time of anaesthesia induction after 2 h were similar to baseline

values after overnight fasting. However, 7 ml kg⁻¹ is a rather large liquid meal volume. Extrapolating these results to smaller ingested liquid meal volumes with identical caloric density suggests that residual gastric volumes may decline to baseline levels within ≤1 h but data to prove this are still required.

Therefore, the objective of the current study is to compare residual GCV_w and gastric emptying half-life 1 h after administration of 3 vs 7 ml kg⁻¹ of a sugared clear liquid meal after overnight fasting in healthy volunteer children.

Methods

This prospective, blinded, randomized crossover trial was performed in healthy volunteer children. It was approved by the

local ethical committee (ref: KEK-ZH-Nr. 2009-0147, amendment 3) and registered with ClinicalTrials.gov (ref: NCT01133691). Inclusion criteria were age between 6 and 14 yr, ASA physical status class I or II and capacity to fast overnight and to lie still for 2–3 min in an MRI scanner. Exclusion criteria were gastrointestinal disease, gastrointestinal functional disturbance, claustrophobia, and any other psychiatric disorders. Children participated after being informed as adequate to their age with informed written parental consent and were rewarded with a gift voucher. All volunteers participated twice within a week under similar conditions and, at the same time, they were instructed to fast from midnight until the liquid nutrient test meal was administered perorally in the morning. The liquid nutrient test meal consisted of either 3 or 7 ml kg⁻¹ clear fluid [noncarbonated commercially available raspberry syrup diluted with tap water, drinking solution with identical caloric density of 135 kJ dl⁻¹ (0.32 kcal ml⁻¹) and carbohydrate concentration 8 g dl⁻¹] in a randomized sequence. The participants had to drink this fluid in <5 min, and no other fluid or food was allowed until the end of the investigation. The times of last meal or fluid in the evening were recorded.

To evaluate gastric volumes, MRI was performed after overnight fasting about 30 min before syrup ingestion ('baseline'), immediately after syrup ingestion ('0 min'), and exactly 30 and 60 min thereafter ('30 min', '60 min'). A 1.5 Tesla system (Signa Twinspeed HDxt, GE Medical Systems, Milwaukee, WI, USA) with an eight-channel, eight-element phased array coil, which covers the entire stomach, was used for acquisition of axial 5 mm slices as previously described.⁶ Random string codes were used to identify the MRI scans and allow for blinded evaluation, which was performed by one investigator on a workstation with standard post-processing software under supervision by an expert radiologist. Gastric volumes were determined by tracing manually gastric fluid or solid content with bright signal and gastric air with dark signal on every slice. The respective areas were then added and multiplied with slice thickness to obtain absolute gastric content volume (GCV) and gastric air volume (GAV). GCV and GAV were divided by body weight to calculate the body weight-corrected volumes (GCV_w, GAV_w), with the body weight-corrected total gastric volume (TGV_w) as sum.

The study was powered to show a difference of 0.65 ml kg⁻¹ in GCV_w (SD 0.85) measured 60 min after ingestion of between 3 and 7 ml kg⁻¹ syrup with a two-sided α of 0.05 and a power of 0.8 in a crossover design, based on the results of previous examinations⁶ and assuming a gastric emptying half-life of 30 min.

Data are presented as median (range) unless indicated otherwise. The Wilcoxon test was used to compare volumes pair-wise, considering a two-tailed *P*-value of <0.05 to designate statistical significance. Pearson's *R* was calculated for intra-individual correlation of GCV_w and overnight fasting times. Assuming an exponential (EXP) time course of GCV_w after fluid intake, half-life, $T_{1/2}$, was obtained for each individual gastric contents emptying curve and for

the decline of mean/median GCV_w values. $T_{1/2}$ was calculated as $T_{1/2} = \text{LN}(0.5) B^{-1}$, with *B* as non-standardized regression coefficient from simple linear regression of the logarithms of GCV_w values and time. Microsoft Office Excel 2003 (Microsoft Corporation, Redmond, WA, USA) and SPSS Statistics 17.0 (SPSS Inc., Chicago, IL, USA) were used for data analysis.

Results

Fourteen volunteer school age children (for characteristics, see Table 1) participated in this study and completed all scheduled examinations, in total 112 MRI scans, without any adverse events or delays. Duration of overnight fasting from last food and fluid ingestion until baseline examination was similar on both occasions [12.3 (10.3–14.3) h/12.4 (10.5–14.1) h, *P*=0.26, and 11.4 (9.5–13.8) h/11.7 (9.9–14.1) h, *P*=0.13, respectively, for 3/7 ml kg⁻¹ group) and correlated intra-individually (*R*=0.61, *P*=0.02, and *R*=0.63, *P*=0.02).

GCV_w and TGV_w values for both occasions are compared in Table 2 (the corresponding parametric values may be found in the Supplementary material, Table S1). Baseline GCV_w values were similar (*P*=0.93) but showed no significant

Table 1 Characteristics of volunteering children (overall: *n*=14; female: *n*=3; male: *n*=11). *According to '2000 CDC Growth Charts for the United States: Method and development' (<http://iea.de/perz/index.htm>). †BMI, weight height⁻²

Age	11.1 (8.2–12.5) yr
Weight	37 (23–50) kg
Percentile of weight*	51 (4–95)
Height	144 (129–157) cm
Percentile of height*	51 (15–97)
Body mass index (BMI) [†]	17.8 (13.8–21.1) kg m ⁻²

Table 2 Comparison of median (range) of body weight corrected gastric content/total gastric volumes (GCV_w/TGV_w) and gastric emptying half-lives before ('baseline') and after either 3 or 7 ml kg⁻¹ raspberry syrup. *Wilcoxon test

	3 ml kg ⁻¹ syrup	7 ml kg ⁻¹ syrup	<i>P</i> *
Body weight-corrected gastric fluid volume (GCV _w) (ml kg ⁻¹)			
Baseline	0.39 (0.04–1.00)	0.34 (0.07–0.75)	0.93
0 min	3.19 (2.11–4.09)	7.08 (5.81–8.11)	0.001
30 min	1.02 (0.13–1.68)	2.80 (0.86–3.92)	0.001
60 min	0.45 (0.04–1.55)	1.33 (0.30–2.60)	0.002
Body weight-corrected total gastric volume (TGV _w) (ml kg ⁻¹)			
Baseline	1.01 (0.40–3.23)	1.14 (0.30–2.03)	0.25
0 min	4.47 (2.85–7.15)	8.34 (7.06–12.93)	0.001
30 min	1.48 (0.88–5.41)	3.56 (1.28–9.49)	0.001
60 min	1.23 (0.08–2.69)	2.12 (0.61–7.33)	0.005
Gastric emptying half-life $T_{1/2}$ (min)			
	20 (10–62)	27 (13–43)	0.73

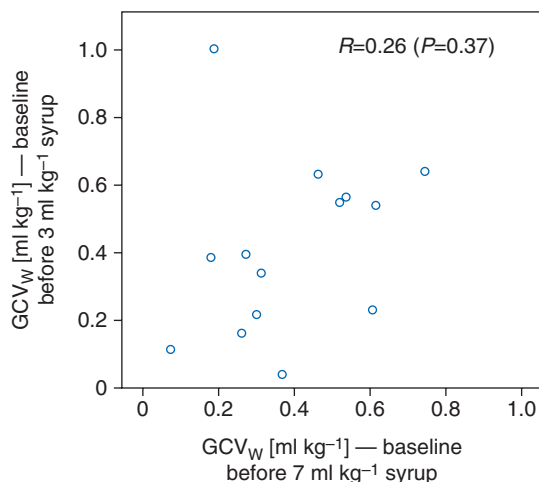


Fig 1 Scatter plot and intra-individual correlation of baseline body weight corrected gastric content volumes (GCV_w) after overnight fasting on 2 different days.

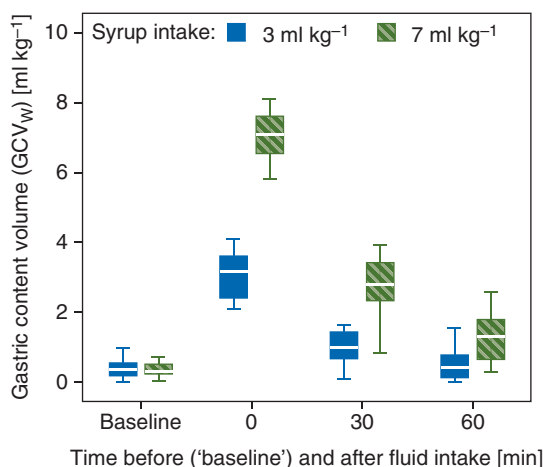


Fig 2 Box plot of body weight corrected gastric content volume (GCV_w) before ('baseline') and after clear liquid meal intake, comparing 3 and 7 ml kg^{-1} raspberry syrup.

intra-individual correlation (Fig. 1). Gastric emptying after ingestion of the liquid test meals is illustrated in Figure 2. After 60 min, GCV_w was still significantly smaller for 3 ml kg^{-1} when compared with 7 ml kg^{-1} ingested liquid volume. GCV_w had also declined into the range of baseline GCV_w after the 3 ml kg^{-1} liquid test meal volume (no difference between GCV_w at baseline and after 60 min, $P=0.39$) whereas 60 min after 7 ml kg^{-1} syrup intake, GCV_w was still significantly higher than the corresponding baseline value ($P=0.001$).

The gastric emptying half-lives calculated with mean and median GCV_w values were 23.9 min and 21.0 min,

respectively, after 3 ml kg^{-1} liquid meal test volume, and with both mean and median GCV_w values 24.7 min after 7 ml kg^{-1} . The individual $T_{1/2}$ showed large variation and did not differ significantly between both liquid test meal volumes (Table 2).

The changes of TGV_w followed those of GCV_w (Table 2).

Discussion

The main finding of this pilot study was that the volume of residual gastric contents declined to baseline within 1 h after ingestion of the smaller liquid test meal volume of 3 ml kg^{-1} . GCV_w values were significantly higher after 7 than after 3 ml kg^{-1} ingested liquid volume 60 min after intake. The data obtained in this study group after ingestion of 7 ml kg^{-1} are basically in accordance with and confirm those previously obtained and published.⁶

It is highly desirable and of clinical relevance to achieve safe gastric residual volumes within 1 h after fluid ingestion. Prolonged preoperative fasting times occur in spite of liberal fasting rules (e.g. ASA guidelines),³ which are related to organizational delays, lack of fluid administration by parents, or operation schedules that optimize utilization of operating theatre capacity rather than patient care. Preoperative timing and preparation could be considerably facilitated by reducing clear fluid fasting time to 1 h. The current practice of preoperative prescription could consecutively be replaced by a 'stop of fluid on demand' strategy.

The study findings underline the impact of the volumes of ingested liquid on residual gastric volumes, which have been used as a surrogate for the risk of pulmonary aspiration during anaesthesia induction.¹ The so-called risk volumes have been defined previously but of course other factors may be relevant⁷ and the value of the gastric volume determination has been questioned.⁸ Nevertheless, the current study indicates that it may be possible to choose drinking volumes reasonable for children's well-being and small enough to allow for gastric emptying to baseline values within 1 h. Although we do not know the 'real' risk volume for pulmonary aspiration, gastric volumes after overnight fasting and thus similar residual volumes after gastric fluid emptying may probably be considered as safe.

This study also showed that half-life of gastric emptying was similar after 3 and 7 ml kg^{-1} ingested liquid volume. Previous investigations in adults demonstrated different emptying rates for different fluids, with caloric load,⁹ carbonation and carbohydrate levels,¹⁰ and nutrient composition¹¹ as determining factors. Additional factors may be subject of future studies, such as the influence of solid food, perioperative drugs, preoperative stress, trauma, or pain on gastric emptying rate.

MRI has been shown to be a reliable method for assessment of gastric content and emptying.^{5 12 13} While the current results are consistent with prior-reported baseline gastric contents volumes in healthy volunteer children, measurement in sedated children undergoing clinically indicated abdominal MRI have shown larger gastric residual volumes even after prolonged fasting.⁵

Thus, the presented preclinical results may be interpreted cautiously with regard to their application in clinical practice: only healthy school age children were investigated because a high degree of cooperation was required to perform the MRI measurements. The participants were not anaesthetized or undergoing any invasive procedure and received no medication whereas clinical patients may be stressed in the pre-anaesthetic period, suffer from pain and receive various perioperative drugs. Furthermore, the calculated half-lives should be regarded as approximation. A constant emptying rate was assumed to estimate half-life, although an exponential function may have limitations especially in the early postprandial phase¹³; however, the analysis of this early phase is not possible with our data because of 30 min intervals between subsequent measurements and because minor variations in drinking velocity cannot be excluded.

In conclusion, residual gastric content volume 1 h after ingestion of a sugared clear fluid depends on the amount of liquid volume ingested. In healthy volunteer children, GCV_w 60 min after intake of 3 ml kg⁻¹ syrup is significantly smaller than after 7 ml kg⁻¹ and within the range of baseline after overnight fasting. Emptying half-life is similar for different volumes of ingested liquid with identical caloric density.

Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

Acknowledgements

We would like to thank Mrs M. Studhalter, MRI technician, for her dedicated support during MRI assessment and all the volunteering children and their parents for participating.

Declaration of interest

None declared.

Funding

Departmental resources.

References

- 1 Cook-Sather SD, Litman RS. Modern fasting guidelines in children. *Best Pract Res Clin Anaesthesiol* 2006; **20**: 471–81

- 2 Brady M, Kinn S, Ness V, O'Rourke K, Randhawa N, Stuart P. Preoperative fasting for preventing perioperative complications in children. *Cochrane Database Syst Rev* 2009; CD005285
- 3 Santhosh J. Practice guidelines for preoperative fasting and the use of pharmacologic agents to reduce the risk of pulmonary aspiration: application to healthy patients undergoing elective procedures: an updated report by the American Society of Anesthesiologists Committee on Standards and Practice Parameters. *Anesthesiology* 2011; **114**: 495–511
- 4 Engelhardt T, Wilson G, Horne L, Weiss M, Schmitz A. Are you hungry? Are you thirsty? - fasting times in elective outpatient pediatric patients. *Paediatr Anaesth* 2011; **21**: 964–8
- 5 Schmitz A, Kellenberger CJ, Neuhaus D, et al. Fasting times and gastric contents volume in children undergoing deep propofol sedation – an assessment using magnetic resonance imaging. *Paediatr Anaesth* 2011; **21**: 685–90
- 6 Schmitz A, Kellenberger CJ, Liamlahi R, Studhalter M, Weiss M. Gastric emptying after overnight fasting and clear fluid intake: a prospective investigation using serial magnetic resonance imaging in healthy children. *Br J Anaesth* 2011; **107**: 425–9
- 7 Bouvet L, Mazoit JX, Chassard D, Allaouchiche B, Boselli E, Benhamou D. Clinical assessment of the ultrasonographic measurement of antral area for estimating preoperative gastric content and volume. *Anesthesiology* 2011; **114**: 1086–92
- 8 Schreiner MS. Gastric fluid volume: is it really a risk factor for pulmonary aspiration? *Anesth Analg* 1998; **87**: 754–6
- 9 Kwiatek MA, Menne D, Steingoetter A, et al. Effect of meal volume and calorie load on postprandial gastric function and emptying: studies under physiological conditions by combined fiber-optic pressure measurement and MRI. *Am J Physiol Gastrointest Liver Physiol* 2009; **297**: G894–901
- 10 Ploutz-Snyder L, Foley J, Ploutz-Snyder R, Kanaley J, Sagendorf K, Meyer R. Gastric gas and fluid emptying assessed by magnetic resonance imaging. *Eur J Appl Physiol Occup Physiol* 1999; **79**: 212–20
- 11 Lobo DN, Hendry PO, Rodrigues G, et al. Gastric emptying of three liquid oral preoperative metabolic preconditioning regimens measured by magnetic resonance imaging in healthy adult volunteers: a randomised double-blind, crossover study. *Clin Nutr* 2009; **28**: 636–41
- 12 Fruehauf H, Goetze O, Steingoetter A, et al. Intersubject and intrasubject variability of gastric volumes in response to isocaloric liquid meals in functional dyspepsia and health. *Neurogastroenterol Motil* 2007; **19**: 553–61
- 13 Fruehauf H, Menne D, Kwiatek MA, et al. Inter-observer reproducibility and analysis of gastric volume measurements and gastric emptying assessed with magnetic resonance imaging. *Neurogastroenterol Motil* 2011; **23**: 854–61