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Gastric emptying after overnight fasting and clear fluid intake: a prospective investigation using serial magnetic resonance imaging in healthy children†

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Editor's key points

- There are few data on residual gastric volumes in fasting children.
- This study estimated gastric air and fluid volumes for up to 120 min after ingestion of 7 ml kg^{-1} clear fluids.
- Fasting gastric volumes were greater than previous studies.
- Median half time for gastric emptying was <30 min, but with large inter-individual variations.
- These data support the existing guidelines of 2 h fluid fast before elective surgery.

Background. Current guidelines recommend preoperative fasting of 2 h for clear fluids, which is often exceeded in routine clinical practice. Existing data on residual gastric volumes in children do not consider fluid intake within <2 h and rely on the aspiration of gastric contents via a gastric tube. This study evaluated the emptying of clear fluids from the stomach using magnetic resonance imaging (MRI).

Methods. Healthy volunteers aged 6–14 years were asked to fast overnight. MRI scans to assess gastric volumes were obtained before and immediately after drinking 7 ml kg^{-1} of diluted raspberry syrup and then every 30 min up to 120 min. Volumes were determined by a blinded investigator and indexed gastric fluid/air volumes (GFV_w/GAV_w) and half-life ($t_{1/2}$) of GFV_w course after clear fluid intake were calculated.

Results. Sixteen children, median age 9.2 (range 6.4–12.8) years, were investigated. Median (range) GFV_w was 0.62 (0.15–0.97) ml kg^{-1} before and 6.68 (4.77–7.78) ml kg^{-1} immediately after fluid intake, and 2.92 (0.43–5.04), 1.27 (0.28–3.62), 0.42 (0.07–2.49), and 0.32 (0.04–1.13) ml kg^{-1} 30, 60, 90, and 120 min thereafter. Median GFV_w declined exponentially ($t_{1/2}$=26.1 min). Median individual $t_{1/2}$ was 23.6 (range 17.9–47.8) min. GAV_w showed considerable intra- and inter-individual variation.

Conclusions. In healthy school children, gastric emptying after ingestion of clear fluid occurs with a median half-life time of <30 min but with considerable inter-individual variation.

Keywords: age groups, child; diagnostic imaging, magnetic resonance imaging; diet, fasting diet; preoperative period; surgical procedures, operative; upper gastrointestinal tract, stomach

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Short fasting times in children are appropriate to improve hydration, patient comfort, and cooperation at time of induction of anaesthesia. Established liberal fasting guidelines, prescribing minimal pre-anaesthetic fasting of 2 h for clear fluids,[1] are often exceeded in clinical routine.[2–4]

Magnetic resonance imaging (MRI) produces high-resolution images that allow discrimination between gastric wall, air, and fluid contents. *In vitro* measurements show excellent correlation with phantom volumes.[5] MRI is non-invasive, investigator independent, and reproducible, and allows volumetric assessment of organs without geometrical assumptions. In adults, MRI has been applied to examine gastric volume and emptying[5–11] and in a preoperative fasting context to measure gastric emptying after carbohydrate drinks.[12]

However, most investigations in children rely on aspiration via an oro- or nasogastric tube to determine gastric volume.[13] It has been suggested that this technique might underestimate true gastric contents volume.[14] Moreover, aspiration is limited to fluid so that intragastric air volume has not been considered. So far, published data in children do not include gastric residual volumes within <2 h after drinking clear fluids, and the time course in individual subjects is ignored because repetitive volume measurements are lacking.[13]

The aim of this study was to investigate by means of MRI gastric contents and air volumes and the time course of gastric emptying in healthy children after overnight fasting and ingestion of a defined amount of standardized clear fluid.

†Presented in part at the 2010 annual meeting of the Swiss Society of Anaesthesia and Resuscitation (SGAR).

Preliminary results were presented at the annual meeting 2010 of the Swiss Society of Anaesthesia and Resuscitation (SGAR).[15]

Methods

The study was approved by the local ethics committee (ref: KEK-ZH-Nr. 2009-0147) and registered with ClinicalTrials.gov (ref: NCT01133691). Flyers with general announcement of this study were addressed to potential participants by friends, colleagues, relatives, and their children. Approximately 60 flyers were distributed, and ∼40 parents/children were informed comprehensively. Sixteen healthy children volunteered with written informed consent of their parents, none retracted. Children were informed in details as adequate to their age and rewarded for undertaking the study with a symbolical gift voucher (book, music, or sports store) to the value of SFr 50.

Inclusion criteria were age 6–14 years, ASA physical status class I or II, and the absence of any gastrointestinal disease or functional disturbances. Children without capacity to participate after overnight fasting or who would not keep immobile for 2 to 3 min in an MRI scanner, or suffered from claustrophobia or any other psychiatric disorder were excluded.

Children were not allowed to drink or eat after midnight. After a first MRI to assess residual gastric volumes, children received 7 ml kg^{-1} diluted raspberry syrup to be drunk within 5 min. This clear and non-carbonated liquid was prepared in a standardized manner, using commercially available raspberry syrup and drinking water (energy content 135 kJ and carbohydrate concentration 8 g per 100 ml drinking solution). Further, MRI scans were obtained immediately after fluid intake and subsequently after 30, 60, 90, and 120 min.

All MRI scans were performed on a 1.5 Tesla system (Signa Twinspeed HDxt, GE Medical Systems, Milwaukee, Wisconsin, USA) using an 8-channel, 8-element phased array coil covering the entire stomach. After a coronal localizer, contiguous axial steady-state free precession images (FIESTA) were acquired in a single breath-hold of 20 s with the following imaging parameters: flip angle 45°, repetition time 2.7 ms, echo time 1.1 ms, 0.75 NEX, bandwidth 125 kHz, matrix 160×256, field of view 35×25.5 cm^2, slice thickness 5 mm.

Random string codes were used to identify all MRI scans and allow for blinded evaluation. On a workstation with standard postprocessing software, fluid contents with bright signal as well as gastric air and other gas with dark signal were traced manually on every slice by one investigator, supervised by an expert radiologist. Gastric fluid volume (GFV) and gastric air volume (GAV) were calculated by multiplying measured areas with slice thickness and then adding all respective slice volumes. To obtain indexed volumes (GFV_w, GAV_w), GFV and GAV were divided by body weight.

An exponential (EXP) time course of GFV_w after fluid intake was assumed in case of linear correlation between logarithms (LN) of GFV_w and fasting time. Half-life $t_{1/2}$ of individual and medium GFV_w reduction were obtained as $t_{1/2}$=LN(0.5) B^{-1}, with B as non-standardized regression coefficient from simple linear regression. Median GFV_w values after fluid intake were also fitted into an exponential function using special curve fitting software (IDL 7.1, ITT Visual Information Solutions, Boulder, CO, USA). Regression coefficients (Pearson) between individual $t_{1/2}$ as well as gastric volumes and probable confounders were determined. The Wilcoxon test was used to compare volumes pair-wise, considering a two-tailed P-value <0.05 to designate statistical significance. Data are presented as median (range) unlessindicated otherwise. 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

Ninety-six MRI scans with median GFV 33 (range 1–312) ml and GAV 33 (3–223) ml were acquired in 16 volunteers (Tables 1 and 2).

Inter-individual variation in GFV_w increased after drinking (Fig. 1A and C). Up to 1 h after drinking the syrup, GFV_w had declined to <50% of the corresponding maximum measured GFV_w in 15 of 16 children (94%), and GFV_w was <2 or <1 ml kg^{-1} in 14 or 7 out of 16 children (88 or 44%), respectively (Fig. 2). After 90 and 120 min, GFV_w was less than the initial value after overnight fasting in 10 of 16 participants (63%). After 120 min, median GFV_w did not differ significantly

Table 1 Characteristics of volunteering children (overall: n=16; female: n=6; male: n=10) presented as median (range). *According to '2000 CDC Growth Charts for the United States: Method and development' (http://iea.de/perz/index.htm). [§]BMI, body mass index calculated as weight (kg) height^{-2} (m)

Age (years)	9.2 (6.4–12.8)
Weight (kg)	31.8 (21.6–40.7)
Percentile of weight*	44 (6–85)
Height (cm)	140 (120–161)
Percentile of height*	54 (16–100)
BMI[§] (kg m^{-2})	15.7 (14.1–19.3)

Table 2 Body weight corrected gastric fluid/air volume (GFV_w/GAV_w) after overnight fasting/before fluid intake ('Pre') and subsequently after drinking 7 ml kg^{-1} raspberry syrup (immediately, then every 30 min). Data presented as median (range)

	GFV_w (ml kg^{-1})	GAV_w (ml kg^{-1})
Pre	0.62 (0.15–0.97)	1.33 (0.20–5.30)
0–5 min	6.68 (4.77–7.78)	1.82 (0.12–6.25)
30 min	2.92 (0.43–5.04)	2.03 (0.38–7.28)
60 min	1.27 (0.28–3.62)	1.60 (0.25–6.12)
90 min	0.42 (0.07–2.49)	0.93 (0.18–6.44)
120 min	0.32 (0.04–1.13)	0.58 (0.13–1.98)

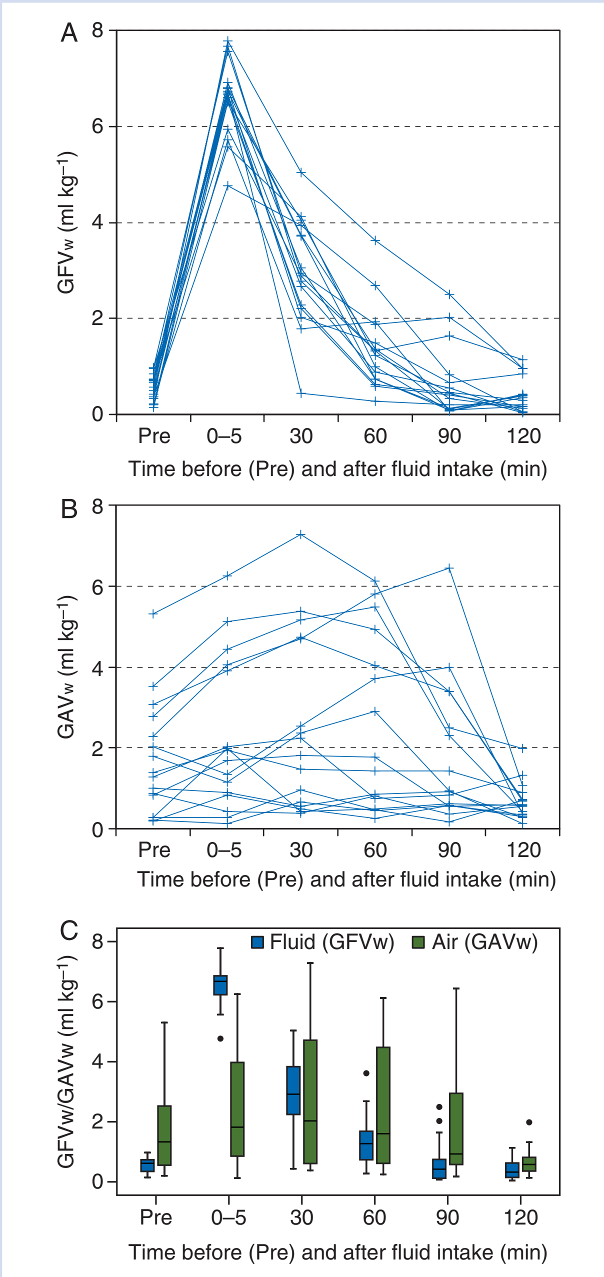

Fig 1 Individual time courses of body weight corrected gastric fluid volume (GFV_w) (A), body weight corrected air volume (GAV_w) (B), and corresponding box plot (C): after overnight fasting/before fluid intake ('Pre') and subsequently after drinking 7 ml kg^{-1} raspberry syrup (immediately, then every 30 min).

from the initial value after overnight fasting (P=0.096) and no case was >2 ml kg^{-1}.

Median values of GFV_w declined exponentially after ingestion of syrup, as illustrated in Figure 1C ($t_{1/2}$=26.1 min, R=−0.988, P<0.01). With IDL curve fitting software, a similar half-life time was calculated ($t_{1/2}$=24.8 min; $Y=A$ EXP(B X)+C with A=6.68, B=−0.028, C=0.004). Not all the individual GFV_w curves showed perfect exponential decline

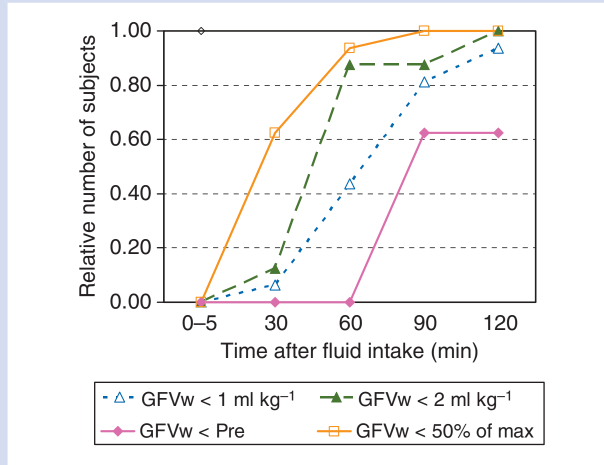

Fig 2 Time course of body weight corrected gastric fluid volume (GFV_w): cumulated relative number of subjects (n/16) at defined times after fluid intake with GFV_w<1 ml kg^{-1}, GFV_w<2 ml kg^{-1}, GFV_w<corresponding GFV_w before fluid intake ('Pre') or GFV_w<50% of corresponding maximum GFV_w 0–5 min post-syrup ('50% of max.').

[R=−0.92 (−0.79 to −0.99)], and the estimated individual half-life times varied considerably [23.6 (17.9–47.8) min].

GAV_w showed more variation compared with GFV_w, especially after overnight fasting and immediately after fluid ingestion (Fig. 1B and C). GAV_w continued to increase until 30–90 min post-syrup in most children, but declined below the initial value after 120 min (P=0.008). The course of GAV_w after fluid intake was only weakly related to time (R=−0.30, P<0.01, n=80). Except for the examinations immediately and 30 min after drinking, median GAV_w was larger than median GFV_w, (P<0.05 before and 90/120 min after drinking; P=0.13 after 60 min).

Neither $t_{1/2}$, nor GFV_w, nor GAV_w correlated with age, weight/height percentile, or BMI.

Discussion

This study aimed to assess time course of gastric contents in healthy children after overnight fasting and drinking clear fluid, using MRI. The major finding was that GFV decreased rapidly with a median half-life of <30 min after drinking 7 ml kg^{-1} of a standardized clear fluid.

Baseline GFV_w of 0.62 ml kg^{-1} assessed with MRI was higher than most gastric volumes in other paediatric studies reviewed by Brady and colleagues.[13] This supports the prior suggestion that gastric volume may be underestimated by the aspiration technique with gastric tube and syringe.[14] The same was true when gastric contents were collected with the help of endoscopy. Median volumes of 0.3 and 0.2 ml kg^{-1} were found in children requiring oesophago-gastroduodenoscopy who underwent bone marrow transplantation or were in the control group with other gastrointestinal disorders, respectively.[16] However, human data indicating a clear threshold volume for the risk of pulmonary aspiration are lacking, as described by Cook-Sather and Litman.[17]

MRI studies in adults have shown the following elimination half-times: 38 min for 500 ml of glucose 10%;[6] 100–130 min for several meals and liquid nutrients;[7 8] 21, 31, 47, and 107 min for water, non-carbonated carbohydrates, carbonated carbohydrates, and carbonated cola;[11] 47 *vs* 78/82 min for 400 ml of a clear carbohydrate solution compared with 300/400 ml of carbohydrate solution containing additional glutamine and antioxidants in 20 volunteers.[12] In contrast to other investigators who corrected for gastric secretion by labelling meals with gadolinium to quantify progressive dilution through gastric or saliva secretion,[7] in our current study on children no contrast agent was administered.

GAV_w showed immense intra- and inter-individual variation and did not empty in strictly time-dependent manner as previously described.[11] While intragastric air plays a role in the gastric accommodation of meals[8] its impact on regurgitation, vomiting, and pulmonary aspiration during anaesthesia induction remains unclear.

While the incidence of pulmonary aspiration with severe morbidity is low in children anaesthetized for elective surgery,[18] there are several advantages of a short fasting period,[17] such as prevention of dehydration, hypoglycaemia, improved quality of induction, and patient comfort. The presented data support that the existing guidelines of 2 h fluid fast are appropriate and an extension is not required. Further reduction in the pre-anaesthetic fasting time for clear fluid might be beneficial to optimize perioperative organizational processes and to further improve patient comfort. However, the impact of a smaller amount of liquid and previous light meals on gastric emptying in children requires further investigation, especially in the light of the inter-individual variability of half-life time and residual gastric volumes.

Several limitations may be considered. In contrast to the healthy children volunteering to our study, patients in pre-anaesthetic situations may suffer from pain or fear, possibly impairing gastric emptying. Furthermore, the results may not be transferable to children with higher ASA classification or gastrointestinal disorders. The number of volunteers participating in this study is relatively small but did allow for a prospective design with standardized drinks, controlled conditions, scheduled serial measurements, and a standardized and blinded evaluation.

In conclusion, gastric emptying after ingestion of clear fluid in healthy school children was observed with a median half-life of GFV of $<$30 min. Half-life and residual gastric volume within the first hour after drinking show considerable inter-individual variation. MRI is a suitable, non-invasive, and safe technique for determination of gastric volumes in children without need of contrast agents or invasive procedures.

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Conflict of interest

None declared.

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