Effect of Early Emptying on Quantitation and Interpretation of Liquid Gastric Emptying Studies of Infants and Young Children

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This study assesses the effect of emptying that occurs during feeding on quantitation and interpretation of liquid gastric emptying studies of infants and young children. **Methods:** Forty-nine ^{99m}Tc-sulfur colloid liquid gastric emptying studies of 44 children (22 boys, 22 girls; mean age, 20 mo; age range, 2–46 mo) fed orally or by gastrostomy tubes were evaluated. Gastric residuals quantitated by 2 commonly used methods, the first of which does not account for early emptying and the second of which does, were compared. With the first method, residual relative to activity in the stomach at the start of imaging (R_0) was quantified by comparing activity in a region of interest (ROI) drawn about the stomach on the final image to activity in an ROI drawn about only the stomach at the start of imaging. With the second method, residual relative to total dose (R_t) was quantified by comparing activity in the same final ROI to activity in an ROI that included stomach and small bowel at the start of imaging. Studies were interpreted independently for R_0 and R_t considering a value >70% as evidence of delayed emptying. **Results:** R_t was lower than R_0 by 15%–16% for the entire population, for patients fed orally, and for patients fed by gastrostomy tube. These differences reached statistical significance ($P < 0.0001$). In 31 of 49 studies, R_t was lower than R_0 by ≥10%. In 8 studies, emptying classified as delayed on the basis of R_0 was classified as nondelayed on the basis of R_t. Clinical decisions based on R_t did not require later management changes that would have indicated that treatment of gastric dysmotility had been postponed in any patient. **Conclusion:** Emptying that occurs during feeding should be factored into quantitation of liquid gastric emptying in infants and young children. Not recognizing and accounting for early emptying results in overestimated gastric residuals and can lead to classification of emptying as delayed in children whose residuals of the total administered dose are within a recognized range of normal.

Key Words: gastric emptying; children

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Liquids normally empty from the stomach in an exponential fashion without a lag phase (*1–3*). This could impact on scintigraphic quantitation of gastric emptying when the time required for liquid ingestion is relatively prolonged if the quantitative technique does not adjust for early gastric emptying.

Liquid may be ingested slowly by infants fed orally. Infants undergoing gastric emptying studies are generally fed in their accustomed fashion, typically in their caretaker's arms, before initiation of image acquisition. The imaging team has little control over the time an infant will take to ingest a set volume of liquid. Gastrostomy tube feedings of young children can also be relatively prolonged. This reflects the small caliber of the tubes and the low feeding rates and volumes to which these children are accustomed.

Not all techniques of quantifying gastric emptying account for emptying that begins immediately on ingestion. This study assesses the effect of emptying that occurs during feeding on quantitation and interpretation of liquid gastric emptying studies of infants and young children. We compared gastric residuals that are quantitated by 2 commonly used methods, 1 that does not account for early emptying and 1 that does.

MATERIALS AND METHODS

Forty-nine liquid gastric emptying studies of 44 children (22 boys, 22 girls; mean age, 20 mo; age range, 2–46 mo) were reviewed. This included all studies performed at our institution on children in this age group over a 15-mo interval excluding studies of patients who vomited during the course of the examination. Oral feedings were used for 16 studies of 16 children. Gastrostomy feedings were used for 33 studies of 29 children. One child had 1 study performed with oral feeding and another study performed with gastrostomy tube feeding.

Children were fed whatever liquid was used for their usual feeding. The time used for feeding was determined by the rate at which a bottle-fed infant took the liquid meal or, for children with gastrostomies, the time used for their usual feedings. ^{99m}Tc-sulfur colloid (0.55 MBq/kg; minimum, 7.4 MBq) was added to the initial portion of the feeding. After ingestion of radiolabeled liquid, feeding was continued using tracer-free liquid to a volume that was determined on the basis of the patient's age and usual feeding volume. The types and volumes of feeding are summarized in Table 1. Feeding was completed before beginning image acquisition. The time between initiation of feeding and the start of imaging (T_f) was recorded. Imaging was performed in the posterior projection using a γ camera (Siemens Orbiter or Diacam; Siemens Gammasonics, Hoffmann Estates, IL) fitted with a high-resolution collimator.

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TABLE 1
Summary of Results

Group	n	Age* (mo)	Vol* (mL)	Type of feeding	T_f* (min)	R_g* (%)	R_t* (%)	$R_g - R_t$* (%)
All studies	49	20 ± 13	47.8 ± 27.5	Formula, 43; milk products, 6	6.7 ± 2.8	47.2 ± 29.4	31.6 ± 23.1	15.7 ± 11.6†
Oral feeding	16	19 ± 14	60.0 ± 33.2	Formula, 12; milk products, 4	8.4 ± 3.3	54.7 ± 28.5	38.5 ± 21.0	16.2 ± 12.4†
Gastrostomy tube	33	21 ± 13	41.8 ± 22.4	Formula, 31; milk products, 2	5.8 ± 2.2	43.6 ± 29.5	28.2 ± 23.6	15.4 ± 11.3†

*Mean ± SD.
†$P < 0.0001$.

Images were recorded at a rate of 1 frame/30 s using an ICON acquisition program (Siemens Gammasonics).

Gastric residual at 1 h was quantified by 2 decay-corrected methods. Both used a region of interest (ROI) drawn about only the stomach on the final image. For the first method, the residual was quantified by comparing total counts in the gastric ROI on the final image with total counts within an ROI drawn about only the stomach on the initial postfeeding image. This value, designated R_g, reflects the amount of tracer within the stomach after 60 min of imaging relative to tracer that was within the stomach at the start of imaging. For the second method, the residual was quantified by comparing total counts in the gastric ROI on the final image with total counts within an ROI drawn about stomach and bowel on the initial postfeeding image. This value, designated R_t, reflects the amount of tracer within the stomach after 60 min of imaging relative to the total administered dose.

Differences between R_g and R_t were evaluated using paired Student t tests. Feeding times for patients fed orally and gastrostomy tube patients were compared using 2-sample t tests. $P < 0.05$ was considered significant. Data analysis was performed using SPSS version 8.0 (SPSS Inc., Chicago, IL) and SAS version 7.12 (SAS Institute, Cary, NC) software.

Study interpretations were rendered independently for R_g and R_t, considering a value greater than 70% as evidence of delayed gastric emptying. Records of all patients in whom gastric emptying was classified as delayed on the basis of $R_g > 70\%$ but as nondelayed on the basis of $R_t \leq 70\%$ were reviewed.

RESULTS

The time used for feeding (T_f) ranged from 2 to 15 min with a mean of 6.7 ± 2.8 min. The mean time was shorter for patients fed by gastrostomy tube than for those fed orally ($P = 0.002$). This was proportionate to a lower mean feeding volume for patients fed by gastrostomy tube (Table 1).

Results of the comparison between R_g and R_t are summarized in Table 1. R_t was lower than R_g by 15%–16% for the entire population, for patients fed orally, and for patients fed by gastrostomy tube. These differences were statistically significant ($P < 0.0001$). In 31 of 49 (63.3%) studies, R_t was lower than Rg by ≥10%. The distribution of differences between R_g and R_t, expressed by subtracting R_t from R_g for each study, is summarized in Table 2.

In 11 patients, gastric emptying was classified as delayed on the basis of $R_g > 70\%$. Gastric emptying was characterized as nondelayed on the basis of $R_t \leq 70\%$ in 8 of these patients, whose quantitative results are summarized in Table 3. Their clinical data are summarized in Table 4. In 3 patients, clinical management included steps (2 gastrostomy placements, 1 oral dietary supplementation) that may not have been taken if gastric emptying were considered delayed. For 1 child, work-up proceeded and resulted in a biopsy-proven diagnosis of eosinophilic esophagitis. The continued use of prokinetics in 1 patient was supported by quantitative improvement in gastric emptying from an earlier study in which R_g and R_t both exceeded 70%. Spontaneous improvement occurred in 1 patient, and management was unaffected in 1 patient. Treatment for delayed gastric emptying was initiated for 1 patient whose R_g fell just within the normal range (68%).

DISCUSSION

Performance, evaluation, and interpretation of gastric emptying studies in infants and young children present distinct challenges beyond those encountered in adult patients. Previously emphasized factors contributing to the challenges associated with these studies include the absence of established normal ranges for gastric residual in children, age-related differences in gastric emptying rates, inability to standardize the meals used in children, and patient motion (*4–21*). This study indicates that gastric emptying that occurs during the time required for feeding introduces an additional variable that requires consideration. Routine application of techniques that do not account for immediate liquid emptying, such as the 1 used to quantify Rg in our patients, results in an overestimated gastric residual in infants and young children. This was observed in patients fed orally (Fig. 1) and in patients fed by gastrostomy tube. (Fig. 2). Rapid bolus administration of the feeding to children fed by gastrostomy tube might decrease the impact

TABLE 2
Distribution of Differences Between R_g and R_t

$R_g - R_t$ (%)	All patients	Oral feedings	Gastrostomy feedings
≤5	10	2	8
6–9	8	5	3
10–19	17	5	12
20–29	5	0	5
≥30	9	4	5

TABLE 3
Comparison of R_g and R_t in Patients with Delayed Emptying by R_g and Nondelayed Emptying by R_t

No. of patients	Age* (mo)	T_f* (min)	R_g* (%)	R_t* (%)	$R_g - R_t$* (%)
8	21 ± 15	7.0 ± 3.5	84.6 ± 8.0	57.1 ± 8.6	27.5 ± 8.2†

*Mean ± SD.
†$P < 0.0001$.

TABLE 4
Clinical Data in Patients with Delayed Emptying by R_g and Nondelayed Emptying by R_t

Age (mo)	Sex	Study indication	R_g (%)	R_t (%)	Clinical outcome
6	F	CP; recurrent vomiting while receiving GJ feedings	96	61	Marked symptomatic improvement after Nissen fundoplication and Stamm gastrostomy
43	F	Mitochondrial disorder, developmental delay, seizures; recurrent vomiting and poor appetite	75	43	Weight gain after gastrostomy
18	M	Failure to thrive and poor appetite	89	57	Weight gain after oral dietary supplements begun
20	M	Growth failure; recurrent vomiting	88	48	Eosinophilic esophagitis diagnosed by biopsy, treated with steroids
14	M	S/P head trauma, with anoxic encephalopathy and seizures; vomiting and feeding intolerance*	80	57	Clinical improvement with continued use of prokinetics
10	M	Hydrocephalus; known GER and recurrent vomiting	88	68	Spontaneous clinical improvement without intervention
11	M	Leigh syndrome; recurrent vomiting while receiving GJ feedings	72	56	No change in clinical management, continued on GJ feedings
45	M	Complex congenital heart disease; S/P gastrostomy tube with recurrent vomiting	90	67	Clinically improved after prokinetics begun

*Follow-up of previous study (R_g, 94%; R_t, 77%) after initiation of prokinetics.

CP = cerebral palsy; GJ = gastrojejunostomy; S/P = status post; GER = gastroesophageal reflux.

on early emptying but would less closely mimic the feedings that they are routinely receiving. Acquiring images during gastrostomy tube feedings is practical and would provide visualization of early emptying as it occurs but would not eliminate its effect on quantified residual.

Because liquid empties from the stomach without a lag phase (*1–3*), it is not surprising that time required for feeding before image acquisition could have a significant effect on quantitative analysis. It is important to note, however, that the effect of early emptying on quantitated gastric residual is not linearly proportional to time used for feeding. Factoring the mean time before imaging (6.7 min) into the 60 min used for image acquisition reveals that, on the average, imaging accounted for 90% of the total time, yet mean R_t (31.6%) was only 68% of mean R_g (47.2%). The disproportionate effect can be understood if 1 considers that liquid may empty most rapidly during the period shortly after ingestion (*4,21*).

Change in the interpretation of a study is more important than a change in the numeric value of a gastric residual. In agreement with a recent extensive review of the subject (*21*) and based on extrapolation of published data in infants (*22*) and young children whose gastric function was considered retrospectively as normal (*23*), we used a gastric residual of

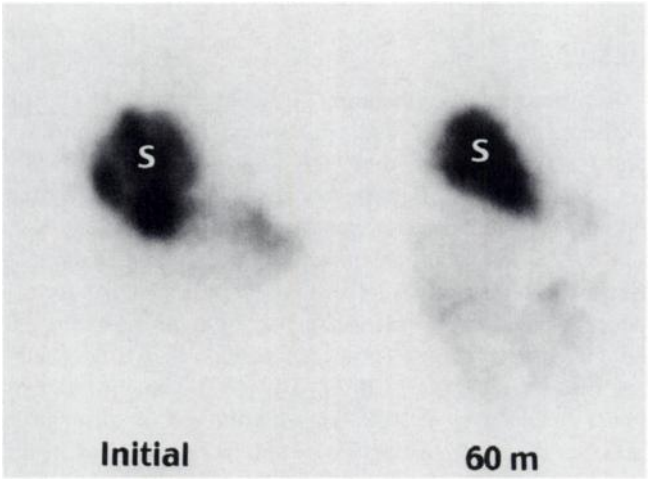

FIGURE 1. Initial postfeeding and final (60 min) images of 18-mo-old male child fed orally. S = stomach. At initiation of imaging, tracer is already present within bowel. Further gastric emptying occurred during 60 min of image acquisition. T_f = 8 min, R_g = 89%, and R_t = 57%.

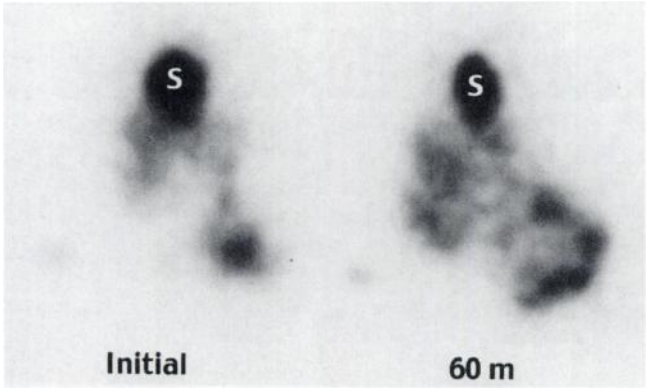

FIGURE 2. Initial postfeeding and final (60 min) images of 42-mo-old female child fed by gastrostomy tube. S = stomach. Initial image shows that tracer is already present within bowel. During 60 min of observation, additional gastric emptying occurred. T_f = 9 min, R_g = 58%, and R_t = 25%.

70% at 60 min as the upper limit of normal. We recognize that this value is based on extrapolation of data from studies that did not differentiate between R_g and R_t. Using this value, 8 of 11 studies considered abnormal on the basis of R_g values had R_t values within the normal range. The technique used for quantification of gastric residual frequently had an impact on study interpretation.

A central issue with regard to study interpretation and quantitation is whether the difference in quantitated gastric residual was clinically significant. This is difficult to answer adequately because children in whom gastric emptying studies are performed typically have multiple medical problems and variable clinical courses with or without intervention. Information provided by a gastric emptying study is used in conjunction with clinical parameters and often supplements other studies. Clinical discretion is particularly important given that establishment of pediatric standards for gastric emptying studies in controls with normal gastric function is quite difficult because of ethical and other considerations that have been reviewed by Heyman (*21*). In this study, management decisions based on an R_t suggestive of nondelayed gastric emptying in the face of an R_g that suggested delayed gastric emptying impacted on some patients' care. Such decisions did not require later changes in management that would have indicated treatment of gastric dysmotility had been postponed in any patient. One patient, who was treated on the basis of delayed gastric emptying after a study showed an R_t just within the range considered to be normal but an R_g considered to be elevated, serves as a reminder that no single quantitative value firmly distinguishes between delayed and nondelayed gastric emptying.

CONCLUSION

We recommend that early emptying should be taken into account in clinical practice when liquid gastric emptying studies of infants and young children are performed and in any attempts to establish pediatric standards for gastric emptying. One method to do this is to quantify the residual on the basis of the total administered dose as reflected by counts within an ROI that includes stomach and bowel on the initial postfeeding image. Lack of recognition of and accounting for early emptying results in overestimated gastric residuals and can lead to classification of gastric emptying as delayed in children whose gastric residuals of the total administered dose are within a recognized range of normal.

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