

# Feeding Post-Pyloromyotomy: A Meta-analysis

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abstract

**CONTEXT:** Postoperative emesis is common after pyloromyotomy. Although postoperative feeding is likely to be an influencing factor, there is no consensus on optimal feeding.

**OBJECTIVE:** To compare the effect of feeding regimens on clinical outcomes of infants after pyloromyotomy.

**DATA SOURCES:** Cumulative Index to Nursing and Allied Health Literature, The Cochrane Central Register of Controlled Trials, Embase, and Medline.

**STUDY SELECTION:** Two reviewers independently assessed studies for inclusion based on a priori inclusion criteria.

**DATA EXTRACTION:** Data were extracted on methodological quality, general study and intervention characteristics, and clinical outcomes.

**RESULTS:** Fourteen studies were included. Ad libitum feeding was associated with significantly shorter length of stay (LOS) when compared with structured feeding (mean difference [MD]  $-4.66$ ; 95% confidence interval [CI],  $-8.38$  to  $-0.95$ ;  $P = .01$ ). Although gradual feeding significantly decreased emesis episodes (MD  $-1.70$ ; 95% CI,  $-2.17$  to  $-1.23$ ;  $P < .00001$ ), rapid feeding led to significantly shorter LOS (MD  $22.05$ ; 95% CI,  $2.18$  to  $41.93$ ;  $P = .03$ ). Late feeding resulted in a significant decrease in number of patients with emesis (odds ratio  $3.13$ ; 95% CI,  $2.26$  to  $4.35$ ;  $P < .00001$ ).

**LIMITATIONS:** Exclusion of non-English studies, lack of randomized controlled trials, insufficient number of studies to perform publication bias or subgroup analysis for potential predictors of emesis.

**CONCLUSIONS:** Ad libitum feeding is recommended for patients after pyloromyotomy as it leads to decreased LOS. If physicians still prefer structured feeding, early rapid feeds are recommended as they should lead to a reduced LOS.



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Hypertrophic pyloric stenosis is a common cause of gastric outlet obstruction in children <3 months of age<sup>1</sup> and is characterized by forceful or projectile vomiting after feeding. The universally accepted treatment for hypertrophic pyloric stenosis is Ramstedt's pyloromyotomy, a safe and effective surgical procedure that is curative. However, vomiting is common after surgery, with up to 90% of patients experiencing episodes of emesis.<sup>2</sup> Although usually benign, vomiting does increase patient discomfort, length of stay (LOS), and parental anxiety.<sup>2,3</sup> Although postoperative feeding regimens are likely to be a causative factor in emesis, there exists no consensus on the ideal time to commence feeding, the ideal approach to feeding, or how feeding should be accelerated. Although early feeding has recently been championed as it may lead to earlier hospital discharge,<sup>4</sup> delayed feeding after surgery has traditionally been advocated as normal gastric peristalsis does not return until 24 hours after pyloromyotomy.<sup>5</sup> It is also for this reason that gradual advancement of the amount and strength of feeding has historically been preferred over a rapid approach, as the depression of peristalsis does not support frequent feedings.<sup>6</sup> Finally, it is unclear whether the more modern approach of ad libitum feeding is superior to standardized feeding regimens in reducing the amount of postoperative emesis. As a result of this lack of consensus, feeding regimens are currently prescribed based on surgeon preference and are highly individualized.<sup>4</sup>

We performed a systematic review of available literature to thoroughly evaluate the effect of feeding regimens on postoperative emesis, LOS, and other relevant clinical outcomes. Results of the study will allow recommendations on the

prescribing of feeding regimens after pyloromyotomy.

## METHODS

### Generation of Research Question

To identify a controversial topic in the management of hypertrophic pyloric stenosis that was in need of additional research or consensus, we used the Delphi method to survey 13 pediatric surgeons. After 2 rounds of questionnaires, determination of the ideal postoperative feeding protocol was ranked first among issues raised by responders. Questionnaires were sent out on behalf of the Canadian Association of Paediatric Surgeons Evidence-Based Resource (<https://www.caps.ca/evidence-based-resource/>), an online resource that encourages evidence-based practice in pediatric surgery by providing up-to-date evidence on a number of issues that are of concern to pediatric surgeons.

### Inclusion and Exclusion Criteria

We included English-language studies that compared  $\geq 2$  different feeding regimens in children ( $\leq 18$  years of age) whose hypertrophic pyloric stenosis was treated by pyloromyotomy. We excluded editorials, case studies, and noncomparative primary studies.

### Literature Search

To identify existing literature we searched Cumulative Index to Nursing and Allied Health Literature (1982 onwards), The Cochrane Central Register of Controlled Trials, Embase (1980 onwards), and Medline (1946 onwards) on January 30, 2015 (see Supplemental Information for sample search strategy). We identified additional publications by hand searching the reference sections of all relevant articles and searching gray literature.

## Screening

Two researchers independently assessed all citations identified by the literature search for relevance. At both a title and abstract level and a full-text level, researchers reached consensus on which articles should proceed to the next screening stage or the final analysis. Disagreements were resolved by discussion or third-party consultation when necessary.

## Data Extraction

Data were extracted for characteristics of the general study (eg, study design, country, year of publication), patients (eg, gender, age, and weight), pyloromyotomy (eg, open or laparoscopic), and postoperative feeding (eg, feeding regimen classification). Studies were classified into 3 feeding regimen groups (ad libitum versus structured, early versus late, and gradual versus rapid feeding) and could be classified into >1 feeding regimen group, as appropriate. Outcome variables were also extracted, including the primary outcome of LOS and secondary outcomes of number of patients with emesis episodes, frequency of emesis episodes, complications, readmissions, and emesis after discharge. All data extracted were verified by a second reviewer. Disagreements during extraction were resolved by discussion or third-party consultation when necessary.

## Assessing Methodological Quality

We assessed publications for their methodological quality by using tools appropriate to the study design. Nonrandomized studies were assessed according to the Methodological Index for Non-Randomized Studies (MINORS) criteria,<sup>7</sup> and randomized controlled trials were assessed through the Cochrane "Risk of Bias" tool.<sup>8</sup> Researchers independently performed quality assessment of publications and reached consensus for final scores through discussion.

When consensus could not be reached, a third party was consulted.

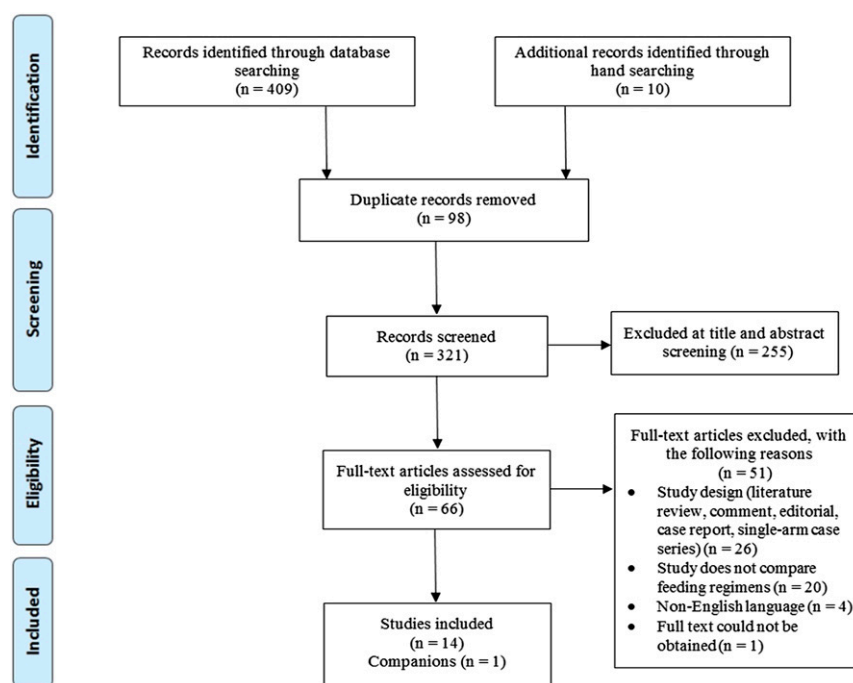
## Analysis

We pooled count and continuous data by using inverse variance methods. Count data were expressed as odds ratios (ORs) with 95% confidence intervals (CIs), and continuous data were expressed as mean differences (MDs) with 95% CIs. Forest plots were used to visualize the data. We assessed statistical heterogeneity of the included studies by using the  $I^2$  test with 95% CIs. When heterogeneity was low (as indicated by an  $I^2$  value  $\leq 30\%$ ), a fixed-effect model was used; otherwise, a random effects model was used. Publication bias would be assessed via funnel plots only if a sufficient number of included studies ( $\geq 10$ ) reported on the primary outcome of LOS. A sensitivity analysis was performed for the early versus late feeding regimen group, where feeding within the early feeding group must occur within 4 hours after surgery. This more stringent definition of early feeding allowed a more consistent comparison between studies and a more specific assessment of the effect of early versus late feeding on postoperative clinical outcomes. Subgroup analyses were also attempted for the primary outcome of LOS for potential predictors of postoperative emesis including preoperative vomiting, duration of symptoms, dehydration of patients, gastroesophageal reflux, pyloric thickness, admission weight, operative weight, type of Ramstedt's pyloromyotomy (open or laparoscopic), and perioperative medication.<sup>9,10</sup>

## RESULTS

### Study Characteristics

Our literature search identified 419 citations. After deduplication and title and abstract screening, 66 articles were assessed at a



**FIGURE 1**  
PRISMA flow diagram.

full-text level. Of these, 14 studies (and 1 companion study<sup>11</sup>) met our predefined eligibility criteria and were included in this systematic review (Fig 1).<sup>1-4,9,12-20</sup> Seven of the 14 studies compared feeding regimens that differed with respect to time of first feed (early versus late feeding),<sup>2-4,12-14,20</sup> 6 studies compared the approach to feeding (ad libitum versus structured feeding),<sup>1,3,16-19</sup> and 4 studies compared advancement of feeding (gradual versus rapid feeding)<sup>4,9,14,15</sup> (Table 1 and Supplemental Table 3). Of the 14 studies included, only 3 (21%) used a randomized controlled trial study design,<sup>12,14,19</sup> and the remaining 11 studies (79%) used a nonrandomized comparative control approach.<sup>1-4,9,13,15-18,20</sup> The majority originated in the United States ( $n = 7$ , 50%)<sup>1,4,15-19</sup> or the United Kingdom ( $n = 3$ , 21%),<sup>2,12,14</sup> with 2 studies originating in Ireland (14%),<sup>13,20</sup> 1 in the Netherlands (7%),<sup>3</sup> and 1 in Austria (7%)<sup>9</sup> (Table 1). A total of 2124 patients were followed in the 14 included studies. The gender of patients was similar to published

male/female ratios at 5:1 (with individual studies ranging from ~3.5:1 to 8.5:1).<sup>21</sup>

### Methodological Quality

The methodological quality of the 3 included randomized controlled trials<sup>12,14,19</sup> was assessed with the Cochrane Risk of Bias tool<sup>22</sup> (Table 2). Adibe et al<sup>9</sup> were thorough in their reporting and rigorous in their methods, resulting in a low risk of bias for “sequence generation,” “incomplete outcome data,” and “selective reporting.” The majority of items were not described in Turnock and Rangecroft,<sup>12</sup> and therefore 5 of the 7 risk of bias outcomes were assessed as unclear. Wheeler et al<sup>14</sup> also did not describe 3 of the 7 items, and although their method of sequence generation was assessed to be low risk, allocation concealment (unmarked, folded sheets) had a high risk of bias. In all 3 studies blinding was not possible for patients, personnel, or outcome assessors, and because outcomes may be influenced by this lack of blinding, these

**TABLE 1** Characteristics of Included Studies

Author (y), Total <i>N</i>	Study Design	Country, Site	Gender (M/F)	Mean Wt, kg, Mean (SD) or Median (Range)	Mean Age, Wk, Mean (SD) or Median (Range)	Duration of Illness or Symptoms, d Mean (SD or Range)	Open or Laparoscopic?	Feeding Regimen Classification	MINORS Assessment, <sup>a</sup> /24
Leahy and Fitzgerald (1982) <sup>20</sup> <i>N</i> = 67	Prospective comparative trial	Ireland	60/7	NR	(1.43–15)	NR	NR	Early versus late	14
Wheeler et al (1990) <sup>14</sup> <i>N</i> = 74	RCT	United Kingdom (England)	64/10	Wt at admission: 3.89 (2.71–5.76)	Age at admission: 5.7 (2–16)	NR	Open	Early versus late  Gradual versus rapid	N/A (see Table 2)
Turnock and Rangecroft (1991) <sup>12</sup> <i>N</i> = 100	RCT	United Kingdom (England)	NR	NR	NR	NR	NR	Early versus late	N/A (see Table 2)
Georgeson et al (1993) <sup>4</sup> <i>N</i> = 223	Retrospective comparative trial	United States	186/37	Wt at admission: 3.9 (0.7)	Age at diagnosis: 5.2 (2.5)	Regimen A: 7.0 (6.8) Regimen B: 10.3 (10.7) Regimen C: 6.8 (4.4) Regimen D: 6.4 (4.9)	NR	Early versus late  Gradual versus rapid	13
Carpenter et al (1999) <sup>18</sup> <i>N</i> = 289	Retrospective comparative trial	United States	232/57	4.2 (0.9)	5.8 (4.6)	NR	NR	Ad libitum versus structured	14
Gollin et al (2000) <sup>15</sup> <i>N</i> = 81	Retrospective comparative trial	United States	64/17	NR	5.3 (2–12)	Group 1: 8.3 (1–21) Group 2: 7.1 (1–28) Group 3: 6.1 (1–28)	NR	Gradual versus rapid	14
Lee et al (2001) <sup>2</sup> <i>N</i> = 101	Retrospective comparative trial	United Kingdom (Scotland)	87/14	Wt at presentation: 3.9 (2.1–6.0)	Age at presentation: 5.1 (1.1–12.4)	NR	NR	Early versus late	12
Garza et al (2002) <sup>17</sup> <i>N</i> = 36	Prospective comparative trial	United States	28/8	Wt at operation: 4.0 (0.9)	Age at operation: 5 (1.7)	NR	Open	Ad libitum versus structured	14
Puapong et al (2002) <sup>16</sup> <i>N</i> = 56	Prospective comparative trial	United States	NR	Wt at presentation: 4.0 (0.7)	Age at presentation: 5.1 (2.0)	Control: 6.2 (6.3); Ad libitum: 6.0 (4.2)	Open	Ad libitum versus structured	15
van der Bilt et al (2004) <sup>3</sup> <i>N</i> = 164	Retrospective comparative trial	Netherlands	143/21	Wt at surgery: 3.9 (0.7)	Age at surgery: 5.1 (2.2)	<4 h: 11 (10) >4 h: 12 (10)	Laparoscopic	Early versus late  Ad libitum versus structured	16
Adibe et al (2007) <sup>1</sup> <i>N</i> = 227	Retrospective comparative trial	United States	183/44	NR	5.1 (0.2)	NR	Laparoscopic	Ad libitum versus structured	14

**TABLE 1** Continued

Author (y), Total N	Study Design	Country, Site	Gender (M/F)	Mean Wt, kg, Mean (SD) or Median (Range)	Mean Age, Wk, Mean (SD) or Median (Range)	Duration of Illness or Symptoms, d Mean (SD or Range)	Open or Laparoscopic?	Feeding Regimen Classification	MINORS Assessment, <sup>a</sup> /24
El-Gohary et al (2010) <sup>13</sup> N = 513	Retrospective comparative trial	Ireland	440/73	NR	Age at operation: 5.7 (0.3–27.7)	10 (1–60)	Open	Early versus late	12
Adibe et al (2014) <sup>19</sup> N = 150	RCT	United States	131/19	Wt at presentation: 4.0 (1.0)	Age at presentation: 5.67 (4.18)	NR	Laparoscopic	Ad libitum versus structured	N/A (see Table 2)
Castellani et al (2014) <sup>9</sup> N = 43	Retrospective comparative trial	Austria	36/7	Wt at presentation: 3.674 (0.779)	Age at presentation: 5.86 (2.43)	NR	Laparoscopic	Gradual versus rapid	14

F, female; M, male; N/A, not applicable; NR, not reported; RCT, randomized controlled trial.  
<sup>a</sup> See Supplemental Table 4 to see how items within MINORS were scored for each study.

domains were assessed as having a high risk of bias.

The remaining 11 nonrandomized studies<sup>1–4,9,13,15–18,20</sup> were assessed for methodological quality with the MINORS tool,<sup>7</sup> for which the majority of items were assessed similarly across studies (Table 1; see Supplemental Table 4 for greater detail). Few or no studies reported on

the items “prospective collection of data” (reported in only 1 of 11 [9%] studies<sup>16</sup>), “unbiased assessment of the study endpoint” (0 in 11 [0%] studies), and “prospective calculation of the study size” (0 in 11 [0%] studies). The remaining 9 items were widely reported but with varying degrees of adequacy. As a result, the total MINORS scores of the studies

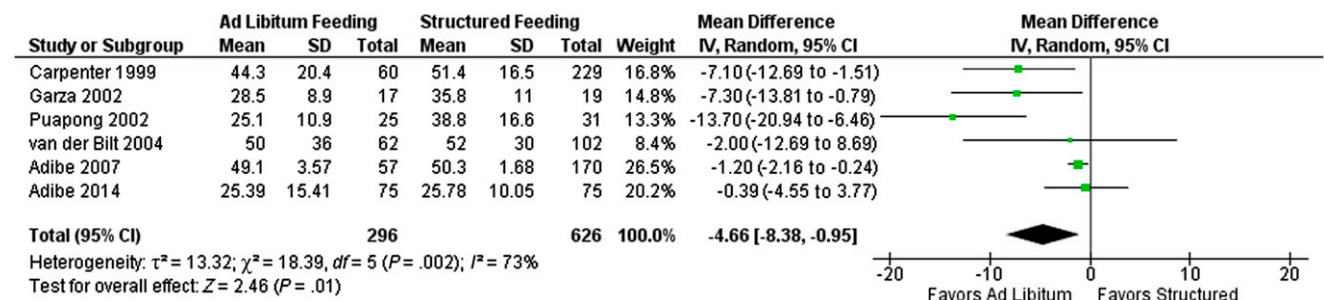
were similar, ranging from 12 to 16, with a median score of 14.

**Primary Outcome Analysis: LOS**

Meta-analysis of the 6 studies<sup>1,3,16–19</sup> that reported on the LOS for ad libitum versus structured feeding regimen indicated that LOS was significantly shorter for an ad libitum feeding regimen (MD –4.66; 95% CI, –8.38 to –0.95; *I*<sup>2</sup> 73%; *P* = .01) (Fig 2). Another 4 studies examined LOS as affected by early versus late feeding regimens.<sup>3,4,13,14</sup> Although early feeding was favored over late, the results were not statistically significant (MD –12.07; 95% CI, –32.46 to 8.31; *I*<sup>2</sup> 94%; *P* = .25) (Fig 3). When a sensitivity analysis was performed on the 2 studies that classified “early feeding” as first feeding occurring at ≤4 hours, early feeding was still favored although not

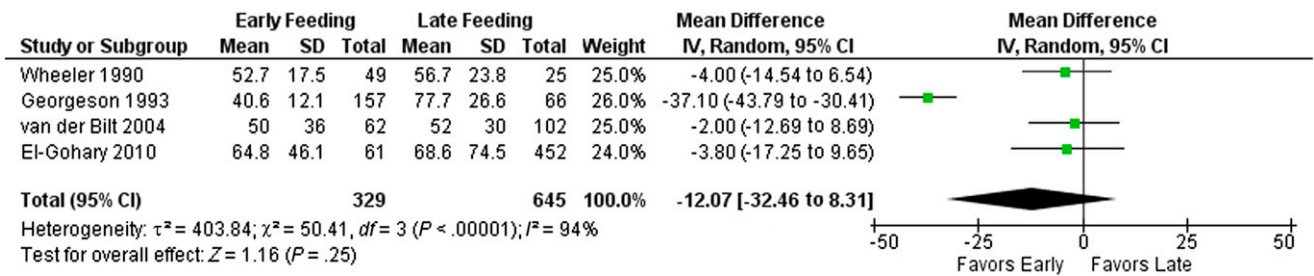
**TABLE 2** Methodological Quality of Randomized Controlled Trials, Assessed With the Cochrane Risk of Bias Tool<sup>22</sup>

Cochrane Risk of Bias Item	Wheeler et al (1990) <sup>14</sup>	Turnock and Rangecroft (1991) <sup>12</sup>	Adibe et al (2014) <sup>19</sup>
Adequate sequence generation	Low	Unclear	Low
Allocation concealment	High	Unclear	Unclear
Blinding of participants and personnel	High	High	High
Blinding of outcome assessors	High	High	High
Incomplete outcome data	Unclear	Unclear	Low
Selective outcome reporting	Unclear	Unclear	Low
Other sources of bias	Unclear	Unclear	Unclear

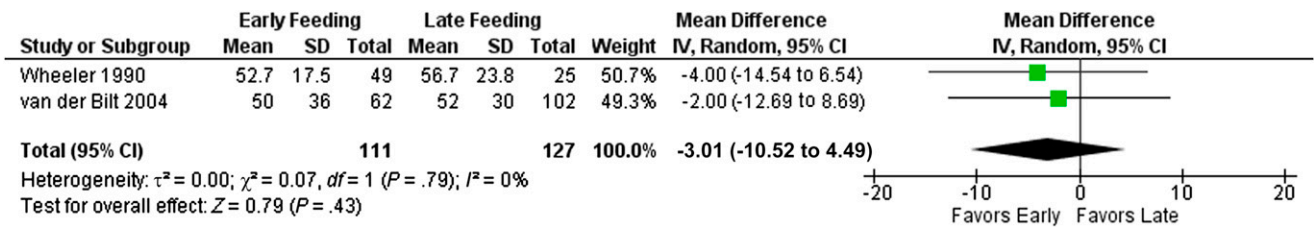


**FIGURE 2**

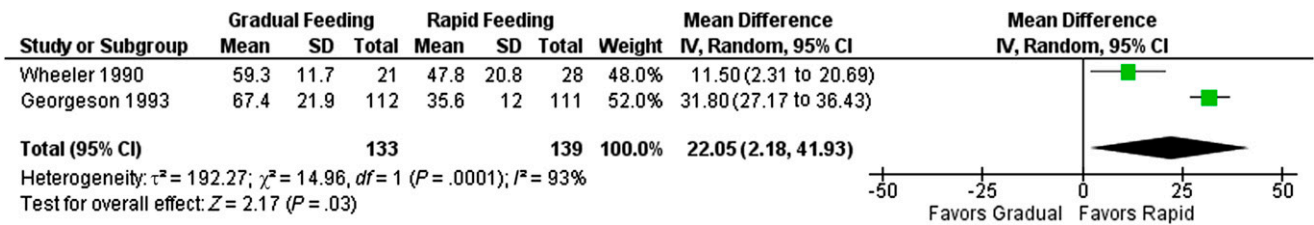
Forest plot for LOS in ad libitum versus structured feeding.



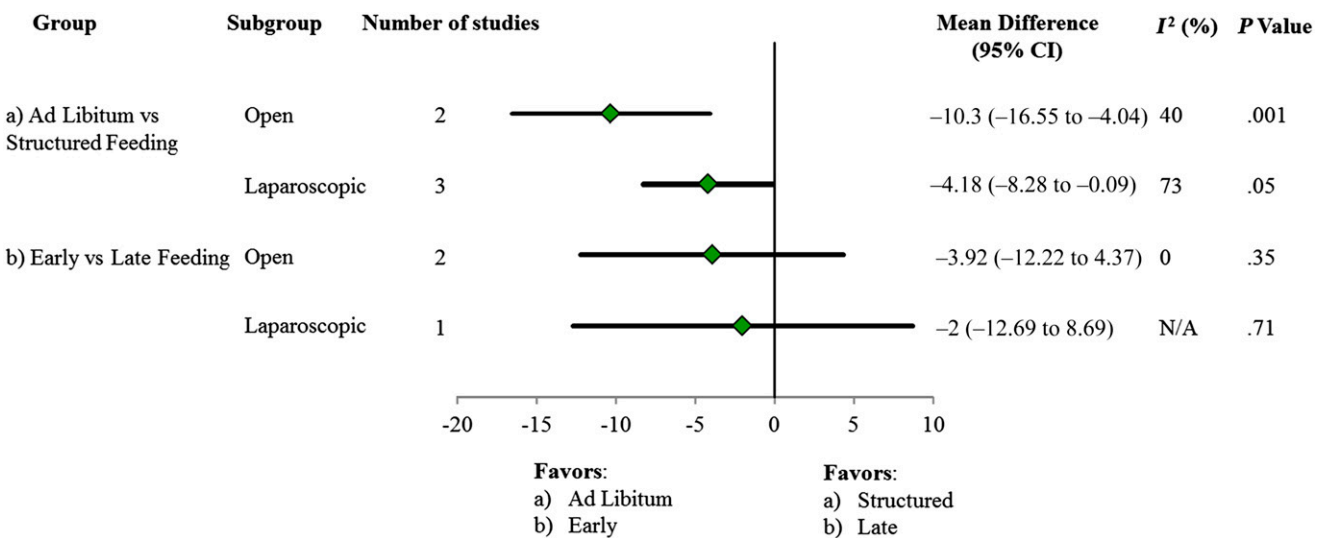
**FIGURE 3**  
Forest plot for LOS in early versus late feeding.



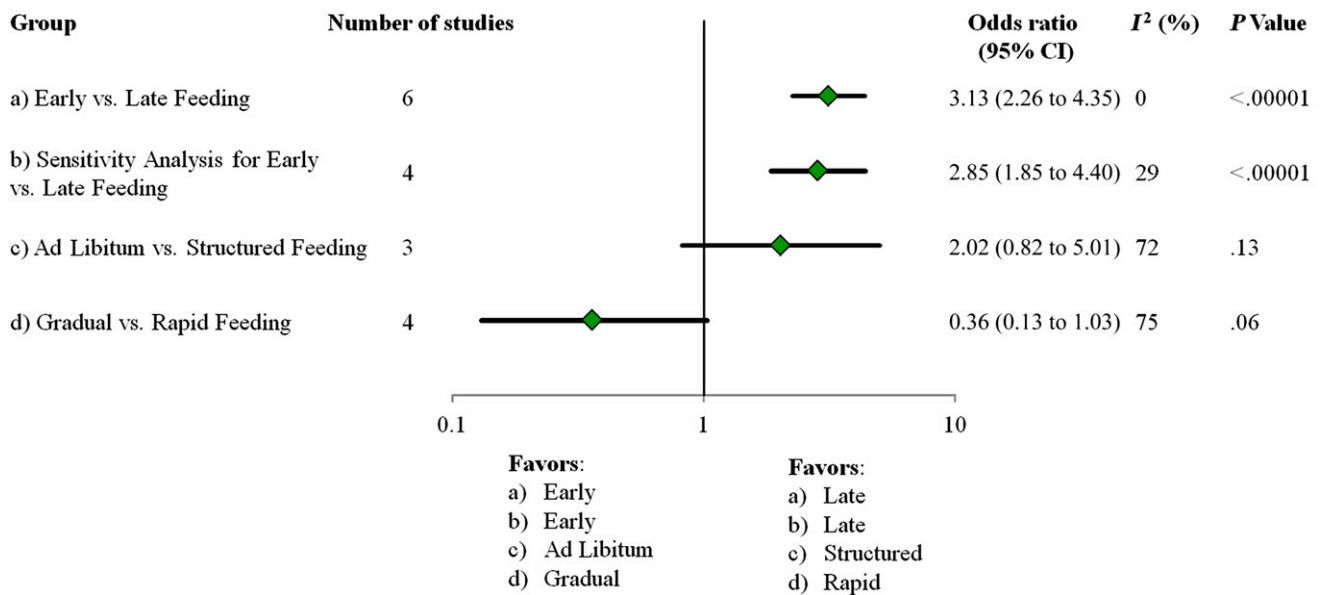
**FIGURE 4**  
Forest plot for sensitivity analysis of LOS in early versus late feeding.



**FIGURE 5**  
Forest plot for LOS in gradual versus rapid feeding.

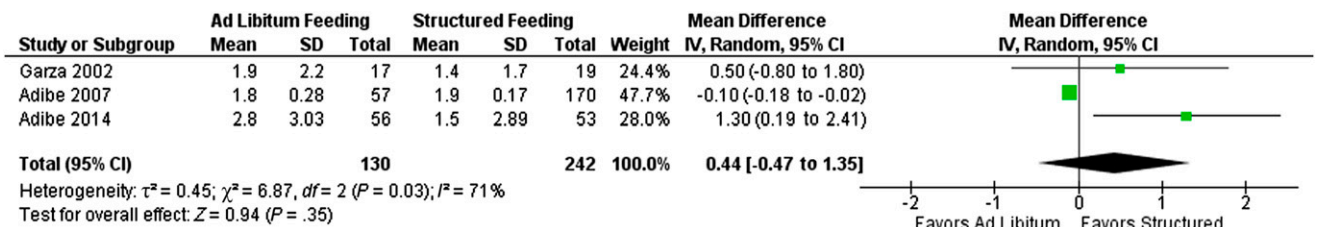


**FIGURE 6**  
Forest plot for subgroup analysis based on operative approach for LOS in ad libitum versus structured and early versus late feeding.



**FIGURE 7**

Forest plot for number of patients with postoperative emesis in early versus late, ad libitum versus structured, and gradual versus rapid feeding.



**FIGURE 8**

Forest plot for number of emesis episodes per patient in ad libitum versus structured feeding.

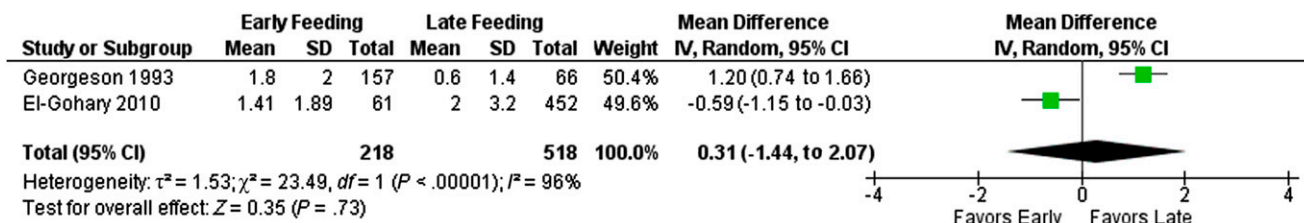
in a statistically significant manner, and heterogeneity significantly improved (MD -3.01; 95% CI, -10.52 to 4.49;  $I^2$  0%;  $P = .43$ ) (Fig 4). The 2 studies that examined the effect of gradual versus rapid feeding on LOS both favored rapid feeding,<sup>4,14</sup> resulting in a significantly shorter LOS in the rapid feeding group (MD 22.05; 95% CI, 2.18 to 41.93;  $I^2$  93%;  $P = .03$ ) (Fig 5). Subgroup analysis based on operative approach indicated that ad libitum and early feeding are favored, whether open or laparoscopic pyloromyotomy is performed (Fig 6). Additional subgroup analyses were not possible because of an insufficient number of studies. Publication bias also could not be assessed, because the minimum number of studies needed for this assessment ( $\geq 10$ ) was not

reached for any 1 feeding group for this outcome.

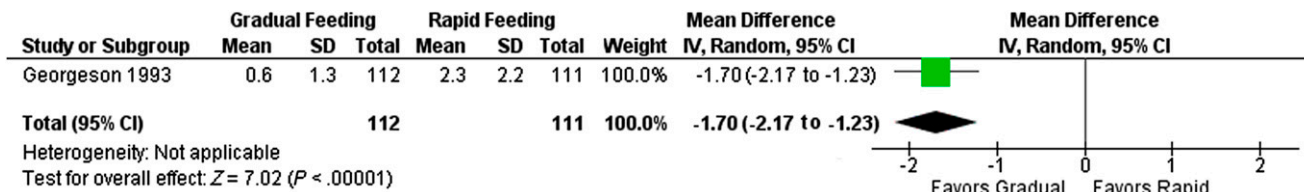
### Secondary Outcome Analysis: Number of Patients With Postoperative Emesis

The number of patients experiencing postoperative emesis was reported in 10 of the 14 included studies,<sup>2-4,9,12,14-16,19,20</sup> with 3 studies examining ad libitum versus structured feeding,<sup>3,16,19</sup> 6 studies examining early versus late feeding,<sup>2-4,12,14,20</sup> and 4 studies examining gradual versus rapid feeding.<sup>4,9,14,15</sup> Meta-analysis of studies indicated that prescribing a late feeding regimen significantly decreased the odds of patients experiencing postoperative emesis when compared with an early feeding regimen (OR 3.13; 95%

CI, 2.26 to 4.35;  $I^2$  0%;  $P < .00001$ ) (Fig 7). When only those studies that classified “early” feeding as at or within 4 hours after surgery were analyzed using sensitivity meta-analysis, the effect was less pronounced but still statistically significant (OR 2.85; 95% CI, 1.85 to 4.40;  $I^2$  29%;  $P < .00001$ ) (Fig 7). When ad libitum versus structured feeding was examined, a structured feeding regimen was favored as it decreased the odds of the patients experiencing postoperative emesis; however, the result was not statistically significant (OR 2.02; 95% CI, 0.82 to 5.01;  $I^2$  72%;  $P = .13$ ) (Fig 7). Finally, meta-analysis results indicated that gradual feeding reduces the likelihood that patients will experience emesis, although not in a statistically significant manner,



**FIGURE 9**  
Forest plot for number of emesis episodes per patient in early versus late feeding.



**FIGURE 10**  
Forest plot for number of emesis episodes per patient in gradual versus rapid feeding.

when compared with rapid feeding (OR 0.36; 95% CI, 0.13 to 1.03;  $I^2$  75%;  $P = .06$ ) (Fig 7).

### Secondary Outcome Analysis: Number of Emesis Episodes per Patient

The effect of feeding regimen on number of emesis episodes per patient was reported in 3 studies comparing ad libitum and structured feeding,<sup>1,17,19</sup> 2 comparing early and late feeding,<sup>4,13</sup> and 1 comparing gradual and rapid feeding.<sup>4</sup> Patients experienced an overall lower frequency of vomiting when a structured feeding regimen was prescribed, as compared with an ad libitum feeding regimen (MD 0.44; 95% CI, -0.47 to 1.35) (Fig 8). When early and late feeding were compared, late feeding was slightly favored because it led to less vomiting per patient (MD 0.31; 95% CI, -1.44 to 2.07) (Fig 9). However, MDs from both ad libitum versus structured feeding and early versus late feeding were not statistically significant ( $P = .35$  and  $P = .73$ , respectively), and the level of variability between the 2 studies within the meta-analysis was high ( $I^2$  71% and  $I^2$  96%, respectively). Therefore, these results should be

interpreted with caution. Gradual feeding was favored over rapid feeding, because it significantly decreased the number of emesis episodes per patient (OR -1.70; 95% CI, -2.17 to -1.23;  $P < .00001$ ) (Fig 10).

### Outcome Analysis: Additional Clinically Relevant Outcomes

A number of clinically relevant outcomes showed no significant difference between feeding regimens. These outcomes included postoperative complications,<sup>1,18</sup> where patients experienced no complications with either ad libitum or structured feeding regimens; emesis after discharge,<sup>3</sup> where the MD between early ad libitum and late structured feeding was nearly 1 (MD 1.05; 95% CI, 0.39 to 2.88;  $P = .92$ ) (Supplemental Fig 11); and readmissions, for which 6 of the 8 studies reporting on this outcome indicated no readmissions.<sup>1,4,15-18</sup> Exceptions were studies by van der Bilt et al,<sup>3</sup> in which 3% ( $n = 2$ ) of early ad libitum feeding patients were readmitted compared with 0% of late structured feeding patients, and Adibe et al,<sup>19</sup> in which 2 patients in each of the ad libitum and structured feeding groups were

readmitted (MD 2.11; 95% CI, 0.28 to 15.90;  $I^2$  26%;  $P = .47$ ) (Supplemental Figs 12-14).

### DISCUSSION

To our knowledge, this is the first systematic review to examine how the timing, approach, and advancement of feeding regimens affect clinically relevant outcomes such as number of patients with emesis, number of emesis episodes per patient, and LOS. Meta-analysis results indicate that the number of patients who experience postoperative emesis is significantly lower in patients who are prescribed a late feeding regimen, compared with an early feeding regimen. When sensitivity analysis was performed for studies where “early” feeding was defined as first feed at  $\leq 4$  hours after surgery, late feeding was still favored in a statistically significant manner. These results probably are caused by cessation of peristalsis that is observed for the first 4 to 6 hours postoperatively and the continued depression of gastric motility for an additional 16 to 24 hours after pyloromyotomy<sup>5,23</sup> as gastroparesis is known to cause nausea and emesis in a variety

of medical conditions.<sup>24</sup> This is also probably why a structured feeding regimen was favored over ad libitum for this outcome, as ad libitum feeding patients are usually offered full-strength feeds once fully awake, whereas structured feeding regimens often have a period of nothing by mouth (NPO) followed by low-strength and low-volume feeds. Depressed gastric peristalsis would also account for the decrease in number of patients with postoperative emesis observed in gradual feeding regimens when compared with rapid, because gradual feeding slowly reintroduces formula or breast milk in a manner that reflects the gradual progression of gastric motility to preoperative levels. However, it must be noted that while meta-analysis results favor structured feeding over ad libitum and gradual feeding over rapid, the difference was not found to be statistically significant in terms of the number of patients with emesis. Therefore, physicians should exercise caution when using these results to inform practice.

The number of emesis episodes per infant was reduced in a non-statistically significant manner in the late and structured feeding groups when compared with early and ad libitum feeding regimens, respectively. These results are in keeping with the traditionally held belief that because gastric function returns slowly after pyloromyotomy, a similarly cautious method of reintroducing feeds would result in less emesis.<sup>16</sup> Based on this reasoning, one might expect to see a large difference in frequency of emesis episodes between feeding regimens, resulting in a statistically significant effect. However, our meta-analysis results revealed only a small, nonsignificant difference between these regimens (MD 0.44; 95% CI, -0.47 to 1.35 favoring structured over ad libitum feeding, and MD 0.31; 95% CI, -1.44 to 2.07 favoring late

over early feeding). These results may be attributed to the high degree of heterogeneity between studies in both ad libitum versus structured and early versus late feeding regimens ( $I^2$  71% and  $I^2$  96%, respectively), which results from the differing conclusions of the included studies. The addition of several large studies would improve confidence in meta-analysis results regarding how the approach to feeding affects frequency of emesis in patients after pyloromyotomy. When the effect of gradual versus rapid advancement of feeding was examined by meta-analysis, Georgeson et al<sup>4</sup> was the only study that could be included. It showed that gradual feeding significantly reduced the number of emesis episodes per patient, as expected given the decreased gastric motility observed postoperatively. It is interesting to note that Georgeson et al<sup>4</sup> is also 1 of the 2 studies included in the early versus late feeding regimen meta-analysis. To allow an early versus late analysis of this study, 3 groups were pooled to form the early feeding regimen, 2 of which used a rapid feeding schedule and 1 of which used a gradual schedule. The late feeding regimen with which it was compared used a gradual feeding schedule. It is possible that the observed effect of favoring late feeding is an artifact of the decreased frequency of emesis observed with a gradual feeding regimen. Therefore, perhaps the frequency of emesis episodes in this study is more directly linked to the acceleration of feeding, with rapid schedules resulting in a higher frequency of emesis. Additional studies that differ only by time to first feed or by acceleration of feeding would help clarify the true effect of early versus late feeding and gradual versus rapid feeding, respectively.

Patients are discharged after pyloromyotomy shortly after they demonstrate that they can tolerate full feeds. Therefore, it is assumed that LOS is directly related to

the feeding regimen prescribed as early, ad libitum, and rapid feeding regimens are designed to reach full feeding before late, structured, or gradual feeding regimens, respectively. However, the progression of feedings and discharge of patients may be stalled by emesis, allowing the possibility that this assumption will not hold true in all situations. A recent literature review conducted by Graham et al<sup>25</sup> concluded that ad libitum feeding did allow patients to reach full-strength feeds more quickly, thereby decreasing time to discharge. However, the same review showed no shorter time to discharge in early feeding regimens as compared with delayed feeding. Results of our primary outcome meta-analysis were fairly similar in their conclusions; while ad libitum and rapid feeding patients experienced a significantly shorter LOS, early feeding patients showed only a non-statistically significant decrease in LOS. It is interesting to note that at first glance these results do not seem to agree with the meta-analysis results that were previously discussed. For example, one would expect that more emesis episodes per patient would delay time to tolerated full feeding. However, the greater frequency of emesis experienced in rapid feeding and early feeding regimens did not translate to a greater LOS. Similarly, early, ad libitum, and rapid feedings increased the number of patients with emesis, but this increase did not seem to affect LOS. This indicates that despite increased emesis, these patients are still able to tolerate full feeds sooner. This result may be a function of how the feeding regimens were designed, often with substantial time disparity between groups concerning when full feeding is scheduled to be reached. For example, in Wheeler et al<sup>14</sup> the rapid feeding group was fed over 16 hours, whereas the gradual feeding group was fed over 48 hours. Even if the gradual feeding group

experiences an increase in frequency or number of patients with emesis, this group has an extra 32 hours to reach tolerated full feeding before the gradual feeding group even reaches their scheduled full feed (which the patients might not even tolerate). This is also often the case in ad libitum versus structured feeding, as patients in ad libitum groups feed once awake from anesthesia (often within a few hours after surgery), whereas structured feedings often occur progressively over a longer period of time. Finally, the difference observed in time to full feeding in early versus late feeding regimens was often not as substantial, perhaps resulting in the non-statistically significant difference between these groups concerning LOS.

Overall, no postoperative complications were identified in included studies. Readmissions were similarly uncommon, with only 0.3% of patients ( $n = 6/2124$ ) having to return to the hospital postoperatively. Because emesis is a common occurrence in all feeding regimens, these results indicate that vomiting is of no real clinical consequence. This finding is supported by previous studies that found that postoperative emesis does not appear to adversely affect patients and could not be used as a predictor of more serious complications.<sup>18</sup>

There are several limitations to our systematic review. We were not able to include non-English-language primary studies in our analysis, and therefore it is possible that some relevant evidence is missing from our results. The studies that were included in our meta-analyses also

often had a high level of statistical heterogeneity ( $I^2$ ) between them. Additionally, only 21% ( $n = 3$ ) of the included studies were randomized controlled trials, with the majority of the remaining studies being retrospective comparative studies of moderate methodological quality (MINORS scores ranging from 12 to 16 out of a possible 24). Finally, we were not able to analyze publication bias or the effect of numerous potential predictors of postoperative emesis on the LOS because we had an insufficient number of studies. To resolve a number of these problems, more large randomized controlled clinical trials of high methodological quality are needed. These trials would allow more confidence in meta-analysis results and more definite conclusions about feeding regimen effectiveness. In the future, authors should also focus on comparing only 1 aspect of the feeding regimen at a time. Doing so will help clarify which aspect of feeding is leading to the observed effect.

## CONCLUSIONS

It is recommended that an ad libitum feeding regimen be prescribed after pyloromyotomy. Ad libitum feeding significantly decreases the LOS when compared with a structured feeding regimen. Additionally, neither the difference in number of patients with emesis nor the frequency of emesis in those patients was statistically significant between ad libitum and structured feeding regimen groups. If structured feeding is still preferred, it is recommended that a rapid feeding regimen be used because it significantly decreases the LOS.

Patients on a rapid feeding regimen are more likely to experience emesis and at a greater frequency than those on a gradual feeding regimen; however, this effect appears to have no negative bearing on patient outcomes. The timing of the first feed (early versus late) does not significantly affect clinical outcomes, with the exception of number of patients with emesis (for which late feeding was favored). Although the evidence is not conclusive regarding whether early or late feeding should be prescribed, it is recommended that patients follow an early feeding regimen as patients who experience little or no emesis on this regimen should have a shorter LOS. Surprisingly, these conclusions differ from those of a literature review conducted by Graham et al,<sup>25</sup> despite the fact that they are informed by many of the same studies.<sup>1-4,12,14-18,20</sup> This difference probably reflects the different method used to compile evidence (literature review versus meta-analysis) and the slightly different classification system used (where our systematic review also examines acceleration of feeds). Additionally, we have included several studies that were published since Graham et al,<sup>25</sup> including a high-quality randomized control trial.<sup>19</sup>

## ABBREVIATIONS

CI: confidence interval  
LOS: length of stay  
MD: mean difference  
MINORS: Methodological Index  
for Non-Randomized  
Studies  
NPO: nothing by mouth  
OR: odds ratio

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