



Health Policy &
Clinical Effectiveness Program
Evidence Based
Clinical Practice Guideline

Hypertrophic Pyloric Stenosis

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(see Development Process for evidence search dates)

Introduction

Hypertrophic pyloric stenosis (HPS) is one of the most common gastrointestinal disorders during early infancy, with an incidence of 1-2:1000 live births. This condition presents in infants most commonly between the ages of 2 and 8 weeks of life. In HPS, hypertrophy of the circular muscle of the pylorus results in constriction and obstruction of the gastric outlet. Gastric outlet obstruction leads to non-bilious, projectile emesis, loss of hydrochloric acid with the development of hypochloremic, metabolic alkalosis, and dehydration. Surgical myotomy is the primary approach to the management of HPS.

Target Population

Inclusions: These guidelines are intended for use in children less than 3 months of age with signs, symptoms or exam findings suggesting a diagnosis of HPS.

Exclusions: These guidelines are not intended for use in patients with:

- Suspected sepsis
- Bilious vomiting suggesting intestinal obstruction
- History or presence of significant comorbidities or chronic conditions which would alter approaches to care

Epidemiology

The cause of pyloric stenosis is unknown. Genetic, familial, gender, and ethnic origin can influence the incidence rates of HPS.. Males outnumber females in every series by a ratio of 4-5:1 (*Applegate 1995 [D]*, *Mackay 1986 [D]*, *Poon 1996 [D]*). There is a higher risk for developing HPS in offspring of parents with this condition and, in many series, first-born males are frequently encountered (*Murtagh 1992 [S]*).

Guideline Recommendations

References in parentheses () Evidence strengths in brackets []
(See last page for definitions)

Clinical Assessment

History of Symptoms

1. It is recommended that practitioners consider the diagnosis of HPS in an otherwise healthy infant between the age of 2 and 12 weeks of life who presents with projectile and/or frequent episodes of **non-bilious** emesis with or without associated weight loss. Increasing frequency and volume of vomiting, despite trials of small frequent feedings of formula, breastmilk and pedialyte, often are suggestive of HPS (*Smith 1999 [D]*, *Breaux 1986 [D]*).

Physical Exam

1. In an infant with the above history, palpation of the hypertrophic pyloric muscle mass (also called the olive) in the epigastrium or right upper quadrant (RUQ) by a skilled examiner is pathognomonic for the diagnosis of HPS. If the olive is palpated, no additional diagnostic testing may be necessary. Gastric distension or visible gastric peristalsis, seen as a wave of contraction from the left upper quadrant to the epigastrium, may be seen in some cases (*Murtagh 1992 [S]*, *Spicer 1982 [S]*). The inability of a clinician to palpate an olive does not rule out the diagnosis of HPS (*Forman 1990 [C,D]*).

- **Note 1:** Several methods for olive palpation are recommended (*Garcia 1990 [S]*, *Spicer 1982 [S]*). One method is described below.
 - i. Remove the child's clothing so as to expose the abdomen. Allow patient to relax by sucking on sugar water while lying supine in the parent's lap.
 - ii. Gently elevate the child's feet and flex the legs (this relaxes the abdominal wall).
 - iii. Place examining hand between the child's legs so that the fingers rest on the abdominal wall. Using fingertips, palpate the inferior margin of the liver edge,
 - iv. Slide fingertips under the liver edge and superiorly under liver, then posteriorly to the back of the abdomen.
 - v. With fingers flexed and palpating the posterior abdomen, draw fingers inferiorly along abdominal wall. The "olive" will pop under the fingers.

- vi. The mobility of the pyloric olive in all 4 directions distinguishes HPS from a retroperitoneal mass.
 - vii. When palpable, the olive will feel smooth and hard, oblong, and approximately 1.5 – 2.0 centimeters in size.
- **Note 2:** The ability to palpate the olive varies with the experience and persistence of the examiner and ranges from 40-100% (Murtagh 1992 [S]).

Estimating Dehydration in HPS

1. Dehydration may be encountered in patients with HPS. Estimating dehydration is an important first step in determining optimal approaches to diagnose HPS. Acute body weight changes provide the best measure of dehydration in a young child (Duggan 1996 [C], Gorelick* 1997 [C]). Mucous membrane hydration, capillary refill time (Saavedra 1991 [D]), absence of tears, and alterations in mental status are the next best associated measures. The presence of any three or more of these latter four signs has a sensitivity of 87% and specificity of 82% for detecting a deficit of 5% or more (Duggan 1996 [C], Gorelick* 1997[C]). (See Table 1).

* Population studied was one month to 5 years of age. Other considerations may apply for children less than one month of age.

Laboratory Assessment

1. The assessment of electrolyte status is not routinely indicated in the early diagnosis of HPS. Once a diagnosis is confirmed, it is recommended that the electrolyte status of the patient be checked pre-operatively and any significant abnormalities in electrolytes or hydration status be addressed prior to surgery. The CHMCC Department of Anesthesiology suggests a pre-operative bicarbonate level of # 30 meq/L, be achieved before surgical correction is performed (Local expert consensus [E], Bissonnette 1991[S], Habre 1999 [D], Goh 1990 [C], Graham 1993[D]).
- **Note 1:** Earlier studies indicated that up to 10% of patients with HPS present with electrolyte abnormalities including hypokalemia and hypochloremic alkalosis (Chen 1996 [D], Pappadakis 1999 [D]). More recent studies report fewer metabolic derangements (Poon 1996 [D]).

Referral for Further Evaluation of HPS

1. In children who present with HPS symptoms but are deemed to be well hydrated, factors influencing the next step include the time of day, severity of symptoms and social situation. If the child is well hydrated and the social situation permits, the patient may be scheduled for an elective outpatient radiologic evaluation or direct referral to a pediatric surgeon within 24 hours of this visit. Under these circumstances, parents are instructed to call if signs and symptoms of dehydration develop (Abbas 1999 [D]).

- **Note 1:** Palpation of an olive by an experienced examiner, such as a pediatric surgeon, may obviate need for a confirmatory imaging study. This is due to the high specificity of positive exam ((Forman 1990 [C,D], Breaux 1986 [D], Macdessi 1993 [D], Godbole 1996 [C], Hulka 1997 [Q], White 1998 [Q]).

2. It is recommended that the infant be referred to the Emergency Department for evaluation and treatment with IV fluids if dehydration is suspected clinically or the social situation warrants more immediate action (Local expert consensus [E]).

Radiologic Assessment

1. The diagnosis of HPS can be made with imaging by an ultrasound exam (US) or fluoroscopic upper gastrointestinal series (UGI). These imaging tests have similar performance in terms of sensitivity and specificity for the diagnosis of HPS (See Table 2). In the absence of a large prospective comparison study with ROC analysis or a meta-analysis of existing studies, neither test can be proved as clearly superior in the diagnosis of HPS. UGI is superior to US in diagnosing some other conditions associated with vomiting in infants, such as gastroesophageal reflux, malrotation, and gastric webs (Cohen 2000[E]). However, sonography has certain advantages over UGI, including the absence of ionizing radiation exposure and lack of oral contrast use which eliminates the risk of barium aspiration or intraperitoneal barium spillage during surgery. This has led to US becoming the standard or preferred initial imaging method when HPS is the most likely diagnosis (Blumhagen 1983 [C & D], Khamapirad 1983 [D], Hayden 1984 [D], Stunden 1986 [C], Weiskittel 1989 [O], Garcia 1990 [S], Rollins 1991 [C], Hernanz-Schulman 1994 [D], Cohen 2000 [E]).

- 2. A persistent pyloric muscle thickness >3-4mm or pyloric length >15-18 mm in the presence of functional gastric outlet obstruction is generally considered in the diagnostic range for HPS by US. There is not strong agreement in the literature regarding the optimal size threshold for diagnosis. Many studies show pyloric size overlap between HPS and non-HPS cases, and the diagnostic performance of specific size thresholds varies across studies (Haller 1986 [E], Stunden 1986 [C], Mollitt 1987 [D], Lund Kofoed 1988 [C], Blumhagen 1988 [C and D], Westra 1989 [C], Philippin 1989 [D], O'Keefe 1991 [D], Lamki 1993 [C and D], Hernanz-Schulman 1994 [D], Neilson 1994 [D], Godbole 1996 [C], Rohrschneider 1998 [C], Cohen 1998 [D]). The use of smaller diagnostic size thresholds may be more applicable in younger or smaller neonates (Cohen 2000 [E]). With any size cut-off there is a reciprocal relationship of sensitivity and specificity, where a larger size cut-off will increase specificity at the expense of sensitivity, and a smaller size cut-off will increase sensitivity at the expense of specificity. The dynamic evaluation of gastric emptying by real-time US is important, particularly in cases with borderline size measurements (Strauss 1981 [D], Ball 1983 [C], Stunden 1986 [C], Mollitt 1987 [D], Hernanz-Schulman 1994 [D], Nielson 1994 [D], Godbole 1996 [C], Cohen 1998 [D], Rohrschneider 1998 [D]). Many experienced sonologists rely more on a subjective visual impression of the pyloric size and gastric emptying than on pyloric measurements (Hayden 1984 [D], Blumhagen 1986 [E], Westra 1989 [C], Godbole 1996 [C]).**

- **Note 1:** An US exam is technically nondiagnostic when the pyloric region is inadequately visualized. This may occur from excessive patient motion or from obscuration or displacement out of the field of view by excessive gastric contents. At the discretion of the sonologist, a nasogastric tube may be placed to empty the stomach and facilitate pyloric visualization. If the US exam remains nondiagnostic due to technical factors, an UGI is suggested.
- **Note 2:** Cases with borderline pyloric size measurements by US may represent pylorospasm or HPS in evolution. Persistent pyloric muscular thickening and functional gastric outlet obstruction suggests HPS. If pyloric muscular thickening and gastric outlet obstruction are transient, pylorospasm is implied (Cohen 1998 [D]).

- **Note 3:** Despite careful attention to pyloric size measurements and pyloric function by real-time US observation, some US exams may be inconclusive, particularly those with borderline size measurements. Patients with an inconclusive US exam may undergo an UGI or may be followed closely clinically with repeated physical exams and/or additional imaging studies as indicated. Follow-up is highly recommended as some of these cases may progress to frank HPS, with reported time periods ranging from a few days to greater than one month (Tunell 1984 [C], Blumhagen 1988 [D], O'Keefe 1991 [D], Lamki 1993 [C and D], Hallam 1995 [D], Godbole 1996 [C], Bergami 1996 [C]).

- 3. An UGI is favored over US as the most cost-effective initial imaging study when:**
- The clinical presentation of the vomiting infant is atypical for HPS (e.g. bilious emesis, emesis present since birth, patient age extreme) and favors other conditions more amenable to diagnosis by UGI such as GER or malrotation (Olson 1998 [Q], Hulka 1997 [D], Foley 1989 [C], Forman 1990 [C,D]).**
 - An UGI is planned if the US is negative (a negative US leading to an UGI does not save the patient radiation exposure and increases the overall cost of imaging (Cohen 2000 [E]).**
- **Note 1:** The primary criterion for the diagnosis of HPS by UGI is a narrowed, elongated pyloric channel with pyloric mass effect on the stomach and duodenum. This may produce a string sign, double tract sign, beak sign, or pyloric teat sign. Ancillary findings of HPS on UGI are gastric hyperperistalsis, large volume gastric residue, and delayed gastric emptying (Shopfner 1964 [D], Shuman 1967 [D], Cremin 1968 [D]).
 - **Note 2:** As with US, some UGI studies may be inconclusive. These cases may undergo an US or be followed closely clinically with repeated physical exams and/or additional imaging studies as indicated.

Diagnostic Algorithm

See Figure 1.

Surgical Correction:

HPS is corrected surgically by Ramstedt pyloromyotomy. The pylorus may be accessed by various incision techniques including transverse right upper quadrant,

circumbilical, and laproscopic. All methods are considered acceptable practice with minimal differences in outcomes noted (*Hingston 1996 [D]*, *Tan 1986 [C]*, *Poli-Merol 1996 [C]*, *Leinwand 1999 [D]*, *Fujimoto 1999 [C]*, *Fitzgerald 1990 [D]*).

Anesthetic Management

1. Infants with HPS have a functional gastric outlet obstruction that may place them at a greater risk for aspiration of gastric contents during induction of anesthesia (*Cook-Sather 1998 [E]*). Regardless of whether the stomach contents were aspirated prior to the infant's arrival in the operating theater, it is recommended that precautions be taken to prevent pulmonary aspiration. These maneuvers include oral/nasogastric suction prior to induction of anesthesia and maintaining cricoid pressure (Sellick's maneuver) during induction of anesthesia (*Bissonnette 1991[S]*).

Pain Management

1. Pain management is important for optimal patient outcomes. It is recommended that pain be routinely assessed using standard age appropriate scales (*Salentera 1999 [C]*, *AHCPR Guidelines 1992 [E]*).
2. It is recommended that the Neonatal Infant Pain Scale be utilized for pain assessment.

Note 1: Valuable information regarding pain management may also be obtained through the measurement of physiologic changes, behavioral observation, and caregiver/parental input (*Finley 1998 [S]*).

3. It is recommended that the wound be infiltrated with a local anesthetic (i.e. bupivacaine 0.125% up to 1ml/kg) at the conclusion of the surgical procedure. Wound infiltration with local anesthetic has been shown to decrease postoperative analgesic requirements (*Habre 1999 [D]*).
4. Further analgesia, if necessary, may be accomplished via the administration of acetaminophen (15 mg/kg/dose every 4-6 hours. Not to exceed 5 doses in 24 hours.) (*Bissonnette 1991 [S]*, *Habre 1999 [D]*). Use of opioids may potentiate the risk of respiratory depression in infants undergoing pyloromyotomy (*Habre 1999 [D]*). Therefore, it is recommended that narcotics not be administered in the routine post-operative pain management of these infants.

Surgical Site Infection Prophylaxis

1. It is recommended that one dose of Cefazolin, 25 mg/kilogram of body weight, be used to decrease the risk of surgical site infection in all patients. In the event of penicillin allergy, it is recommended that Clindamycin, 10 mg/kilogram of body weight, be the alternative antibiotic of choice.

- **Note 1:** Staphylococcus aureus is the most common organism associated with wound infections in patients who have undergone pyloromyotomy (*Rao 1989 [D]*, *Mangram 1999 [E]*).

2. To assure adequate blood level at the time of incision, it is recommended that antibiotics be given approximately 30 minutes prior to surgery (*Mangram 1999 [E]*, *Anonymous 1997 [S]*). Therefore, it is recommended that prophylactic antibiotics be given in the perioperative care before induction and the practice of giving antibiotics "on call to the OR" be discouraged as delays in patient transport or schedule changes may result in suboptimal blood and tissue levels (*Page 1993 [S]*, *Silver 1996 [D]*).

- **Note 1:** For cephalosporins, adequate blood levels are achieved and sustained for 3-4 hours. If the interval between antibiotic administration and closure of the surgical incision is greater than 4 hours, the administration of an additional dose may be considered (*Mangram 1999 [E]*).
- **Note 2:** Although rates of infection appear to be higher in the umbilical route, the administration of antibiotics reduced the risk of infection in both groups (*Leinwand 2000 [D]*).

Feeding Advancement

1. Vomiting following pyloromyotomy is usually self limiting. Although frequency of vomiting is related to type of feeding regimen, duration is independent of the timetable or composition of post-operative dietary regimen (*Carpenter 1999 [D]*, *Georgeson 1993 [D]*, *Gollin 2000 [D]*, *Wheeler 1990 [C]*). It is recommended that following pyloromyotomy, infants be fed early and with regular formula or breast milk.

- **Note 1:** The composition of feeding, and the rate of advancement (*Georgeson 1993 [D]*, *Leinwand 2000 [D]*, *Gollin 2000 [D]*) may affect the incidence or severity of vomiting post-regimen, but ultimately does not affect time to full

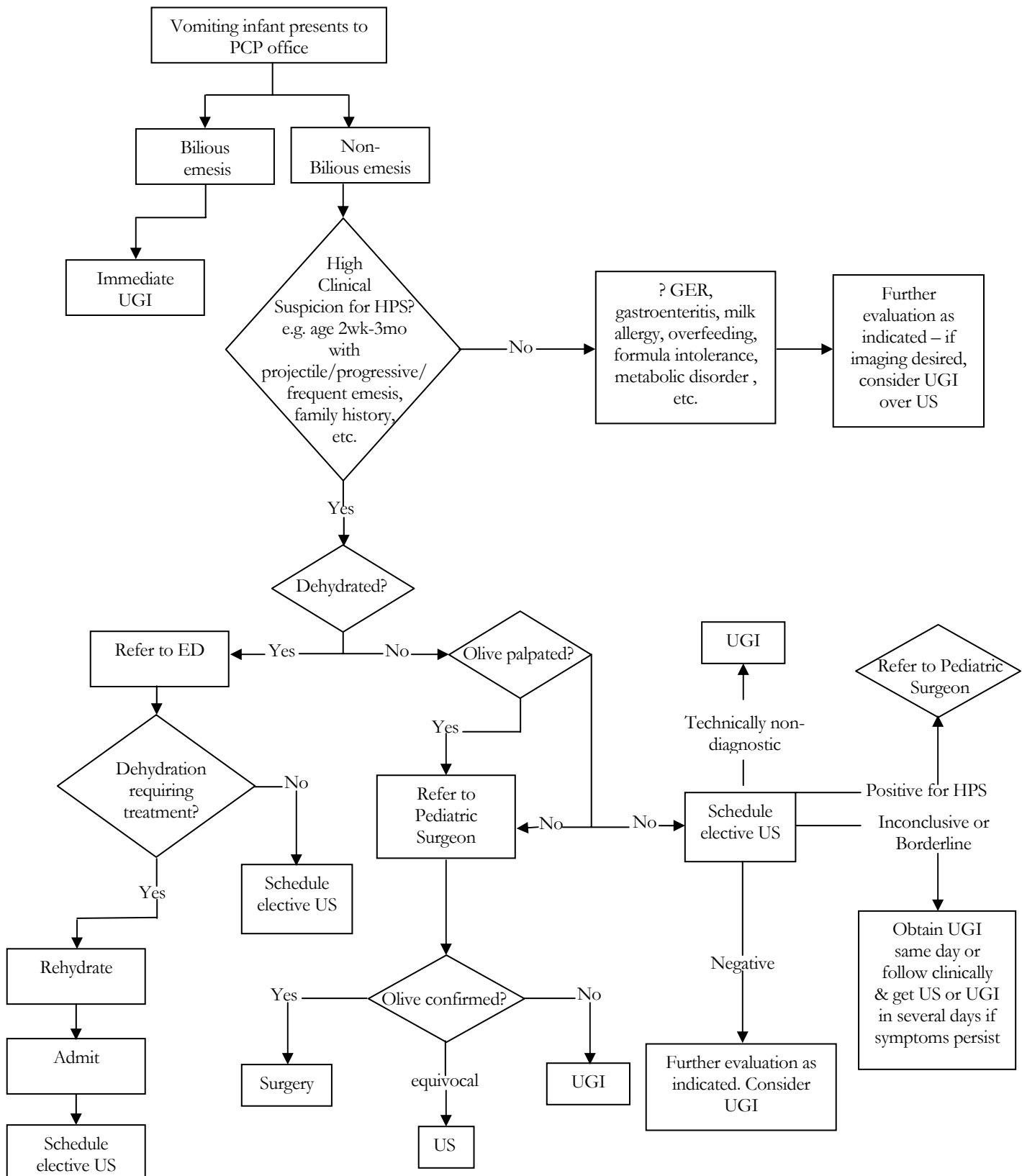
feedings, discharge or post operative weight gain (Foster 1989 [D]). (See table 3).

- **Note 2:** Duration of post-procedure vomiting is variable, with reports of 3.5% to 24% of infants with continued emesis more than 48 hours after surgery (Carpenter 1999 [D], Scharli 1968 [C], Wheeler 1990 [C]).
- **Note 3:** The most significant predictor of post-operative emesis is the duration and severity of pre-operative vomiting and is frequently manifested by electrolyte abnormalities (Gollin 2000 [D]).
- **Note 4:** Postoperatively, infants may be fed volumes based on feedings taken pre-operatively (Local expert consensus [E]).

Discharge Criteria

1. **Otherwise healthy infants may be discharged once they have tolerated two to three full feedings and/or at the discretion of the Health Care Provider** (Carpenter 1999 [D]). Infants with significant pre-operative vomiting, severe electrolyte imbalance, or malnutrition may need a longer period of recovery.
2. **Counseling of parents regarding post-operative emesis, assessment of hydration status, and signs and symptoms of infection are essential components of patient/family education** (ocal expert consensus [E]).

FIGURE 1.
Diagnostic Algorithm for Hypertrophic Pyloric Stenosis



* During off hours when an experienced sonographer is less readily available, an UGI may also be performed as an initial study.

TABLE 1. Physical Parameters Associated with Degree of Dehydration

- 1). Dehydration is usually quantitated based on the % of total body weight loss.
- 2). A weight loss of less than 3-5% can be difficult to discern clinically.
- 3). Determining weight gain following rehydration is often the only way to assess the degree of actual dehydration that existed at onset of therapies.
- 4). Any 3 of the first four parameters in this table predict dehydration of >5%, with a sensitivity of 87% and specificity of 82% (*Duggan, 1996, Gorelick 1997*).

Parameter	Mild (<6%)	Moderate (6-9%)	Severe (>9%)
MUCOUS MEMBRANES	Slightly dry	Dry	Dry
EXTREMITIES	Warm, good refill	Delayed refill	Mottled, poor refill
TEARS	Normal	Normal to absent	Absent
MENTAL STATUS	Normal	Normal to listless	Normal to Coma
Blood pressure	Normal	Normal	Normal/decrease
Pulse "quality"	Normal	Normal/ decrease?	Moderate decrease
Heart Rate	Normal	Increased	Increase or decrease
Skin Turgor	Normal	Decreased	Decreased
Fontanel	Normal	Sunken	Sunken
Eyes	Normal	Sunken	Deeply sunken
Urine Output	Slight decrease	< 1ml/kg/hr	< 1ml/kg/hr
Thirst	Slight increase	Moderate increase	May be unresponsive

Table 2: Diagnostic Performance of Imaging Studies for HPS

Author	Year	Modality	Exams	Sensitivity	Specificity	Accuracy	PPV	NPV	HPS Prevalence	Diagnostic Criterion
Shopfner	1964	UGI	70	84%*					100%	
Baghdassarian**	1965	UGI	30	100%					100%	
Shuman	1967	UGI	46	96%					100%	
Cremin	1968	UGI	27			89%				
Breaux**	1986	UGI	137	97%					100%	
Forman	1990	UGI	35	100%	100%	100%	100%	100%	34%	
Huddy	1991	UGI	9	100%	75%	89%	83%	100%	56%	
Macedessi	1993	UGI	46 86	93% 1988-1991 89% 1974-1987					100%	
Strauss	1981	US	20	100%	80%	95%	94%	100%	75%	PD 1.5 cm
Blumhagen	1981	US	35	91%	100%	94%	100%	86%	66%	PMT 4 mm
Ball	1983	US	27	80%	100%	89%	100%	80%	56%	PD 1.5 cm
"			27	93%	100%	96%	100%	92%	56%	PMT 4 mm
Pilling	1983	US	55	81%	100%	89%	100%	79%	58%	PD 1.5 cm
Khamapirad	1983	US	30	100%	86%	93%	89%	100%	53%	PD 1 cm
Blumhagen	1983	US	169	92%	100%	96%	100%	92%	55%	PMT 4 mm
Wilson**	1984	US	50	52%	100%	72%	100%	60%	58%	PD 1.5 cm
"			50	93%	90%	92%	93%	90%	58%	PMT 4 mm
"			33	100%	100%	100%	100%	100%	48%	PML 2 cm
Dell' Agnola	1984	US	17	100%	100%	100%	100%	100%	82%	PMT 4 mm
Tunell**	1984	US	91	95%	100%	98%	100%	96%	44%	PML 1.9 cm
"			91	93%	90%	91%	88%	94%	44%	PMT 4 mm
"			91	80%	96%	89%	94%	86%	44%	PD 1.3 cm
Stunden	1986	US	200	100%	100%	100%	100%	100%	56%	PCL 16 mm
Mollitt	1987	US	73	100%	100%	100%	100%	100%	42%	PMT 4 mm, PD 13 mm PL 17 mm
Carver	1988	US	39	100%	100%	100%	100%	100%	51%	PMI 0.4
Blumhagen	1988	US	326	98%	100%	99%	100%	99%	34%	PMT 4 mm
Westra	1989	US	75	100%	100%	100%	100%	100%	29%	PV 1.4 mL
Philippin	1989	US	157 157 157	77% 80% 84%	98% 100% 96%				40% 40% 40%	PD 14 mm PCL 18 mm PMT 4 mm
Forman	1990	US	41	89%	100%	96%	100%	92%	44%	PMT 4 mm or PL 16 mm
Rollins	1991	US	100	100%	100%	100%	100%	100%	44%	PMT 4mm or PD 15 mm
Hernanz-Schulman	1994	US	150	100%	100%	100%	100%	100%	44%	PMT 3 mm
Neilson	1994	US	147	97%	99%	98%	99%	98%	46%	PCL 16 mm, PD 11 mm, PMT 2.5 mm
Godbole	1996	US	127	99%	100%	99%	100%	98%	65%	PMI > 0.46
Rohrschneider	1998	US	85			100% 96% 94% 92%				PMT 3 mm PV 1.2 mL PML 15 mm PD 11 mm
Lowe	1999	US	84	96%	94%				40%	PR 0.27

* Cited in article text as accuracy. ** Non-diagnostic studies excluded from analysis.

The studies abstracted in Table 2 are a subset of numerous publications and are chosen to be representative of the diagnostic performance of UGI and US for HPS. The studies are variably limited by sample size and design. The statistics are as cited by the references; otherwise, they are calculated from 2x2 contingency tables derived from the raw data provided in the references.

PMT = Pyloric Muscle Thickness PML = Pyloric Muscle Length PCL = Pyloric Channel Length PL = Pyloric Length
PD = Pyloric Diameter PV = Pyloric Volume PMI = Pyloric Muscle Index PR = Pyloric Ratio PPV = Positive Predictive Value
NPV = Negative Predictive Value

Table 3. Comparison of Feeding Regimens on Post-Op Vomiting

Composition	Rate	Length NPO	Reference	Vomiting
D5W ½ strength formula FS formula	12 feedings – odd # feeds – 15cc sterile water; even # feeds 4 cc sterile water +2 x n ml formula. n=feeding #. The 2nd feed comes 4h after the first, then q2h x2 then; q1.5 hrs x 8. Then ad lib.	Overnight >10 hrs	Georgeson et al, 1993	29%
	Same schedule as above	6-8 hrs		35%
	2 feeding* 3 feedings* 2 feeding* *advancing 15-30cc with each feeding, starting at 15cc with each set.	6 hrs		55%
	Pedialyte FS formula	30cc q1h x6 30cc q1h x6 then ad lib		83%
Pedialyte ½ strength formula Full strength Formula	Advance q 3 hrs 15 ml x1; 30 ml x1 30 ml x1; 60 ml x1 60 ml x1; 75-90 ml; ad lib	6 hours	Gollin et al, 2000	54%
Pedialyte ½ strength formula FS formula	Advance q2h 30 ml x3 30 ml x4 45 ml x4; 60 ml x4; 75-90 ml q3h	6 hours		48%
FS formula	30 ml x1; 60 ml x1; 75-90 ml x1; ad lib	1 hour		50%
D5W ¼ strength formula ½ strength formula	5 ml; 1 hr later 10 ml 1hr later 15ml; then advancing to full feeds in 24 hrs	4 hrs	Leahy & Fitzgerald 1982	73%
½ strength 2/3 strength full strength	on Day 2 on Day 3 on Day 4	24 hrs		47%
D5W ½ str. Milk FS milk	Advance q2h 5cc D5W, 5cc ½ str. Milk 10cc D5W; 10cc ½ str. Milk 15cc D5W; 15cc ½ str. Milk 25 cc D5W; 25cc ½ str. Milk 35cc D5W; 25cc ½ str milk 45cc D5W; 45 cc ½ str. Milk FS milk ad lib q3-4 hrs	4 hours	Turnock & Rangecroft 1991	78%
	Advance q3h 15cc x2; 30cc x2; 30cc x2; 45 cc x1 ad lib q3-4	18 hours		62%
D5W ½ strength feed	5ml q1h x4; 10ml q1h x3 10ml q1h x3; then q2hrs give 15ml x3; 30 ml x2	4 hrs	Wheeler et al, 1990	
¾ strength feed FS feed	30 ml x2 30ml x2; 45ml x2; 60 ml x2; 75ml x2; then ad lib	4 hrs		
D5W FS feed	40 ml q4h x1 80 ml q4h x3 then ad lib	24 hours		
FS Feed	ad lib			

REFERENCES

(Note: Some references included in this listing are not cited in the guidelines and are included for those interested in pursuing a further in-depth review of these subjects.)

1. [Abbas, A. E., S. M. Weiss, and D. T. Alvear](#) 1999. Infantile hypertrophic pyloric stenosis: delays in diagnosis and overutilization of imaging modalities *Am Surg.* **65**:73-6.
2. [Abreu e Silva, F. A., U. M. MacFadyen, A. Williams, and H. Simpson](#) 1986. Sleep apnoea during upper respiratory infection and metabolic alkalosis in infancy *Arch Dis Child.* **61**:1056-62.
3. [Alain, J. L., D. Grousseau, B. Longis, M. Ugazzi, and G. Terrier](#) 1996. Extramucosal pyloromyotomy by laparoscopy *J Laparoendosc Surg.* **6 Suppl 1**:S41-4.
4. [Alain, J. L., D. Grousseau, and G. Terrier](#) 1991. Extramucosal pyloromyotomy by laparoscopy *Surg Endosc.* **5**:174-5.
5. [Ali Gharaibeh, K. I., F. Ammari, G. Qasaimeh, B. Kasawneh, M. Sheyyab, and M. Rawashdeh](#) 1992. Pyloromyotomy through circumumbilical incision *J R Coll Surg Edinb.* **37**:175-6.
6. [Andropoulos, D. B., M. B. Heard, K. L. Johnson, J. T. Clarke, and R. W. Rowe](#) 1994. Postanesthetic apnea in full-term infants after pyloromyotomy *Anesthesiology.* **80**:216-9.
7. [Applegate, M. S., and C. M. Druschel](#) 1995. The epidemiology of infantile hypertrophic pyloric stenosis in New York State, 1983 to 1990 *Arch Pediatr Adolesc Med.* **149**:1123-9.
8. [Baghdassarian, O. M., and J. J. Vanhoutte](#) 1965. Water-soluble contrast media in the roentgenographic diagnosis of hypertrophic pyloric stenosis in infants *Radiology.* **85**:689-92.
9. [Ball, T. I., G. O. Atkinson, Jr., and B. B. Gay, Jr.](#) 1983. Ultrasound diagnosis of hypertrophic pyloric stenosis: real-time application and the demonstration of a new sonographic sign *Radiology.* **147**:499-502.
10. [Beilin, B., E. Vatahsky, H. B. Aronson, and M. Weinstock](#) 1985. Naloxone reversal of postoperative apnea in a premature infant *Anesthesiology.* **63**:317-8.
11. [Bennett, E. J., H. L. Augee, and M. T. Jenkins](#) 1968. Pyloric stenosis *Clin Anesth.* **3**:276-86.
12. [Benson, C. D.](#) 1970. Infantile pyloric stenosis. Historical aspects and current surgical concepts *Prog Pediatr Surg.* **1**:63-88.
13. [Bergami, G., L. Rossi, S. Malena, M. Patricolo, A. Alessandri, and A. Vecchioli Scaldazza](#) 1996. [Ultrasonography in hypertrophic stenosis of the pylorus: clinico- therapeutic implications in borderline cases] *Radiol Med (Torino).* **92**:78-81.
14. [Beynon, J., R. Brown, C. James, and R. Fernando](#) 1987. Pyloromyotomy: can the morbidity be improved? *J R Coll Surg Edinb.* **32**:291-2.
15. [Bissonnette, B., and P. J. Sullivan](#) 1991. Pyloric stenosis *Can J Anaesth.* **38**:668-76.
16. [Blumhagen, J. D.](#) 1986. The role of ultrasonography in the evaluation of vomiting in infants *Pediatr Radiol.* **16**:267-70.
17. [Blumhagen, J. D., and J. B. Coombs](#) 1981. Ultrasound in the diagnosis of hypertrophic pyloric stenosis *J Clin Ultrasound.* **9**:289-92.
18. [Blumhagen, J. D., L. Maclin, D. Krauter, D. M. Rosenbaum, and E. Weinberger](#) 1988. Sonographic diagnosis of hypertrophic pyloric stenosis *AJR Am J Roentgenol.* **150**:1367-70.
19. [Blumhagen, J. D., and H. G. Noble](#) 1983. Muscle thickness in hypertrophic pyloric stenosis: sonographic determination *AJR Am J Roentgenol.* **140**:221-3.
20. [Bourchier, D., K. P. Dawson, and J. C. Kennedy](#) 1985. Pyloric stenosis: a postoperative ultrasonic study *Aust Paediatr J.* **21**:189-90.
21. [Breaux, C. W., Jr., and K. E. Georgeson](#) 1986. Hypertrophic pyloric stenosis: a review of 216 cases from 1980 to 1984 *Ala Med.* **55**:34-7.
22. [Breaux, C. W., Jr., K. E. Georgeson, S. A. Royal, and A. J. Curnow](#) 1988. Changing patterns in the diagnosis of hypertrophic pyloric stenosis *Pediatrics.* **81**:213-7.
23. [Breaux, C. W., Jr., J. S. Hood, and K. E. Georgeson](#) 1989. The significance of alkalosis and hypochloremia in hypertrophic pyloric stenosis *J Pediatr Surg.* **24**:1250-2.
24. [Bristol, J. B., and R. A. Bolton](#) 1981. The results of Ramstedt's operation in a district general hospital *Br J Surg.* **68**:590-2.
25. [Bufo, A. J., C. Merry, R. Shah, N. Cyr, K. P. Schropp, and T. E. Lobe](#) 1998. Laparoscopic pyloromyotomy: a safer technique *Pediatr Surg Int.* **13**:240-2.
26. [Carpenter, R. O., R. L. Schaffer, C. E. Maeso, F. Sasan, J. G. Nuchtern, T. Jaksic, F. J. Harberg, D. E. Wesson, and M. L. Brandt](#) 1999. Postoperative ad lib feeding for hypertrophic pyloric stenosis *J Pediatr Surg.* **34**:959-61.
27. [Carver, R. A., M. Okorie, G. M. Steiner, and J. A. Dickson](#) 1987. Infantile hypertrophic pyloric stenosis--diagnosis from the pyloric muscle index *Clin Radiol.* **38**:625-7.
28. [Castanon, J., E. Portilla, E. Rodriguez, V. Gonzalez, H. Silva, and A. Ramos](#) 1995. A new technique for laparoscopic repair of hypertrophic pyloric stenosis *J Pediatr Surg.* **30**:1294-6.
29. [Chen, E. A., F. I. Luks, B. F. Gilchrist, C. W. Wesselhoeft, Jr., and F. G. DeLuca](#) 1996. Pyloric stenosis in the age of ultrasonography: fading skills, better patients? *J Pediatr Surg.* **31**:829-30.
30. [Chesney, R. W., and I. Zelikovic](#) 1989. Pre- and postoperative fluid management in infancy *Pediatr Rev.* **11**:153-8.
31. [Chipps, B. E., R. Moynihan, T. Schieble, R. Stene, W. Feaster, C. Marr, S. Greenholz, N. Poulos, and D. Groza](#) 1999. Infants undergoing pyloromyotomy are

- not at risk for postoperative apnea. Staff of Sutter Community Hospitals Sleep Disorders Center *Pediatr Pulmonol.* **27**:278-81.
32. [Cohen, H. L., D. S. Babcock, D. C. Kushner, M. J. Gelfand, R. J. Hernandez, W. H. McAlister, B. R. Parker, S. A. Royal, T. L. Slovis, W. L. Smith, J. L. Strife, J. D. Strain, M. B. Kanda, E. Myer, R. M. Decter, and M. S. Moreland](#) 2000. Vomiting in infants up to 3 months of age. *American College of Radiology. ACR Appropriateness Criteria Radiology.* **215 Suppl**:779-86.
 33. [Cohen, H. L., H. L. Zinn, J. O. Haller, P. J. Homel, and J. M. Stoane](#) 1998. Ultrasonography of pylorospasm: findings may simulate hypertrophic pyloric stenosis *J Ultrasound Med.* **17**:705-11.
 34. [Conn, A. W.](#) 1963. Anaesthesia for pyloromyotomy in infancy *Can Anaesth Soc J.* **10**:18-29.
 35. [Cook-Sather, S. D., H. V. Tulloch, A. Cnaan, S. C. Nicolson, M. L. Cubina, P. R. Gallagher, and M. S. Schreiner](#) 1998. A comparison of awake versus paralyzed tracheal intubation for infants with pyloric stenosis *Anesth Analg.* **86**:945-51.
 36. [Cook-Sather, S. D., H. V. Tulloch, C. A. Liacouras, and M. S. Schreiner](#) 1997. Gastric fluid volume in infants for pyloromyotomy *Can J Anaesth.* **44**:278-83.
 37. [Cremin, B. J., and A. Klein](#) 1968. Infantile pyloric stenosis: a 10-year survey *S Afr Med J.* **42**:1056-60.
 38. [Crumrine, R. S.](#) 1971. Postoperative hypoxia in infants and children *Int Anesthesiol Clin.* **9**:83-97.
 39. [Daly, A. M., and A. W. Conn](#) 1969. Anaesthesia for pyloromyotomy: a review (the Hospital for Sick Children, Toronto) *Can Anaesth Soc J.* **16**:316-20.
 40. [Davies, R. P., R. J. Linke, R. G. Robinson, J. A. Smart, and C. Hargreaves](#) 1992. Sonographic diagnosis of infantile hypertrophic pyloric stenosis *J Ultrasound Med.* **11**:603-5.
 41. [Dawson, K. P., and D. Graham](#) 1991. The assessment of dehydration in congenital pyloric stenosis *N Z Med J.* **104**:162-3.
 42. [De Backer, A., T. Bove, Y. Vandenplas, S. Peeters, and P. Deconinck](#) 1994. Contribution of endoscopy to early diagnosis of hypertrophic pyloric stenosis *J Pediatr Gastroenterol Nutr.* **18**:78-81.
 43. [De Caluwe, D., R. Reding, J. de Ville de Goyet, and J. B. Otte](#) 1998. Intraabdominal pyloromyotomy through the umbilical route: a technical improvement *J Pediatr Surg.* **33**:1806-7.
 44. [dell'Agnola, C. A., V. Tomaselli, C. Colombo, and A. M. Fagnani](#) 1984. Reliability of ultrasound for the diagnosis of hypertrophic pyloric stenosis *J Pediatr Gastroenterol Nutr.* **3**:539-44.
 45. [Dierdorf, S. F., and G. Krishna](#) 1981. Anesthetic management of neonatal surgical emergencies *Anesth Analg.* **60**:204-15.
 46. [Donnellan, W. L., and L. M. Cobb](#) 1991. Intraabdominal pyloromyotomy *J Pediatr Surg.* **26**:174-5.
 47. [Downey, E. C., Jr.](#) 1998. Laparoscopic pyloromyotomy *Semin Pediatr Surg.* **7**:220-4.
 48. [Dube, S., P. Dube, J. F. Hardy, and R. E. Rosenfeld](#) 1990. Pyloromyotomy of Ramstedt: experience of a nonspecialized centre *Can J Surg.* **33**:95-6.
 49. [Duggan, C., M. Refat, M. Hashem, M. Wolff, I. Fayad, and M. Santosham](#) 1996. How valid are clinical signs of dehydration in infants? *J Pediatr Gastroenterol Nutr.* **22**:56-61.
 50. [Eckstein, H. B., and M. Agrawal](#) 1982. Congenital hypertrophic pyloric stenosis--a 20-year review of 282 surgically treated infants *Z Kinderchir.* **36**:50-2.
 51. [Eriksen, C. A., and C. J. Anders](#) 1991. Audit of results of operations for infantile pyloric stenosis in a district general hospital *Arch Dis Child.* **66**:130-3.
 52. [Feldman, D., N. Reich, and J. M. Foster](#) 1998. Pediatric anesthesia and postoperative analgesia *Pediatr Clin North Am.* **45**:1525-37.
 53. [Finkelstein, M. S., G. A. Mandell, and K. V. Tarbell](#) 1990. Hypertrophic pyloric stenosis: volumetric measurement of nasogastric aspirate to determine the imaging modality *Radiology.* **177**:759-61.
 54. [Finley, G. A., and P. J. McGrath](#) 1998. Measurement of pain in infants and children. IASP Press, Seattle.
 55. [Fitzgerald, P. G., G. Y. Lau, J. C. Langer, and G. S. Cameron](#) 1990. Umbilical fold incision for pyloromyotomy *J Pediatr Surg.* **25**:1117-8.
 56. [Foley, L. C., T. L. Slovis, J. B. Campbell, J. D. Strain, L. A. Harvey, and D. W. Luckey](#) 1989. Evaluation of the vomiting infant *Am J Dis Child.* **143**:660-1.
 57. [Ford, W. D., J. A. Cramer, and A. J. Holland](#) 1997. The learning curve for laparoscopic pyloromyotomy *J Pediatr Surg.* **32**:552-4.
 58. [Forman, H. P., J. C. Leonidas, and G. D. Kronfeld](#) 1990. A rational approach to the diagnosis of hypertrophic pyloric stenosis: do the results match the claims? *J Pediatr Surg.* **25**:262-6.
 59. [Foster, M. E., and W. G. Lewis](#) 1989. Early postoperative feeding--a continuing controversy in pyloric stenosis *J R Soc Med.* **82**:532-3.
 60. [Freund, H., Y. Berlatzky, R. Katzenelson, and M. Schiller](#) 1976. Diagnosis of pyloric stenosis *Lancet.* **1**:473.
 61. [Fujimoto, T., G. J. Lane, O. Segawa, S. Esaki, and T. Miyano](#) 1999. Laparoscopic extramucosal pyloromyotomy versus open pyloromyotomy for infantile hypertrophic pyloric stenosis: which is better? *J Pediatr Surg.* **34**:370-2.
 62. [Garcia, V. F., and J. G. Randolph](#) 1990. Pyloric stenosis: diagnosis and management *Pediatr Rev.* **11**:292-6.
 63. [Georgeson, K. E., T. J. Corbin, J. W. Griffen, and C. W. Breaux, Jr.](#) 1993. An analysis of feeding regimens after pyloromyotomy for hypertrophic pyloric stenosis *J Pediatr Surg.* **28**:1478-80.

64. [Godbole, P., A. Sprigg, J. A. Dickson, and P. C. Lin](#) 1996. Ultrasound compared with clinical examination in infantile hypertrophic pyloric stenosis *Arch Dis Child*. **75**:335-7.
65. [Goh, D. W., S. K. Hall, P. Gornall, R. G. Buick, A. Green, and J. J. Corkery](#) 1990. Plasma chloride and alkalaemia in pyloric stenosis *Br J Surg*. **77**:922-3.
66. [Golladay, E. S., J. R. Broadwater, and D. L. Mollitt](#) 1987. Pyloric stenosis--a timed perspective *Arch Surg*. **122**:825-6.
67. [Gollin, G., H. Dosloughlu, P. Flummerfeldt, M. G. Caty, P. L. Glick, J. E. Allen, and R. G. Azizkhan](#) 2000. Rapid advancement of feedings after pyloromyotomy for pyloric stenosis *Clin Pediatr (Phila)*. **39**:187-90.
68. [Gomes, H., and P. Lallemand](#) 1992. Infant apnea and gastroesophageal reflux *Pediatr Radiol*. **22**:8-11.
69. [Gomes, H., and B. Menanteau](#) 1983. Sonography of normal and hypertrophic pylorus *Ann Radiol (Paris)*. **26**:154-60.
70. [Gorelick, M. H., K. N. Shaw, and K. O. Murphy](#) 1997. Validity and reliability of clinical signs in the diagnosis of dehydration in children *Pediatrics*. **99**:E6.
71. [Graham, D. A., N. Mogridge, G. D. Abbott, J. C. Kennedy, P. M. Kempthorne, and J. R. Davidson](#) 1993. Pyloric stenosis: the Christchurch experience *N Z Med J*. **106**:57-9.
72. [Graham, J. A.](#) 1970. Muscle water and electrolytes in pyloric stenosis *Lancet*. **1**:386-9.
73. [Graif, M., Y. Itzhak, I. Avigad, S. Strauss, and T. Ben-Ami](#) 1984. The pylorus in infancy: overall sonographic assessment *Pediatr Radiol*. **14**:14-7.
74. [Greason, K. L., W. R. Thompson, E. C. Downey, and B. Lo Sasso](#) 1995. Laparoscopic pyloromyotomy for infantile hypertrophic pyloric stenosis: report of 11 cases *J Pediatr Surg*. **30**:1571-4.
75. [Habre, W., C. Schwab, I. Gollow, and C. Johnson](#) 1999. An audit of postoperative analgesia after pyloromyotomy *Paediatr Anaesth*. **9**:253-6.
76. [Hallam, D., B. Hansen, B. Bodker, S. Klintorp, and J. F. Pedersen](#) 1995. Pyloric size in normal infants and in infants suspected of having hypertrophic pyloric stenosis *Acta Radiol*. **36**:261-4.
77. [Haller, J. O., and H. L. Cohen](#) 1986. Hypertrophic pyloric stenosis: diagnosis using US *Radiology*. **161**:335-9.
78. [Hamada, Y., M. Tsui, M. Kogata, K. Hioki, and T. Matsuda](#) 1995. Surgical technique of laparoscopic pyloromyotomy for infantile hypertrophic pyloric stenosis *Surg Today*. **25**:754-6.
79. [Hayden, C. K., Jr., L. E. Swischuk, T. E. Lobe, M. Z. Schwartz, and T. Boulden](#) 1984. Ultrasound: the definitive imaging modality in pyloric stenosis *RadioGraphics*. **4**:517-30.
80. [Hernanz-Schulman, M., W. W. Neblett, 3rd, D. B. Polk, and J. E. Johnson](#) 1998. Hypertrophied pyloric mucosa in patients with hypertrophic pyloric stenosis *Pediatr Radiol*. **28**:901.
81. [Hernanz-Schulman, M., L. L. Sells, M. M. Ambrosino, R. M. Heller, S. M. Stein, and W. W. Neblett, 3rd](#) 1994. Hypertrophic pyloric stenosis in the infant without a palpable olive: accuracy of sonographic diagnosis *Radiology*. **193**:771-6.
82. [Hingston, G.](#) 1996. Ramstedt's pyloromyotomy--what is the correct incision? *N Z Med J*. **109**:276-8.
83. [Horne, J., T. D. Watson, 3rd, A. H. Giesecke, Jr., P. R. Raj, and E. W. Ahlgren](#) 1973. Prolonged apnea in an infant following the use of succinylcholine *Anesthesiology*. **39**:545-7.
84. [Horwitz, J. R., and K. P. Lally](#) 1996. Supraumbilical skin-fold incision for pyloromyotomy *Am J Surg*. **171**:439-40.
85. [Huddy, S. P.](#) 1991. Investigation and diagnosis of hypertrophic pyloric stenosis *J R Coll Surg Edinb*. **36**:91-3.
86. [Hulka, F., J. R. Campbell, M. W. Harrison, and T. J. Campbell](#) 1997. Cost-effectiveness in diagnosing infantile hypertrophic pyloric stenosis *J Pediatr Surg*. **32**:1604-8.
87. [Hulka, F., T. J. Campbell, J. R. Campbell, and M. W. Harrison](#) 1997. Evolution in the recognition of infantile hypertrophic pyloric stenosis *Pediatrics*. **100**:E9.
88. [Hulka, F., M. W. Harrison, T. J. Campbell, and J. R. Campbell](#) 1997. Complications of pyloromyotomy for infantile hypertrophic pyloric stenosis *Am J Surg*. **173**:450-2.
89. [Jamroz, G. A., S. H. Blocker, and W. H. McAlister](#) 1986. Radiographic findings after incomplete pyloromyotomy *Gastrointest Radiol*. **11**:139-41.
90. [Janik, J. S., E. R. Wayne, and J. P. Janik](#) 1996. Pyloric stenosis in premature infants *Arch Pediatr Adolesc Med*. **150**:223-4.
91. [Karayan, J., L. LaCoste, and J. Fusciardi](#) 1991. Postoperative apnea in a full-term infant *Anesthesiology*. **75**:375.
92. [Keller, H., D. Waldmann, and P. Greiner](#) 1987. Comparison of preoperative sonography with intraoperative findings in congenital hypertrophic pyloric stenosis *J Pediatr Surg*. **22**:950-2.
93. [Khamapirad, T., and P. A. Athey](#) 1983. Ultrasound diagnosis of hypertrophic pyloric stenosis *J Pediatr*. **102**:23-6.
94. [Kovalivker, M., I. Erez, N. Shneider, E. Glazer, and L. Lazar](#) 1993. The value of ultrasound in the diagnosis of congenital hypertrophic pyloric stenosis *Clin Pediatr (Phila)*. **32**:281-3.
95. [Kumar, V., and W. C. Bailey](#) 1975. Electrolyte and acid base problems in hypertrophic pyloric stenosis in infancy *Indian Pediatr*. **12**:839-45.
96. [Kurth, C. D., A. R. Spitzer, A. M. Broennle, and J. J. Downes](#) 1987. Postoperative apnea in preterm infants *Anesthesiology*. **66**:483-8.

97. [Lamki, N., P. A. Athey, M. E. Round, A. B. Watson, Jr., and M. J. Pflieger](#) 1993. Hypertrophic pyloric stenosis in the neonate--diagnostic criteria revisited *Can Assoc Radiol J.* **44**:21-4.
98. [Leahy, A., and R. J. Fitzgerald](#) 1982. The influence of delayed feeding on postoperative vomiting in hypertrophic pyloric stenosis *Br J Surg.* **69**:658-9.
99. [Leinwand, M. J., D. B. Shaul, and K. D. Anderson](#) 2000. A standardized feeding regimen for hypertrophic pyloric stenosis decreases length of hospitalization and hospital costs *J Pediatr Surg.* **35**:1063-5.
100. [Leinwand, M. J., D. B. Shaul, and K. D. Anderson](#) 1999. The umbilical fold approach to pyloromyotomy: is it a safe alternative to the right upper-quadrant approach? *J Am Coll Surg.* **189**:362-7.
101. [Lund Kofoed, P. E., A. Host, B. Elle, and C. Larsen](#) 1988. Hypertrophic pyloric stenosis: determination of muscle dimensions by ultrasound *Br J Radiol.* **61**:19-20.
102. [Macdessi, J., and R. K. Oates](#) 1993. Clinical diagnosis of pyloric stenosis: a declining art *Bmj.* **306**:553-5.
103. [MacDonald, N. J., G. J. Fitzpatrick, K. P. Moore, W. S. Wren, and M. Keenan](#) 1987. Anaesthesia for congenital hypertrophic pyloric stenosis. A review of 350 patients *Br J Anaesth.* **59**:672-7.
104. [Mackay, A. J., and A. Mackellar](#) 1986. Infantile hypertrophic pyloric stenosis: a review of 222 cases *Aust N Z J Surg.* **56**:131-3.
105. [Mandell, G. A., and M. S. Finkelstein](#) 1999. The role of ultrasonography in the diagnosis of pyloric stenosis: a decision analysis *J Pediatr Surg.* **34**:376.
106. [Mangram, A. J., T. C. Horan, M. L. Pearson, L. C. Silver, and W. R. Jarvis](#) 1999. Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee *Infect Control Hosp Epidemiol.* **20**:250-78; quiz 279-80.
107. [McNicol, L. R., C. S. Martin, N. G. Smart, and R. W. Logan](#) 1990. Peroperative bupivacaine for pyloromyotomy pain *Lancet.* **335**:54-5.
108. [Mendenhall, M. K., and E. W. Ahlgren](#) 1979. Anesthetic considerations in surgery for gastrointestinal disease *Surg Clin North Am.* **59**:905-17.
109. [Mollitt, D. L., E. S. Golladay, S. Williamson, J. J. Seibert, and S. L. Sutterfield](#) 1987. Ultrasonography in the diagnosis of pyloric stenosis *South Med J.* **80**:47-50.
110. [Murtagh, K., P. Perry, M. Corlett, and I. Fraser](#) 1992. Infantile hypertrophic pyloric stenosis *Dig Dis.* **10**:190-8.
111. [Nadel, F. M., and S. A. Weinzimer](#) 2000. The case of the missing "olive" *Pediatr Ann.* **29**:119-22.
112. [Nagita, A., J. Yamaguchi, K. Amemoto, A. Yoden, T. Yamazaki, and M. Mino](#) 1996. Management and ultrasonographic appearance of infantile hypertrophic pyloric stenosis with intravenous atropine sulfate *J Pediatr Gastroenterol Nutr.* **23**:172-7.
113. [Najmaldin, A., and H. L. Tan](#) 1995. Early experience with laparoscopic pyloromyotomy for infantile hypertrophic pyloric stenosis *J Pediatr Surg.* **30**:37-8.
114. [Naylor, B., J. Radhakrishnan, and D. McLaughlin](#) 1992. Postoperative apnea in infants *J Pediatr Surg.* **27**:955-7.
115. [Neilson, D., and A. S. Hollman](#) 1994. The ultrasonic diagnosis of infantile hypertrophic pyloric stenosis: technique and accuracy *Clin Radiol.* **49**:246-7.
116. [Noseworthy, J., C. Duran, and H. H. Khine](#) 1989. Postoperative apnea in a full-term infant *Anesthesiology.* **70**:879-80.
117. [Nour, S., A. E. MacKinnon, J. A. Dickson, and J. Walker](#) 1996. Antibiotic prophylaxis for infantile pyloromyotomy *J R Coll Surg Edinb.* **41**:178-80.
118. [Nour, S., Y. Mangnall, J. A. Dickson, R. Pearce, and A. G. Johnson](#) 1993. Measurement of gastric emptying in infants with pyloric stenosis using applied potential tomography *Arch Dis Child.* **68**:484-6.
119. [O'Donoghue, J. M., D. M. O'Hanlon, M. M. Gallagher, K. D. Connolly, J. Doyle, and J. R. Flynn](#) 1993. Ramstedt's pyloromyotomy: a specialist procedure? *Br J Clin Pract.* **47**:192-4.
120. [Ohri, S. K., J. M. Sackier, and P. Singh](#) 1991. Modified Ramstedt's pyloromyotomy for the treatment of infantile hypertrophic pyloric stenosis *J R Coll Surg Edinb.* **36**:94-6.
121. [O'Keeffe, F. N., S. D. Stansberry, L. E. Swischuk, and C. K. Hayden, Jr.](#) 1991. Antropyloric muscle thickness at US in infants: what is normal? *Radiology.* **178**:827-30.
122. [Okorie, N. M., J. A. Dickson, R. A. Carver, and G. M. Steiner](#) 1988. What happens to the pylorus after pyloromyotomy? *Arch Dis Child.* **63**:1339-41.
123. [Olson, A. D., R. Hernandez, and R. B. Hirschl](#) 1998. The role of ultrasonography in the diagnosis of pyloric stenosis: a decision analysis *J Pediatr Surg.* **33**:676-81.
124. [Ozsvath, R. R., M. Poustchi-Amin, J. C. Leonidas, and S. S. Elkowitz](#) 1997. Pyloric volume: an important factor in the surgeon's ability to palpate the pyloric "olive" in hypertrophic pyloric stenosis *Pediatr Radiol.* **27**:175-7.
125. [Page, C. P., J. M. Bohnen, J. R. Fletcher, A. T. McManus, J. S. Solomkin, and D. H. Wittmann](#) 1993. Antimicrobial prophylaxis for surgical wounds. Guidelines for clinical care *Arch Surg.* **128**:79-88.
126. [Papadakis, K., E. A. Chen, F. I. Luks, M. S. Lessin, C. W. Wesselhoeft, Jr., and F. G. DeLuca](#) 1999. The changing presentation of pyloric stenosis *Am J Emerg Med.* **17**:67-9.
127. [Perry, E. P., I. A. Fraser, and A. Rhodes](#) 1988. Ultrasound and pyloric stenosis *Lancet.* **2**:391.
128. [Philippin, U., and M. Zieger](#) 1989. [Sonography of hypertrophic pyloric stenosis. Statistical analysis of the values and the diagnostic criteria] *Radiologe.* **29**:386-90.

129. [Pilling, D. W.](#) 1983. Infantile hypertrophic pyloric stenosis: a fresh approach to the diagnosis Clin Radiol. **34**:51-3.
130. [Poli-Merol, M. L., S. Francois, F. Lefebvre, M. A. Bouche Pillon-Persyn, G. Lefort, and S. Daoud](#) 1996. Interest of umbilical fold incision for pyloromyotomy Eur J Pediatr Surg. **6**:13-4.
131. [Poon, T. S., A. L. Zhang, T. Cartmill, and D. T. Cass](#) 1996. Changing patterns of diagnosis and treatment of infantile hypertrophic pyloric stenosis: a clinical audit of 303 patients J Pediatr Surg. **31**:1611-5.
132. [Rao, N., and G. G. Youngson](#) 1989. Wound sepsis following Ramstedt pyloromyotomy Br J Surg. **76**:1144-6.
133. [Rasmussen, L., L. P. Hansen, and S. A. Pedersen](#) 1987. Infantile hypertrophic pyloric stenosis: the changing trend in treatment in a Danish county J Pediatr Surg. **22**:953-5.
134. [Rawal, N.](#) 1994. Postoperative pain and its management Ann Acad Med Singapore. **23**:56-64.
135. [Reyna, T. M., and P. A. Reyna](#) 1995. Gastroduodenal disorders associated with emesis in infants Semin Pediatr Surg. **4**:190-7.
136. [Riggs, W., Jr., and L. Long](#) 1971. The value of the plain film roentgenogram in pyloric stenosis Am J Roentgenol Radium Ther Nucl Med. **112**:77-82.
137. [Rohrschneider, W. K., H. Mittnacht, K. Darge, and J. Troger](#) 1998. Pyloric muscle in asymptomatic infants: sonographic evaluation and discrimination from idiopathic hypertrophic pyloric stenosis Pediatr Radiol. **28**:429-34.
138. [Rollins, M. D., M. D. Shields, R. J. Quinn, and M. A. Wooldridge](#) 1989. Pyloric stenosis: congenital or acquired? Arch Dis Child. **64**:138-9.
139. [Rollins, M. D., M. D. Shields, R. J. Quinn, and M. A. Wooldridge](#) 1991. Value of ultrasound in differentiating causes of persistent vomiting in infants Gut. **32**:612-4.
140. [Romsing, J.](#) 1996. Assessment of nurses' judgement for analgesic requirements of postoperative children J Clin Pharm Ther. **21**:159-63.
141. [Romsing, J., and S. Walther-Larsen](#) 1997. Peri-operative use of nonsteroidal anti-inflammatory drugs in children: analgesic efficacy and bleeding Anaesthesia. **52**:673-83.
142. [Rothenberg, S. S., J. H. Chang, and J. F. Bealer](#) 1998. Experience with minimally invasive surgery in infants Am J Surg. **176**:654-8.
143. [Royal, R. E., D. N. Linz, D. L. Gruppo, and M. M. Ziegler](#) 1995. Repair of mucosal perforation during pyloromyotomy: surgeon's choice J Pediatr Surg. **30**:1430-2.
144. [Saavedra, J. M., G. D. Harris, S. Li, and L. Finberg](#) 1991. Capillary refilling (skin turgor) in the assessment of dehydration Am J Dis Child. **145**:296-8.
145. [Safdar, C. A., and M. A. Hashmi](#) 1992. Antibiotic prophylaxis in paediatric surgery J Pak Med Assoc. **42**:286-8.
146. [Salantera, S., S. Lauri, T. T. Salmi, and R. Aantaa](#) 1999. Nursing activities and outcomes of care in the assessment, management, and documentation of children's pain J Pediatr Nurs. **14**:408-15.
147. [Sauerbrei, E. E., and G. G. Paloschi](#) 1983. The ultrasonic features of hypertrophic pyloric stenosis, with emphasis on the postoperative appearance Radiology. **147**:503-6.
148. [Scharli, A. F., and J. F. Leditschke](#) 1968. Gastric motility after pyloromyotomy in infants. A reappraisal of postoperative feeding Surgery. **64**:1133-7.
149. [Scorpio, R. J., and S. W. Beasley](#) 1993. Pyloromyotomy: why make an easy operation difficult? J R Coll Surg Edinb. **38**:299-301.
150. [Scorpio, R. J., H. L. Tan, and J. M. Hutson](#) 1995. Pyloromyotomy: comparison between laparoscopic and open surgical techniques J Laparoendosc Surg. **5**:81-4.
151. [Sellers, W. F., and D. E. Sibson](#) 1992. Empty the stomach by endoscopy before pyloromyotomy Anesth Analg. **74**:315.
152. [Shopfner, C. E., E. H. Kalmon, and C. G. Coin](#) 1964. The diagnosis of hypertrophic pyloric stenosis??? **91**:796-800.
153. [Shuman, F. I., D. B. Darling, and J. H. Fisher](#) 1967. The radiographic diagnosis of congenital hypertrophic pyloric stenosis J Pediatr. **71**:70-4.
154. [Silver, A., A. Eichorn, J. Kral, G. Pickett, P. Barie, V. Pryor, and M. B. Dearie](#) 1996. Timeliness and use of antibiotic prophylaxis in selected inpatient surgical procedures. The Antibiotic Prophylaxis Study Group Am J Surg. **171**:548-52.
155. [Sitsen, E., N. M. Bax, and D. C. van der Zee](#) 1998. Is laparoscopic pyloromyotomy superior to open surgery? Surg Endosc. **12**:813-5.
156. [Smith, G. A., L. Mihalov, and B. J. Shields](#) 1999. Diagnostic aids in the differentiation of pyloric stenosis from severe gastroesophageal reflux during early infancy: the utility of serum bicarbonate and serum chloride Am J Emerg Med. **17**:28-31.
157. [Spicer, R. D.](#) 1982. Infantile hypertrophic pyloric stenosis: a review Br J Surg. **69**:128-35.
158. [Spitz, L.](#) 1979. Vomiting after pyloromyotomy for infantile hypertrophic pyloric stenosis Arch Dis Child. **54**:886-9.
159. [Strauss, S., Y. Itzchak, A. Manor, Z. Heyman, and M. Graif](#) 1981. Sonography of hypertrophic pyloric stenosis AJR Am J Roentgenol. **136**:1057-8.
160. [Stunden, R. J., G. W. LeQuesne, and K. E. Little](#) 1986. The improved ultrasound diagnosis of hypertrophic pyloric stenosis Pediatr Radiol. **16**:200-5.
161. [Sury, M. R., A. McLuckie, and P. D. Booker](#) 1990. Local analgesia for infant pyloromyotomy. Does wound infiltration with bupivacaine affect postoperative behaviour? Ann R Coll Surg Engl. **72**:324-7; discussion 327-8.

162. [Swischuk, L. E., C. K. Hayden, Jr., and K. R. Tyson](#) 1980. Atypical muscle hypertrophy in pyloric stenosis *AJR Am J Roentgenol.* **134**:481-4.
163. [Swischuk, L. E., C. K. Hayden, Jr., and K. R. Tyson](#) 1981. Short segment pyloric narrowing. Pylorospasm or pyloric stenosis? *Pediatr Radiol.* **10**:201-5.
164. [Tam, P. K., H. Saing, J. Koo, J. Wong, and G. B. Ong](#) 1985. Pyloric function five to eleven years after Ramstedt's pyloromyotomy *J Pediatr Surg.* **20**:236-9.
165. [Tan, K. C., and A. Bianchi](#) 1986. Circumbilical incision for pyloromyotomy *Br J Surg.* **73**:399.
166. [Teehan, E. P., and E. Garrow](#) 1993. A new incision for pyloromyotomy *Int Surg.* **78**:143-5.
167. [Tetzlaff, J. E., D. W. Annand, M. A. Pudimat, and H. F. Nicodemus](#) 1988. Postoperative apnea in a full-term infant *Anesthesiology.* **69**:426-8.
168. [Theroux, M. C.](#) 1998. Tracheal intubation for awake versus paralyzed infants with pyloric stenosis *Anesth Analg.* **87**:1455; discussion 1456-7.
169. [Tomomasa, T., A. Takahashi, Y. Nako, H. Kaneko, M. Tabata, Y. Tsuchida, and A. Morikawa](#) 1999. Analysis of gastrointestinal sounds in infants with pyloric stenosis before and after pyloromyotomy *Pediatrics.* **104**:e60.
170. [Touloukian, R. J., and E. Higgins](#) 1983. The spectrum of serum electrolytes in hypertrophic pyloric stenosis *J Pediatr Surg.* **18**:394-7.
171. [Tuller, M. A., and F. Mehdi](#) 1971. Compensatory hypoventilation and hypercapnia in primary metabolic alkalosis. Report of three cases *Am J Med.* **50**:281-90.
172. [Tunell, W. P., and D. A. Wilson](#) 1984. Pyloric stenosis: diagnosis by real time sonography, the pyloric muscle length method *J Pediatr Surg.* **19**:795-9.
173. [Turnock, R. R., and L. Rangecroft](#) 1991. Comparison of postpyloromyotomy feeding regimens in infantile hypertrophic pyloric stenosis *J R Coll Surg Edinb.* **36**:164-5.
174. [Uejima, T.](#) 1989. Postoperative apnea *Anesthesiology.* **70**:721.
175. [Ukabiala, O., and J. Lister](#) 1987. The extent of muscle hypertrophy in infantile hypertrophic pyloric stenosis does not depend on age and duration of symptoms *J Pediatr Surg.* **22**:200-2.
176. [Weiskittel, D. A., D. L. Leary, and C. E. Blane](#) 1989. Ultrasound diagnosis of evolving pyloric stenosis *Gastrointest Radiol.* **14**:22-4.
177. [Westra, S. J., C. J. de Groot, N. J. Smits, and C. R. Staalman](#) 1989. Hypertrophic pyloric stenosis: use of the pyloric volume measurement in early US diagnosis *Radiology.* **172**:615-9.
178. [Wheeler, R. A., A. S. Najmaldin, N. Stoodley, D. M. Griffiths, D. M. Burge, and J. D. Atwell](#) 1990. Feeding regimens after pyloromyotomy *Br J Surg.* **77**:1018-9.
179. [White, M. C., J. C. Langer, S. Don, and M. R. DeBaun](#) 1998. Sensitivity and cost minimization analysis of radiology versus olive palpation for the diagnosis of hypertrophic pyloric stenosis *J Pediatr Surg.* **33**:913-7.
180. [Wilson, D. A., and J. J. Vanhoutte](#) 1984. The reliable sonographic diagnosis of hypertrophic pyloric stenosis *J Clin Ultrasound.* **12**:201-4.
181. [Wolf, A. R., R. A. Lawson, C. M. Dryden, and F. W. Davies](#) 1996. Recovery after desflurane anaesthesia in the infant: comparison with isoflurane *Br J Anaesth.* **76**:362-4.
182. [Yamataka, A., K. Tsukada, Y. Yokoyama-Laws, M. Murata, G. J. Lane, M. Osawa, T. Fujimoto, and T. Miyano](#) 2000. Pyloromyotomy versus atropine sulfate for infantile hypertrophic pyloric stenosis *J Pediatr Surg.* **35**:338-41; discussion 342.
183. [Yip, W. C., J. S. Tay, and H. B. Wong](#) 1985. Sonographic diagnosis of infantile hypertrophic pyloric stenosis: critical appraisal of reliability and diagnostic criteria *J Clin Ultrasound.* **13**:329-32.
184. [Zeidan, B., J. Wyatt, A. Mackersie, and R. J. Brereton](#) 1988. Recent results of treatment of infantile hypertrophic pyloric stenosis *Arch Dis Child.* **63**:1060-4.
185. [Zhang, A. L., D. T. Cass, K. P. Dawson, and T. Cartmill](#) 1994. A medium term follow-up study of patients with hypertrophic pyloric stenosis *J Paediatr Child Health.* **30**:126-8.

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Development Process

The process by which this guideline was developed is documented in the Guideline Development Process Manual; a Team Binder maintains minutes and other relevant development materials. The recommendations contained in this guideline were formulated by an interdisciplinary working group which performed systematic and critical literature reviews, using the grading scale that follows, and examined current local clinical practices.

To select evidence for critical appraisal by the group for the update of this guideline, the Medline, EmBase, CINAHL, and the *Cochrane*

CCHMC Evidence Grading Scale			
M	Meta-analysis or Systematic Review	S	Review Article
A	Randomized controlled trial: large sample	E	Expert opinion or consensus
B	Randomized controlled trial: small sample	F	Basic Laboratory Research
C	Prospective trial or large case series	L	Legal requirement
D	Retrospective analysis	Q	Decision analysis
O	Other evidence	X	No evidence

databases were searched. Evidence from 2000 and before was verified for inclusion in the guidelines. Evidence from January 2001 to January 2007 was reviewed to generate an unrefined, “combined evidence” database using a search strategy focused on answering clinical questions relevant to hypertrophic pyloric stenosis, employing a combination of Boolean searching on human-indexed thesaurus terms (e.g., MeSH headings using an OVID MedLine interface) and “natural language” searching on keywords in the title, abstract, and indexing terms. The citations were reduced by eliminating duplicates, non-English articles, and adult articles. The resulting titles, abstracts, and full text articles were reviewed by a methodologist to eliminate low quality and irrelevant citations. During the course of the guideline development, additional clinical questions were generated and subjected to the search process, and some relevant review articles were identified. December, 2000 was the last date for which literature was reviewed for the previous version of this guideline. The details of that review strategy are not documented. However, all previous citations were reviewed for appropriateness to this revision.

Appropriate companion documents have been developed to assist in the effective dissemination and implementation of the guideline. Experience with the implementation of earlier publications of this guideline has provided learnings which have been incorporated into this revision. Once the guideline has been in place for four years, the development team reconvenes to explore the continued validity of the guideline. This phase can be initiated at any point that evidence indicates a critical change is needed.

Recommendations have been formulated by a consensus process directed by best evidence, patient and family preference and clinical expertise. During formulation of these recommendations, the team members have remained cognizant of controversies and disagreements over the management of these patients. They have tried to resolve controversial issues by consensus where possible and, when not possible, to offer optional approaches to care in the form of information that includes best supporting evidence of efficacy for alternative choices.

The guidelines have been reviewed and approved by clinical experts not involved in the development process, senior management, Risk Management & Corporate Compliance, other appropriate hospital committees, and other individuals as appropriate to their intended purposes. The guideline was developed without external funding. All Team Members and Clinical Effectiveness support staff listed have declared whether they have any conflict of interest and none were identified.

Copies of this Evidence-based Care Guideline (EBCG) and its companion documents are available online and may be distributed by any organization for the global purpose of improving child health outcomes. Website address:

<http://www.cincinnatichildrens.org/svc/alpha/h/health-policy/ev-based/default.htm> Examples of approved uses of the EBCG include the following:

- copies may be provided to anyone involved in the organization's process for developing and implementing evidence based care guidelines;
- hyperlinks to the CCHMC website may be placed on the organization's website;
- the EBCG may be adopted or adapted for use within the organization, provided that CCHMC receives appropriate attribution on all written or electronic documents; and
- copies may be provided to patients and the clinicians who manage their care.

Notification of CCHMC at HPCEInfo@cchmc.org for any EBCG, or its companion documents, adopted, adapted, implemented or hyperlinked by the organization is appreciated.

Important Information

NOTE: These recommendations result from review of literature and practices current at the time of their formulation. This guideline does not preclude using care modalities proven efficacious in studies published subsequent to the current revision of this document. This document is not intended to impose standards of care preventing selective variances from the recommendations to meet the specific and unique requirements of individual patients. Adherence to this guideline is voluntary. The physician in light of the individual circumstances presented by the patient must make the ultimate judgment regarding the priority of any specific procedure.

Additionally for more information about CCHMC guidelines and the guideline development process, contact the Health Policy & Clinical Effectiveness office at: 513-636-2501 or HPCEInfo@cchmc.org.