Gastroesophageal Reflux, Esophageal Function, Gastric Emptying, and the Relationship to Dysphagia before and after Antireflux Surgery in Children

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Objectives To assess gastroesophageal reflux (GER), esophageal motility, and gastric emptying in children before and after laparoscopic fundoplication and to identify functional measures associated with postoperative dysphagia.

Study design Combined impedance-manometry, 24-hour pH-impedance, and gastric-emptying breath tests were performed before and after laparoscopic anterior partial fundoplication. Impedance-manometry studies were analyzed with the use of conventional analysis methods and a novel automated impedance manometry (AIM) analysis.

Results Children with therapy resistent GER disease (n = 25) were assessed before fundoplication, of whom 10 (median age 6.4 years; range, 1.1-17.1 years; 7 male; 4 with neurologic impairment) underwent fundoplication. GER episodes reduced from 97 (69-172) to 66 (18-87)/24 hours (P = .012). Peristaltic contractions were unaltered. Complete lower esophageal sphincter relaxations decreased after fundoplication (92% [76%-100%] vs 65% [29%-91%], P = .038). Four (40%) patients developed postoperative dysphagia, which was transient in 2. In those patients, preoperative gastric emptying was delayed compared with patients without postoperative dysphagia, 96 minutes (71-104 minutes) versus 48 minutes (26-68 minutes), P = .032, and AIM analysis derived dysphagia risk index was greater (56 [15-105] vs 2 [2-6] P = .016). Two patients underwent a repeat fundoplication.

Discussion Fundoplication in children reduced GER without altering esophageal motility. Four patients who developed dysphagia demonstrated slower gastric emptying and greater dysplasia risk index preoperatively. AIM analysis may allow detection of subtle esophageal abnormalities potentially leading to postoperative dysphagia. *(J Pediatr 2013;162:566-73)*.

Gastroesophageal reflux (GER), the passage of gastric contents into the esophagus, occurs in the majority of infants and children.[1] It is referred to as GER disease when GER causes troublesome symptoms and/or complications.[1,2] Current medical treatment is primarily based on the suppression of gastric acid secretion by proton pump inhibitors, although the efficacy for the reduction of symptoms of GER in children has not been proven.[3] When patients continue to experience severe symptoms and/or esophagitis despite treatment, antireflux surgery may be considered, although the indications for this surgery are poorly defined in children.[1,4-6] Furthermore, objective methods to identify patients who are more likely to respond well to antireflux surgery have not been defined.[7,8]

The primary goal of antireflux surgery is to reduce GER without inhibiting the passage of swallowed substances into the stomach. Postoperative dysphagia is the most frequently reported complication.[8,9] Dysphagia is thought to be caused by fundoplication-induced restriction at the esophagogastric junction. Different types of fundoplication have been developed (eg, Nissen, Thal, Toupet), and postoperative rates of dysphagia differ between the different techniques. Patients undergoing the Thal fundoplication have the lowest postoperative dysphagia incidence rates.[9,10]

Multichannel intraluminal impedance is a technique that enables the assessment of the velocity and direction of flow of liquids and gasses through the esophagus.[11] A combined manometry and impedance assembly enables the determination of the relationship between esophageal pressures and esophageal bolus clearance. Until recently, analyses of impedance and pressure had not yielded any variables predictive of postoperative complications, and there are no markers to identify adults or children with a greater risk for postoperative dysphagia.[7,12-17]

An automated impedance manometry (AIM) method for the objective, reliable, and reproducible assessment of pharyngeal function in relation to ineffective pharyngeal swallowing and deglutitive aspiration has been

AIM	Automated impedance manometry
GEBT	Gastric-emptying breath test
GER	Gastroesophageal reflux
IBP	Intrabolus pressure
LES	Lower esophageal sphincter
PeakP	Peak pressure
TLESRs	Transient lower esophageal sphincter relaxations

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described.[18-21] This novel method has been used to assess new-onset dysphagia after antireflux surgery in adults by combining esophageal function measures with dysphagia scores.[21]

The aim of this study is to assess GER, esophageal motility, and gastric emptying in children before and after laparoscopic anterior partial fundoplication by the use of both conventional methods of analysis and AIM to identify functional measures that are associated with the onset of postoperative complications such as dysphagia.

Methods

Between 2007 and 2010 children (with and without neurologic impairment) who were scheduled to undergo a fundoplication were studied before and the procedure. The study was conducted in the Wilhelmina Children's Hospital/UMC, Utrecht and Emma Children's Hospital/AMC, Amsterdam. Before any study procedures, informed consent from the patients' parents was obtained. The study was approved by the ethics committees of both hospitals.

Patients with severe GER disease not responding to conservative (such as lifestyle, dietary, and behavioral advice) or medical therapy (including high-dose proton pump inhibitor use, promotility agents, and GABA-B agonists in some children) in whom a fundoplication was considered were eligible to enroll in the study. Children who had undergone any previous esophageal or diaphragmatic surgery and those who had other structural abnormalities other than an esophageal hiatal hernia were excluded.

All medication known to affect gastric and esophageal motility and acid suppressants were stopped 3 days before the study. To assess esophageal motility and GER, a combined manometry and pH-impedance study was performed followed by 24-hour pH-impedance monitoring. Furthermore, a gastric-emptying breath test (GEBT) was performed, and reflux questionnaires were completed.

Manometry and pH-Impedance Protocol

Subjects fasted for at least 4 hours before the study. A stationary, combined water-perfused manometry and impedance assembly was positioned transnasally into the esophagus with the sleeve straddling the lower esophageal sphincter (LES). A single-use pH-impedance catheter (Unisensor pHTip disposable catheter; Medical Measurement Systems, Enschede, The Netherlands) was used. The manometry and pH-impedance catheter were adjusted for the age and height of the patients.

After a 10-minute adaptation period, patients received bolus challenges, 3 mL in infants and 5 mL in older children, administered at intervals of >60 seconds. A total of 5 liquid (saline or fruit juice) and 5 semisolid boluses (thickened formula or EFT-Viscous; Sandhill Scientific, Highlands Ranch, Colorado) were administered to the patient in both the upright and supine positions (total 20 boluses in each patient).

Manometric and impedance data were recorded during the study on the Stationary Solar Gastro System (Medical Measurement Systems, Enschede, The Netherlands). Manometry and impedance tracings were analyzed for esophageal motility following the currently accepted standard[22,23] in terms of the shape of the peristaltic contraction, peak amplitudes, LES relaxations, transient lower esophageal sphincter relaxations (TLESRs), occurrence of GER, and clearance of the swallow. Furthermore, a novel, automated analysis based on impedance and manometry findings (ie, AIM analysis) was performed.

Esophageal AIM Analysis

This method has been described recently by Myers et al,[21] and details are available in the **Appendix** (available at www.jpeds.com). In short, bolus flow characteristics as measured by impedance are combined with esophageal contractile characteristics, giving insight in the functionality of the esophagus during bolus clearance. Raw impedance and manometry data are extracted and processed in a specifically designed MATLAB (The MathWorks Inc, Natick, Massachusetts) algorithm. Different measures were extracted, such as the intrabolus pressure (IBP), the slope of the IBP over time, and time from nadir impedance to peak contraction. From these, the dysphagia risk index is derived.[21] **Figure 1** provides a simplified description of the AIM analysis and the measures used to derive the dysplasia risk index.

24-Hour pH-Impedance

The pH-impedance catheter was left in place for 24 hours after the stationary combined manometry impedance protocol and positioned on the basis of manometric detection of the LES. Data were recorded on an Omega ambulatory device (Medical Measurement Systems). Patients were instructed to record symptoms carefully during the study in a written diary and by pressing the symptom recording button. Patients were encouraged to maintain daily routine as much as possible.

The 24-hour pH-impedance tracings were analyzed manually according to the accepted guidelines.[24] We included liquid, mixed, and gas GER for this analysis. Symptom association probability was calculated.[25]

Impedance baseline values represent mucosal integrity[26] and increase on proton pump inhibitor treatment[27] in infants. To assess the impact of fundoplication on impedance baseline values, we calculated the impedance baseline in an automated way as previously described.[28]

GEBT

A ^{13}C Na-octanoate (a stable isotope) breath test (GEBT) was performed to assess gastric emptying time. In patients >7 years of age or who were able to eat a pancake within 15 minutes, a solid gastric-emptying test was performed (a 137-g pancake with 100 mg of ^{13}C labeled Na-octanoate). For younger patients or who were unable to eat a pancake within 15 minutes, 100 mg of ^{13}C labeled Na-octanoate was added to a liquid study meal (infant formula or full cream milk). Breath samples were taken at 5-minute intervals during the first 30 minutes and at 15-minute intervals for the remaining