# Polyethylene Glycol: A Game-Changer Laxative for Children

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**ABSTRACT**

Constipation is a common problem in children worldwide. It can also be a chronic problem persisting for many months to years. Successful treatment of constipation requires long-term use of laxatives. Commonly used laxatives in children include milk of magnesia, lactulose, mineral oil, and polyethylene glycol. Compared with other laxatives, polyethylene glycol (with and without electrolytes) is a relatively new laxative used during the last decade. Recent studies report excellent efficacy and safety of polyethylene glycol for the long-term treatment of constipation in children. Because of excellent patient acceptance, polyethylene glycol has become a preferred choice of laxative for many practitioners. This article reviews the recently published pediatric literature on biochemistry, efficacy, safety, patient acceptance, and pharmacoeconomics of polyethylene glycol.

**Key Words:** children, constipation, polyethylene glycol

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Functional constipation with or without encopresis is a common problem in children and is diagnosed by using Rome III criteria (1). The scope of the problem is worldwide, with the pediatric prevalence ranging from 0.7% to 29.6% (2). Constipation is estimated to account for 3% of visits to general pediatric clinics in the United States (3). In a survey of 7 academic centers in the United States, constipation was a problem in 18% of 33,115 pediatric gastroenterology outpatient visits in 2009 (4). Constipation is also a chronic problem in children and can last for many months to years. It can cause significant physical morbidity and psychosocial stress in children and is associated with a significantly lower quality of life (5). Childhood constipation has a significant effect on the use of medical care services, resulting in a cost of $3.9 billion/year in the United States (6).

The North American Society of Pediatric Gastroenterology, Hepatology, and Nutrition has published recommendations for the treatment of constipation in infants and children (7). The management approach involves steps such as education, disimpaction, maintenance therapy, and behavioral modification. The laxatives recommended for long-term maintenance therapy include magnesium hydroxide (milk of magnesia), lactulose, mineral oil (liquid paraffin), and polyethylene glycol (PEG) (7). Magnesium hydroxide, lactulose and mineral oil have been used for many decades in childhood constipation while, PEG has been used since 2000. This review describes biochemistry, efficacy, safety, and pharmacoeconomics of PEG as reported in recent pediatric studies.

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## PEG BIOCHEMISTRY AND MECHANISM OF ACTION

PEG is a polymer of the formula $H(OCH_2CH_2)nOH$ in which n is 68–84 (8). The commonly used compound in the United States is PEG 3350, which is a mixture of different-sized molecules with a mean molecular weight between 3200 and 3700 g/mol (9). PEG 4000 also has similar properties with an approximate molecular weight of 4000 g/mol and is used in some other parts of the world. PEG is a nontoxic water-soluble polymer that is minimally absorbed in the gastrointestinal tract. After oral ingestion, 96.3% to 100% of PEG is recovered in feces and the rest is excreted in urine (9).

PEG is a biologically inert substance and is not metabolized by the colonic bacteria. It does not carry an electrical charge and therefore cannot influence the movement of other solutes. PEG acts as an osmotic laxative because of its chemical properties (10). The laxative effect is achieved not only by the osmotic effect but also because of PEG's ability to form a unique interaction with the water molecules. This interaction alters the physical chemistry of the solution, which leads to a sequestration of more water (10). When administered by mouth, PEG increases the water content of the stools. The effect of PEG is dose dependent, and a higher dose of PEG leads to watery stools (11). Following oral ingestion of PEG, it can take 24 to 48 hours to see the effect in the form of passage of loose stools (12).

## PEG FORMULATIONS

PEG 3350 without electrolytes is available as a powder in the United States and Canada. It is approved by the Food and Drug Administration for use in adults only and is available as over-the-counter medication in the United States. The commonly used brands available in the North American market are MiraLax, Glycolax, and Restoralax. They are available as 17-g powder packs or bottles containing 119 to 510 g. The bottles have measuring caps that contain 17 g of powder when filled. Manufacturers' recommendations are to mix 17 g (a capful) in 4 to 8 oz of liquid. Most pediatric studies report the use of formulation of 17 g in 8 oz of liquid. We have observed that children often complain of grit when mixed with water, and therefore we recommend various beverages such as fruit juices, sports drinks, and milk. We discourage soda because it can cause gaseous distension and discomfort.

PEG with electrolytes (PEG + E) is used in Europe, Australia, and other parts of the world. The added electrolytes include sodium chloride, potassium chloride, sodium bicarbonate, and sodium sulfate in varying concentrations. It is available as sachets of varying sizes and in many brands including Movicolon, Movocol, and Transipeg.

Compared with other laxatives such as milk of magnesia, lactulose, or mineral oil, PEG has a slight disadvantage because it needs to be prepared in a solution before administration; however, mixing in a beverage of a patient's choice improves acceptance of and compliance with PEG compared with other laxatives.

## PEG EFFICACY

### PEG Open-Label Studies

The initial report on the use of PEG for constipation in adults was published in 2000 (8). We performed the first pediatric study assessing the efficacy and the optimal dose of PEG 3350 for the treatment of constipation and encopresis in children (13). In this open-label study, 20 children with chronic constipation were treated with an initial dose of 1 $g \cdot kg^{-1} \cdot day^{-1}$ of PEG for 8 weeks. Weekly stool frequency increased significantly while receiving PEG therapy from 2.3 to 16.9 and stool consistency improved from hard to soft. The mean average dose was 0.8 $g \cdot kg^{-1} \cdot day^{-1}$ and there were no adverse effects (13). Following these promising results of short-term therapy, we assessed long-term efficacy of PEG in children. We studied 74 children taking PEG for >8 months (range 3–30 months) for constipation and encopresis (14). Significant improvement was observed in soiling frequency, stool frequency, and consistency. By physician assessment, successful treatment was observed in 93% of children with constipation and 52% of children with constipation and encopresis. Loss of efficacy was not found with long-term use with PEG therapy (14). Another open-label study from Australia also confirmed the efficacy of PEG + E for a 12-week therapy of constipation in children (15). Following these open-label studies, further studies were performed to compare PEG with other laxatives. Studies were also performed to assess efficacy of PEG for fecal impaction and bowel preparation and for use in infants and younger children.

### PEG Comparison Studies

Table 1 shows various pediatric studies comparing PEG or PEG + E to other laxatives from different parts of the world during the last few years (16–27). All studies were prospective, although only a few were randomized controlled trials. In these studies, patients used different doses of PEG and PEG + E for different durations of therapy and had different outcome criteria.

Two well-designed studies assessed the efficacy of PEG compared with a placebo for short-term treatment of constipation in children. Thomson et al (16) observed significant improvement in pain during defecation and defecation frequency with PEG + E compared with placebo in a crossover study in 47 British children. Nurko et al (17) compared different doses of PEG (0.2 g/kg, 0.4 g/kg, 0.8 g/kg) with placebo for 2-week therapy in 103 children with constipation in the United States. Significant increases in bowel movement frequency and straining improvement were observed with all doses of PEG compared with placebo (17).

Six studies from different parts of the world compared the efficacy of PEG with lactulose in a total of 562 children with a study duration ranging from 2 weeks to 6 months (18–23). Five studies assessed the efficacy in children with functional constipation, whereas 1 study involved children with neurogenic constipation resulting from meningomyelocele (23). PEG was used in 4 studies, whereas PEG + E was used in 2 other studies. Also, these studies had different outcome measures and different doses of medications, and therefore cannot be pooled together for meta-analysis; however, the authors in all of these studies concluded that both PEG and PEG + E were more effective than lactulose for childhood constipation (Table 1). Lactulose was commonly used as a first line of therapy for children in Europe with constipation. After reporting higher success rates with PEG compared with lactulose (56% vs 29%; $P = 0.02$) in a double-blind randomized controlled multicenter trial, Voskuijl et al (19) recommended that PEG should be the laxative of first choice in childhood constipation.

Loening-Baucke and Pashankar (24) compared PEG with milk of magnesia for the treatment of constipation with fecal incontinence in a randomized prospective study during 12 months. Use of both laxatives led to a significant improvement in bowel movement frequency, incontinence episodes, and abdominal pain at 1, 3, 6, and 12 months compared with baseline; however, no significant improvement was noted with PEG compared with

TABLE 1. Studies comparing PEG with other laxatives

| Authors | N | Study design | Duration | Results |
|---|---|---|---|---|
| Thomson et al (16) | 47 | PEG + E 6.9–41.4 g/day vs placebo | 2 wk | PEG + E more effective than placebo |
| Nurko et al (17) | 103 | PEG 0.2, 0.4, 0.8 $g \cdot kg^{-1} \cdot day^{-1}$ vs placebo | 2 wk | PEG more effective than placebo |
| Gremse et al (18) | 37 | PEG 10 $g \cdot m^{-2} \cdot day^{-1}$ vs lactulose 1.3 $g \cdot kg^{-1} \cdot day^{-1}$ | 2 wk | PEG more effective than lactulose |
| Voskuijl et al (19) | 91 | PEG + E 2.9–5.9 g/day vs lactulose 6–12 g/day | 8 wk | PEG + E more effective than lactulose |
| Dupont et al (20) | 98 | PEG 4–8 g/day vs lactulose 3.3–6.6 g/day | 3 mo | PEG more effective than lactulose |
| Candy et al (21) | 53 | PEG + E 6.6–13.3 g/day vs lactulose 10 g/day | 3 mo | PEG + E more effective than lactulose |
| Rendeli et al (22) | 67 | PEG 0.5 $g \cdot kg^{-1} \cdot day^{-1}$ vs lactulose 1.5 $g \cdot kg^{-1} \cdot day^{-1}$ | 6 mo | PEG more effective than lactulose |
| Wang et al (23) | 216 | PEG 20 g/day vs lactulose 15 mL/day | 2 wk | PEG more effective than lactulose |
| Loening-Baucke and Pashankar (24) | 79 | PEG 0.7 $g \cdot kg^{-1} \cdot day^{-1}$ vs MOM 1.2 $mL \cdot kg^{-1} \cdot day^{-1}$ | 12 mo | PEG equally effective as MOM |
| Gomes et al (25) | 38 | PEG 0.5 $g \cdot kg^{-1} \cdot day^{-1}$ vs MOM 1 $mL \cdot kg^{-1} \cdot day^{-1}$ | 6 mo | PEG equally effective as MOM |
| Rafati et al (26) | 160 | PEG 1–1.5 $g \cdot kg^{-1} \cdot day^{-1}$ vs liquid paraffin 1–1.5 $mL \cdot kg^{-1} \cdot day^{-1}$ | 4 mo | PEG equally effective as liquid paraffin |
| Quitadamo et al (27) | 100 | PEG 0.5 $g \cdot kg^{-1} \cdot day^{-1}$ vs fiber + fructose 16.8 g/day | 8 wk | PEG + E equally effective as fiber + fructose |

MOM = milk of magnesia; PEG + E = polyethylene glycol with electrolytes; PEG = polyethylene glycol.

milk of magnesia (62% vs 43%; $P > 0.05$) after 12 months of therapy (24). In a small study from Brazil, Gomes et al (25) also observed similar results when PEG was compared with magnesium hydroxide in children with functional constipation. In both studies, PEG acceptance rate was significantly higher compared with that of milk of magnesia (24,25).

Rafati et al (26) compared PEG with liquid paraffin in children with constipation and encopresis from Iran. Both laxatives showed similar efficacy in improving defecation frequency and decreasing encopresis frequency during 4 months of therapy, but PEG was associated with less adverse effects (26). In a well-designed randomized study, Quitadamo et al (27) compared PEG + E and a mixture of acacia fiber, psyllium fiber, and fructose for the treatment of chronic functional constipation in children from Italy. Compliance was better with PEG compared with the fiber mixture (96% vs 72% for 8 weeks; $P < 0.01$), but improvement in constipation was similar (83% PEG vs 78% fiber mixture; $P = 0.78$) during 8 weeks of therapy (27).

In adults, PEG and PEG + E were shown to be equally effective in the treatment of constipation (28). Although no similar pediatric comparative study has been performed, it is likely that both forms are equally effective in children because of the chemical properties of PEG.

In summary, these comparison studies show that PEG is superior to placebo and lactulose in efficacy for childhood constipation. PEG is equally as effective as milk of magnesia, liquid paraffin, and the fiber mixture but has a better acceptance rate.

## PEG for Fecal Disimpaction

Fecal disimpaction is an important step in the treatment of childhood constipation. PEG electrolyte lavage solution has been used in the past for disimpaction with excellent efficacy; however, it often requires nasogastric tube administration and is associated with adverse effects such as nausea, vomiting, and abdominal distension. Table 2 shows studies using PEG for fecal disimpaction in children (21,29–32). Youssef et al (29) evaluated the efficacy and safety of 4 different doses of PEG for fecal disimpaction in children. They reported successful disimpaction (90%–95%) with higher doses (1 and 1.5 $g \cdot kg^{-1} \cdot day^{-1} \times 3$ days) of PEG. Adverse effects were mild, and no clinically significant electrolyte abnormalities were observed with PEG therapy (29). Candy et al (21) reported a similar high success rate of 92% for disimpaction in British children receiving PEG + E in an open-label study. In a retrospective study, Guest et al (30) reviewed 112 children receiving PEG + E and 101 receiving enemas and suppositories for fecal impaction in 5 centers in England and Wales. Children in the PEG group had a higher rate of successful disimpaction compared with the enema group (97% vs 73%; $P < 0.01$) (30).

Two prospective randomized studies compared PEG therapy to rectal enema for fecal disimpaction in children. Bekkali et al (31) used daily enemas in 46 children and PEG therapy in 44 children for 6 days. They reported equal efficacy of both regimens for disimpaction (80% with enemas vs 68% with PEG), defecation frequency, and abdominal pain, but fecal incontinence and watery stools were more common with PEG therapy (31). Miller et al (32) gave a single milk and molasses enema to 40 children and PEG therapy for 3 days to 39 children presenting with fecal impaction to the pediatric emergency department. On day 1, significant symptomatic improvement was noted with the enema compared with PEG and at day 5 there was no difference in groups. Half of the children in the enema group were ''upset,'' whereas no one in the PEG group was ''upset'' with therapy. The authors reported superior efficacy of enema therapy for immediate relief of symptoms of fecal impaction (32). This result is not surprising because PEG therapy can take up to 2 days to achieve optimal effect (12).

The approach to fecal disimpaction depends on the urgency for disimpaction and physician's and patient's preference. Although the rectal approach leads to faster disimpaction within hours, it is invasive and unpleasant. Additionally, enemas are useful for disimpaction of the distal colon only. PEG therapy should be considered as a therapeutic option for disimpaction. It is effective and well accepted by children, although it can take 2 to 3 days to achieve complete disimpaction.

## Use of PEG in Younger Children

Infants and younger children were included in most pediatric studies evaluating PEG as a therapy for constipation; however, few studies specifically addressed the issue of using PEG in children younger than 3 years. Michail et al (33) used PEG in 28 constipated children younger than 18 months of age in a dose of 0.78 $g \cdot kg^{-1} \cdot day^{-1}$ for 6 months. They reported successful relief of constipation in 97% of children with mild adverse effects of flatus and transient diarrhea (33). Loening-Baucke et al (34) reviewed the charts of 75 constipated children younger than 2 years of age. PEG was given

TABLE 2. PEG Studies for fecal disimpaction

| References | N | Design | Duration | Results |
|---|---|---|---|---|
| Youssef et al (29) | 40 | Prospective dose-finding study PEG 0.25, 0.5, 1, and 1.5 $g \cdot kg^{-1} \cdot day^{-1}$ | 3 days | PEG higher doses (1 and 1.5 $g \cdot kg^{-1} \cdot day^{-1}$) more effective than lower doses |
| Candy et al (21) | 63 | Prospective open-label study PEG + E 54–83 g/day | 7 days | 92% successful disimpaction with PEG + E |
| Guest et al (30) | 213 | Retrospective comparison study PEG + E 54 g/day vs 2 enemas + 1 suppository | 5 days | PEG + E more effective than enema/suppositories |
| Bekkali et al (31) | 90 | Prospective comparison study PEG 1.5 $g \cdot kg^{-1} \cdot day^{-1}$ vs daily enema | 6 days | PEG equally effective as daily enema |
| Miller et al (32) | 79 | Prospective comparison study PEG 1.5 $g \cdot kg^{-1} \cdot day^{-1}$ vs 1 enema | 5 days | PEG less effective than 1 enema for immediate relief |

PEG + E = polyethylene glycol with electrolytes; PEG = polyethylene glycol.

in a dose of 0.8 to 1.1 g · kg$^{-1}$ · day$^{-1}$ for 11 months. Constipation was relieved in 85% to 91% of children. PEG acceptance was extremely good and the only adverse effect was mild transient diarrhea. Laboratory evaluation (electrolytes, liver, and renal function tests) was done in a few children receiving PEG therapy, and all of the tests were normal (34). These 2 retrospective studies only included 32 children younger than 1 year (33,34). Dupont et al (20) conducted a double-blind randomized evaluation of clinical and biological tolerance of PEG and lactulose in constipated children younger than 3 years. Efficacy of PEG was better than lactulose regarding stool consistency and use of additional laxatives. Adverse effects were mild and similar in both groups except for more episodes of vomiting and flatulence in lactulose group. Biochemical profiles were normal in both groups (20). These studies suggest that PEG is generally well tolerated in young children and effectively relieves constipation. Because the data in infants (younger than 1 year) are limited, the practitioners should be cautious using PEG in this age group.

## PEG Dose

In adults, the usual recommended dose of PEG is 17 g/day for the treatment of constipation. Variable doses of PEG and PEG + E have been used in different pediatric studies. Some authors aimed to find the optimal dose of PEG for the effective treatment of constipation in children. In our first study, 20 children with chronic constipation were treated with an initial dose of 1 g · kg$^{-1}$ · day$^{-1}$ of PEG for 8 weeks (13). We asked parents to adjust the dose every third day to achieve 2 soft painless stools per day. The mean average effective dose was 0.8 g · kg$^{-1}$ · day$^{-1}$ with a wide range from 0.3 to 1.4 g · kg$^{-1}$ · day$^{-1}$ (13). We used a similar strategy of dose adjustment to achieve soft painless stools in 2 long-term studies. In a comparison study with milk of magnesia for 12 months, the average effective dose ranged from 0.6 to 0.7 g · kg$^{-1}$ · day$^{-1}$ in 39 children (24). In another long-term study, the effective dose was 0.8 g · kg$^{-1}$ · day$^{-1}$ in 83 children receiving PEG for >8 months (range 3–30) (35). Nurko et al (17) recommended a starting dose of 0.4 g · kg$^{-1}$ · day$^{-1}$ because a higher dose (0.8 g · kg$^{-1}$ · day$^{-1}$) of PEG was associated with more abdominal pain and incontinence in a short 2-week study. In young children, Dupont et al (36) determined that a daily dose of approximately 0.5 g · kg$^{-1}$ · day$^{-1}$ of PEG is effective in >90% of constipated children and in 60% of children with incontinence.

In summary, the effective dose of PEG varies from 0.4 to 0.8 g · kg$^{-1}$ · day$^{-1}$, although the range is wide. Because the degree of constipation can vary from mild to severe and can also change over time, there is no standard fixed dose for children. Because the effect of PEG can take 1 to 2 days, we recommend asking parents to change the dose every third day to achieve the effective dose that results in painless soft stools. In many children, once the dose is determined, parents need to change it only occasionally depending on the situation.

## PEG for Bowel Preparation for Colonoscopy

Several bowel preparations have been used in children for colonoscopy (37). PEG-based bowel preparations have gained popularity in recent years (38). We performed the first pediatric study using PEG for bowel preparation for colonoscopy in a dose of 1.5 g · kg$^{-1}$ · day$^{-1}$ for 4 days (12). We noted excellent or good bowel preparation in >91% of children. The acceptance was excellent, with no significant clinical or biochemical adverse effects. The obvious drawback of this regimen was the long duration of 4 days (12).

Following these successful results, PEG was used for bowel regimen in different doses for different durations (Table 3) (12,39–45). These studies also used different measures to assess the efficacy of bowel preparation; however, all of the authors reported satisfactory efficacy using PEG and recommended it as one of the favorable options for bowel preparation. In prospective studies, efficacy of bowel preparation was high (>89%) when PEG was used for 2 to 4 days (12,39,40). The efficacy dropped to 75% when PEG was given for a few hours on the day before colonoscopy (44,45).

Nausea, vomiting, and abdominal pain were the commonly reported adverse effects with PEG bowel regimen. The incidence of these symptoms ranged from 4% to 19%, with PEG regimen lasting for 2 to 4 days (12,39–41). These adverse effects did not result in

TABLE 3. PEG studies for bowel preparation for colonoscopy

| Authors | N | Study design and regimen | Efficacy results |
|---|---|---|---|
| Pashankar et al (12) | 46 | Prospective study: PEG 1.5 g · kg$^{-1}$ · day$^{-1}$ × 4 days; clears for 1 day | Excellent/good in 91% of children |
| Safder et al (39) | 149 | Prospective study: PEG 1.5 g · kg$^{-1}$ · day$^{-1}$ × 4 days; clears for 1 day | Adequate prep in 89% of children |
| Phatak et al (40) | 111 | Prospective study: PEG 2 g · kg$^{-1}$ · day$^{-1}$ × 2 days; bisacodyl 5 mg/day × 2 days; clears for 1 day | Excellent/good in 92% of children |
| Jibaly et al (41) | 30 | Prospective study: PEG 1.9 g · kg$^{-1}$ · day$^{-1}$ × 2 days; clears for 2 days (bisacodyl in 63%) | Satisfactory prep in 96% of children |
| Adamiak et al (42) | 272 | Retrospective study: PEG 238–255 g in 1.9 L in sports drink 2 h | Effective in 93% of children |
| Terry et al (43) | 30 | Randomized single-blind comparison: PEG 1.5 g · kg$^{-1}$ · day$^{-1}$ × 2 days vs senna 15–30 mL/day × 2 days; clears for 1 day | Excellent/good scores in 88% with PEG vs 29% with senna |
| Walia et al (44) | 44 | Prospective study: PEG 136 to 255 g in 32–64 oz of Gatorade in 3 h; clears for 1 day | Excellent/good in 75% of children |
| Abbas et al (45) | 46 | Prospective study: PEG 238 g in 1.9 L of Gatorade in 3 h; clears for 1 day | Effective in 77% of children |

PEG = polyethylene glycol.

discontinuation of bowel regimen in any of the studies. When PEG regimen was given in a few hours, the incidence of nausea, vomiting, and abdominal pain were much higher, ranging from 16% to 60% (44,45). Laboratory evaluation of electrolytes and renal function tests before and after PEG regimen showed a statistically significant, but clinically insignificant, changes (12,44,45).

In summary, a longer duration of PEG (2–4 days) is associated with higher efficacy and lower incidence of adverse effects. A shorter duration of PEG regimen has obvious advantages, but is associated with lower efficacy and higher incidence of adverse effects. A physician can prescribe a suitable PEG-based bowel regimen depending on the patient's preference and condition (38). An addition of a stimulant laxative such as bisacodyl or senna can increase efficacy of PEG bowel preparation.

## PEG SAFETY

Long-term laxative therapy is needed in many children with chronic constipation. Although commonly used laxatives such as lactulose, milk of magnesia, and mineral oil are safe, they can be associated with adverse effects (7). Lactulose is fermented by colonic bacteria and can cause abdominal cramps and flatulence. Milk of magnesia can cause hypermagnesemia in infancy and in children with renal impairment (7). Mineral oil is contraindicated in neurologically impaired children because of the risk of aspiration and lipoid pneumonia. Compared with these laxatives, PEG is safe because it is a nontoxic, biologically inert, water-soluble substance that is minimally absorbed in the gastrointestinal tract and not fermented by the colonic bacteria.

Studies in adults have shown that PEG is not associated with any major adverse effects (8). To assess the safety of PEG, we studied 83 children taking PEG for a mean duration of 8.7 months (range 3–30) (35). The clinical adverse effects were transient diarrhea (10%), bloating/flatulence (6%), and abdominal pain (2%). The biochemical profile including serum electrolytes, osmolality, albumin, liver, and renal function tests was normal except for transient alanine aminotransferase elevation unrelated to PEG therapy (35).

Similar to our observations, other studies have also confirmed the safety of PEG in children for the long-term treatment of constipation. Adverse effects observed with PEG therapy are uncommon and include diarrhea, bloating, and abdominal pain (24,35). In 1 study, these effects were similar to that observed with placebo (16). Diarrhea observed with PEG therapy is dose dependent and responds to dose reduction. Allergic reaction is rare and was reported in 1 child (24).

Dupont et al (20) reported no significant PEG-related changes in serum iron, electrolytes, protein, albumin, folate, and vitamins A and D levels in young children (6 months–3 years) receiving PEG therapy for 3 months. Use of a high dose (1.5–2 g · $kg^{-1}$ · $day^{-1}$) of PEG for fecal disimpaction and bowel preparation for colonoscopy in children is associated with statistically significant but clinically insignificant electrolyte changes (12,29). In a long-term study of 12 months, periodic evaluation of complete blood account, electrolytes, liver and renal function tests did not show any significant abnormalities associated with PEG therapy (24). Overall, PEG appears to be safe for use in children.

## PEG ACCEPTANCE

Adequate dose and laxative compliance are the 2 most important factors necessary for successful resolution of chronic constipation (14). Long-term compliance has been a problem in the past with laxatives such as milk of magnesia, mineral oil, and lactulose in children because of poor palatability. PEG has a distinct advantage because it is a tasteless and odorless powder that can be mixed in a beverage of the patient's choice. Because of this property, PEG has become a ''game-changer'' laxative with high patient acceptance in children. Using this strategy, we observed that patients in our study preferred PEG over other laxatives such as milk of magnesia and mineral oil (13). In our long-term study, 93% of children reported favoring taking daily PEG solution, with 90% compliance with PEG during the mean duration of 8.7 months (35).

In a comparison study, medication refusal was a significant problem in children taking milk of magnesia (35%) compared with PEG (5%) for 12 months for chronic constipation (24). Similarly, in another study from Brazil, PEG acceptance rate was significantly higher than milk of magnesia (91% vs 33%) in children during 6 months of therapy (25).

In contrast to PEG, PEG + E has a salty taste because of the presence of electrolytes. Two studies in adults indicate that PEG is better accepted than PEG + E. In a double-blind randomized crossover trial of 100 adult volunteers, 84 preferred PEG, whereas only 7 preferred PEG + E (46). In another study from Finland, 31% of elderly patients taking PEG + E complained of ''bad'' or ''very bad'' taste compared with 12% of patients taking PEG (28). No pediatric trials have compared PEG and PEG + E.

These studies indicate that PEG without electrolytes has an excellent acceptance rate in children on long-term therapy. PEG + E, although equally effective, has the slight disadvantage of a salty taste.

## PEG PHARMACOECONOMICS

Childhood constipation has a significant effect on the cost of health care. Liem et al noted that constipation was a significant factor requiring more health services, resulting in significantly higher health costs of $3430 every year for children with constipation compared with $1099 every year for children without constipation (6). Only a small part of this cost was the result of laxative prescription ($39), whereas most expenditures were the result of additional outpatient and emergency department visits (6).

In children, milk of magnesia, mineral oil, lactulose, and PEG are commonly used for therapy of constipation and have variable costs. For a 5-year-old child weighing 20 kg, daily use of mineral oil, milk of magnesia, and lactulose will cost approximately 33, 37, and 60 cents, respectively, in the United States. In contrast, PEG is slightly more expensive, costing 80 cents per day. In addition, a slight increase in the cost of PEG is realized because it is often mixed in a beverage, whereas other medications are given directly.

No pediatric studies compare the cost-effectiveness of different laxatives. Guest et al (30) compared the clinical and economic effects of using PEG with electrolytes in an outpatient setting compared with enemas and suppositories to treat fecal impaction in children in England and Wales. Children receiving PEG had higher successful rates of disimpaction and fewer hospitalizations in 12 weeks following disimpaction. The total National Health Service cost of disimpaction and subsequent therapy for children receiving PEG was estimated to be £694 compared with £2759 for children receiving enemas (30). In another study from the United Kingdom, PEG was shown to be slightly more cost-effective compared with lactulose for treatment of constipation as regards success of therapy, health care use, and quality-adjusted life-years in adults (47).

Despite slightly higher costs, the use of PEG is increasing rapidly in children in the United States and many countries because of efficacy and patient acceptance compared with other laxatives. A review of National Ambulatory and Hospital Care Surveys showed that PEG was prescribed in 39.6% of the pediatric visits

for constipation during 2001 to 2004 in the United States (48). A similar increasing trend was reported in the use of PEG from 2003 to 2007 for constipation in children in France (49).

## SUMMARY

PEG is an osmotic laxative used in children in the last few years. It is more effective than lactulose for the treatment of childhood constipation. It is equally effective compared with milk of magnesia and mineral oil for the long-term treatment of constipation but has a much better acceptance rate. It also has been used successfully for fecal disimpaction and bowel preparation for colonoscopy in children. It is a safe medication without any significant adverse effects. Because PEG can be mixed in a beverage of the patient's choice, it has excellent long-term patient acceptance. PEG has therefore become a ''game-changer'' laxative for the treatment of constipation in children. Further studies are required to assess use of PEG in infants and to compare PEG with and without electrolytes for efficacy, safety, and patient acceptance in children with constipation.

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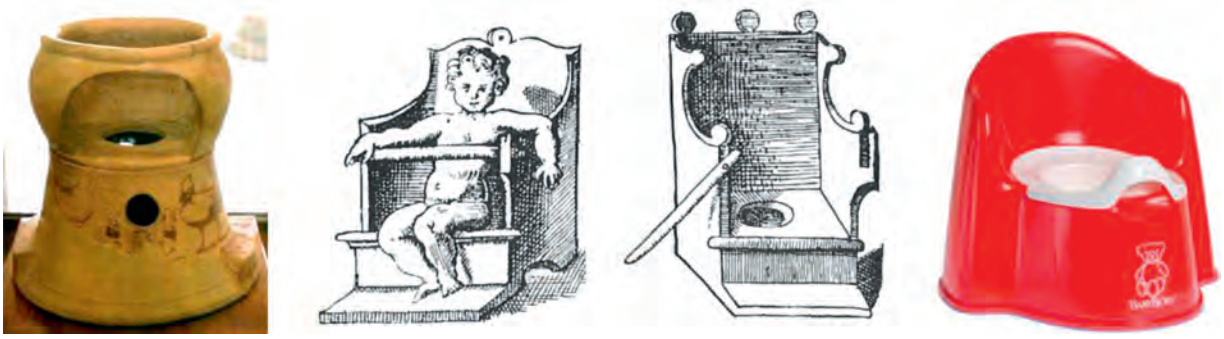
## The Potty Chair

The potty chair has ancient roots, and compared with contemporary models, little has changed for 3 millennia. The figure on the left is a Greek terracotta model (c. 6th century BCE) from the Agora Museum in Athens (photo by author); the center figure is a model designed by Ferrarius (c. 1577); from *De Arte Medica Infantium*; the figure at right is a modern version, manufactured by Baby Bjorn.



—Submitted by Angel R. Colón, MD