Review Article

Nutritional Management of Regurgitation in Infants

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Infantile regurgitation is a frequently occurring problem. Throughout the world, anxious parents are imploring physicians to eliminate their infant's regurgitation. General practitioners, pediatricians and pediatric gastroenterologists strive to alleviate infantile regurgitation and its related parental stress. In this paper we define the scope of the problem and analyze the optimal, cost-efficient management approach to simple regurgitation in infants. The intent of this paper is to disseminate this information to practicing physicians and other health care professionals in an attempt to minimize the impact of this annoying problem of infancy and to eliminate confusion and expensive diagnostic tests and use of sub-optimal treatment modalities. Parental reassurance and dietary management by feeding thickened formula are important components in managing regurgitation in infants while maintaining optimal nutritional intake for adequate growth and development.

Key teaching points:

- Regurgitation is a commonly occurring problem which affects 50% of all babies; it generally resolves spontaneously at about 6 to 12 months of age.
- Regurgitation causes few clinical problems, but may be accompanied by intense irritability, feeding disorders, or failure to thrive.
- In most infants, medical intervention for regurgitation is directed at managing the problem until it resolves spontaneously.
- Parental reassurance and dietary management by feeding thickened formula are important components of managing infants while maintaining optimal nutritional intake for adequate growth and development.

INTRODUCTION

Regurgitation is a common problem of infants throughout the world, affecting up to half of all babies at 2 months of age [1–5]. Regurgitation occurs quite frequently with peak incidence at 3 months of age and typical resolution by 6 to 12 months of age. Most infants do not experience long-term clinical problems; however, symptoms can result in significant parental anxiety and infant discomfort.

Regurgitation may occur in children who are normal and do not have complications of gastroesophageal reflux (GER), such as nutritional deficits, esophagitis, blood loss, strictures, apnea or airway manifestations. In contrast, when regurgitation is accompanied by the above mentioned reflux-mediated problems, the infants are defined as having GER disease (GERD) and often require referral and comprehensive assessment by a subspecialist [6]. Infants with uncomplicated regurgitation are frequently perceived by their parents as having a problem, and

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their parents often seek medical attention. These infants may be subjected to cumbersome tests to rule out pathology. However, a nutritional therapeutic trial may be the most effective, cost-efficient treatment, leading to improvement of the problem and diminution of parental stress.

EPIDEMIOLOGY

Reflux, regurgitation, and vomiting are often confused. Reflux is a normal, physiologic event occurring in virtually everyone [1]. Reflux and regurgitation are effortless, as contrasted to rumination or vomiting, which involve effort [1,7–13]. Regurgitation is the effortless return of gastric contents into the mouth [14]. The prevalence of regurgitation varies and has been reported as occurring in up to 67% of 4-month-olds [1,5,15]. The incidence of regurgitation in infants does not differ substantially by gender. There is also no difference in the incidence of regurgitation in breastfed and formula-fed infants. However, infantile regurgitation is generally accepted by nursing mothers, but is not acceptable to many mothers of formula-fed babies.

Approximately 70% of parents of infants (newborn to 6 months of age) who have sought medical remedy for their infant's regurgitation consider it a problem for their baby [3,4]. Furthermore, about 20% of parents of normal infants (i.e., have not sought any medical intervention) regard their baby's regurgitation as a problem [3,4]. In the population of infants with diagnosed reflux, 80% regurgitate more than once a day, as do 40% of normal infants. In the majority of infants, regurgitation is uncomplicated, self-limiting, and generally resolves spontaneously by 12 months of age [14]. The incidence of regurgitation decreases to 1% at 1 year of age [16].

There is a continuum between normal infants with GER and those with severe GERD which leads to disability, discomfort, or impairment of function [1]. Very low birth weight infants are more likely to have excessive regurgitation and GERD. This results in further complications, such as apnea, bradycardia, or worsened bronchopulmonary dysplasia in 3 to 10% of these infants [1]. Children with cow's milk allergy, respiratory disease, or central nervous system disorders and spasticity may be prone to experiencing severe GERD [1,17]. However, the regurgitation associated with cow's milk allergy may be related to the allergic response rather than to reflux disease. The pinnacle of the GER iceberg represents 2% of patients that may need sub-specialist referral and intervention (Fig. 1) [1]. Regurgitation may affect the weight, and even the height of an infant producing failure to thrive that is serious enough to warrant aggressive intervention.

It should be noted that normal infants have been reported to experience three or four episodes of reflux during a 5-minute period of intermittent fluoroscopic evaluation [18]. In babies over the age of 12 months, this drops to less than one or two episodes. Vandenplas studied 285 normal babies with pH probe

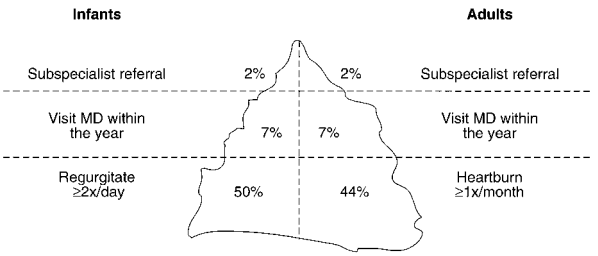

Fig. 1. The GER Iceberg. Adapted from the American Pseudo-obstruction and Hirschprung's Disease Society (APHS) Pediatric Committee Outreach Program slide kit on GER in infants and children.

monitoring during population screening related to SIDS [19]. The number of episodes of reflux peaked at 4 to 6 months of age. At 4 months of age, these infants refluxed six times a day. The amount of time in the total day during which the pH was less than four (which included the aspect of clearance of the reflux) also peaked at about 4 months of age, then decreased down to the adult level [20,21].

Infants do not tend to have severe, grossly visible esophagitis as a manifestation of GER. Histologically, there may be increased papillary height and increased basal layer that represent reflux esophagitis, with or without inflammatory cells [22]. This has been seen in more than half of babies with abnormal parameters on pH probe studies [23]. Two out of three infants that are considered to have GERD have abnormal parameters for esophageal epithelial histology.

PATHOPHYSIOLOGY

Factors contributing to the high incidence of infantile regurgitation, GER, or GERD include: transient LES relaxations, decreased gravitational and peristaltic clearance of the refluxed material from the distal esophagus, and slow gastric emptying.

Esophageal clearance occurs in two directions: up-clearing with regurgitation and vomiting, or the so-called escape defense, and down-clearing, which is determined by several factors (e.g., esophageal peristaltic waves, gravity, and saliva) [24,25]. Swallowed saliva is alkaline and helps to neutralize the acidity of the refluxed material. The bolus-effect of swallowed saliva also helps clear the esophagus. Gravity may help clear the esophagus as well.

The resistance of the mucosa to the noxious effect of the refluxed material (acid, pepsin, chymotrypsin, trypsin, bile, etc.) is different from person to person and may be genetically determined. Prostaglandin tissue levels are known to influence the mucosal resistance: the higher the prostaglandin level, the lower the mucosal resistance. Tissue prostaglandin content increases in relation to GER.

The tonic lower esophageal sphincter pressure (LESP) and esophageal clearing peristalsis may also be reduced or disordered in children with reflux [26–28]. LESP decreases postprandially in both normal infants and infants with reflux [29]:

however, only 20% of all reflux episodes occur in relation to a tonically decreased LESP. The pressure of this sphincter constitutes one of the most relevant defense mechanisms to prevent GER [30]. Both gastric contractions and gastrin increase the LESP [31].

Transient LES relaxations (TLESRs) (which are the normal mechanism for belching) are defined as independent of swallowing (but may have a purpose of gastric venting) and are the major mechanism promoting reflux episodes [32,33]. Most reflux episodes occur in relation to TLESRs, and are unassociated with peristalsis [34]. However, it is not the TLESR that is pathologic in GERD, but defective control mechanisms of the phenomenon. Gradual functional maturation of the LES may explain the benign course of infantile GER [27,35].

Infants with regurgitation and reflux have been observed to have decreased swallowing rates and reduction of esophageal peristalsis during sleep [28,29,36]. These infants may not necessarily experience slow gastric emptying [37–39], even though delayed gastric emptying contributes to reflux. Regurgitation is more common when infants are seated versus when they are in a prone position; therefore increased intragastric pressure may also be a factor [40,41]. Regurgitation may possibly be a protective mechanism against the over-feeding which is common in these infants.

The presence of regurgitation is also related to meal size and type of feeding. Bolus feeding or very rapid ingestion of liquids or solids increases intragastric pressure. The normal response to increased intra-abdominal pressure leads to an equal or greater increase in the LESP to prevent reflux. However, once reflux occurs, esophageal nerve endings are rapidly stimulated, which increases the local prostaglandin tissue levels and the irritated vagal nerve endings to bring about pylorospasm. Small bowel motility is decreased with casein in comparison to whey. However, the casein or whey predominance of formulas does not influence the frequency of reflux during postprandial periods in neurologically impaired children [14,20].

The type of material regurgitated may be most important in reflux leading to GERD. The noxious effect of pepsin on the esophageal mucosa is greater than that of acid alone [42]. The presence of duodeno-gastric reflux may also play a role. At acid pH, it is the conjugated bile salts, and at neutral pH it is the deconjugated bile salts and trypsin, that are injurious to the mucosa [43]. Bile salts increase the permeability of the esophageal mucosa to acid. For this reason, mixed refluxate (containing duodenal as well as gastric components) can be more noxious to the mucosa than acidic refluxate (containing gastric contents alone).

Thus, GER itself is an important mechanism favoring additional reflux (which could lead to GERD) because of the effect of refluxate on the esophageal mucosa in exacerbating this vicious cycle [44,45]. Refluxate contains acid, which in contact with the esophageal mucosa produces an increase in the regional blood flow and the local tissue content of prostaglandin E2. Prostaglandins increase the permeability of the mucosa to acid, which enhances the susceptibility of the mucosa for inflammation. Inflammation of the mucosa of the lower part of the esophagus causes an impairment of the LES (favoring reflux), causing a dysmotility of the LES (favoring reflux), finally worsening esophagitis. The reverse is also true; the esophageal motor defects present in infants with esophagitis may resolve following healing of the esophagitis [28].

The following is an attractive speculation regarding the physiopathologic mechanisms of GER. The starting phenomenon in about half of infants and children with GER may be delayed gastric emptying. The gastric distention stimulates mechanoreceptors in the gastric wall near the cardia, causing a vago-vagal mechanism with an abnormal neural control of the LESP by the central nervous system. As a consequence, there is defective LES motility and an increase in TLESRs, favoring GER. Ineffective acid clearance without adequate neutralization of the pH by saliva, and inefficient volume clearance by inefficient motility enhances the noxious effect of the refluxate. Finally, the mucosal resistance, which may be partially genetically determined, contributes to the development of reflux esophagitis.

Other disorders such as cow's milk allergy, motor abnormalities, poor muscle tone, and spasticity in infants with severe neurologic disorders [1,17,46] may exacerbate reflux and regurgitation.

CLINICAL PICTURE

In most infants, regurgitation causes few clinical problems [47], but in some infants it may be accompanied by intense irritability, feeding disorders, or failure to thrive. Furthermore, GER may be manifest by more than 40 symptoms and may be the sign of severe disease. Thus, distinguishing simple reflux and regurgitation from GERD may be challenging for both the general pediatrician and the pediatric gastroenterologist (Table 1).

Excessive crying and irritability may be the infant's response to pain associated with burning sensations in the esophagus. This pain may lead to feeding problems (e.g., refusal to feed, early satiety) [48]. Respiratory problems may also result, such as recurrent hoarseness, coughing, wheezing, and aspiration. Parental anxiety is likely to increase from the infant's frequent regurgitation and fussiness.

Infants with frequent regurgitation may have more serious complications, such as failure to thrive, recurrent respiratory infections, or "near-miss" sudden infant death syndrome (SIDS) [17]. In infants with impaired swallowing and depressed ability to arouse themselves, the reflux of gastric contents into the pharynx during sleep could be fatal [49]. Apnea and cyanosis, asthma, and hematemesis are other problems that may result from GERD. Unusual presentations are rumination and Sandifer's syndrome, in which the infant presents with distonic movements and assumes a rigid neck position that appears to relieve pain in the esophagus [17].

Table 1. Symptoms of GER

Common symptoms include:
• Regurgitation, vomiting
• Esophagitis
• Excessive crying, irritability
• Feeding problems (refusal to eat, early satiety)
• Respiratory problems (recurrent cough, wheeze, aspiration)
• Parental anxiety
Unusual symptoms include:
• Failure to thrive
• Respiratory problems (recurrent infections, "near-miss SIDS", apnea and cyanosis, asthma)
• Rumination
• Sandifer's syndrome
• Hematemesis

In a study by Shepherd, 99% of infants and children with GER (n=126) experienced frequent regurgitation. Feeding problems were present in 52%, and 49% had signs of esophageal pain. Nearly half (49%) of the infants and children also had respiratory problems, such as recurrent cough or wheeze, apnea and cyanosis, or recurrent aspiration. Despite these symptoms, by 10 months of age 55% of the infants were symptom-free and by 18 months, 81% of toddlers were asymptomatic [50].

The challenges in diagnosing simple regurgitation lie in avoiding inappropriate investigation while not missing other causes of vomiting [1]. Babies whose parents' main complaint is the mess made by frequent regurgitation, for the large part only require conservative measures (i.e., parental reassurance, positioning, feeding thickened infant formula). The social costs to parents should not be minimized as their infant's frequent regurgitation may prevent them from engaging in many activities and may damage clothes, furniture, carpets, etc. Infants who do not respond to conservative treatment may need intervention with medication or surgery.

To identify the specifics of feeding and regurgitation in a cost-efficient manner, Orenstein recommends the use of a parental questionnaire to elucidate whether the infant is a "happy spitter" or has more significant reflux [3,4]. From the questionnaire, a score is calculated which separates infants with GERD from normal babies with a high degree of sensitivity and specificity. Based on this questionnaire, Orenstein developed a diagnostic algorithm that categorizes babies who have regurgitation. They are initially divided into simple or complex regurgitation (the latter associated with failure to thrive, projectile emesis, or an ill appearance). All of the latter infants require additional evaluation to rule-out metabolic disease, gastrointestinal tract partial obstructions (e.g., malrotation with intermittent volvulus), and central nervous system disease.

Regurgitation and reflux are commonly associated with general feeding problems. Shepherd studied behavior and food intake in GERD infants, and assessed the mothers' interaction with their babies [51]. The mothers in this study demonstrated significantly more negative feelings and behaviors than control mothers (Table 2). GERD was associated with considerably lower energy intakes than controls. The infants' feeding assessment schedules revealed that GERD infants had substantially fewer adaptive skills and readiness behavior for solid foods, more food refusal, and more food loss. As well, these infants were fed inappropriate food textures compared to control infants. Data indicated that infants with reflux had more behavioral difficulties than controls. It was concluded that on a standardized objective assessment, GERD infants had significant feeding problems affecting both behavior and food intake. They displayed a lack of development of age-appropriate feeding habits. The contribution of feeding habits to morbidity in reflux had been previously underestimated.

TREATMENT

In most infants, medical intervention for regurgitation is directed at managing the problem until it corrects itself [17]. Conservative therapies generally have little or no risk, may be of considerable benefit, and are recommended in all cases of simple regurgitation. When begun in early infancy, conservative management is expected to benefit most patients [47]. A working-group of eminent members of The European Society

Table 2. Feeding Patterns in Infants with GERD

Results of an Infant Feeding Questionnaire
Mothers of GERD infants reported additional:
• Negative feeding behaviors ($p<0.001$)
• Food changes (30 vs. 13; $p<0.001$)
• Regurgitation ($p<0.0001$)
• Respiratory symptoms ($p<0.005$)
Mothers of GERD infants reported fewer:
• Self-feeding skills ($p<0.001$)
• Enjoyable feeds ($p<0.001$)
Results of Standardized Feeding Assessment by Videotape
GERD infants had significantly more:
• Food refusals (25% vs. 1%)
• Back arching and panic reactions (33% vs. 3%)
• Swallowing difficulties and choking (30% vs. 3%)
• Food loss and drooling (58% vs. 13%)
GERD infants had significantly fewer:
• Readiness behaviors (50% vs. 75%)
• Adaptive skills, such as chewing, spoon use (16% vs. 79%)
Results of Testers Rating of Infant Behavior
GERD infants had significantly more:
• Demanding behavior (5.7 vs. 1.8)
• Difficult behavior (5.7 vs. 3.5)
GERD infants had significantly less:
• Approachable behavior (4.7 vs. 6.3)
• Cooperative behavior (4.8 vs. 6.6)
• Vocalization (4.2 vs. 5.6)
• Adaptation (4.9 vs. 6.5)
GERD infants had no difference in:
• Activity
• Persistence
• Intensity

for Pediatric Gastroenterology, Hepatology and Nutrition published regurgitation management guidelines in 1996, including both dietary and non-dietary recommendations (Fig. 2) [16].

Conservative therapy or lifestyle changes are low-risk, offer significant benefit, and can be instituted for the large proportion of infants who have problems that cause parental frustration. Regurgitation may be reduced with inexpensive and effective treatments that provide adequate nutrients and promote normal growth and development. Conservative treatment (i.e., positioning and thickening of the formula) and early intervention (before 3 months of age) are preferred [15,50,52]. This approach benefits most infants. Pharmacotherapy is generally reserved for an actual documented problem (e.g., esophagitis, airway manifestations, recurrent pneumonia, asthma, and weight deficits). Some pediatric gastroenterologists utilize pharmacotherapy in an attempt to prevent the above mentioned problems. Immediate diagnostic evaluation is indicated if an infant has symptoms which could be life-threatening, such as failure to thrive, aspiration, apnea, or SIDS [16,53].

Surgery is indicated in infants with reflux disease which has not resolved with medical therapy. Infants with potentially hazardous symptoms or infants whose symptoms respond well to pharmacological therapy, but who have recurrent relapses when medications are withdrawn, are surgical candidates [1].

Conservative therapy starts with parental reassurance and counseling. An infant's feeding problems (i.e., refusal to eat, frequent regurgitation), sleeping difficulties, and excessive crying are likely to cause substantial, even acute, parental distress. Parents should understand that excellent results are generally achieved with conservative treatment of regurgitation [47]. Parents should be counseled about the widespread prevalence of the problem and its generally non-threatening nature. Explaining the etiology and diagnosis of regurgitation may facilitate diminution of parental fears. Instruction on feeding techniques is also useful. Parents should be taught to refrain from

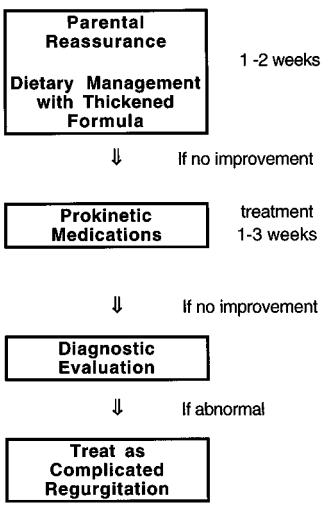

Fig. 2. Treatment of Regurgitation.

"jiggling" their infant after feeding and to avoid pressure on the infant's abdomen [1,54]. It may also be helpful to assure parents that crying does not make regurgitation worse. Crying raises intra-abdominal pressure and in normal infants also raises the LESP to an equal or greater amount, thus preventing reflux. In Orenstein's study, crying and sleeping appeared to decrease reflux frequency and duration [55]. The success of parental reassurance is difficult to quantify and parental anxiety may not diminish until the infant's symptoms subside.

For many years, infant positioning, specifically placing the infant in a prone position (often with the head elevated 30°), was a cornerstone of regurgitation treatment [17]. This was associated with less crying than when infants with regurgitation were placed in a seated position, although the head-elevated prone position was no more effective than flat-prone in reducing signs of GER [56,57]. Currently, flat-prone positioning is not recommended for infants with simple regurgitation, because many studies have shown that the flat-prone sleeping position is associated with a higher incidence of SIDS [58]. Although this may largely be due to confounding effects of puffy, potentially suffocating bedding, the use of prone-flat position therapy as a first-line approach to simple regurgitation is no longer recommended [16]. The relationship between SIDS and the sleeping position of the infant is limited to the prone-flat position. Although it has not been thoroughly studied, there is no established relationship between SIDS and the prone-30° elevated (anti-Trendelenburg) position.

One study demonstrated that placing the baby in a left lateral position decreased reflux somewhat [59]. This position may be an alternative to prone for the postural management of infants with regurgitation. However, another study showed that lateral positioning, in comparison to supine positioning, decreases the risk for SIDS by about half. Thus, supine is the only recommended position to minimize SIDS. Any positioning is quite difficult to maintain, particularly in older infants, who often become slumped or change posture. Postprandial positioning may not be beneficial and could even be detrimental if not maintained appropriately. Placing an infant in a supine position is the current general recommendation for sleep positioning.

NUTRITIONAL MANAGEMENT

Nutritional management of infants with regurgitation is a very important component of conservative treatment. Good nutrition is essential for normal growth and development, while malnutrition impairs gastrointestinal motility [48]; therefore, optimizing nutritional status is an early treatment goal.

Clinicians have suggested that smaller-volume, more-frequent feedings which maintain adequate daily caloric intake alleviate reflux and regurgitation [1,17]. The efficacy of this recommendation has not been proven and in practice is difficult to apply [14]. The additional burden that smaller, more-frequent feedings places on the parents may yield ineffective

results and contribute to parental anxiety. Furthermore, the reduced formula volumes may also cause distress to the hungry infant who does not want to stop feeding. However, feeding volume should be reduced in infants who are overfed.

Thickened infant formula for bottle-fed babies has been shown to relieve regurgitation, improve sleep, and increase caloric retention [54,60]. Dietary management by feeding thickened infant formulas has been found to be useful as the first step in treating bottle-fed infants who present with simple reflux and regurgitation, as well as excessive regurgitation [16,17,47,54]. Thickened feedings cannot be used with breast-fed infants, nor is their efficacy ascertained in complicated reflux [16].

Several groups have investigated the efficacy of dietary management by feeding thickened formulas to infants with regurgitation. Vandenplas showed a positive effect in infants 6 to 8 weeks old [60]. Dietary management by feeding carob bean gum-thickened formulas decreased the number of regurgitation episodes and is an effective measure for treating regurgitation [60]. Orenstein found that infants fed formula thickened with dry rice cereal had a decreased volume, as well as a decreased frequency of regurgitation, compared to when the same infants were fed unthickened formula (Fig. 3) [54]. Feeding the thickened formula also resulted in decreased crying time and increased sleeping time in the 90-minute postprandial study period (Fig. 4) [54].

Although varied individual responses were observed, Ramenofsky and Leape concluded that dietary management of regurgitation by feeding rice cereal thickened formula was effective at decreasing reflux in infants ages 1 week to 12 months [41]. Bailey did not show a significant effect on GER in infants fed apple juice with or without rice cereal [61]. However, apple juice has a high osmolality, and thus may itself increase the frequency of reflux by delaying gastric emptying.

Dry rice cereal, manufactured by milling rice, is a common thickener; the usual recommendation is to add 4 g (1 tablespoon) per 30 mL (1 ounce) of formula. Another thickening agent is locust or carob bean gum, which is refined from the carob tree, *Ceratonia siliqua,* and is used mainly in Europe. This gum is a galactomannan, a galactose-type polymer with side chains of D-galactose. It is added to formula at a concentration of 1 g/L. Carob bean gum, a soluble fiber, provides no

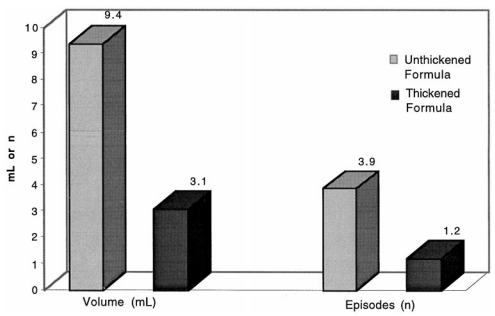

Fig. 3. Effect of Thickened Formula on Emesis.

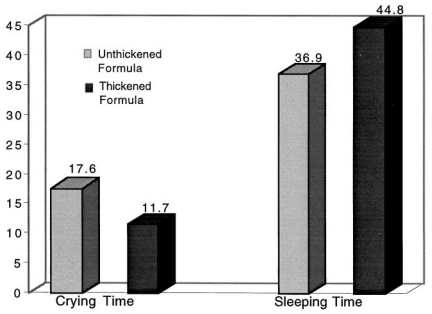

Fig. 4. Effect of Thickened Formula on Crying and Sleeping Time.

nutritional value and passes undigested into the colon where it may be fermented by bacteria. Less commonly used thickening agents include pectin and cellulose, potato starch, as well as corn-derived products.

Digestibility of Thickeners

The two main carbohydrates used for thickening formula are rice starch and carob bean gum. The digestibility of rice starches has been shown to be excellent (>95%) in 1- and 3-month old infants. Lifschitz has demonstrated that rice cereal was 84–96% absorbed by infants ages 2 to 4 months who were evaluated both during acute diarrhea and 2 weeks following recovery [62]. It has been demonstrated that the increase in nitrogen in stools of babies fed rice-cereal supplemented formula is merely bacterial nitrogen, indicating that there are no losses from the system itself when rice cereal is added [63].

Fed to infants in normal quantities, infant formula supplemented with complex-carbohydrate, such as rice cereal, does not affect absorption or calcium and iron bioavailability [64]. However, there are some disadvantages associated with the use of separate thickeners. Thickened formulas may be difficult to feed and must be fed using enlarged nipple holes. The quick feeding that results from the enlarged nipple hole may cause the infant to ingest excessive air or formula, which can in turn favor reflux and regurgitation. The addition of rice cereal alters the composition of the feed because the cereal is added to a nutritionally complete formula. Caloric density is increased and the relative contributions from fat, protein, and carbohydrate are altered. In some infants, rice cereal may cause constipation.

There are also disadvantages associated with the use of carob bean gum, pectin, and cellulose to thicken formulas. Carob bean gum passes undigested into the colon, where fermentation may cause abdominal pain, colic, and diarrhea [65]. Researchers in France reported that absorption of a compound containing pectin and silicium was associated with the formation of a urinary stone [66]. Faverge and Gratecos also reported an intragastric lactobezoar in a 4-month-old infant who had received a pectin and silicium thickened formula for 15 days [67]. Montagne reported cases of intestinal obstruction in infants fed formulas thickened with pectin and cellulose [68]. Although small amounts of fiber are recommended for weaning

foods, the Conference on Dietary Fiber in Childhood cautioned that, in very young children, high-fiber diets may result in reduced energy, reduced caloric intake and poor growth [69].

Pre-Thickened Infant Formulas

A nutritionally-balanced and convenient pre-thickened formula may offer advantages to infants and parents. Several pre-thickened formulas are now commercially available around the world. The common feature of these products is increased viscosity over routine infant formulas. The thickening agents most commonly used are rice starch, carob bean gum, and potato starch. In 1992, the Commission of European Communities stated that precooked or gelatinized starch could be added to infant formulas up to a concentration of 2 g/100 mL, but not in excess of 30% of the total carbohydrate content [70]. Locust bean gum is accepted as an additive in foods for special medical purposes (e.g., medical foods for therapeutic diets) for infants and young children, but not as an additive in formula for infants and young children in good health (recommendation of the Scientific Committee for Food of the European Commission, March 21, 1997).

Because starch is integrated into the formulation of pre-thickened formula, the amount of starch ingested is lower than the amount typically provided when parents add starch to infant formulas. Nutrient ratios of commercial formula are unaffected by the use of rice starch and are within pediatric and regulatory guidelines. Pre-thickened formula is a well-tolerated, calorically and nutritionally balanced infant feeding, and it does not require that bottle nipple holes be enlarged to achieve an adequate flow.

Before feeding, the viscosity of a pre-thickened formula is about 10 times higher than that of routine infant formula (60 versus 6 centipoises [cps] when measured at 30 rotations per minute). In contrast, the viscosity of routine infant formula thickened with rice cereal (4 g of rice cereal per 30 mL of formula) is about 170 cps (Fig. 5) [71]. The lower viscosity of pre-thickened formula also facilitates its smooth flow through a standard nipple and makes it easy to feed. When ingested, the viscosity of a pre-thickened formula increases dramatically in the stomach, to a level similar to that of rice cereal-thickened formula when the pH becomes more acidic; such a pH change occurs when infant formula mixes with gastric acid in the stomach [72,73]. The exact mechanism for this increase in viscosity is not known, but is probably due to physical interaction between the starch and protein components in the product. At pH 5.4, the viscosity of regular formula is 18 cps and the viscosity of rice starch mixed with water is 43 cps. The viscosity of pre-thickened formula, however, is several times higher (532 cps), suggesting that the thickening action at low pH is not due to either the starch or protein alone [73].

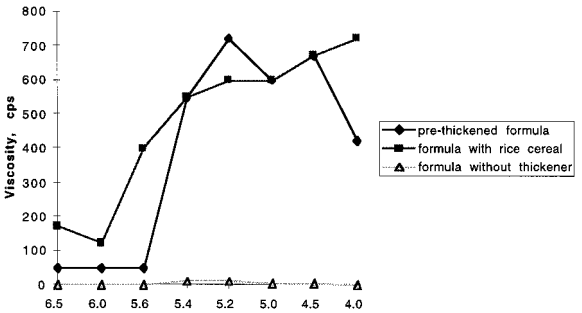

Fig. 5. Viscosity of Infant Formulas.

CONCLUSION

Regurgitation is generally self-limiting, albeit an annoying problem of infancy. Although regurgitation is quite common and often resolves spontaneously, effective treatment is available. Positioning and small, frequent feedings have limited efficacy in alleviating regurgitation. Parental reassurance and dietary management by feeding thickened infant formula are important components of managing infants while maintaining optimal nutritional intake for adequate growth and development. Feeding pre-thickened infant formula provides additional nutritional advantages beyond that of "home-made" thickening agents. Furthermore, pre-thickened formula does not require additional parental preparation time nor does it contribute to feeding problems associated with conventionally thickened formulas. Infants with symptoms of simple regurgitation may benefit from a therapeutic trial consisting of parental reassurance and a thickened infant formula.

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