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# 56 Viral Gastroenteritis

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Viral agents are the most common causes of acute gastroenteritis, a syndrome of acute vomiting and diarrhea associated with inflammation of the stomach, small intestines, or large intestines. Among children, viral gastroenteritis remains a leading cause of pediatric morbidity and mortality worldwide.[1,2] With the discovery of norovirus[3] and rotavirus[4] in the early 1970s, and subsequent development of improved diagnostic strategies for these and other enteric viruses,[5,6] the importance of viral agents as causes of diarrheal disease has been increasingly appreciated. The global introduction of highly effective rotavirus vaccines has resulted in substantial reductions in the burden of rotavirus gastroenteritis and recognition of norovirus as a major cause of acute gastroenteritis.[7–12]

## ETIOLOGIC AGENTS

A small group of viruses accounts for most cases of acute gastroenteritis among children. These include group A rotaviruses, human caliciviruses (including noroviruses and sapoviruses), enteric adenoviruses (types 40 and 41), and human astroviruses.[7] Other viruses frequently are detected in children suffering from diarrheal illnesses; however, the prevalence of many of these other viruses in healthy children has not been determined, and therefore a causal association with diarrhea has not been established.

Rotaviruses (family Reoviridae) are 100-nm particles consisting of an outer capsid, an inner capsid, and a core.[13] The double-stranded RNA genome is composed of 11 segments that code for 6 structural proteins and 6 nonstructural proteins. The outer capsid is composed of 2 proteins: VP7 (G protein, for glycoprotein) and VP4 (P protein, for protease-cleaved protein). These proteins are the principal antigens to which neutralizing antibodies are directed and account for the classification scheme for rotavirus strains.[14]

Caliciviruses are nonenveloped, 27- to 40-nm, single-stranded RNA viruses in the family Caliciviridae.[15] Human caliciviruses are divided into 2 genera: norovirus and sapovirus. Noroviruses include numerous genetically related viruses, further divided into 6 genogroups (I–VI), 3 of which (I, II, and, rarely, IV) are associated with human disease. At least 9 and 22 genotypes, respectively, have been identified for genogroups I and II.[16] Despite this extensive genetic diversity among noroviruses, genogroup II genotype 4 (GII.4) viruses are the most common causes of norovirus outbreaks worldwide[17]; the emergence of new GII.4 strains occurs every 2 to 4 years and can be associated with a global increase in gastroenteritis outbreaks.[18–20] Efforts to cultivate noroviruses in available cell culture systems or to develop an animal model have been unsuccessful, and this failure has hampered the development of simple diagnostic tests and the evaluation of disinfectants.[21] Important progress has been made by using B cells, but this system is not widely available.[22]

Astroviruses are nonenveloped, 28-nm, single-stranded RNA viruses in the family Astroviridae. Until 2008, human astroviruses were thought to be limited to 8 closely related genotypes (serotypes), now referred to as the "classic" human astroviruses (HAstV 1–8). HAstV genotype 1 is most commonly detected, followed by types 2 to 5; however, more than a single serotype usually circulates in communities during each season.[23] Non–type 1 viruses can predominate in a season, and greater serotype diversity can be found in developing countries.[23–25]

Adenoviruses are 70- to 100-nm, nonenveloped, double-stranded DNA viruses in the family Adenoviridae.[26] Although 7 species of adenoviruses (classified as HAdV A–G) containing at least 51 different genotypes can cause human infection, species F (genotypes 40 and 41) adenoviruses typically cause gastroenteritis.[27]

Many studies report the detection of viruses in stool samples from children with diarrheal illness. A key method to establish a causal association between a virus and a disease is to observe a higher prevalence among children with gastroenteritis compared with asymptomatic children (Table 56.1).

Many other viruses have been found in fecal specimens, but the data are inconclusive regarding the pathogenicity for many of these viruses. Reports of the clinical characteristics of patients infected with the severe acute respiratory syndrome (SARS) coronavirus and with the more recently described Middle East respiratory syndrome (MERS) coronavirus have noted diarrhea in approximately one fourth of cases.[28,29]

## EPIDEMIOLOGY

All the major enteric viruses are transmitted primarily through close person-to-person contact by the fecal-oral route.[30] Noroviruses, in addition, are easily spread through contaminated food and water and therefore are major causes of foodborne disease.[31–33] Noroviruses are present in the vomitus of ill people, and droplet spread through exposure to vomitus has been demonstrated to be a mechanism of spread in both healthcare and public settings.[34–36] Contact with a symptomatic child is a major

**TABLE 56.1** Positivity Rates of Viral Pathogens Among Children <5 Years of Age With Acute Gastroenteritis and Healthy Controls: United States, 2008 to 2009[7]

| | Acute Gastroenteritis (N = 1564) | Healthy Controls (N = 1000) |
|---|---|---|
| **Agent** | **No. (%)** | **No. (%)** |
| Group A rotaviruses | 282 (18) | 2 (<1) |
| Noroviruses | 334 (21) | 40 (4) |
| Adenoviruses 40/41 | 186 (12) | 18 (2) |
| Sapoviruses | 80 (5) | 42 (4) |
| Parechoviruses | 76 (5) | 44 (4) |
| Astroviruses | 75 (5) | 30 (3) |
| Bocaviruses | 22 (1) | 24 (2) |
| Aichiviruses | 4 (<1) | 0 (0) |

determinant of norovirus infection. Children <5 years of age seem to be more contagious than older children and adults and therefore play key roles in norovirus transmission to all age groups.[37] The modes of transmission of adenoviruses are less well understood, but transmission is presumed to occur primarily through close contact by fecal-oral spread. Spread through fomites is possible for each of the agents, and it can play an important role in disease acquired in institutional and group childcare settings.[38]

Common viral gastroenteritis viruses are globally distributed. Although traditionally temperate climates are associated with a strong winter peak of rotavirus, a meta-analysis showed that the level of country development was a stronger predictor of seasonality than was geographic location or climate.[39] Since the introduction of routine vaccination in the United States, the rotavirus season has diminished substantially in magnitude, and it has also been delayed in some years.[12,40] A biennial pattern of lower, delayed rotavirus seasons followed by slightly higher peaks has emerged in the US. (Fig. 56.1).[12,40,41] In low-income and tropical settings, rotaviruses typically circulate year-round.[39,42,43] Noroviruses circulate year-round in most areas, but a clear wintertime seasonality to outbreaks is present, particularly in healthcare settings.[31,44,45] Astroviruses typically peak during winter and sapoviruses peak during early spring months in temperate countries.[7,46] The seasonality of adenoviruses is less distinct, and transmission has been described year-round, with summertime epidemics.[7,47]

The highest rates of severe rotavirus infections occur in the first 2 years of life; most hospitalizations and severe dehydrating disease occur between 4 and 23 months of age.[48–50] Infections in the first 3 months are less common and are often asymptomatic, probably because of protection from maternally acquired antibodies.[48,51] Rotaviruses can infect children more than once, with each subsequent infection less severe as a result of immunity that develops following infection.[48] Severe rotavirus disease among older children and adults is less common, but infection can occur in people exposed to younger children in childcare settings and schools. Outbreaks also occur in long-term care facilities.[52]

Before the introduction of rotavirus vaccines, rotaviruses accounted for 25% to 50% of hospitalizations for gastroenteritis among children <5 years of age and for 5% to 20% of milder cases in people who sought care in clinics.[49,53] Following vaccine introduction, the rates of rotavirus-associated healthcare use substantially decreased (see Fig. 56.1).[11,12] Population-based surveillance in the US detected rotavirus in 13% of children hospitalized for gastroenteritis and in 6% of pediatric outpatient visits for gastroenteritis.[11] Globally, rotavirus causes approximately 500,000 deaths/year in children less than 5 years of age, and deaths among children in the poorest countries account for more than 85% of the total.[1,54] In middle-income countries (Mexico and Brazil) where rotavirus vaccines were introduced in 2006, sustained reductions were documented in diarrhea-associated pediatric mortality rates (Fig. 56.2).[9,10] Rotavirus-associated death is rare in developed countries.[55,56]

Noroviruses now are recognized as the most common causes of both endemic disease and outbreaks of gastroenteritis.[11,32,57] Noroviruses are estimated to cause 19 to 21 million illnesses a year in the US that result in 1.7 to 1.9 million outpatient visits, 400,000 emergency department visits, 56,000 to 71,000 hospitalizations, and 570 to 800 deaths.[32] Globally, norovirus is estimated to cause 18% of the cases of severe diarrheal disease in children <5 years old (17% of inpatient cases and 24% of community episodes).[58] Following the introduction of rotavirus vaccines and the subsequent decline in rotavirus disease burden, noroviruses have overtaken rotavirus to become the predominant causes of severe gastroenteritis in the pediatric population.[11,59,60] Among children <5 years old who were studied in an active surveillance network in the US, norovirus accounted for 21% of gastroenteritis cases requiring medical attention, including 17% of children admitted to the hospital and 28% of outpatients (see Table 56.1).[11]

All age groups are affected by noroviruses, but the disease incidence is highest in children <5 years of age.[61] Noroviruses are the most commonly reported causes of foodborne disease in the US, whereas internationally, estimates vary widely.[32,62] Common foods associated with outbreaks include those that are uncooked or handled after cooking (which can be contaminated by ill food handlers), as well as shellfish harvested from contaminated water. Healthcare facilities, including nursing homes and hospitals, are the most common settings of norovirus outbreaks; other environments such as childcare facilities and cruise ships are frequently affected.

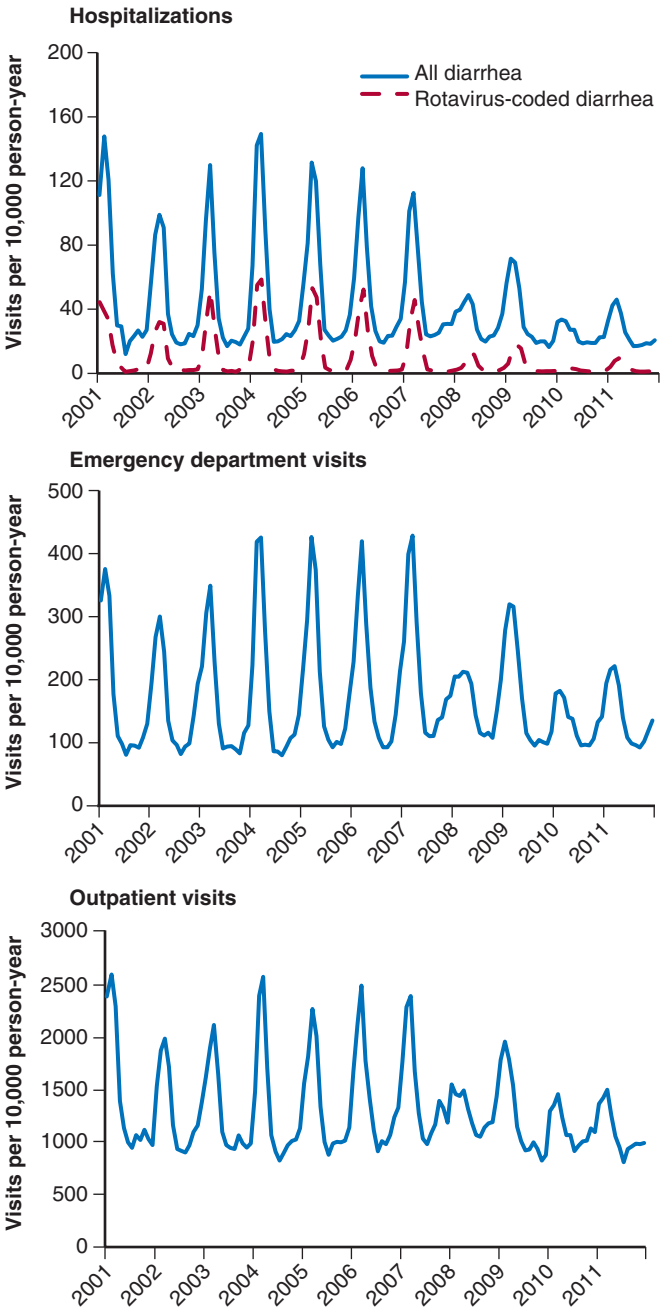


**FIGURE 56.1** Diarrhea-associated healthcare use rates among United States children <5 years of age, 2001 to 2011. (From Leshem E, Moritz RE, Curns AT, et al. Rotavirus vaccines and health care utilization for diarrhea in the United States (2007–2011). Pediatrics 2014;134(1):15–23.)

Sapoviruses are most commonly associated with sporadic gastroenteritis, usually among young children.[63,64] Outbreaks caused by sapoviruses are less common and tend to occur in older adults.[65] Sapoviruses were detected in approximately 10% of all gastroenteritis episodes in England and Finland and in 4% of hospitalized cases in Finland among children <2 years of age.[66,67] In the US, sapoviruses were detected in 5% of pediatric diarrhea cases compared with 4% among healthy controls ($P < 0.01$) (see Table 56.1).[7] Sapovirus infections tend to be less severe than norovirus infections; vomiting is common, and diarrhea may not be present.[7,67]

Although astroviruses have been detected in all age groups, most infections are in children <2 years of age and tend to be less severe than

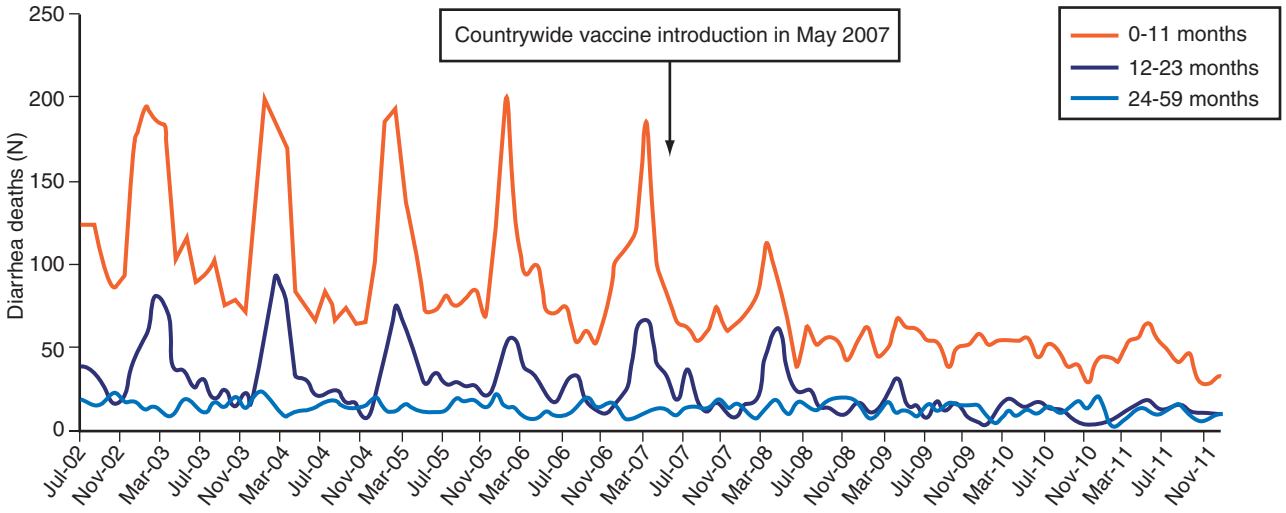


**FIGURE 56.2** Number of diarrhea-related deaths among children aged <5 years from July 2002 through December 2011 in Mexico according to age group. (From Gastanaduy PA, Sanchez-Uribe E, Esparza-Aguilar M, et al. Effect of rotavirus vaccine on diarrhea mortality in different socioeconomic regions of Mexico. Pediatrics 2013;131(4): e1115–1120.)

rotavirus infections.[68] Serosurveys in the US have shown that >90% of children have antibodies to human astroviruses by 6 to 9 years of age.[69] Disease in adults is uncommon, but it can occur in outbreak settings.[70] Astroviruses are usually detected in <10% of young children treated for gastroenteritis in outpatient clinics or in hospitals, but these viruses are occasionally found at higher frequencies.[7,47,71] Although astroviruses primarily cause sporadic disease, outbreaks have been reported in a range of settings, and astroviruses can be common causes of nosocomial gastroenteritis in children's hospitals.[72]

Most enteric adenovirus infections occur in children <2 years of age, and these viruses appear to be less important causes of gastroenteritis among adults.[7,73,74] Enteric adenoviruses were shown to account for 5% to 12% of hospitalizations for acute gastroenteritis in children and can be common causes of healthcare-associated diarrhea.[7,75] Enteric adenoviruses are detected in 1% to 12% of children with community-associated diarrhea.[7,76,77]

## PATHOGENESIS

After oral inoculation, viruses infect cells of the small intestinal villi.[78] Infection of the mature villous enterocytes, which have both digestive and absorptive functions, leads to cell death and sloughing of the villus cells. In a normal host, infection resolves as the number of susceptible mature enterocytes decreases secondary to cell death and as the host generates an immune response. Viruses are shed in the stool during the acute illness in large quantities. Rotaviruses, noroviruses, and astroviruses can also be shed for 1 to 2 days before illness and for several days following resolution of symptoms.[30,38] Although viral gastrointestinal infections are generally confined to the intestine, rotavirus and norovirus infections can result in antigenemia and the presence of nucleic acid in blood of ill patients, but extraintestinal disease is rare.[79,80] Asymptomatic infection is common, especially for norovirus,[66] and is thought to play a role in disease transmission.[81]

Immunity to rotavirus is acquired, and multiple infections typically are required until the child is fully protected against disease.[48,82,83] After a primary infection, homotypic immunity is stronger, but immunity seems to broaden to other serotypes with subsequent infections.[48] Wide estimates of the duration of immunity to norovirus range from 6 months to 4 to 9 years after natural infection occurs; however, heterotypic immunity may be limited.[37,84] Because diarrheal disease caused by astrovirus, adenovirus, and sapovirus is largely restricted to children, immunity is believed to be long-lasting.

A correlation exists between the expression of histo–blood group antigens (HBGAs) and susceptibility to norovirus and possibly rotavirus infections.[85–92] HBGAs comprise a diverse family of carbohydrates expressed on the mucosal epithelia of the respiratory, genitourinary, and digestive tracts; HBGAs are recognized as receptors allowing norovirus attachment and cellular entry. The expression of HBGAs is determined by 3 gene families expressing the *ABO* (A/B enzymes), secretor *(FUT2)* gene, and Lewis-type *(FUT3)* gene. Single nucleotide gene polymorphisms can inactivate the expression of these gene products, thereby breaking a link in the norovirus binding and infection process. Mutations in the *FUT2* gene leading to the absence of HBGA expression (nonsecretor phenotype) have been associated with resistance to infection, in particular to GII.4 noroviruses, which are the predominant global genotype.[85,86,88,89,93–96] HGBA expression appears to vary by ethnicity; 20% to 25% of the US. white population consists of nonsecretors compared with 2% of persons of Meso-American or Hispanic ancestry. In East Asia, different secretor mutations (*A385T* and *FUT3*) observed in Chinese and Vietnamese children confer lower risk of norovirus infections.[91,97] Evidence points to lower susceptibility of nonsecretors to rotavirus infections in various populations.[90–92]

## CLINICAL MANIFESTATIONS

Although these viruses differ genetically and structurally, the clinical presentations of acute gastroenteritis caused by these agents are indistinguishable. After a short incubation period, infections with any of the viruses lead to an acute onset of gastroenteritis (Table 56.2). Vomiting is often an early sign, common in rotavirus infection, and particularly pronounced in norovirus and sapovirus infections.[7,98] Typically diarrhea is watery, and without blood, mucus, or fecal leukocytes. Fever occurs in approximately half of children with rotavirus infection and in approximately one fourth of children with nonrotavirus viral gastroenteritis, and it is often an early sign. Vomiting and fever frequently cease within 1 to 3 days, whereas diarrhea can persist longer, especially in rotavirus infections. Other symptoms include abdominal cramps, malaise, and seizures.[7,99]

The most important and common complication of viral gastroenteritis is dehydration, often associated with electrolyte abnormalities. Malabsorption can occur during the illness and persist for weeks following infection. Extraintestinal complications are rare, but encephalitis, seizures, acute myositis, hemophagocytic lymphohistiocytosis, acute flaccid paralysis, and sudden infant death syndrome have been described in children with rotavirus infections.[13,99,100] The association of these complications with rotavirus infection remains unclear. Severe and prolonged diarrhea associated with each agent has been reported among children with malnutrition and among children with congenital or acquired immunodeficiencies.[101–105]

Although viral causes of gastroenteritis are not distinguishable by clinical signs and symptoms, clinical characteristics of cases in outbreak settings have been helpful in predicting the presence of noroviruses.

**TABLE 56.2** Epidemiologic Features of Viral Causes of Gastroenteritis

| Feature | Rotavirus | Noroviruses | Sapoviruses | Astroviruses | Adenoviruses |
|---|---|---|---|---|---|
| **Predominant age of illness** | <5 yr | All ages | <5 yr | <2 yr | <2 yr |
| **Mode of transmission** | Person-to-person through fecal-oral route, fomites | Person-to- person through fecal-oral and vomitus-oral, fomites, food or water | Person-to- person through fecal-oral route | Person-to-person through fecal-oral route | Person-to- person through fecal-oral route |
| **Incubation period** | 1–3 days | 12–48 hr | 12–48 hr | 1–4 days | 3–10 days |
| **Symptoms** | | | | | |
| Diarrhea | Explosive, watery | Watery with acute onset | Watery; milder than rotavirus | Watery; milder than rotavirus | Watery; milder than rotavirus; can be prolonged |
| Vomiting | 80%–90% | >50%; often dominant symptom | Less common than rotavirus | Less common than rotavirus | Less common than rotavirus |
| Fever | Frequent | Less common, usually mild | Less common, usually mild | Less common, usually mild | Less common, usually mild |
| **Illness duration** | 2–8 days | 1–5 days | 1–4 days | 1–5 days | 3–10 days |
| **Clinical diagnosis** | Stool EIA or LPA | RT-PCR | RT-PCR | Stool EIA (not available in United States) | Stool EIA |

EIA, enzyme immunoassay; LPA, latex particle agglutination; RT-PCR, reverse transcriptase–polymerase chain reaction.
Modified from Peck AJ, Bresee JS. Viral gastroenteritis. In: McMillan JA, Feigin RD, De Angelis CD, Jones MD Jr (eds). Oski's Pediatrics, 4th ed. Philadelphia, Lippincott Williams & Wilkins, 2006, pp. 1288–1294.

Kaplan and colleagues[98] found that outbreaks that met simple epidemiologic and clinical criteria were likely to have been caused by noroviruses. These criteria included (1) failure to detect a bacterial or parasitic pathogen in stool specimens, (2) the occurrence of vomiting in >50% of patients, (3) mean duration of illness of 12 to 60 hours, and (4) mean incubation period of 24 to 48 hours. The "Kaplan criteria" have been validated and are used by local health departments for the diagnosis of outbreaks in the absence of laboratory testing for norovirus.[106]

## DIAGNOSIS

Laboratory diagnosis of viral gastroenteritis is made by detection of viral antigen or nucleic acid in fresh, whole stool samples obtained during the acute illness. Commercially available assays to detect rotavirus antigen in stools offer easy and inexpensive methods to diagnose infection in children. These tests are available as either enzyme immunoassay (EIA) or a latex particle agglutination test for group A rotaviruses, designed to detect the VP6 protein.[13] Antigen detection tests generally have high (90% to 95%) sensitivity and specificity.[93] Other methods of rotavirus detection include electron microscopy, viral isolation, and RNA polyacrylamide gel electrophoresis. Reverse transcription–polymerase chain reaction (RT-PCR) is rarely used in clinical practice because of the test's high sensitivity; it may detect virus when that virus is not causing disease.[107] Serologic testing for rotavirus infection is possible but impractical and thus is not widely available in clinical care settings.

Real-time RT-PCR is the preferred laboratory method for detecting noroviruses. This assay is highly sensitive and can detect as few as 10 norovirus copies per reaction and provide a semiquantitative estimate of viral load. The assay is generally used to detect norovirus in stool, but it can also be used for vomitus, foods, water, and environmental specimens for outbreak investigations, although with reduced sensitivity. Conventional PCR followed by sequence analysis of the PCR products is used for norovirus genotyping.[108] Given the exquisite sensitivity of RT-PCR for norovirus and the high frequency that the virus can be found in healthy persons,[11,66,109] diagnostic results should be interpreted in light of clinical characteristics and, if available, the background level of detection in a control population. A commercial EIA for norovirus was approved in the US in 2011; however, this assay has low sensitivity and is not recommended for diagnosing norovirus infection in sporadic cases. Norovirus EIA can be useful in outbreak investigations.[110–112]

Commercial EIAs for detection of astrovirus viral antigen in stool are available in Europe, but not in the US. RT-PCR is a sensitive and specific method for detection of astroviruses.[113] RT-PCR, serologic assays, and electron microscopy are used primarily in research settings. Similarly, RT-PCR, EIA, and latex particle agglutination kits are available commercially and provide highly sensitive and specific antigen detection of enteric adenoviruses.[26] All viral agents of gastroenteritis are detectable by electron microscopy and immune electron microscopy, but these tests are seldom used because of their relatively low sensitivity and specificity, expense, and required expertise.

## TREATMENT

No specific therapies are available for viral gastroenteritis. Case management depends on accurate and rapid assessment of the severity of dehydration, correction of fluid loss and electrolyte disturbances, and maintenance of adequate hydration and nutrition.[113] Treatment with oral rehydration solution (ORS) containing appropriate glucose-electrolyte solutions is sufficient for most patients. ORS use a protein sodium-glucose cotransporter 1 (SGALT1) that facilitates solute absorption across the luminal membrane. Water passively follows the osmotic gradient generated by transcellular transport of electrolytes and nutrients. In 2004, the World Health Organization recommended use of low-osmolarity ORS (245 mOsm/L), which has been shown to decrease stool output and vomiting in comparison with children treated with traditional ORS (311 mOsm/L). Intravenous rehydration can be required for children with severe dehydration (≥10% fluid deficit, shock, or near shock), intractable vomiting, or ORS treatment failure. Factors such as young age, unusual irritability or drowsiness, progressive course of symptoms, or uncertainty of diagnosis can indicate a need for close observation.

Breastfed infants should continue to nurse on demand. In children who are not breastfed, change to a lactose-free diet may result in earlier resolution of acute diarrhea and reduce treatment failure.[114] Children taking solid foods should continue to receive their usual diet during episodes of diarrhea, although substantial amounts of foods high in simple sugars should be avoided because the osmotic content may worsen diarrhea. Evidence on the use of oral probiotics (e.g., *Lactobacillus* spp.) to reduce the duration of diarrhea caused by rotavirus is conflicting.[115–117] Zinc, used both as supplement and treatment, reduces the severity, duration, and incidence of diarrhea in low- to middle-income settings and is considered one of the mainstays of treatment in developing countries[118,119]; however, the role of zinc supplementation in high-income settings has not been extensively studied. Because viral agents account for most cases of infectious gastroenteritis in children,

**Key Points:** Epidemiology, Clinical Features, Diagnosis, Treatment, and Prevention of Viral Gastroenteritis

**EPIDEMIOLOGY**

- Viruses account for most cases of acute gastroenteritis among children. These include rotaviruses, noroviruses, enteric adenoviruses (types 40 and 41), astroviruses, and sapoviruses.
- Viral gastroenteritis occurs in endemic and epidemic forms. Rotaviruses and noroviruses are the major causes of endemic disease, with seasonal peaks during the winter months in temperate climates. Noroviruses are the main causes of epidemic disease.
- Following introduction of rotavirus vaccine, rates of rotavirus gastroenteritis have decreased substantially, and currently noroviruses are the major causes of acute gastroenteritis in the United States.

**CLINICAL FEATURES**

- The clinical characteristics of illnesses caused by different viruses generally are indistinguishable. These include watery diarrhea and, in some cases, vomiting and fever.
- The most common severe complication of viral gastroenteritis is dehydration, often with electrolyte abnormalities.
- Prolonged diarrhea has been reported among children with malnutrition and among immunocompromised patients.

**DIAGNOSIS**

- Laboratory diagnosis of viral gastroenteritis is best made by detection of viral antigen or nucleic acid in fresh, whole stool samples obtained during the acute illness.
- Commercially available assays to detect rotavirus antigen in stools offer an easy and inexpensive method to diagnose infection in children.

**TREATMENT**

- No specific therapies are available for viral gastroenteritis.
- The mainstays of therapy include assessment of dehydration severity, correction of fluid loss and electrolyte disturbances, and maintenance of adequate nutrition.
- Oral rehydration using oral rehydration solution with appropriate glucose-electrolyte solutions is sufficient for most patients.
- Zinc is used for treatment in low-income countries.

**PREVENTION**

- Rotavirus vaccines have been added to routine immunization programs in more than 75 countries and have substantially reduced diarrhea-associated healthcare use and acute gastroenteritis-associated mortality rates.
- Except for rotavirus, prevention of viral gastroenteritis is limited to nonspecific strategies including breastfeeding, hand hygiene, and strict adherence to hygiene guidelines including use of Environmental Protection Agency–approved cleaners for food preparation areas and contaminated surfaces.

antimicrobial therapy is not usually indicated for children (see Chapter 55).[120]

## PREVENTION

The best public health intervention to reduce the incidence of severe viral gastroenteritis is the implementation of live, oral rotavirus vaccines in routine immunization programs. Rotavirus vaccines are attenuated strains given in multiple doses designed to replace a child's first exposure to wild-type rotavirus with strains that will not cause disease but will generate an adequate immune response to confer protection. Currently, 2 rotavirus vaccines are licensed in the US.[121] A third vaccine has been evaluated in India.[122] Additional vaccines are in development and may be available within several years.

As of 2015, rotavirus vaccines have been added to routine immunization programs in more than 75 countries, and these vaccines exert a dramatic impact with rapid and sustainable reductions in diarrhea-associated healthcare use and acute gastroenteritis–associated mortality rates.[9,10,12,40,123] Vaccine efficacy was shown to be very high in high- and middle-income settings and moderate in low-income populations[124–128]; however, vaccines may have their greatest impact in these low-income settings because of the higher burden of disease. The World Health Organization issued a global recommendation for the use of rotavirus vaccines.[129] Vaccine effectiveness in real-life routine use across various demographic and geographic settings has been good.[130,131]

Except for rotavirus, prevention of viral gastroenteritis is limited to nonspecific strategies. Breastfeeding confers some protection against rotavirus infection, and probably other viral infections, in young infants. Good hygiene, including meticulous handwashing practices, is an effective prevention strategy and should be encouraged, particularly in institutional settings, such as childcare centers and hospitals.[132] Significantly reducing transmission of viral agents of gastroenteritis requires strict adherence to recommendations because of the low infectious dose and the high quantity of viruses excreted in stool (and often vomitus) from infected persons and because these viral agents are quite stable in the environment. Noroviruses are relatively resistant to environmental disinfection; cleaning contaminated surfaces and food preparation areas with Environmental Protection Agency–approved cleaners is effective in settings where viral gastroenteritis outbreaks occur.[132,133]

Although experimental vaccines against noroviruses are in development, proof that these vaccines could protect against natural infection remains to be established.[134,135] These vaccines are based on virus-like particles and showed promise in volunteer challenge studies when they were administered both intranasally and intramuscularly. No vaccines against other viral gastroenteritis agents are yet in human trials.

*All references are available online at www.expertconsult.com.*

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