Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Prevention and Control

Due to their intimate association with the germplasm of their hosts, the control of endogenous viral elements poses a unique set of problems. Obviously, although eradication has worked well for eliminating exogenous retroviruses from some experimental and commercial populations of animals, there is little chance of selectively breeding out the thousands of endogenous viral elements in the typical animal genome. Central to the issue of control, therefore, are the enabling tools of rapid diagnostics and a large database on the physiological roles of individual proviral elements. In terms of rapid diagnostics, the development of DNA chip technology has resulted in a massive increase in DNA-typing ability over previously available methods. Whereas in the past, establishing the profiles of endogenous elements was a painstakingly slow process, DNA chip technology has the potential to facilitate data acquisition at an unprecedented speed. Thus, it may soon be feasible to establish the complete genetic profile for endogenous viral elements in any individual on a routine basis. Rapid diagnostics will also aid the process of defining the interrelationships between individual endogenous proviruses and their hosts.

The potential benefit for endogenous viral profiling in humans lies in the identification of carriers of the particular endogenous elements that are associated with morbidity states. Once such genetic risk factors have been determined, lifestyle adjustments can be made to avoid environmental factors that might compound the risks, and available treatment programs can be fine tuned to address specific disease potentials. For applications in other areas, such as farm animal health, molecular profiling of endogenous viral elements can be integrated with existing selection programs to reduce viral particle prevalence in food products, and to increase natural resistance to viral infection.

See also: **Diagnostic techniques: Detection of viral antigens, nucleic acids and specific antibodies, Isolation and identification by culture and microscopy; Immune response: Cell mediated immune response, General features; Human immunodeficiency viruses (*Retroviridae*): Molecular biology, Anti-retroviral agents, General features; Retroviral Oncogenes.**

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ENTERIC VIRUSES

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Introduction

Viruses are amongst the first microorganisms to colonize the germ-free intestine after birth, where they encounter conditions ideal for growth, including warmth, an abundant supply of nutrients and continual replenishment of susceptible cells. Many viruses identified in feces, including reoviruses, adenoviruses and enteroviruses, have the capacity to replicate in the intestine without causing clinical symptoms. Other viruses detected in feces may be derived from swallowed secretions originating in the respiratory tract, from plant viruses ingested in food, or from phages released after bacterial lysis. Many viruses use the gastrointestinal tract as a portal of entry and may replicate there before initiating systemic disease (e.g. poliovirus, hepatitis A and E). A diverse group of viruses (rotaviruses, adenoviruses, caliciviruses, astroviruses, coronaviruses) replicate in the epithelial cells lining the small intestine, causing sufficient destruction to result in the symptoms of enteric infection, including diarrhea, vomiting, fever and dehydration. A further group of viruses of systemic origin (e.g. measles virus, cytomegalovirus

Table 1 Viruses implicated in the etiology of acute diarrhea

Virus	*Family*	*Size (nm)*	*Genome*	*Host range*
Rotavirus	*Reoviridae*	70	dsRNA	
Group A				All mammalian and avian species
Group B				Pigs cattle, sheep, rats, humans
Group C				Pigs, ferrets, humans
Group D, F, G				Avian species
Group E				Pigs
Adenovirus Subgenus F Ad40, Ad41	*Adenoviridae*	70	dsDNA	Humans
Calicivirus	*Caliciviridae*	35–40	ssRNA	Humans, cattle, pigs, chickens, dogs
Astrovirus	*Astroviridae*	28–30	ssRNA	Humans, cattle, pigs, cats, dogs, avian species
Parvovirus	*Parvoviridae*	18–26	ssDNA	Cattle, cats, dogs, mink (humans)
Coronavirus	*Coronaviridae*	80–120 (pleomorphic fringed)	ssRNA	Pigs, cattle, foals, mice, rabbits, dogs, cats, turkeys (humans)
Torovirus	*Coronaviridae*	80–120 (pleomorphic fringed)	ssRNA	Cattle, horses (goats, sheep, pigs, rabbits, mice, humans)
Picobirnavirus	*Birnaviridae*	32–35	dsRNA	(Rats, cattle, pigs, hamsters, guinea pigs, humans)

ds, Double-stranded; ss, single-stranded. The role of the virus as an etiological agent of diarrhea is not proven in the species in parentheses.

(CMV), human immunodeficiency virus (HIV)) may multiply in gut-related cells, again causing symptoms of enteritis.

The diversity of viruses excreted in feces confused the interpretation of initial tissue culture-based surveys aimed at detecting etiological agents of acute nonbacterial gastroenteritis. It was only after electron microscopy revealed noncultivable viruses in diarrheal stools and not in control specimens that many viruses causing acute enteritis could be identified and studied in detail. Viruses belonging to at least seven different genera have now been implicated in the etiology of acute enteritis in animals, avian species and humans (**Table 1**).

History

The symptoms of acute diarrhea were described in the earliest medical writings, long before the concept of infectious agents was considered. Reports of viral enteritis are impossible to identify with accuracy because of the nonspecific nature of the symptoms resulting from injury to intestinal epithelial cells. However, nineteenth and early twentieth century accounts of 'pseudocholera infantum', as a severe watery diarrhea in young children during winter months, make it likely that rotavirus infection may have been implicated in this often fatal disease.

In 1943 a filtrate of stools from infants with diarrhea induced diarrhea in young calves. Many years later, rotaviruses were identified in calf feces obtained at the time. Similar experiments in the 1960s induced diarrhea in a proportion of human volunteers, giving evidence for involvement of an 'ultrafilterable agent' (presumed to be a virus) in the etiology of epidemic gastroenteritis. Eventually in 1972 the 27 nm Norwalk virus was identified, by immunoelectron microscopy, as a cause of gastroenteritis in older children and adults. In 1973 the 70 nm human rotavirus was identified by electron microscopy in duodenal tissue and stools from young children admitted to hospital for treatment of acute diarrhea. Similar particles had been described in 1963 as a cause of epidemic diarrhea of infant mice, and in 1967 as a cause of diarrhea in calves. Electron microscopy (**Fig. 1**) then revealed a great variety of other noncultivable viruses in stools, some of which have been shown to be etiological agents of acute enteritis in animals and humans, and others for which evidence of an etiological role is still not proven.

Rotaviruses (*Reoviridae*)

Rotaviruses are approximately 70 nm in diameter with a wheel-like appearance (*rota* is Latin for wheel) (**Fig. 2**). The genome is composed of double-stranded

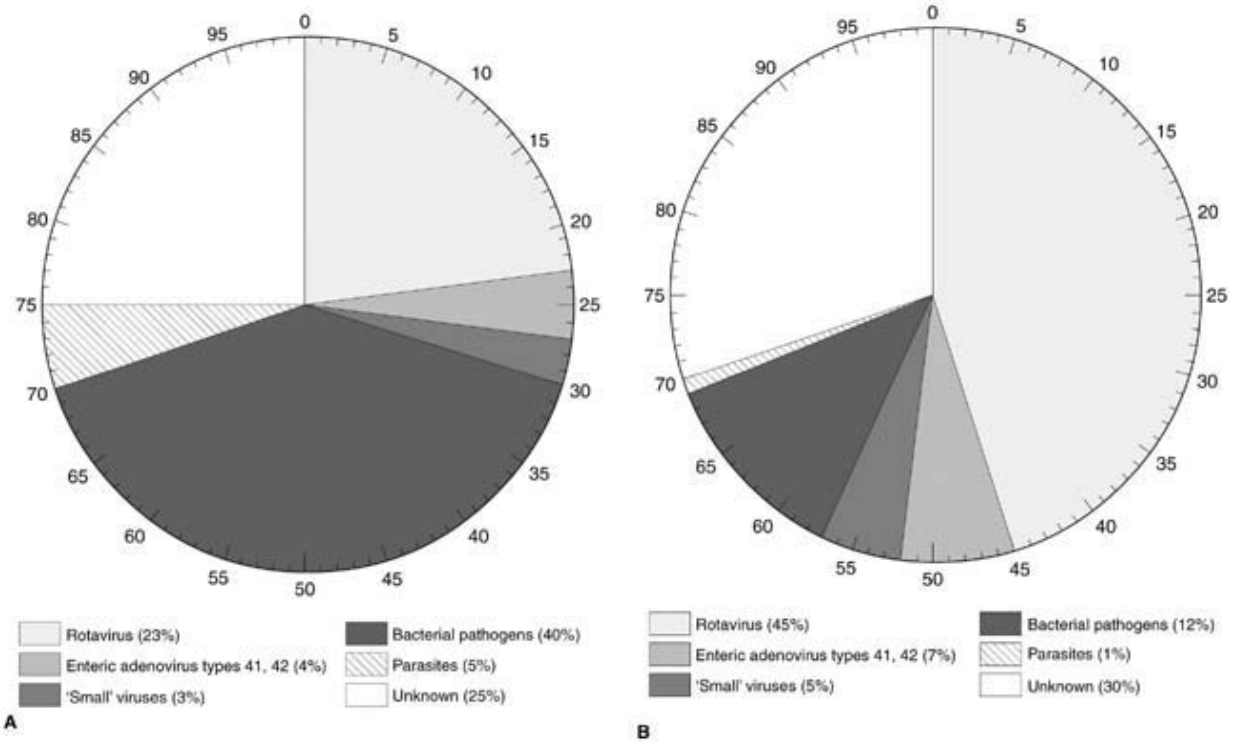

Figure 1 Etiology of severe acute diarrhea in young children in (**A**) developing and (**B**) developed countries (data compiled from published surveys).

RNA which can be separated into 11 segments (genes) by polyacrylamide gel electrophoresis. The inner capsid protein bears non-neutralizing antigenic epitopes that allow serological subdivision of the strains into groups A–F. The majority of human infections studied to date are caused by group A rotaviruses.

Group A rotaviruses

These are ubiquitous in nature and infect the young of all mammalian and avian species. They cause life-threatening diarrhea, predominantly in young children aged 6–24 months, and epidemics of mild to severe diarrhea in newborn animals and birds. Newborn babies are susceptible to infection, but this is often asymptomatic, either because rotaviruses adapted to growth in the neonatal intestine are naturally attenuated and/or because maternally derived antibody reduces the severity of symptoms. Reinfections occur regularly thoughout life. Group A rotaviruses have a worldwide distribution and cause 20–45% of disease in children admitted to hospital. Seasonal epidemics occur in children during the colder months of the year. Infection is endemic throughout the year in tropical countries. Group A rotaviruses present an almost limitless spectrum of genetic variation, but antigenic variation appears more restricted. Rotaviruses are species-specific, although cross-species infections can be induced under experimental conditions. When this occurs, rotavirus replication is minimal, thus reducing the likelihood of horizontal transmission of infection. Occasional zoonotic infections have occurred in humans. There is

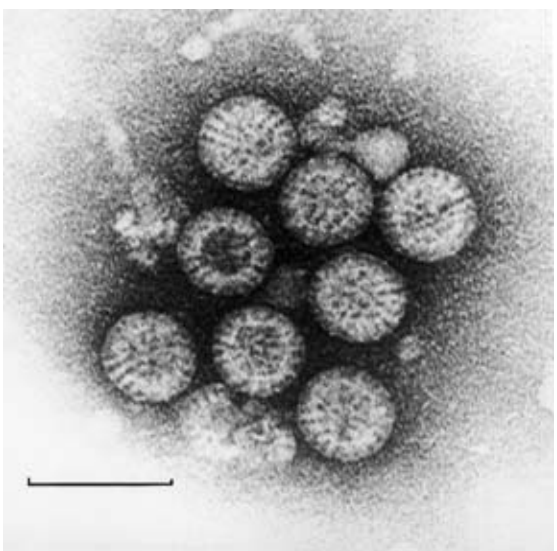

Figure 2 Electron microscopic appearance of negatively stained rotavirus particles. Bar = 100 nm.

a potential for human and animal strains to reassort in nature. During natural group A rotavirus infections, as many as 10^{10} particles ml^{-1} are shed in feces. The virus is highly infectious, spreads rapidly to contacts, and can retain infectivity for several months in the environment, and in sewage.

Group A rotaviruses are divided into serotypes by identification of neutralizing antigens on the two outer capsid proteins VP7 (G-type) and V4 (P-type). To date 14 G-types and 20 P-types have been identified. G1P1A[8] infections have been overwhelmingly predominant in humans worldwide during the past two decades.

The non-group A rotaviruses

Also referred to as 'novel' rotaviruses, pararotaviruses or atypical rotaviruses, these are morphologically identical with group A rotaviruses, although some disintegrate more readily and appear in negatively stained preparations as thin-walled featureless core particles. They show differing patterns of mobility of the 11 genome segments, and to date all have lacked the 7-8-9 gene triplet characteristic of group A rotaviruses. They do not react serologically in assays to identify group A rotaviruses. Attempts to produce reassortants between group A and non-group A rotavirus *in vitro* have been unsuccessful. All appear to be species-specific. All have been difficult to adapt to cell culture, with limited success using swine kidney cells (group B), swine testicular cells and CaCO-2 cells (group C).

Non-group A rotaviruses can be subdivided into serogroups B–G. Group B rotaviruses have been identified in pigs, cattle, sheep, rats and humans. Infections in farm animals may often be asymptomatic or cause only mild symptoms. The numbers of particles shed during infection appear to be less than in group A infections. Their distribution worldwide is uncertain. Serum surveys indicate a moderate prevalence (10–20%) of antibodies to group B rotaviruses in humans in China, the USA and Australia, and group B rotaviruses caused a large epidemic of severe enteritis in older children and adults in China in 1982–1983.

Group C rotavirus infections have been recorded in pigs, ferrets and humans. Infection is thought to be relatively common in pigs in the UK and USA (as judged by serum surveys) but severe disease may be comparatively rare. A similar situation may occur with humans. Antibodies have been detected in 43% of sera from humans (0–75 years), with the highest incidence (60%) in the 71–75 year age group, but severe infections are rare (<2% of children admitted to hospital worldwide). Most symptomatic infections have been associated with family or community outbreaks. Infection with group C rotaviruses has been suggested as a cause of biliary atresia in infant humans.

Groups D, F and G have been identified frequently in chickens, pheasants and turkeys in the UK and USA, where they appear to be more common than group A infections. Group E rotaviruses have been identified in pigs.

The importance of non-group A rotavirus infections in animals and humans will be debatable until suitable diagnostic tests are developed and used widely.

'Enteric' Adenoviruses (*Adenoviridae*)

Adenoviruses are nonenveloped icosahedral particles of 75–80 nm in diameter (**Fig. 3**). The virion contains a genome composed of double-stranded DNA coding for 10 different structural polypeptides. Human adenoviruses are classified into six subgenera, A–F (with different trophisms), each containing one or more serotypes. 'Enteric' adenoviruses causing disease in humans belong to subgenus F, serotypes 40 (Ad40) or 41 (Ad41). Restriction enzyme analysis indicates heterogeneity within both serotypes. Neither replicate in conventional cell culture but can

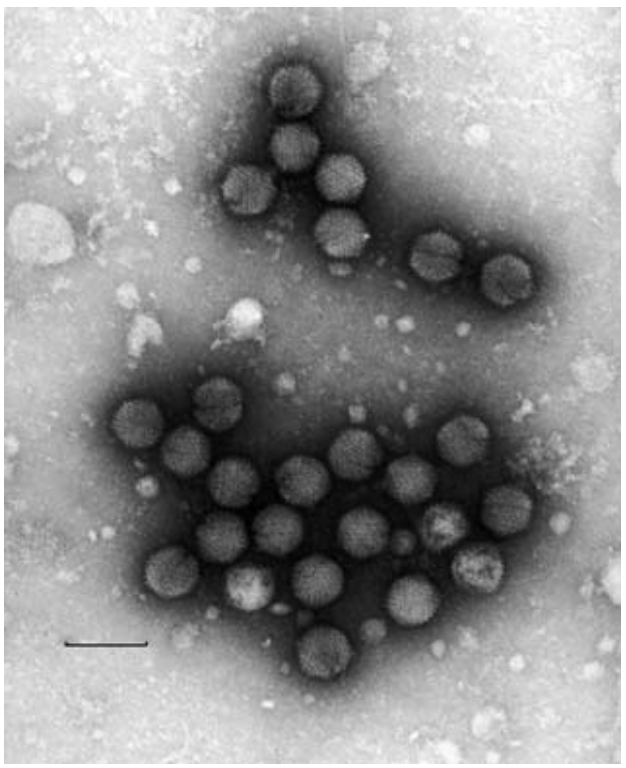

Figure 3 Enteric adenoviruses. Bar = 100 nm.

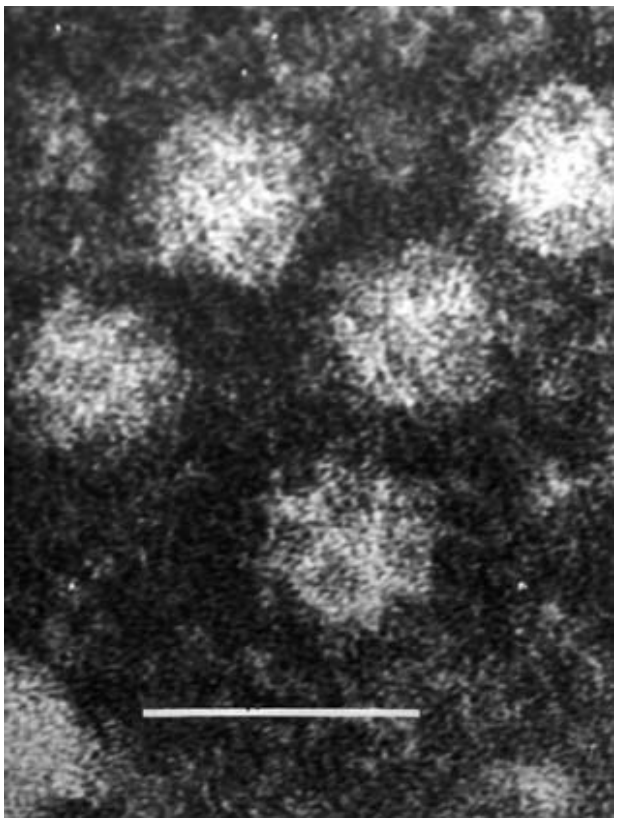

Figure 4 Caliciviruses (HuCV). Bar = 50 nm.

be coaxed to grow in Graham 293 cells (transfected with regions of Ad5).

Enteric adenoviruses (Ad40, Ad41) have been identified worldwide as a cause of severe diarrhea in 7–17% of children admitted to hospital. The relative incidence of Ad40 has declined since 1981, and Ad41 infections have shown a rapid rise in prevalence in North America, Europe and Australia. Enteric adenoviruses are a common cause of nosocomial infection, with an incubation period of 7–8 days. Diarrhea is often protracted, lasting up to 12 days, and viral excretion can be prolonged. Immunodeficiency may enhance enteric adenovirus infections because these viruses have been found more frequently than other enteric viruses in bone marrow transplant patients, and in patients with HIV-associated diarrhea. They cause fatal enteritis in immunodeficient foals.

Adenoviruses (of other serotypes) have been reported to cause hemorrhagic enteritis in turkeys, enteritis in mice and mild diarrhea in weaned piglets. Infections in calves or lambs are rare. 'Nonenteric' adenoviruses are common in human feces, perhaps derived from swallowed respiratory secretions. The ability of adenovirus 7 to colonize the human intestine asymptomatically has led to its suggested use as an oral vaccine vector.

Caliciviruses (*Caliciviridae*)

These are small (35–40 nm) single stranded RNA viruses (**Fig. 4**) 'Classical' caliciviruses show characteristic surface cup-shape indentations (calices), but many other members of this family are described as small round structureless viruses (SRSV) with an amorphous surface structure and a feathery ragged outline. Some of the size variations noted by electron microscopy and/or the relative scarcity of particles detected in feces may be due to proteolytic degradation of particles shed in feces. Caliciviruses possess only a single major structural polypeptide and comprise at least five genogroups. Caliciviruses associated with enteritis appear to be highly species-specific, and have been described in cattle (Newbury agent), pigs, chickens, dogs and humans.

The disease due to human caliciviruses (HuCV) was initially studied in adult volunteers using oral administration of fecal filtrates, leading to the discovery of Norwalk virus in 1972 by immune electron microscopy. This was followed by the description of many other small viruses implicated in gastroenteritis outbreaks. Most of these viruses were named after their geographical origin, e.g. Hawaii agent, Snow Mountain virus, Sapporo virus, Mexico virus, but now are known to have worldwide distribution. Identification and classification within HuCV took an enormous leap forward with the development of reverse transcriptase polymerase chain reaction primer-based hybridization assays, and enzyme immunoassays using recombinant antigens. Preliminary genetically based classification now recognizes three HuCV genogroups represented by Norwalk virus (NV), Snow Mountain agent (SMA) and Sapporo virus. The Sapporo virus genogroup has been detected in 0.5–6.6% of sporadic gastroenteritis in hospitalized children. The NV and SMA genogroups have predominantly caused outbreaks of diarrhea (in all age groups) as a result of ingestion of contaminated food/fluids. Etiological surveys undertaken in the USA have shown that approximately 65% of outbreaks of gastroenteritis in camps, cruise ships, nursing homes, schools and families have been associated with excretion of HuCV. HuCV are still recalcitrant to growth *in vitro*, and these viruses have not been visualized in intestinal tissue, despite repeated attempts.

Astroviruses (*Astroviridae*)

These viruses have a diameter of 28–30 nm and possess a positive-strand RNA genome coding for four structural polypeptides. A surface structure with a five- or six-pointed star-like appearance (hence

astrovirus) can be seen by electron microscopy on 5–10% of particles (**Fig. 5**). These viruses were first described in association with an outbreak of mild diarrhea in newborn infants. Strains have been identified in many animals including calf, lamb, pig, cat, dog, duck and turkey. Experimental infections are usually asymptomatic or produce only mild symptoms, although infected ducklings can develop fatal hepatitis. Infections appear to be host-specific. Seven human serotypes that are serologically distinct from animal strains have been described. Serotype 1 has been responsible for >50% of all human astrovirus infections described to date.

Human astrovirus infections occur worldwide, with peak incidence in winter/spring in temperate climates. Illness is usually mild, with an incubation period of 3–4 days, and is accompanied by seroconversion. Symptomatic astrovirus infection is mainly restricted to young children and can account for severe diarrhea in ≤5% of hospitalized children. Outbreaks of astrovirus gastroenteritis have been observed in nursing homes for the elderly (Marin county agent), among military recruits, and in immunocompromised patients. An enzyme immunoassay incorporating monoclonal antibodies and an RNA probe hybridization assay have been developed recently to facilitate diagnosis. Antibody prevalence surveys show that 65% of 3–4-year-old children and 87% of 5–10-year-old children possess serum antibody. The virus can be propagated in human embryo kidney cells in the presence of trypsin, and in human colonic carcinoma cell lines (CaC02, HT-29).

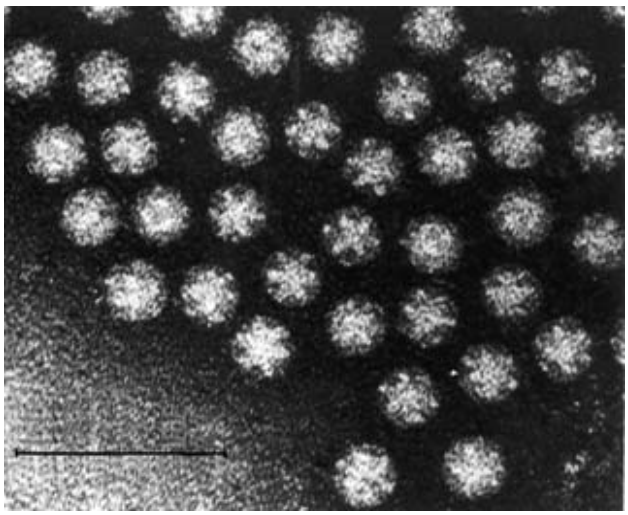

Figure 5 Astroviruses. Bar = 100 nm.

Parvoviruses (*Parvoviridae*)

These are small structureless single-stranded DNA viruses of 18–26 nm diameter. Some have caused severe acute gastroenteritis in cats, dogs, mink and calves. Pathogenesis clearly differs from most other enteric infections, as primary virus replication after ingestion occurs in lymphoid tissues, followed by viremia. Secondary replication (within a few days) occurs within the intestinal epithelium, where infection of crypt cells is widespread. No equivalent infectious agents have been described in humans. A heterogeneous collection of small round featureless viral particles of similar size has been described in diarrheal feces from humans. The particles have a size range of 22–26 nm diameter, with no discernible surface features and no sharply delineated outer edge. They resemble parvoviruses in morphology, size and buoyant density. These particles (Ditchling, W, Paramatta 'cockle agents') have been detected in stools of patients involved in approximately one-third of outbreaks of gastroenteritis attributed to ingestion of shellfish or cold foods. There has been frequent dual infection with other viruses confirmed as etiological agents of enteritis. No serological evidence of infection with these small viruses has been demonstrated. It is possible that these parvovirus-like particles are endemic 'intestinal' viruses that replicate to low titer in crypt cells, and that infection by other enteric viruses stimulates replication of crypt cells, favoring increased replication and fecal shedding of these particles.

Coronavirus/Coronavirus-like Particles (*Coronaviridae*)

Coronaviruses are enveloped single-stranded RNA viruses, visible in feces by electron microscopy as large pleomorphic particles (80–120 nm diameter) with a characteristic corona (crown) projecting as a single or double fringe of 10–20 nm length (**Fig. 6**). Coronaviruses are undisputed causes of epidemic diarrhea in newborn piglets *t*ransmissible gastro*e*nteritis *v*irus (TGEV), calves, foals, mice, rabbits, turkeys, dogs and cats. Large pleomorphic fringed particles resembling coronaviruses have been identified in humans in outbreaks of gastroenteritis among army personnel and hospital nurses, and in newborn babies with bloody diarrhea and necrotizing enterocolitis. Pleomorphic particles resembling coronaviruses have frequently been observed in symptomatic and asymptomatic adults and children living in crowded unhygienic conditions. The significance of many of the fringed particles seen in human feces in relation to enteric symptoms is controversial. In some circumstances, the particles may arise from degenerate fragments of intestinal tissue or they may be

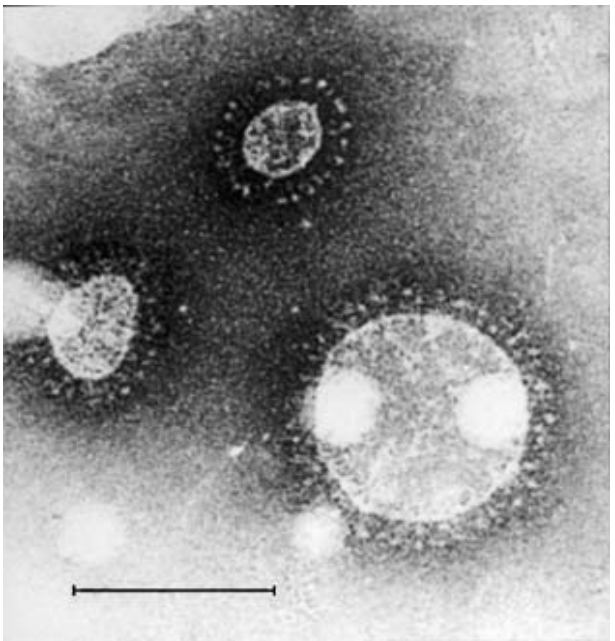

Figure 6 Coronavirus-like particle. Bar = 100 nm.

immunologically related to human respiratory coronaviruses. However, coronavirus-like particles shed in feces by babies with necrotizing enterocolitis replicated in human fetal intestinal organ culture, and homologous seroconversions were demonstrated in paired sera from these infants. Recognition and identification of human enteric coronaviruses requires development of specific diagnostic techniques. Only then will their importance in human infections be resolved.

Toroviruses (*Coronaviridae*)

These are positive-strand RNA viruses classified as a genus within the family *Coronaviridae*. They are visible by electron microscopy of feces as 100–140 nm pleomorphic fringed particles (spherical, kidney-shaped or elongated) with 10–20 nm long peplomers. These viruses infect a number of animal species but appear to be most common in horses (Berne virus) and calves (Breda viruses). Equine infections appear to be asymptomatic. Diarrhea due to Breda viruses has been reproduced experimentally in gnotobiotic calves. With the exception of Berne virus (successfully cultivated in equine dermal cells), none have been adapted to growth *in vitro*. Serum antibody surveys indicate that torovirus infection, but not disease, is widespread among cattle in the UK, Europe and the USA. Antibody has been detected in humans, goats, sheep, pigs, laboratory rabbits and wild mice. Toroviruses have been identified as a cause of diarrhea in humans (including children) in the UK, France, the USA and Canada. Etiological and epidemiological studies require improved methods for detection, and strict criteria to differentiate toroviruses from other 'fringed particles' seen in feces. These viruses may prove to be widespread and of low pathogenicity in the intestinal tract.

'Picobirnaviruses'

These are double-stranded RNA viruses (assumed to be members of the family *Birnaviridae*) initially detected by polyacrylamide gel electrophoresis (PAGE) in 14 of 3134 fecal samples from Brazilian patients with acute gastroenteritis. The 32–35 nm particles resemble viruses found in intestinal contents of rats, calves, pigs, hamsters and guinea pigs. Similar particles have since been reported in approximately 10% of humans (aged 3–70 years) in the UK, and in 10% of HIV-infected patients in the USA. 'Picobirnaviruses' appear to be widespread in humans but their role in human disease is not known.

Enteroviruses/Reoviruses

Routine cell culture of human feces will frequently show reoviruses and enteroviruses (including poliovirus, echoviruses, coxsackieviruses) excreted by patients with and without diarrhea. Most are coincidental infections, unrelated to an etiology of diarrhea, but there is evidence implicating group A coxsackieviruses and echoviruses types 11 and 18 as causes of diarrhea in normal and in immunodeficient patients. Reoviruses can produce diarrhea in animals, including mice, where the intestine is a portal of entry for systemic infection.

Other Viruses

Diarrhea is associated with a variety of other viruses that more characteristically produce systemic infections. Viremia can result in infection of gut epithelium or of cells in the lamina propria. For example, diarrhea is a common and severe complication of *measles* infection in children in tropical countries. CMV infection (in patients with HIV infection or immunoincompetence due to other causes) produces changes ranging from mild inflammation to ulceration and necrosis at all levels of the intestinal tract, associated with gastrointestinal symptoms relative to the level of gut infected. HIV may directly cause an enteropathy, with symptoms of weight loss, diarrhea, vomiting and abdominal pain.

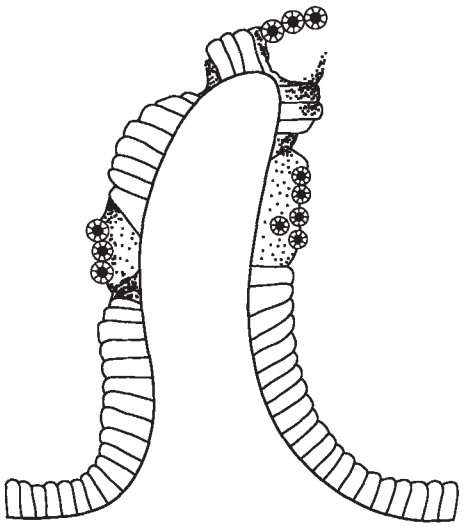

Figure 7 Small intestinal villus infected with rotavirus.

Clinical Features of Enteric Infection

Clinical features of viral enteric infection (regardless of agent) include an abrupt onset of vomiting, fever and diarrhea. Infections in adult humans (particularly with caliciviruses) predominantly involve nausea and vomiting. Profuse watery diarrhea in young children (and other young animals) can lead to dehydration, acidosis and electrolyte imbalance. Feces do not contain blood, white cells or mucus. Abdominal cramps occur but are much less frequent than with bacterial infections. Respiratory symptoms are present in 20–40% of children but may be coincidental. Vomiting usually persists for 24–48 h, and diarrhea for 2–7 days. Depression of mucosal disaccharidase activity leads to lactose malabsorption in a proportion of young children, and may persist and require dietary modification.

Pathology and Histopathology

Most enteric viruses implicated in the etiology of acute diarrhea replicate only in the mature absorptive epithelial cells of the villi of the small intestine (**Fig. 7**). The inability of these cells to undergo further replication *in vitro* has been the main barrier to adaptation of many enteric viruses to cell culture. *In vivo* replication in these cells produces similar histopathological changes in the intestine of animals and humans. Rotaviruses, Norwalk viruses, astroviruses and caliciviruses preferentially infect the upper small intestine, whereas adenoviruses, toroviruses and coronaviruses commonly infect the lower small intestine. Toroviruses also infect the colon. Most enteric viruses have been detected in M cells overlying lymphoid tissue, but do not appear to replicate in lamina propria or lymph nodes. Parvoviruses (and Breda viruses) also infect crypt cells. Only parvoviruses have been conclusively shown to have a viremic phase.

Histological changes observed in gut mucosa at all levels are similar. Initially, epithelial cells (infected and uninfected) are stripped from the sides and tips of villi, which may be denuded. Villi become stunted, and are covered with nonabsorptive cells derived from mitosis of crypt cells. The intestine is rapidly repopulated by mitosis of crypt cells, resulting in restitution of normal villus architecture covered by new mature absorptive villus cells. Crypt cell hyperplasia may be mediated via the hormone enteroglucagon, levels of which are raised in calves after enteric virus infections. The availability of newly regenerated absorptive cells may lead to a brief second wave of viral replication.

Treatment

Treatment consists of replacement of fluid losses, usually by administration of oral fluids containing glucose and electrolytes. Early resumption of normal feeding is encouraged, particularly in malnourished children. Breast-feeding can usually be continued throughout the illness. Lactose malabsorption may be a problem in a proportion of young children: reduction of lactose content in feeds may be required. There is no place for use of antibiotics or antiperistaltic agents in treatment of viral enteritis.

Immune Responses

The humoral immune response has been analyzed in great detail for human rotavirus infection. Specific antibodies detectable in intestinal contents and feces (of immunoglobulin IgA, IgM class) and serum antibodies (IgG, IgA, IgM class) appear during the first week after onset of infection. Serum antibody levels cannot be used as predictors of immunity to reinfection. The level of ingested or persisting antibody in the intestinal lumen can be predictive of immunity. Longitudinal studies of rotavirus infection in children (in developed and developing countries) show that primary infection (symptomatic or asymptomatic) does not confer immunity to reinfections, which are frequent, but does result in clinical immunity to development of severe symptoms during reinfection (**Fig. 8**). Immunity to caliciviruses following infection appears to be influenced by the infecting agent. Sporadic pediatric infections (due to Sapporo viruses) are associated with long-lived immunity. However, immunity to HuCV after epidemic out-

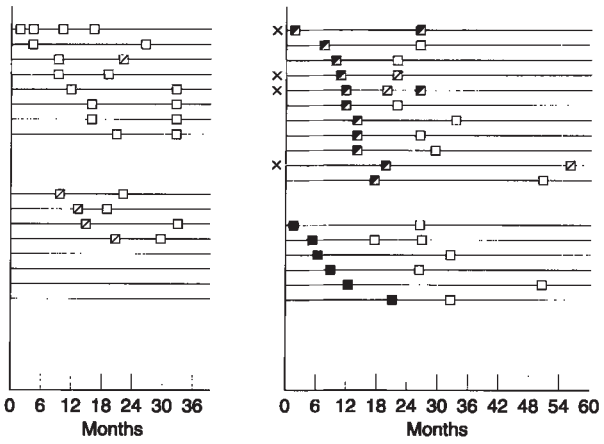

Figure 8 Longitudinal serological surveillance of rotavirus infection in 29 children recruited at birth and studied for 36–60 months (each line represents one child). □, Asymptomatic seroconversion; ▨, mild diarrhea on seroconversion; ◩, moderate diarrhea on seroconversion; ■, severe diarrhea on seroconversion; ×, children with more than one symptomatic infection.

breaks (in older age groups) is short-lived with no apparent protection against reinfection with the same viruses. Adult volunteers given Norwalk virus orally on more than one occasion were either repeatedly ill or persistently well. Volunteer studies with Norwalk virus show that approximately 50% of adults have an inherent resistance to infection (and disease) that has no detectable immunological basis. Cell-mediated immune responses have been demonstrated after rotavirus infection, and are important for cessation of virus excretion. Their role in long-term immunity is not known.

Prevention and Control

Some viral enteric infections, e.g. epidemics of waterborne or food-borne disease, could be controlled by improved sanitation and hygiene. Public health departments need to remain on the alert to monitor outbreaks and identify sources of infection. Infections where fecal/oral person-to-person spread is common are less likely to be controlled by improvements in sanitation. Implementation of strict crossinfection control measures could limit nosocomial spread of some infectious agents in hospitals, daycare centers, etc. However, the development of vaccines, particularly against rotavirus infection, is likely to have the greatest impact in both animals and humans on reduction of morbidity and mortality resulting from enteric viral infections.

See also: **Adenoviruses (*Adenoviridae*): General features; Astroviruses (*Astroviridae*); Birnaviruses – animal (*Birnaviridae*); Coronaviruses (*Coronaviridae*); Diagnostic techniques: Isolation and identification by culture and microscopy; Epidemiology of viral diseases; Immune response: General features; Norwalk and related viruses (*Caliciviridae*); Parvoviruses (*Parvoviridae*): Cats, dogs and mink; Pathogenesis: Animal viruses; Rotaviruses (*Reoviridae*): General features, Molecular biology; Toroviruses (*Coronaviridae*).**

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