Continuing Medical Education

Acute Infectious Gastroenteritis in Infancy and Childhood

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Summary

Background: Despite the introduction of vaccination against rotavirus, and even though it can often be treated on an outpatient basis, acute infectious gastroenteritis is nevertheless the second most common non-traumatic cause of emergency hospitalization in children aged 1 to 5 years, accounting for approximately 9% of cases (39 410 cases in 2017). The most common pathogens are viruses (47% rotavirus, 29% norovirus, and 14% adenovirus).

Methods: This review is based on publications retrieved by a selective search in PubMed employing the terms "acute gastroenteritis children" AND "dehydration" OR "rehydration" OR "prevention," and by manual searching (based, for example, on reference lists and expert knowledge), with subsequent evaluation including consideration of the relevant guidelines.

Results: The degree of dehydration can be judged from weight loss and other clinical findings. In 17 randomized controlled trials conducted on a total of 1811 children with mild or moderate dehydration, oral rehydration with oral rehydration solution was just as effective as intravenous rehydration with respect to weight gain, duration of diarrhea, and fluid administration, and was associated with shorter hospital stays (weighted mean difference, −1.2 days; 95% confidence interval [−2.38; −0.02]). Oral rehydration therapy failed in 4% of patients [1; 7]. In children who are vomiting or who refuse oral rehydration solution, continuous nasogastric application is just as effective as intravenous rehydration and is the treatment of first choice.

Conclusion: In Germany, children with mild or moderate dehydration are often hospitalized for intravenous rehydration therapy, despite the good evidence supporting ambulatory oral rehydration. Obstacles to intersectoral care, the nursing shortage, and inadequate reimbursement must all be overcome in order to reduce unnecessary hospitalizations and thereby lessen the risk of nosocomial infection.

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Every year, nearly half a million children under age five die of acute infectious gastroenteritis around the world (1). In Europe, infants and toddlers become ill one to two times per year, on average (2, e1). In Germany, nearly 40 000 children under age five were admitted to a hospital with acute infectious gastroenteritis in 2017, corresponding to approximately 9% of all hospitalizations for conditions other than trauma in this age group, and five children died (e2). Viral pathogens accounted for 93% of cases among hospitalized children under age 5, with rotavirus accounting for 47%, norovirus 29%, and adenovirus 14% (3, 4). Infants and toddlers are especially vulnerable because of their high daily fluid requirement of 100 to 160 mL per kilogram of body weight (5, e3).

Fluid loss due to vomiting and diarrhea can rapidly amount to three times the circulating blood volume, soon leading to dehydration, with disturbances of electrolyte homeostasis, circulatory function, and organ and tissue perfusion (5).

Frequency

In Germany, nearly 40 000 children under age five were admitted to a hospital with acute infectious gastroenteritis in 2017, corresponding to approximately 9% of all hospitalizations for conditions other than trauma in this age group, and five children died.

Fluid loss

Fluid loss due to vomiting and diarrhea can rapidly amount to three times the circulating blood volume, soon leading to dehydration, with disturbances of electrolyte homeostasis.

TABLE 1

Assessing the degree of dehydration in infants and children on the basis of weight loss, capillary filling time, and clinical manifestations

		No or minimal dehydration	Mild to moderate dehydration	Severe dehydration
Weight loss, in %*1	infant	≤ 5	6–10	>10
	older child	≤ 3	4–6	>6
Capillary refill time*1		normal (<2 sec)	normal to prolonged	prolonged
General condition, consciousness*1		good, awake	agitated, irritable, or tired	apathetic, lethargic, unconscious
Thirst*1		normal	thirsty, drinks avidly	drinks poorly or can no longer drink
Heart rate (for age)*1, *2		normal	normal to increased	tachycardia; with further worsening, bradycardia
Pulse quality*1		normal	normal to reduced	weak to absent
Breathing*1, *2		normal	normal or increased depth	deep, acidotic breathing
Eyes*1		normal	sunken	deeply sunken
Tears*1		present	diminished	absent
Mucous membranes*1		moist	dry	desiccated
Skin turgor*1		disappear immediately	disappear more slowly than normal, but within 2 seconds	persist longer than 2 seconds
Extremities*1		warm	cool	cold, cyanotic
Urine output*1		normal or mildly diminished	diminished	minimal

*1 Weight loss, capillary filling time, and clinical manifestations, based on References 27, e62–e64
*2 age-dependent normal values for heart rate and respiratory frequency: cf. Meyburg et al. (e65)

Learning objectives

This article should enable the reader to:

- judge a patient's degree of dehydration based on weight loss and other clinical signs,
- know which nutrition should be administered to children with acute infectious gastroenteritis, and
- know how to treat clinical dehydration according to degree of severity.

Methods

This review is based on publications retrieved by a selective search in PubMed employing the terms "acute gastroenteritis children" in combination with "dehydration," "rehydration," or "prevention," along with the findings of a manual search and guidelines from Germany and abroad.

Definition and differential diagnosis

Acute infectious gastroenteritis is diagnosed on clinical grounds. Its leading manifestations are sudden loosening of stool consistency and increased stool frequency to more than three times per day (or more than two times per day beyond the patient's usual frequency), sometimes accompanied by vomiting or fever (6, 7).

The main elements of the differential diagnosis in children are other infectious diseases (e.g., [uro-]sepsis, pneumonia, meningitis), metabolic disturbances, intestinal obstruction, and, in school-aged children, appendicitis (6).

Pathogens

Among children under age five in Germany, norovirus is the most common cause of acute infectious gastroenteritis, accounting for 26 272 cases (both ambulatory and hospitalized) reported to the Robert Koch Institute in 2019, followed by rotavirus, with 12 075 cases (for pertinent reporting requirements see *eBox*) (e4). Rotavirus infection generally takes a more serious course and leads more often to hospitalization in Germany, where the vaccination coverage of children is still less

Main clinical manifestations

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Pathogens

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than total (3, 4, e2). Viral infections are more common in the winter and spring (e5–e6). Common causes of bloody diarrhea in children in Germany are *Salmonella spp.* (peak incidence, May to October) and *Campylobacter spp.*; less common causes include *Shigella*, enterohemorrhagic *E. coli*, and *Entamoeba histolytica* (8, e7).

Acute viral and bacterial gastroenteritis cannot be definitively told apart on clinical grounds alone. Bloody, mucous diarrhea and high fever tend to be associated with a bacterial cause (2), while acute viral gastroenteritis is more commonly accompanied by respiratory manifestations and longer-lasting vomiting. Norovirus infections are typified by intense vomiting, sometimes without diarrhea (3). Rotavirus more commonly causes high fever, dehydration, and electrolyte disturbances (9). In Germany, approximately 70 children each year sustain severe complications of rotavirus enteritis (incidence 1.2/100 000 children under age 5, 95% confidence interval [0.9; 1.4/100 000]). These complications include, among others, severe hyponatremia (<125 mmol/L), hypernatremia (>155 mmol/L), and encephalopathy; some patients need intensive care, and the outcome is fatal in rare cases (e8).

Clinical evaluation

The degree of dehydration, which is best judged by the percentage of lost body weight, determines the treatment in acute infectious gastroenteritis (2, 7). The patient's weight before the onset of the illness is generally not precisely known, so the extent of dehydration must be estimated from the findings of the physical examination, carried out on the unclothed child (e9–e10). *Table 1* contains a list of 12 clinical parameters for characterizing the degree of dehydration.

Risk factors

In Europe, the risk of a severe or persistent diarrheal illness is considered to be especially high in the first six (to 12) months of life, or in children weighing less than 8 kg (2, 10, 11). An international consensus holds that infants under two months old should, as a rule, be hospitalized for treatment (12).

In children with diabetes mellitus or other metabolic disturbances, acute infectious gastroenteritis can cause a metabolic derangement needing acute treatment (2). Patients with abnormal fluid and electrolyte absorption due to extensive bowel resection, intestinal failure, or excluded colon (e.g., with an ileostoma) and immune-compromised patients are at high risk for a serious or chronic disease course (e11–e13).

Severe and recurrent infections with *Clostridoides difficile* and other opportunistic pathogens tend to occur in hospitalized children with chronic inflammatory bowel diseases (odds ratio [OR]: 11.42, [10.17; 12.83]) or underlying neoplastic diseases (OR: 3.10, [2.89–3.31]) (e14–e16). Antibiotic administration promotes *Clostridoides difficile* infection, particularly in hospitalized, multimorbid children (e15–e17). In children with chronic inflammatory bowel disease, *Clostridoides difficile* infection can mimic an acute exacerbation (e14). Therefore, testing for toxin-producing *Clostridoides difficile* strains should be carried out before treatment escalation; untreated *Clostridioides difficile* infection increases the risk for colectomy and mortality (e18–e19).

Identification of the pathogen

Diagnostic testing of the stool to identify the pathogen need not be carried out routinely in ambulatory patients (6, 7), as the demonstration of the pathogen is irrelevant to both diagnosis and treatment (2, 13). Microbiological testing is recommended if systemic infection is suspected in a patient with high fever, if the patient is hospitalized, in endemic outbreaks (kindergartens, schools, hospitals), in cases with severe, bloody diarrhea or prolonged illness (>7 days), or if the patient has recently visited a country of high risk for *Shigella* or parasitic infection (low evidence level, expert opinion) (7). Persons at risk for *Clostridoides difficile* infection who have diarrhea should be rapidly tested (6, 13). If there is acute bloody diarrhea, the stool should be tested for shigatoxin-binding *E. coli* (e20). Ten to 15 percent of children with enterohemorrhagic *E. coli* colitis develop hemolytic uremic syndrome, which is characterized by the triad of hemolysis, thrombocytopenia, and elevated renal function parameters, combined with oliguria or anuria (e20–e22).

Laboratory testing

If the patient is severely dehydrated, blood should be drawn for laboratory testing when an intravenous line is inserted. Elevated serum levels of sodium, potassium, glucose, creatinine (≥ 80 µmol/L), and blood urea nitrogen (≥ 11 mmol/L), as well as metabolic acidosis in acid–base status (low bicarbonate ≤ 15 mmol/L and base excess [BE] ≥ −10 mmol), are highly correlated with severe dehydration (14, e23–e24). Hypertonic dehydration (sodium >155 mmol/L) must be treated by a slow lowering of the sodium concentration (0.5 mmol/L/h) in order not to induce cerebral edema; thus, rehydration should be carried out intravenously over a period of 24–48 hours

Clinical evaluation

The degree of dehydration, best judged by the percentage of lost body weight, determines the appropriate treatment. The patient's weight before the onset of the illness is generally not precisely known, so the extent of dehydration must be estimated from the physical findings.

Identification of the pathogen

Diagnostic testing of the stool to identify the pathogen need not be carried out routinely in ambulatory patients, as the demonstration of the pathogen is irrelevant to both diagnosis and treatment.

TABLE 2

Oral rehydration solutions (ORS) suitable for the rehydration of infants and children, and their composition, in comparison with unsuitable household beverages

Preparations on a glucose base	Sodium	Potassium	Chloride	Bicarbonate	Citrate	Glucose		Osmolarity
	mmol/L	mmol/L	mmol/L	mmol/L	mmol/L	g/L	mmol/L	mOsm/L
WHO*1 recommendation	75	20	65	0	10	13.5	75	245
ESPGHAN*1 recommendation	60	20	>25	0	10	13.3–20	74–111	200–250
Available ORS for infants and children*2	60	20	49–60	0	10	16.0–16.2	89–91	229–240

Preparations with polymeric carbohydrates	Sodium	Potassium	Chloride	Bicarbonate	Citrate	Carbohydrates		Osmolarity
	mmol/L	mmol/L	mmol/L	mmol/L	mmol/L	g/L	Of which glucose g/L (mmol/L)	mOsm/L
Carrot-rice gruel base	55	25	40	0	7	42	12 (67)	240
Rice gruel base	55	30	60	25	0	46	5 (28)	220

Household beverages (unsuitable)						Total sugar		
						g/L	mmol/L	
Cola	1.3	1.3		13	0	99.4	551	≈ 750
Apple juice (pressed, not from concentrate)	1.7	27		0	0	100	555	≈ 730
Chicken or vegetable broth	129–174	1.5–5		0	0	1–5.5	5.5–30.5	≈ 450
Tea	0–0.5	0–2.3		0	0	0	0	≈ 5

*1 The differences between the recommendations of the WHO and the ESGPHAN (European Society for Paediatric Gastroenterology, Hepatology and Nutrition) are based on different patterns of gastroenteritis pathogens and the ensuing differences in electrolyte losses in the stool (sodium in stool: >90 mmol/L in cholera; 40–50 mmol/L in rotavirus infection).

*2 Glucose-based ORS that are commercially available in Germany correspond to the ESPGHAN recommendations and may be prescribed (and are reimbursable by statutory health insurance in Germany) up to the patient's 12th birthday for rehydration. (For reimbursability, see:GBA AM-RLAnlage III Verordnungseinschränkungen.)

Note: products containing aspartame are contraindicated in phenylketonuria (PKU). ORS, oral rehydration solution.

Sources: package inserts of oral rehydration solutions, USDA food data central.

(2, 6). If another cause of the clinical manifestations is suspected, the corresponding additional differential diagnostic studies should be performed.

Treatment

The cornerstone of treatment is fluid and electrolyte replacement, along with the administration of nutrients, to prevent or correct severe dehydration and a catabolic state (15). Before treatment is begun, the child should be weighed without clothes, so that the results of treatment can be objectively documented by weight gain.

Oral rehydration therapy

The treatment of choice for mild or moderate dehydration is oral rehydration therapy with a hypo-osmolar (≤ 270 mOsm/L) oral rehydration solution on a glucose or starch basis, in the form of rice, carrots, or a combination *(Table 2)*. This treatment is just as effective as intravenous rehydration with respect to weight gain, duration of diarrhea, and fluid intake, but is associated with a shorter hospital stay (weighted average difference, −1.2 d; [−2.38; −0.02]) (evidence level Ia, based on numerous randomized trials and a Cochrane Review of 17 randomized controlled trials) (7, 16–19, e25). The presence of glucose and sodium in iso-osmolar concentrations promotes active sodium uptake from the bowel lumen by way of the sodium-glucose transporter of the enterocytes, and water uptake follows passively along the gradient. It follows that household drinks such as tea, broth, cola, and apple juice, with their different compositions, are inappropriate for use in the rehydration of infants and toddlers *(Table 2)*.

Laboratory testing

If the patient is severely dehydrated, blood should be drawn for laboratory testing when an intravenous line is inserted.

Oral rehydration therapy

The treatment of choice for mild or moderate dehydration is oral rehydration therapy with a hypo-osmolar (≤ 270 mOsm/L) oral rehydration solution on a glucose or starch basis, in the form of rice, carrots, or a combination.

Oral rehydration therapy can be initiated without delay in the doctor's office or emergency room as soon as the patient has been examined and weighed by a nurse and the parents have been appropriately instructed. The estimated fluid loss is replenished within three to four hours with an oral hypo-osmolar rehydration solution. In toddlers, this usually corresponds to 40–50 mL/kg body weight *(Figure)*. The oral rehydration solution is administered in frequent, small portions; if the patient is vomiting, it can be administered teaspoon by teaspoon, or else via nasogastric tube. Rapid oral rehydration within four hours has been shown not to be inferior to intravenous rehydration with respect to hospitalization rates, and it is therefore suitable for use in the pre-hospital setting before a decision is taken on whether the patient needs to be hospitalized *(Figure)* (18, 20).

If oral administration fails, the placement of a nasogastric tube for continuous administration of the oral rehydration solution is recommended (15). This form of treatment has been found, in four randomized trials, to be just as effective as intravenous therapy for the treatment of moderate dehydration, while shortening the hospital stay and causing fewer adverse effects (electrolyte disturbances, seizures due to hypernatremia) (e26–e29). Under controlled study conditions, oral or nasogastric rehydration fails in only 4.0% (95% CI [3.0–5.0]) and 3.3% of patients, respectively (17). The reasons that oral rehydration can fail in routine clinical practice include recurrent vomiting, refusal of the salty oral rehydration solution by the child, and inadequate instruction of the persons caring for him or her (17, 19, 21, e25, e30–e32).

Rapid nasogastric rehydration over four hours is just as effective as rehydration over twenty-four hours and obviates the need for hospitalization in three-quarters of cases (e33). Nonetheless, both emergency room staff and the patients' parents still prefer intravenous rehydration when oral administration fails (e26, e34–e35). This is because of a lack of knowledge among physicians, nurses, and parents about the advantages of continuous nasogastric rehydration over an intravenous infusion with respect to side effects (phlebitis, seizures, death), efficacy (weight gain, duration of diarrhea and of hospitalization), hospitalization rates, and stress on the child, as multiple intravenous catheters need to be inserted in some cases (17, e34). In Germany, economic considerations also influence decision-making in favor of hospital admission for intravenous rehydration.

Although oral rehydration therapy has been an established cornerstone in the treatment of acute infectious gastroenteritis for more than 40 years, it is still carried out in Germany less often than it should be. This is because of a deficiency of outpatient care structures and of appropriate recompense for the work of the physicians and nurses providing oral or nasogastric rehydration (e36).

Intravenous rehydration therapy

Intravenous rehydration is indicated when

- oral and nasogastric rehydration have failed, or
- the patient displays manifestations of ileus or bilious vomiting, or
- the patient is suffering from severe dehydration, defined as >9% of body weight and characterized by, e.g., neurological manifestations, severe acidosis (pH <7.25, base excess < −15 mmol/L), severe hypo- or hypernatremia, or
- the patient is in shock (6, 15).

Whenever clinical evidence suggests circulatory centralization or kidney failure of prerenal origin, rapid fluid administration is crucial, e.g., with a bolus of 20–40 mL of normal saline per kilogram of body weight. Intravenous rehydration is begun with 20 mL/kg/h of normal saline for 1–4 hours, adapted thereafter depending on the laboratory findings and the amount of diuresis, and switched to oral rehydration as soon as this is tolerated (22, 23).

Supplementary pharmacotherapy

Treating acute infectious gastroenteritis with drugs is no replacement for oral rehydration therapy. A few drugs can be useful as supplementary treatment (7, 12).

Motility reducers

Because of their major side effects, loperamide and other motility-reducing drugs are no longer recommended anywhere in the world for the treatment of acute infectious gastroenteritis in children (6, 7, 24, 25).

Antiemetic drugs

Drugs to combat nausea and vomiting should not be given to children with acute infectious gastroenteritis because of their potential side effects (2, 6, 12, 15, e37). After receiving 39 reports of severe side effects from the administration of dimenhydrinate, including five deaths in children less than three years old, the German Federal Institute for Drugs and Medical Devices (*Bundesinstitut für Arzneimittel und Medizinprodukte,* BfArM) altered the package-insert recommendations for physicians, setting a maximum daily dose of 5 mg/kg up to age three and warning against use of the drug to treat ordinary, mild acute infectious gastroenteritis in

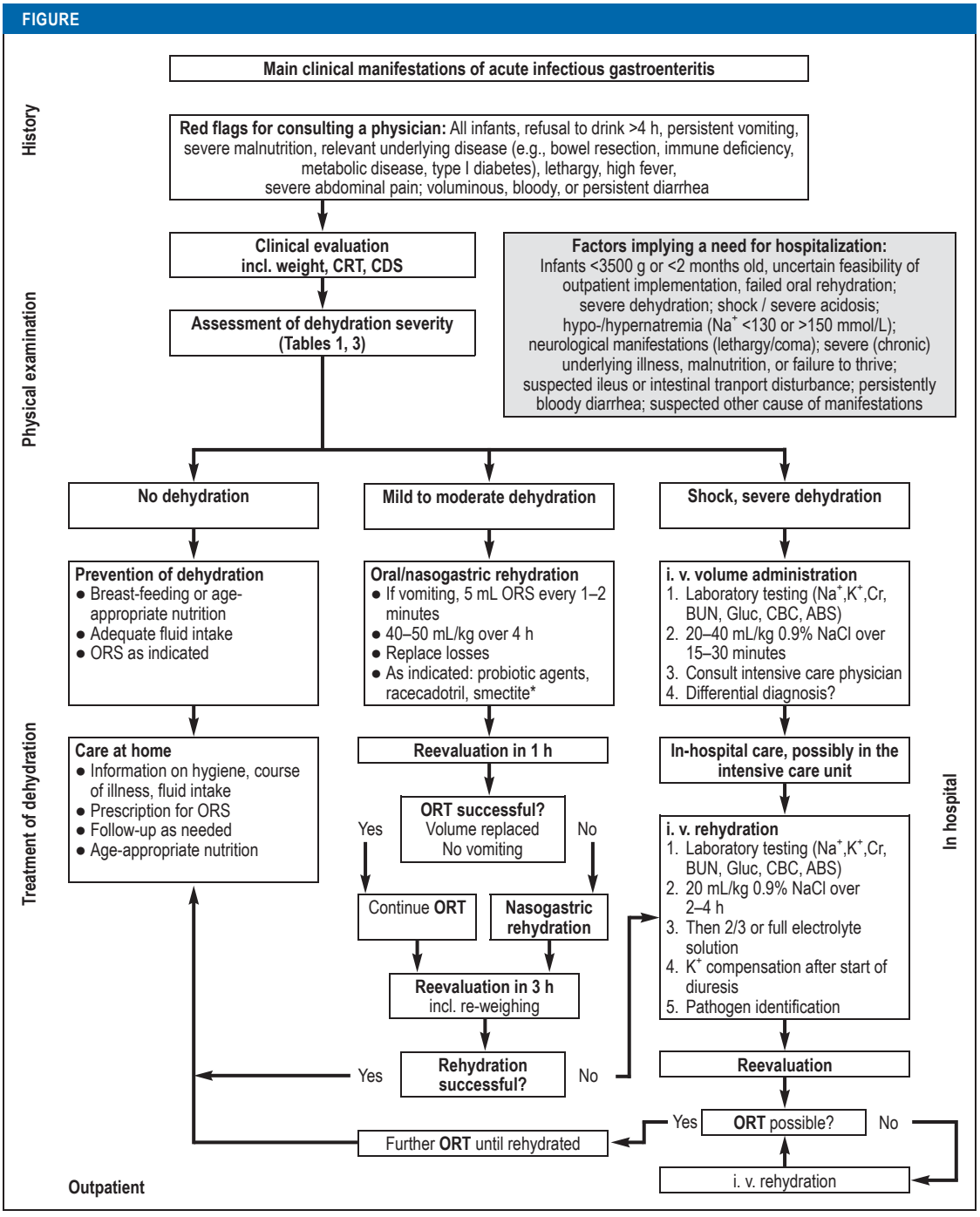
Rehydration in infants and toddlers

Household drinks such as tea, broth, cola, and apple juice, with their different compositions, are inappropriate for use in the rehydration of infants and toddlers.

Rehydration via nasogastric tube

If oral administration fails, the placement of a nasogastric tube for continuous administration of the oral rehydration solution is recommended. This is just as effective as intravenous therapy for the treatment of moderate dehydration, while shortening the hospital stay and causing fewer adverse effects.

FIGURE



Treatment algorithm for acute infectious gastroenteritis depending on the severity of clinical dehydration, according to (e61). Attention: the threshold values for percentage weight loss as an index of the degree of dehydration differ in infants and young children.
ABS, acid–base status; BUN, blood urea nitrogen; CBC, complete blood count; CDS, Clinical Dehydration Score; CRT, capillary refilling time; Cl^-, chloride; Cr, creatinine; i. v., intravenous; K^+, potassium; Na^+, sodium; ORS, oral rehydration solution; ORT, oral rehydration therapy.
* Heterogeneous evidence base—no general recommendation.

Prevention

Hygienic measures, breastfeeding, and rotavirus vaccination are effective preventive measures.

Attendance in community facilities, such as schools

As a pragmatic recommendation, children with acute infectious gastroenteritis should not be allowed to attend any community facilities (e.g. schools) until 48 hours after the last episode of diarrhea or vomiting.

BOX

Treatment-relevant trends based on current publications (2018–2020)

- The Clinical Dehydration Score (CDS) *(Table 3)* may be helpful for the identification of moderate to severe dehydration in infants and toddlers (positive likelihood ratio (LR) 3.90–11.79; negative LR 0.55–0.71) (e66).
- Oral rehydration solutions with added active substances (e.g., tannins) may have a beneficial effect on stool volume and frequency (e67). Gelatin tannate has already been studied in three randomized trials, and a significant reduction of diarrhea and liquid stools in 24 hours has been reported (risk ratio 0.74; p <0.01) (e68), although a further meta-analysis revealed no significant difference compared to placebo (e69).
- Only weak recommendations have been given to date for the use of probiotic agents such as *Saccharomyces boulardii*; *Lactobazillus rhamnosus* GG; and *Lactobazillus reuteri* DSM 17 938, *L. rhamnosus* 19 070–2, and *L. reuteri* DSM 12 246. It is recommended that combinations of *L. helveticus* and *L. rhamnosus* R0011 or *Bacillus clausii* strains should not be used (38). The early administration of a combination of *Lactobacillus rhamnosus* R0011 and *L. helveticus* R0052 had no significant effect on the duration of diarrhea or the rate of complications (39); nor did the administration of *Lactobacillus rhamnosus* GG to toddlers have any effect on the need for intravenous rehydration, diarrhea duration, or stool frequency (40).
- In a meta-analysis of 24 randomized trials with a total of 3482 subjects, ondansetron was found to have a significantly better effect than placebo on the cessation of vomiting (odds ratio 0.28; [0.16; 0.46], high evidence quality) and the avoidance of hospitalization (odds ratio 2.93; [1.69; 6.18]; moderate evidence quality) (26). The use of ondansetron for this indication is off label (note risk of side effects).
- Over the past 10 years, rotavirus vaccination in Germany has led to a decline in the rate of hospitalization of children under age five for disease due to rotavirus (direct RV vaccination efficacy, 86% [83.2; 89.1]) (e70).

this age group (e38). Ondansetron has been found, in randomized trials, to have a beneficial effect on vomiting and on hospitalization rates (evidence level Ia, *Box*) (26). This drug can cause cardiac arrhythmia by prolonging the QT interval; its use in the treatment of acute infectious gastroenteritis is off label (e39, e40).

Probiotic agents

No recommendation can be made on treatment, as the available study data are heterogeneous. The effect sizes of various probiotic agents are, in some cases, either very small or unreported *(Box)* (6, 25, 27, 28, e41).

Antibiotics

Antibiotic treatment is not recommended for patients with acute watery or bloody diarrhea who are otherwise healthy and at least three months old (6, 15, 29). It is indicated if certain pathogens have been identified (*Shigella*, *amoebae*, *Vibrio cholerae*, *Salmonella* with bacteremia or in a high-risk patient, *Clostridioides difficile*, severe infection with *Lamblia* or enterotoxic *Escherichia coli*) or in special clinical situations (neonates, sepsis, severe extra-intestinal manifestation, immune compromise) (2, 6, 29). Empirical antibiotic treatment is determined by the local and regional pathogen and resistance patterns (29).

Adsorbents and antisecretory drugs

Smectite, an intestinal adsorbent, has been shown in 18 randomized controlled trials to shorten the duration of diarrhea. Racecadotril has antisecretory properties and may lower the rate of rehydration failure (e42). Both drugs have a favorable safety profile and can be considered for supplementary treatment alongside oral rehydration therapy (evidence level Ia) (25, e42–e44). Nonetheless, in view of the heterogeneity of the trials and their quality, recommendations for the use of these drugs have only been given reservedly (2, 6, 19).

Dietary recommendations

A special diet, so-called "Heilnahrung" (including lactose-free and low-calorie food) and "diarrhea diets," micronutrients, dilution of baby formula, special teas, and fasting are not recommended (7, 15, 19, 25, 30, e45). Acute infectious gastroenteritis often causes transient carbohydrate intolerance. A meta-analysis of 16 studies showed that the duration of diarrhea was 17.7 hours shorter on average ([−25.32, −10.21], 1467 subjects) when the subjects drank lactose-free rather than standard lactose-containing milk. Numerous studies have been carried out on hospitalized patients. In the two studies carried out on children treated in the outpatient setting (a total of 143 patients), lactose-free

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TABLE 3

Clinical dehydration score (CDS) according to Friedman et al. 2004 (e64)

Physical findings	0	1	2
General appearance	normal	thirsty; restless or lethargic, but irritable when touched	drowsy, limp, cold, sweaty; comatose or not
Eyes	normal	slightly sunken	very sunken
Mucous membranes, tongue	moist	"sticky"	dry
Tears	present	diminished	absent

The scores for each of the four clinical findings are added together to yield the total CDS.
0 = no dehydration, 1–4 = slight to mild dehydration, 5–8 = moderate to severe dehydration.

milk had no advantage; it had no significant effect on stool frequency, stool volume, or weight gain (30). In summary, lactose reduction is not recommended in the outpatient setting, but it should be considered in cases of prolonged or chronic diarrhea, i.e., post-enteritic syndrome (2, 12). Breast-fed children should continue to drink mother's milk in addition to the oral rehydration solution (7, 15). Infants and toddlers that are not being breast-fed should be given their usual food no later than 4 (to 6) hours after the start of rehydration (6, 7, 31).

Prevention

Breastfeeding

A protective effect of breastfeeding is supported by numerous studies; randomized trials are not feasible for ethical reasons. Not being breast-fed increases the incidence (RR: 1.32; [1.06; 1.63]), prevalence (RR: 2.63; [1.04; 6.65]), and mortality of acute infectious gastroenteritis (RR: 1.47; [0.67; 3.25]), among infants (e46–e48) not only in developing or emerging countries, but also in the industrialized world (e49–e51).

Rotavirus vaccination

Monovalent and pentavalent orally administered rotavirus vaccines have been recommended since 2013 by the German Standing Committee on Vaccinations (*Ständige Impfkommission,* STIKO) for the prevention of acute infectious gastroenteritis due to rotavirus (6, 32). The vaccination rate among children born in 2015 is 68% (4). The two available, orally administered live vaccines lower the risk of severe rotavirus enteritis by 84% (RR 0.18, [0.09; 0.26]) and 82% (RR 0.18, [0.08; 0.39]), respectively (33) (e52–e53), and have reduced the rate of hospitalization of children up to age 10 for rotavirus by 51.5%, from an average of 25 440 cases in Germany per year before widespread vaccination (2005–2010) to 12 328 in 2017 (34, 35, e2). If the serial rotavirus vaccinations are given as advised, starting in the 6th week and concluding in the 24th or 32nd, there is no increased risk of intussusception (33, e52–e53).

Prevention of infection

Hygienic measures are necessary to prevent the spread of pathogens in hospitals and doctors' offices. In the United Kingdom, the National Health Service recommends that new hospital facilities should be built with at least 50% single-bed rooms (e54). As the pathogen causing acute gastroenteritis is generally not known when a patient is admitted to the hospital, the grouping of patients by pathogen is not possible. If the patient cannot be kept in a single-bed room, strict "barrier precautions" must be observed. Hygiene training for medical staff, parents, and community facility staff with regard to hand disinfection, hand-washing, and diaper-changing, along with information on how diseases are spread, has been found to reduce transmission rates markedly (36, e55–e56). These measures must be maintained over the long term, because pathogens continue to be excreted even after the symptoms have ceased (e.g., 47 days for norovirus, 57 days for rotavirus), and pathogens may be able to survive as long as 140 days outside the host, depending on environmental factors such as temperature and humidity as well as on the nature of the surface on which they are located (e57–e59). As a pragmatic recommendation, children with acute infectious gastroenteritis should not be allowed to attend any community facilities (e.g. schools) until 48 hours after the last episode of diarrhea or vomiting (6, e60).

The utility of guidelines on acute infectious gastroenteritis

High-quality, evidence-based, practically oriented guidelines have been developed on the national and European levels (2, 6). A randomized trial conducted on pediatricians revealed that those who had undergone special training in the guidelines' recommendations on oral rehydration therapy and the non–evidence-based use of drugs, supplements, and dietary changes implemented these recommendations more reliably; this was reflected in a significantly shorter duration of diarrhea in these pediatricians' patients with acute infectious gastroenteritis, compared to those of other pediatricians who had not been specially trained (37). The German-language S2k guideline on acute infectious gastroenteritis in childhood is intended to improve care and prevent hospitalization whenever possible (6).

Lactose reduction

Lactose reduction is not recommended in the outpatient setting, but it should be considered in cases of prolonged or chronic diarrhea, i.e., post-enteritic syndrome.

To breast-feed or not to breast-feed?

Not being breast-fed increases the incidence, prevalence, and mortality of acute infectious gastroenteritis, among infants not only in developing or emerging countries, but also in the industrialized world.

Conflict of interest statement
All of the authors participated in the development of the German S2k guideline on acute infectious gastroenteritis in infancy, childhood, and adolescence.

Dr. Buderus has served as a paid consultant for Ferring Arzneimittel GmbH. He has received reimbursement of travel and accommodation expenses, as well as lecture honoraria, from Nestlé NNI, Infectopharm Arzneimittel, and AbbVie Deutschland GmbH.

Dr. Classen has served as a paid consultant for Milupa/Danone GmbH. He has received lecture honoraria from Milupa Nutricia GmbH and Infectopharm.

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Prof. Keller has served as a paid consultant for InfectoPharm Arzneimittel and Consilium GmbH.

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► **Supplementary material**

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Only one answer is possible per question. Please select the answer that is most appropriate.

Question 1

Which of the following is a major clinical manifestation supporting the diagnosis of acute infectious gastroenteritis?

a) mild hypotension
b) warm extremities
c) hypokalemia
d) increased stool frequency (≥ 3 ×daily)
e) neck stiffness

Question 2

Which of the following is currently the type of pathogen that most commonly causes acute gastroenteritis in children under age 5 in Germany?

a) adenovirus
b) *Campylobacter*
c) norovirus
d) *Yersinia*
e) *Salmonella*

Question 3

Which of the following is a typical clinical manifestation of severe dehydration in acute gastroenteritis?

a) moist mucous membranes
b) deeply sunken eyes
c) polyuria
d) tears
e) skin folds that disappear immediately upon release

Question 4

Which of the following patients is at elevated risk of complications or of a severe course of acute infectious gastroenteritis?

a) a seven-month-old infant weighing 7 kg
b) a two-year-old who has vomited twice in the past 48 hours
c) a three-year-old child with constipation
d) a five-year-old boy with periodic flatulence
e) a 14-month-old infant who has refused to drink for the past 2 hours

Question 5

In which of the following situations should the electrolytes always be measured in a 1½-year-old patient?

a) weight loss of 500 g
b) blood-tinged stool
c) fever to 39°C
d) four stools in the past 24 hours
e) before intravenous rehydration because of persistent vomiting

Question 6

Which of the following is the appropriate treatment for a 2-year-old child in the given situation?

a) marked, voluminous diarrhea: loperamide
b) two episodes of vomiting and mild dehydration: dimenhydrinate
c) bloody diarrhea, without identification of the pathogen: antibiotics
d) moderate dehydration: oral rehydration with oral rehydration solution
e) during intravenous rehydration: no food intake p.o. for at least 24 hours

Question 7

What measurement should be performed before the start of oral rehydration in every mildly dehydrated child?

a) height, weight, calculation of BMI
b) unclothed weight
c) blood sugar
d) blood pressure
e) arterial blood gases

Question 8

How should rehydration be performed in a mildly to moderately dehydrated child without any particular risk factors?

a) orally, with cola and salted bread sticks, over 24 hours
b) with diluted apple juice, 100 mL/kg, over 24 hours
c) with rehydration solution (90 mmol sodium/L over 12 hours)
d) intravenously, because of the risk of aspiration
e) over four hours, with a hypo-osmolar oral glucose-electrolyte solution

Question 9

When a patient is orally rehydrated, the estimated weight loss is replaced with oral rehydration solution (ORS). How rapidly should the calculated volume be administered in a 2-year-old child?

a) over 1–2 hours
b) over 3–4 hours
c) over 6–8 hours
d) between meals, divided over 24 hours
e) the timing is unimportant as long as the entire volume is given.

Question 10

What measure is recommended for the prevention of acute infectious gastroenteritis?

a) breastfeeding of infants
b) administration of nux vomica
c) feeding only with food heated to extremely high temperatures
d) cohorting of children with infectious gastroenteritis regardless of pathogen
e) regular disinfection of children's hands

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Supplementary material to:

Acute Infectious Gastroenteritis in Infancy and Childhood

by Carsten Posovszky, Stephan Buderus, Martin Classen, Burkhard Lawrenz, Klaus-Michael Keller, and Sibylle Koletzko

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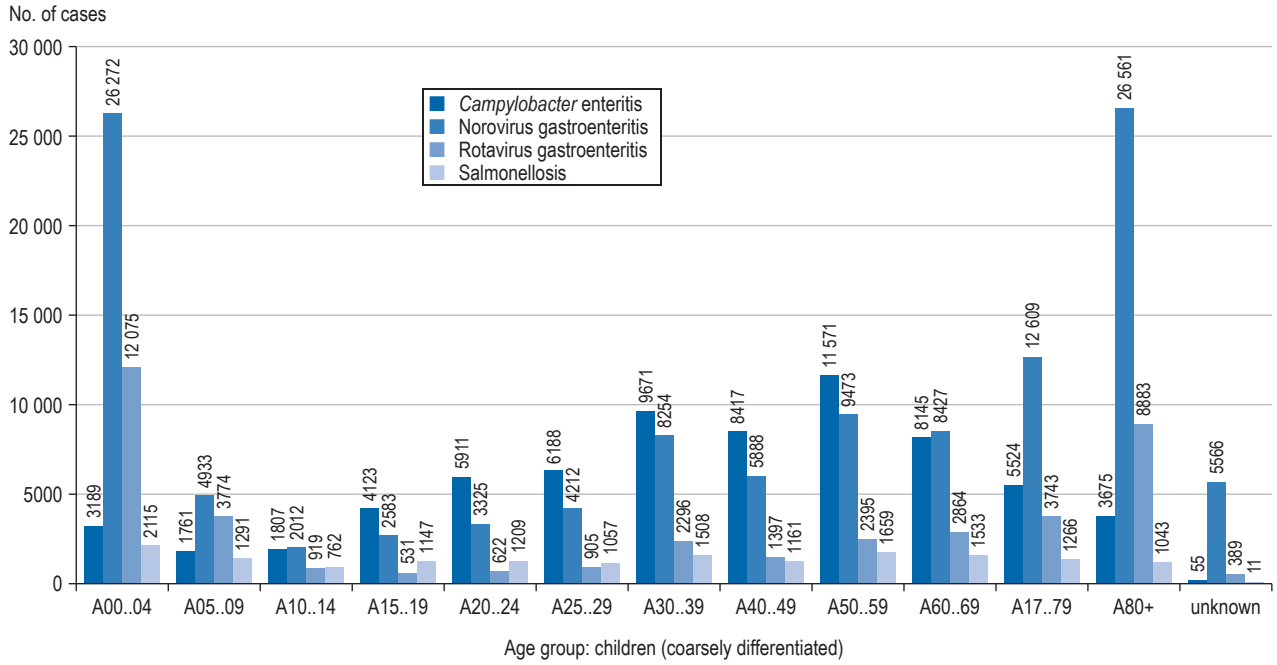
eFigure



Numbers of cases reported to the Robert Koch Institute (RKI): *Campylobacter*, norovirus, and rotavirus enteritis and salmonellosis, classified by age, in 5-year intervals. Source: Robert Koch Institute: survStat@RKI2.0, https://survstat.rki.de, accessed on 11.04.2020

eBOX

Reporting requirements for acute infectious gastroenteritis in Germany

According to the German Law on Protection against Infectious Diseases (*Infektionsschutzgesetz,* IfSG §7), demonstrated infection with norovirus, rotavirus, *Salmonella*, *Shigella*, enteropathic *Yersinia spp.*, *Vibrio cholerae* O1 and O139, *Lamblia*, and *Campylobacter* must be reported by the testing facilities and hospital laboratories (IfSG §8, §11) by name, via the responsible health authority, to the Robert Koch Institute (e71). In case of suspected or confirmed infection or death due to cholera, enteropathic HUS, or typhus (IfSG §6), the diagnosing physician, the head physician of the facility, the head of the pathology diagnostic facility, and members of health and nursing professions whose training is recognized by the State all have a duty to report (IfSG §8). The *eFigure* shows the reported cases of the most common pathogens causing gastroenteritis, as a function of the age of the patients, for the year 2019.