Pediatr Pol 2026; 101 (1): 51-56
DOI: https://doi.org/10.5114/polp.2026.160531
Submitted: 28.11.2025, Accepted: 19.01.2026, Published: 27.03.2026

PEDIATRIA Polska
PISMO POLSKIEGO TOWARZYSTWA PEDIATRYCZNEGO
Polish Journal of PAEDIATRICS
OFFICIAL JOURNAL OF POLISH SOCIETY OF PAEDIATRICS

ORIGINAL PAPER

Characteristics of rotavirus infections in the region of Silesia between June 2019 and August 2022, in terms of mandatory vaccination

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ABSTRACT

Introduction: The aim of this study was to evaluate the impact of mandatory rotavirus vaccination introduced in 2021 and COVID-19 pandemic-related restrictions on the incidence, severity, and clinical characteristics of rotavirus-induced acute gastroenteritis in children hospitalised at the Department of Paediatrics, Medical University of Silesia, between June 2019 and October 2022.

Material and methods: A total of 324 paediatric patients diagnosed with rotavirus infection were included in the analysis. The study compared clinical data before and after the introduction of mandatory vaccination in 2021 in children aged under 6 months and during the COVID-19 pandemic.

Results: The results indicated a significant decrease in non-vaccinated hospitalisations (non-vaccinated/vaccinated patients) from 98.77% before to 79.84% after the introduction of mandatory vaccination. Post-vaccination, the average age of hospitalised patients increased significantly (mean age: 3 years 7 months, compared to the period before vaccination introduction mean age: 1 year 7 months) and the length of hospital stay was reduced. The study also observed a seasonal peak in rotavirus infections from December 2021 to March 2022, contrasting with the absence of seasonality in previous years, likely due to COVID-19 restrictions. Laboratory findings showed no significant differences in blood pH, C-reactive protein, and alanine aminotransferase levels between the pre- and post-vaccination periods, but there was a significant reduction in base excess, suggesting a milder disease course after vaccination.

Conclusions: Mandatory rotavirus vaccination and pandemic restrictions are also known to greatly mitigate the severity of the disease and reduce hospital stay in children. Not only do these measures reduce the incidence of severe rotavirus infection in young patients, but they also decrease the economic burden on healthcare systems and alleviate the suffering of young patients. This leads to health benefits for children as well as the reduction in hospitalisation costs. As a result, children's overall well-being is improved and healthcare resources are more effectively allocated.

KEY WORDS:

seasonality, rotavirus, mandatory vaccination, acute gastroenteritis (AGE).

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INTRODUCTION

Rotaviruses (RV) are the leading cause of acute gastroenteritis (AGE) in children under the age of 5 years. It applies to both hospital-acquired and non-hospital-acquired infections [1, 2]. As well as causing community-acquired gastroenteritis, rotavirus is also an important cause of nosocomial infections. A review of the literature found that among children aged < 5 years, rotavirus gastroenteritis (RVGE) accounted for 47–69% of all hospital-acquired AGE and prolonged hospital stays by 4–12 days in Europe [3]. Rotavirus gastroenteritis has been shown to cause approximately 40% of all outpatient visits for AGE in infants and young children to paediatric primary care practices in Europe and the USA. Furthermore, 30–50% of all hospitalisations for gastroenteritis among US children aged < 5 years are due to rotavirus infection [4, 5].

Many children have asymptomatic infection which facilitates rotavirus circulation in the population. In countries with a temperate climate, the peak incidence occurs in winter and spring [6].

The incubation period of rotavirus infection is 12 to 96 hours. The infection is transmitted through the faecal-oral route, through dirty hands, contaminated objects and by air. Rotaviruses primarily infect mature enterocytes in the intestinal epithelium causing villous atrophy, enhanced epithelial cell turnover and apoptosis [7–9].

Acute gastroenteritis is characterised by the rapid onset of typical symptoms such as diarrhoea, with or without fever, vomiting, nausea and/or abdominal pain. The severity of symptoms is variable with the spectrum of illness, ranging from mild, watery diarrhoea of limited duration to severe diarrhoea with dehydration, vomiting and fever. Clinical presentations differ by age group. Although the disease can occur at any age, the disease most commonly causes clinically significant disease in young infants and children [4]. The basis of treatment remains rehydration and maintaining proper fluid and electrolyte balance [4]. Before the introduction of the rotavirus vaccine, rotavirus caused approximately 440 000 deaths in children aged < 5 each year globally [10]. The Rotavirus vaccine has been available in Poland since 2006. However, until 2020, this immunisation was accessible only voluntarily and chargeable. Finally, in 2021, it was included in the Polish National Immunisation Programme [11, 12].

In Poland, two types of vaccines are available, which are administered orally: Rotarix which includes 2 doses and RotaTeq consisting of 3 doses. Vaccinations should begin after 6 weeks of age, but not later than 12 weeks of age. The entire vaccination course should be completed by 24 weeks of age [3].

Due to the SARS-CoV-2 pandemic, in spring and autumn of 2020, restrictions were introduced in Poland and all over the world, including social distancing, temporary closing of the nurseries, kindergartens and schools, and an order to wash and disinfect hands more often. Due to these measures, studies have shown a significant reduction in the transmission of RV infection [13].

The aim of the study was to assess the impact of mandatory vaccination and pandemic restrictions on the morbidity and severity of rotavirus-induced AEG in children hospitalised at the Department of Paediatrics, the Medical University of Silesia in Katowice between June 2019 and October 2022.

MATERIAL AND METHODS

The research covered 324 patients diagnosed with community- and hospital-acquired AGE caused by rotavirus with laboratory-confirmed RV infection hospitalised between 1 June 2019 and 31 August 2022 at the Department of Paediatrics of the Medical University of Silesia in Katowice, Poland.

The analysis included age, sex, clinical symptoms, time of hospitalisation, month of hospitalisation, results of laboratory tests, introduction of rotavirus vaccination, pandemic restrictions.

The statistical analysis was carried out in the Statistica 13.3 program. A significance level < 0.05 was determined for all analyses. To answer the research questions, the non-parametric Mann-Whitney *U* test was used, supported by the size of the effect, and the rank coefficient of the Glass biserial correlation. The χ^2 was used to assess the incidence. The decision on non-parametric methods of statistical inference was made due to the non-normal distribution of variables, their clear skewness and the existence of extreme and outlier cases. Searching for answers to the research questions regarding the differences in the age of children admitted to the hospital and the length of hospitalisation between the periods before (2019–2020) and after the introduction of vaccination (2021–2022), the Mann-Whitney *U* test was used.

RESULTS

The analysis included 324 paediatric patients aged between 1 month and 14 years 5 months (the mean age was 3 years 3 months). In the study group, 56.2% were boys, while girls constituted 43.8% of all patients. Dividing the patients into two age groups, it was found that 44.1% of patients were under the age of 2 years, while the remaining 55.9% of patients belonged to the age range 2–14 years 5 months old.

The analysis collected data showed that before the introduction of mandatory vaccination (2019, 2020) as many as 80 out of 81 hospitalised children were not vaccinated against RV, while after the introduction of mandatory vaccination, this percentage significantly decreased to 194 from 243 hospitalised children.

The clinical picture included various symptoms among which most often appeared: severe watery diar-

TABLE 1. Frequency of symptoms depending on the age of patients

Age (years)	Diarrhoea (%)	Vomiting (%)	Fever (%)	Dehydration (%)
< 2	95.80	65.03	65.73	93.01
≥ 2	91.16	88.40	72.93	95.03
Total	93.2	78.3	69.9	94.4

TABLE 2. Results of laboratory tests performed in the group of patients

Parameter (normal range)	Value range	Mean	Number of patients with abnormal results, *n/N* (%)
AspAT [U/l]	16–405	51	
Up to 6 months (< 60)			6/46 (13.04)
7–12 months (< 57)			3/27 (11.11)
1–12 years (< 39)			45/240 (18.75)
13–17 years – girls (< 23)			1/1 (100)
13–17 years – boys (< 26)			0/1 (0)
AIAT [U/l]	3–665	28	
Up to 6 months (< 84)			5/46 (10.87)
7–12 months (< 89)			2/26 (7.69)
1–12 years (< 52)			123/239 (51.46)
13–17 years – girls (< 27)			1/1 (100)
13–17 years – boys (< 33)			0/1 (0)
CRP [mg/l] (< 10)	0–219.6	6.6	129/311 (41.48)
BE [mEq/l] (< –5)	–19.4 to 3.3	–5.4	173/324 (52.40)

AIAT – alanine aminotransferase, AspAT – aspartate aminotransferase, BE – base excess, CRP – C-reactive protein

rhoea – 93.2%, vomiting – 78.1%, fever – 69.8%, dehydration signs such as reduced skin elasticity or dry mucous membranes, pallor, abdominal pain, loss of appetite and tiredness. The results by age are shown in Table 1.

Laboratory results of complete blood count, alanine aminotransferase (AIAT), aspartate aminotransferase (AspAT), C-reactive protein (CRP) and arterial blood gases (including base excess) were examined. The results are shown in Table 2.

Differences in the values of selected laboratory parameters were analysed in patients hospitalised before (2019–2020) and after (2021–2022) the introduction of mandatory vaccination. The analysis of laboratory test results showed that the blood pH, CRP and AIAT values did not differ significantly between measurements in the period before the mandatory vaccination and before and after the introduction of mandatory vaccination. However, values of the base excess (BE) were significantly lower in the period after the introduction of mandatory vaccination, which may indicate a milder course of RV infection. Moreover, the AspAT levels were significantly higher in patients hospitalised after the introduction of vaccination. This increase, although small, is the most significant among the presented comparisons (Table 3).

The analysis of the collected medical data revealed the mean age of patients hospitalised due to rotavirus infection after the introduction of mandatory vaccination was higher (mean age: 3 years 7 months; SD = 2 years 8 months) in a statistically significant way compared to the period before their introduction (mean age: 1 year 7 months; SD = 1 year 11 months) (Table 4).

Furthermore, the introduction of mandatory vaccination resulted also in the shortening of the required hospitalisation time (mean time = 4.97 days; SD = 2.57 days) compared to the hospitalisation time before this event (mean time: 6.42 days; SD = 3.78 days).

No seasonality of morbidity and hospitalisations were observed for the periods 2019–2020 and 2020–2021, however in the period 2021–2022 the seasonality is visible in December – March (140 cases, which is 7 times more than in the period August 2020 – November 2021 and 47 times more than in the period December 2020 – March 2021, and also 5 times more than in the same period in 2019–2020).

The results revealed that significantly more hospitalised children did not attend educational institutions. Interestingly, by dividing the groups by the types of facility, significantly more hospitalised youngest children

TABLE 3. Analysis of the differences between the periods before (2019–2020) and after (2021–2022) the introduction of mandatory vaccination

Variables tested	Before mandatory vaccination (2019–2020)			After mandatory vaccination (2021–2022)			*U*	*p*-value	r_g
	n	M_{rank}	Me	*n*	M_{rank}	Me			
AIAT [U/l]	79	153.28	27.00	235	158.92	28.00	8949.500	0.634	0.04
AspAT [U/l]	77	133.11	47.00	235	164.16	53.00	7246.500	0.009	0.20
CRP [mg/l]	81	140.27	4.10	230	161.54	7.40	8041.00	0.067	0.14
BE	81	180.70	–4.40	243	156.43	–5.60	8367.500	0.044	0.15
Blood pH	81	151.43	7.41	243	166.19	7.41	8944.500	0.219	0.009

AIAT – alanine aminotransferase, AspAT – aspartate aminotransferase, BE – base excess, CRP – C-reactive protein, blood pH – blood potential of hydrogen, M_{rank} – mean of ranks, Me – median Mann-Whitney U test result, n – number of observations, p-value – level of significance, r_g – effect size

TABLE 4. Differences between the periods before and after the introduction of mandatory vaccination considering the admission age and the hospitalisation length

Variable tested	Admissions 2019–2020, *n* = 81		Admissions 2021–2022, *n* = 242		*U*	*p*-value	r_g
	M_{rank}	Me	M_{rank}	Me			
Admission age (months)	98.01	1.00	183.42	3.08	4617.500	< 0.001	0.53
Hospitalisation length (hours)	191.15	5.00	152.95	4.00	7521.00	0.001	0.24

M_{rank} – mean of ranks, Me – median, n – number of observations, p-value – level of significance, r_g -–effect size, U – Mann-Whitney U test result

TABLE 5. Analysis of the frequency of hospitalisation regarding children's educational institutions' attendance

Educational institution	Does not attend		Attend		$X^2_{(1)}$	*p*-value
	n	%	*n*	%		
Nursery, *n* = 185	153	82.70	32	17.30	79.141	< 0.001
Kindergarten, *n* = 105	41	39.05	64	60.95	5.038	0.025
School, *n* = 33	14	42.42	19	57.58	0.758	0.384
Overall, *n* = 324	191	59.13	132	40.87	10.777	0.001

n – number of observations, p-value – level of significance

(up to 3 years old) did not attend the nursery compared to those who did. The opposite correlation was observed in the case of kindergartens. Significantly more hospitalised preschool children (3–6 years old) attended kindergartens. Those differences were statistically significant (Table 5).

During the months of mandatory pandemic restrictions such as social distancing, wearing masks, lockdown, and widespread hand sanitising, the number of infections was significantly lower compared to the time before the pandemic, and also to the period after removing restrictions completely.

DISCUSSION

During our study, out of 25,000 hospitalised at the Department of Paediatrics of the Medical University of Silesia in Katowice 324 patients had laboratory-confirmed rotavirus, giving an incidence rate of 12.96 per 1,000 hospitalisations. Another study [14] found that the incidence of rotavirus infection in the paediatric population in hospitals was 1.33–4.96 cases per 100 person-years, which translates into lower rates than those reported in our study. In contrast, studies in Asia [15], particularly in low-income countries, show much higher rates, up to 20 cases per 1,000 hospitalisations. These differences may be due to various factors, such as access to vaccination, sanitation or demographic differences.

Most of our patients were 1–4 years old (53.35%), aligning with other findings from Poland [11] (63.66% of patients 1–4 years old), Vietnam [15] and Spain (62% under the age of 3, compared to 67.2% in our study group) [16]. There were no patients over 14.5 years of age. The introduction of mandatory vaccination had an impact on the average age of hospitalised patients in the study group – the mean hospitalisation age was higher (3 years 7 months; SD = 2 years 8 months) in a statistically significant way compared to the period before their introduction (1 year 7 months; SD = 1 year 11 months).

Analysis of our patient cohort demonstrated a subtle male predominance. The findings from other studies [17, 18] support our observation, indicating a higher prevalence of rotavirus infections among males in their study popula-

tion. Authors suggested that the higher prevalence of rotavirus infections in male children might be linked to a combination of hormonal and chromosomal disparities. Other articles have also reported an increased incidence of rotavirus infections in males in European countries [16, 19], as well as Asian [15, 20], and African countries [21].

Analysis of laboratory test results showed that the blood pH, CRP and AIAT values did not differ significantly between measurements in the period before the mandatory vaccination and after the introduction of vaccination. However, values of the BE were significantly lower in the period after introduction of mandatory vaccination. Moreover, the AspAT levels were significantly higher in patients hospitalised after the introduction of vaccination. This increase, although small, is the most significant among the presented comparisons. This indicates a reduced degree of acid-base imbalance, which may suggest a milder progression of the disease.

In our patient group no seasonality was observed for the periods 2019–2020 and 2020–2021, however in the period 2021–2022 the seasonality was visible in December – March, i.e. in the period from winter to spring. We can conclude that rotavirus infection is seasonal and the lack of seasonality in 2019–2021 was due to the COVID-19 pandemic restrictions. The work by Toczylowski *et al.* [11] confirms our observation that in Poland the seasonality of RVGE peaked between February and May in each year of the study – so also in period from winter to spring, except for 2020, when the COVID-19 pandemic skewed any viable comparison of seasonality. Also another study [22] states a fact that in Europe, North America, and Oceania – in temperate climates, prevalence of disease was the highest during winter months and the lowest during the summer months and detection of rotavirus overlapped with the winter months (November – April).

The analysis collected data showed that after the introduction of mandatory vaccination, the percentage of children who were not vaccinated against RV significantly decreased.

Other research from Poland [5] confirms that no other significant relationships were found between vaccine coverage and hospitalisation rates when the analysis was performed for each age group separately or within the entire study population. But other countries show that reductions in rotavirus hospitalisations ranged around 65–84% in Europe [23]. Also in the United States, after the introduction of the vaccine, there was a decrease in the number of hospitalisations of children due to rotavirus infection [24]. We notice the shortening of the required hospitalisation time after the introduction of mandatory vaccination. Research from Ireland confirmed a reduction in the number of hospitalisations after the introduction of vaccination but they found that there was no significant difference in median length of stay for children hospitalised with rotavirus infection [25].

During the pandemic, the number of hospitalised patients decreased significantly – maintaining social distance, observing hygiene rules and wearing masks may have influenced this. Also, difficult access to health care could be associated with a lower number of hospitalisations. Other researchers have also reached such conclusions [26, 27] suggesting that the interventions implemented for COVID-19 have had a significant impact on reducing the prevalence of common enteroviruses, such as RV and adenoviruses, to a certain extent. Studies conducted in the US in the post-COVID era also show that during the COVID-19 pandemic, rotavirus activity was suppressed [13].

CONCLUSIONS

This study highlights the significant impact of mandatory rotavirus vaccination and pandemic restrictions on the morbidity, severity, and hospitalisation patterns of children with rotavirus-induced AGE in Poland. After the vaccine's introduction in 2021, the percentage of unvaccinated hospitalised children dropped significantly, reflecting better protection, particularly in younger age groups. The average age of hospitalised children increased, indicating that vaccinated children were protected from severe illness. Additionally, the disease course was milder post-vaccination, with improvements in metabolic balance and shorter hospital stays, demonstrating the vaccine's effectiveness in reducing disease severity and speeding up recovery.

Seasonality in rotavirus infections became evident after the easing of pandemic restrictions, with peak cases occurring in the winter months. The absence of seasonality during the pandemic years (2019–2021) was linked to public health measures, which also led to a significant reduction in hospitalisations. This emphasises the role of social distancing, enhanced hygiene, and mask-wearing in curbing viral spread. The study also found higher hospitalisation rates among children attending nurseries and kindergartens, highlighting the importance of maintaining preventive measures in educational settings.

In conclusion, mandatory vaccination has successfully reduced the incidence and severity of rotavirus infections, while the COVID-19 pandemic demonstrated the additional benefits of public health interventions in limiting viral transmission. Ongoing monitoring of rotavirus patterns is the next essential step to observe the long-term effects of these changes.

DISCLOSURES

1. Institutional review board statement: Not applicable.
2. Assistance with the article: None.
3. Financial support and sponsorship: None.
4. Conflicts of interest: None.

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