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DIARRHEA-ASSOCIATED MORTALITY IN CHILDREN LESS THAN 5 YEARS OF AGE IN THE UNITED STATES, 2005–2016

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Abstract

Diarrheal disease morbidity decreased after the 2006 US introduction of rotavirus vaccine. We calculated diarrheal death rates for children who were <5 years of age during 2005–2016. Death rates declined from 2.3/100,000 (2005–2006) to 1.7/100,000 (2014–2016). Declines were seen among 1- to 23-month olds, white and black children. Further exploration of the role of rotavirus vaccine in decreasing deaths among children is warranted.

Keywords

diarrhea; mortality; pediatric; rotavirus; immunization

Diarrheal deaths among US children have steadily declined with time. Secular trends reported through analysis of International Classification and Diagnostic (ICD) codes reported via death certificates to the National Center for Health Statistics (NCHS) show a gradual decline in death rates in children <5 years, decreasing from 31/100,000 in 1968 to 6.4/100,000 in 1985,[1] with subsequent stabilization through 1991. This decreasing trend may have been because of improved sanitation conditions, access to medical care and improved management of severe diarrhea.

After nationwide rotavirus vaccine introduction in 2006, substantial decreases in rotavirus detections, hospitalizations and emergency department visits[2,3] occurred. The effect of vaccination on pediatric diarrheal deaths has not been examined and is challenging because

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of data consistency issues. A report evaluating diarrheal deaths reported to NCHS compared death rates in 1992–1994 with those in 2005–2006, indicating a slight increase in diarrheal mortality among children <5 years of age, from 1.6/100,000 in 1992–1994 to 2.3/100,000 in 2005–2006, with infants bearing the burden for this increase.[4] Because of ICD-10 coding assignment errors during 1999–2004, analyses of diarrheal deaths among young children was not conducted during that period. Therefore, to assess the effect of rotavirus vaccination on diarrheal deaths among US children, we examined trends in diarrheal mortality during the pre-rotavirus vaccine period (2005–2006) when coding errors were no longer present, compared with postvaccine years (2008–2016).

MATERIALS AND METHODS

We examined multiple cause-of-death mortality for children 1–59 months of age reported via death certificates to NCHS for 2005–2016, excluding 2007, the transitional year after vaccine introduction. Diarrhea-associated deaths were defined using ICD-10 codes listed in any position on the death certificate (Table, Supplemental Digital Content 1, http://links.lww.com/INF/D283).

Using national census data, we calculated overall diarrhea-associated death rates, as well as death rates by sex, age group and race, per 100,000 children <5 years of age. We report rate ratios and 95% CI comparing each of 3 postvaccine periods (2008–2010, 2011–2013 and 2014–2016) to the prevaccine period (2005–2006) using Poisson regression. We calculated the proportion of deaths occurring in the rotavirus season (January–June) as compared with the nonrotavirus season (July–December) by age group, comparing the proportion who died in-season in each post vaccine period to the prevaccine reference period using a χ^2 test with postvaccine<0.05 considered statistically significant.

RESULTS

During 2005–2016, 4355 diarrhea-related deaths among 1- to 59-month-olds were reported to NCHS. In the prevaccine period, 32 (3%) of diarrheal deaths included specific codes indicating viral-diarrhea, while in the postvaccine periods, this was specified in 30 (2%), 20 (2%) and 34 (3%) deaths, respectively. Males, 1- to 11-month-olds, and black children had higher death rates in all time periods (Table 1). The overall death rate among children <5 years was 2.3/100,000 in the prevaccine period. This remained stable in 2008–2010, but decreased to 1.7/100,000 in both 2011–2013 and 2014–2016 [rate ratio: 0.73 (95% CI: 0.67–0.80) and 0.71 (95% CI: 0.65–0.78), respectively], indicating a 26.7% reduction (95% CI: −32.9 to −19.9) in 2011–2013 and a 28.6% (95% CI: −34.7 to −21.9) reduction in 2014–2016. By 2014–2016, declines in death rates were seen among children 1–23 months of age (Fig., Supplemental Digital Content 2, http://links.lww.com/INF/D284), both sexes, and black and white children, compared with 2005–2006.

In the prevaccine period, a higher proportion of diarrheal deaths occurred in the rotavirus season among all age groups, except for those 1–3 months of age. Among 4- to 11-month-olds, 56% of deaths occurred in-season in the prevaccine period, while 51% occurred in-season in both 2011–2013 and 2014–2016. For 12- to 23-month-olds, 57% of deaths

occurred in-season before vaccine introduction, 53% during 2011–2013 and 58% in the last postvaccine period. Finally, among the oldest 24- to 59-month age group, 68% of deaths occurred in-season in 2005–2006, and 61%, 59% and 58% in each successive postvaccine period, respectively. None of these changes were statistically significant. Among 1- to 3-month-olds, 44% of deaths occurred in-season in the prevaccine period, increasing to 50%, 51% and 50% in 2008–2010, 2011–2013 and 2014–2016, respectively ($P < 0.05$ for each postvaccine period compared with prevaccine).

DISCUSSION

Compared with the 2 years before rotavirus vaccine implementation, diarrheal death rates among US children <5 years of age old decreased significantly during 2010–2016, concurrent with increase in full-series rotavirus vaccine coverage from 43.9% in 2009 to 74.1% in 2016 in 18- to 35-month-old children.[5,6] This is in line with findings from Mexico and Malawi, where, after introduction of rotavirus vaccine, a 41% and 31% reduction in diarrhea-associated deaths were reported, respectively.[7,8] Additionally, the decline in mortality in our study was greater and achieved faster by 4- to 11-month-olds, who experienced a 50% decline in mortality by 2011–2013; in 2014–2016, the 11- to 23-month-olds also experienced a similar decrease. These age groups bear the greatest burden of rotavirus disease, and collectively these data support that the declines observed may be, in part, due to the effect of vaccination. However, we did not observe greater declines in diarrheal deaths during the rotavirus season months. We also recorded a decrease in diarrheal mortality among 1- to 3-month-olds who were too young to be vaccinated against rotavirus, suggesting other factors may also contribute to the decreasing diarrhea-associated deaths among US children.

In each period analyzed, racial disparities existed. While death rates decreased among both white and black children during the study period, black children had between 3–5.5 times the death rate of white children. While the general decline in death rates is encouraging, further exploration of reasons for the higher death rates among blacks and interventions targeted at further reducing the rate, such as improving rotavirus vaccine coverage, which trails that for whites by 10 percentage points[5] in the most recent coverage estimates, are warranted.

This analysis was subject to several limitations. First, an error in the ICD coding system before 2005 precluded inclusion of more than 2 years of prevaccine data, thus limiting comparison years. Next, the timing and geospatial pattern of the rotavirus season has shifted in the US since vaccine introduction[2] and we were unable to adjust for these changes, thereby potentially masking effects of shifting seasons on in-season declines in mortality. Finally, we did not have enough individual level data on rotavirus as the etiology of diarrheal death, thus we cannot definitely attribute the decline in diarrheal deaths in our analysis to the rotavirus vaccine program.

All-cause diarrheal mortality has declined among all <5-year-olds in the later years post-rotavirus vaccine implementation compared with prevaccine years; further research to assess the role of rotavirus vaccine in decreasing pediatric deaths is warranted.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

REFERENCES

1. Kilgore PE, Holman RC, Clarke MJ, et al. Trends of diarrheal disease–associated mortality in US children, 1968 through 1991. JAMA 1995;274: 1143–1148. [PubMed: 7563485]
2. Aliabadi N, Tate JE, Haynes AK, et al. ; Centers for Disease Control and Prevention (CDC). Sustained decrease in laboratory detection of rotavirus after implementation of routine vaccination —United States, 2000–2014. MMWR Morb Mortal Wkly Rep 2015;64:337–342. [PubMed: 25856253]
3. Payne DC, Staat MA, Edwards KM, et al. ; New Vaccine Surveillance Network (NVSN). Direct and indirect effects of rotavirus vaccination upon childhood hospitalizations in 3 US Counties, 2006–2009. Clin Infect Dis 2011;53:245–253. [PubMed: 21705316]
4. Esposito DH, Holman RC, Haberling DL, et al. Baseline estimates of diarrhea-associated mortality among United States children before rotavirus vaccine introduction. Pediatr Infect Dis J 2011;30:942–947. [PubMed: 21691244]
5. Hill HA, Elam-Evans LD, Yankey D, et al. Vaccination coverage among children aged 19–35 months - United States, 2016. MMWR Morb Mortal Wkly Rep 2017;66:1171–1177. [PubMed: 29095807]
6. Elam-Evans LD, Yankey D, Singleton JA, et al. ; Centers for Disease Control and Prevention (CDC). National, state, and selected local area vaccination coverage among children aged 19–35 months - United States, 2013. MMWR Morb Mortal Wkly Rep 2014;63:741–748. [PubMed: 25166924]
7. Richardson V, Hernandez-Pichardo J, Quintanar-Solares M, et al. Effect of rotavirus vaccination on death from childhood diarrhea in Mexico. N Engl J Med 2011;365:772–773. [PubMed: 21864191]
8. Bar-Zeev N, King C, Phiri T, et al. ; VacSurv Consortium. Impact of monovalent rotavirus vaccine on diarrhoea-associated post-neonatal infant mortality in rural communities in Malawi: a population-based birth cohort study. Lancet Glob Health. 2018;6:e1036–e1044. [PubMed: 30103981]

TABLE 1.

Death Rates for Children <5 Years of Age Who Died of Diarrhea-associated Causes, By Time Period and Demographic Characteristics, United States 2005–2016

	Prerotavirus Vaccine	Postrotavirus Vaccine					
	2005–2006	2008–2010		2011–2013		2014–2016	
	Death Rate (No.*)	Death Rate (No.*)	Rate Ratio (95% CI)†	Death Rate (No.*)	Rate Ratio (95% CI)†	Death Rate (No.*)	Rate Ratio (95% CI)†
Overall estimate	2.3 (463)	2.3 (473)	1.01 (0.93–1.09)	1.7 (340)	**0.73 (0.67–0.80)**	1.7 (330)	**0.71 (0.65–0.78)**
Characteristics							
Gender							
Female	2 (195)	2 (196)	0.99 (0.87–1.12)	1.5 (147)	**0.75 (0.66–0.86)**	1.6 (154)	**0.79 (0.69–0.91)**
Male	2.6 (268)	2.7 (278)	1.02 (0.92–1.14)	1.9 (193)	**0.72 (0.64–0.81)**	1.7 (176)	**0.66 (0.58–0.74)**
Age group (mo)							
1–3	7.9 (320)	9 (364)	**1.14 (1.03–1.25)**	6.6 (260)	**0.83 (0.75–0.92)**	6.1 (244)	**0.77 (0.70–0.86)**
4–11	2.3 (94)	1.7 (70)	**0.75 (0.62–0.91)**	1.2 (46)	**0.50 (0.40–0.62)**	1.2 (48)	**0.52 (0.42–0.65)**
12–23	0.8 (31)	0.5 (21)	0.70 (0.49–0.99)	0.4 (17)	**0.57 (0.39–0.83)**	0.4 (14)	**0.48 (0.32–0.70)**
24–59	0.1 (19)	0.1 (18)	0.93 (0.61–1.41)	0.1 (17)	0.89 (0.58–1.35)	0.1 (24)	1.24 (0.84–1.84)
Race							
White	1.6 (248)	1.7 (265)	1.07 (0.96–1.20)	1.2 (187)	**0.77 (0.68–0.87)**	1.2 (182)	**0.76 (0.67–0.86)**
Black	6.1 (195)	5.5 (185)	0.89 (0.79–1.02)	3.8 (130)	**0.63 (0.54–0.72)**	3.7 (124)	**0.60 (0.52–0.69)**
American Indian	1.7 (6)	1.7 (6)	0.97 (0.46–2.03)	1.2 (5)	0.70 (0.32–1.53)	1.5 (6)	0.85 (0.40–1.81)
Asian/Pacific Islander	1.4 (15)	1.5 (17)	1.08 (0.69–1.71)	1.6 (18)	1.14 (0.73–1.79)	1.4 (18)	1.06 (0.67–1.66)

Bolded values indicate significance, which was defined by the 95% confidence interval not crossing[1]

*Average annual number.

†Compared with reference period of 2005–2006. 2007 excluded from analysis. Rotavirus vaccine coverage in the United States per National Immunization Survey (NIS)[5,6]: 43.9% (2009), 59.2% (2010), 67.3 (2011), 68.6% (2012), 72.6% (2013), 71.7% (2014), 73.2% (2015), 74.1% (2016).