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Associations Among School Absenteeism, Gastrointestinal and Respiratory Illness, and Income — United States, 2010–2016

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Control of communicable diseases in children, including respiratory and diarrheal illnesses that affect U.S. school-aged children, might require public health preventive efforts both in the home and at school, a primary setting for transmission. National Health Interview Survey (NHIS) data on school absenteeism and gastrointestinal illness in the United States during 2010–2016 were analyzed to identify associations among income, illness, and absenteeism. Prevalence of gastrointestinal and respiratory illnesses in the 2 weeks preceding the survey increased as income decreased. Although the likelihood of missing any school days during the past year decreased with reduced income, among children missing school, those from low-income households missed more days of school than did children from higher income households. Although the reason for absenteeism cannot be ascertained from this analysis, these data underscore the importance of preventive measures, such as hand hygiene promotion and education, and the opportunity for both homes and schools to serve as an important point for implementation of public health preventive measures, including hand hygiene practice and education.

Data from the 2010–2016 NHIS (*1*) were analyzed. NHIS is an annual, national survey on household and child health in the noninstitutionalized U.S. population, administered continually throughout the year. Estimates based on these data are designed to meet National Center for Health Statistics standards (standard errors ≤0.3) (*1*). Family income data were linked to information about the school-aged child (5–17 years) with regard to 1) any school absenteeism in the last year, 2) number of days absent, and 3) gastrointestinal illness or respiratory illness (occurrence of a cold) during the 2 weeks preceding the interview. Income was assessed using NHIS-computed income brackets and by annual federal poverty level* thresholds computed by the U.S. Census Bureau (by family size). The statistical software R (version 3.4.3, R Foundation for Statistical Computing) was used to compare school absenteeism, illness, and income using linear and logistic regression models, unadjusted and adjusted for age and sex of the child and year of survey. P-values <0.05 were considered statistically significant.

* The federal poverty level represents an indicator used to define the boundary for those eligible for federal aid. It is defined by the U.S. Department of Health and Human Services annually each January to adjust for inflation and is proportional to the size of the household (e.g., by 2018 guidelines, a two-person household with an income of $15,500 would be below the poverty level, but a single-person household with the same income would not).

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A total of 645,209 respondents provided income information, and 61,482 (9.6%) were selected to provide data about their school-age child's health and days of school missed. Respondents varied across income categories, with 31% earning <$35,000 per year and 19% below the federal poverty level (Table 1). Sixty-nine percent of children missed ≥1 day of school the previous year, and approximately 15% missed ≥6 days (mean = 3.3 days per child). In the 2 weeks preceding the survey, prevalences of gastrointestinal and respiratory illnesses were 5% and 13%, respectively.

Reported school absence during the previous school year and reported respiratory or gastrointestinal illness during the previous 2 weeks were categorized by household income (Table 2). Compared with children in each of the other income categories, children in the lowest income bracket households (earning <$35,000 per year) had lower likelihood of missing school during the previous year (65% versus 67%–73%) and higher prevalence of gastrointestinal illness (6% versus 4%–5%) and respiratory illness (14% versus 12%–13%) in the previous 2 weeks. Adjusting for age, sex, and year of survey, children in the lowest income bracket were 4%–12% less likely to miss school (95% confidence interval [CI] = 1%–16%), but 12%–28% more likely to have had a recent gastrointestinal illness (95% CI = 2%–35%). Children in the lowest income bracket were also 6%–11% more likely to have had a respiratory illness, although comparisons with each of the next two highest income brackets ($35,000–$49,999 and $50,000–$74,999) were not statistically different.

Results were similar when comparing children living below the federal poverty level with those at or above it. Children living below the poverty level were significantly less likely to have missed school during the past year (65% versus 70%), and also significantly more likely to have had a gastrointestinal illness (6% versus 5%) or respiratory illness (14% versus 13%) in the preceding 2 weeks (Table 2). Specifically, children living below the poverty level were 9% less likely to have missed a day of school during the last year (95% CI = 6%–12%), but were 22% more likely to have had a gastrointestinal illness (95% CI = 15%–28%) and 6% more likely to have had a respiratory illness (95% CI = 1%–11%) during the 2 weeks preceding the survey.

Among children whose parents reported respiratory or gastrointestinal illness during the preceding 2 weeks, the percentage who missed any school during the last year increased with increasing income level. Among children who had gastrointestinal illness, 84.6% (family income <$35,000), 86.1% ($35,000–$49,999), 90.3% ($50,000–$74,999), 89.6% ($75,000–$99,999), and 87.4% (≥$100,000) missed school in the past year. Similarly, 83.7% of children living below the poverty level with gastrointestinal illness missed school, compared with 88.3% of those living at or above the poverty level. Among children in the household income brackets listed above who had a respiratory illness during the preceding 2 weeks, 78.5%, 79.7%, 80.5%, 82.3%, and 81.3%, respectively, missed school, and 77.6% of children living in households below the federal poverty level missed school compared with

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TABLE 1. Number and percentage of respondents reporting school absences among children aged 5–17 years, by federal poverty level (FPL) status, income, school absence, and gastrointestinal and respiratory illnesses — National Health Interview Survey, 2010–2016

	No. of respondents (%)							
	Year							
Characteristic	2010	2011	2012	2013	2014	2015	2016	Total
Below FPL*	1,540 (19.6)	1,748 (19.6)	1,860 (19.9)	1,783 (19.5)	1,895 (19.8)	1,570 (18.0)	1,164 (14.7)	**11,560 (18.8)**
Annual income								
<$34,999	2,643 (33.6)	3,001 (33.6)	3,179 (34.0)	2,979 (32.7)	2,919 (30.6)	2,466 (28.2)	1,914 (24.1)	**19,101 (31.1)**
$35,000–$49,999	1,056 (13.4)	1,252 (14.0)	1,190 (12.7)	1,216 (13.3)	1,145 (12.0)	984 (11.3)	790 (10.0)	**7,633 (12.4)**
$50,000–$74,999	1,300 (16.5)	1,424 (16.0)	1,493 (16.0)	1,430 (15.7)	1,396 (14.6)	1,328 (15.2)	1,158 (14.6)	**9,529 (15.5)**
$75,000–$99,999	879 (11.2)	979 (11.0)	1,124 (12.0)	1,039 (11.4)	1,092 (11.4)	916 (10.5)	953 (12.0)	**6,982 (11.4)**
≥$100,000	1,991 (25.3)	2,263 (25.4)	2,366 (34.0)	2,460 (27.0)	2,999 (31.4)	3,039 (34.8)	3,119 (39.3)	**18,237 (30.0)**
School days absent during previous year								
0	2,275 (28.9)	2,722 (30.5)	3,230 (34.5)	2,849 (31.2)	3,099 (32.4)	2,700 (30.9)	2,410 (30.4)	**19,285 (31.4)**
Any	5,594 (71.1)	6,197 (69.5)	6,122 (65.5)	6,275 (68.8)	6,452 (67.6)	6,033 (69.1)	5,524 (69.6)	**42,197 (68.6)**
1–2	2,150 (27.3)	2,524 (28.3)	2,725 (29.1)	2,627 (28.8)	2,779 (29.1)	2,553 (29.2)	2,364 (29.8)	**17,722 (28.8)**
3–5	2,136 (27.1)	2,365 (26.5)	2,207 (23.6)	2,353 (25.8)	2,421 (25.3)	2,157 (24.7)	2,005 (25.3)	**15,644 (25.4)**
6–10	857 (10.9)	874 (9.8)	811 (8.7)	866 (9.5)	866 (9.1)	900 (10.3)	788 (9.9)	**5,962 (9.7)**
≥11	451 (5.7)	434 (4.9)	379 (4.1)	429 (4.7)	386 (4.0)	423 (4.8)	367 (4.6)	**2,869 (4.7)**
Mean days absent (SD)	3.65 (7.30)	3.36 (7.10)	2.95 (6.02)	3.29 (6.37)	3.07 (6.31)	3.40 (6.88)	3.32 (6.64)	**3.28 (6.66)**
Illness during past 2 weeks								
Gastrointestinal	413 (5.3)	470 (5.3)	399 (4.3)	437 (4.8)	476 (5.0)	392 (4.5)	371 (4.7)	**2,958 (4.8)**
Respiratory	1,041 (13.2)	1,255 (14.1)	995 (10.6)	1,299 (14.2)	1,210 (12.7)	1,111 (12.7)	997 (12.6)	**7,908 (12.9)**

Abbreviation: SD = standard deviation.

* FPL represents an indicator used to define the boundary for those eligible for federal aid; FPL is defined by the U.S. Department of Health and Human Services annually each January to adjust for inflation and is proportional to the size of the household.

TABLE 2. Number and percentage of respondents reporting school absence and illness among children aged 5–17 years, by income and federal poverty level (FPL) status — National Health Interview Survey, 2010–2016

	No. of respondents (%)						
	Income					Poverty status*	
Characteristic	<$35,000	$35,000–$49,999	$50,000–$74,999	$75,000–$99,999	≥$100,000	Below FPL	At or above FPL
School days absent							
0	6,710 (35.1)	2,497 (32.7)	2,831 (29.7)	1,906 (27.3)	5,341 (29.3)	4,108 (35.5)	13,781 (29.7)
Any	12,391 (64.9)	5,136 (67.3)	6,698 (70.3)	5,076 (72.7)	12,896 (70.7)	7,452 (64.5)	32,546 (70.3)
PR (95% CI)	Referent	1.04 (1.00 to 1.07)	1.08 (1.05 to 1.12)	1.12 (1.08 to 1.16)	1.09 (1.0 to 1.12)	Referent	1.09 (1.0 to 1.12)
aPR† (95% CI)	Referent	1.04 (1.00–1.07)	1.08 (1.05–1.12)	1.12 (1.09–1.16)	1.09 (1.07–1.12)	Referent	1.09 (1.07–1.12)
1–2	4,499 (23.6)	2,065 (27.1)	2,814 (29.5)	2,203 (31.6)	6,141 (33.7)	2,640 (22.8)	14,077 (30.4)
3–5	4,562 (23.9)	1,919 (25.1)	2,512 (26.4)	1,955 (28.0)	4,696 (25.7)	2,767 (23.9)	12,071 (26.1)
6–10	2,079 (10.9)	752 (9.9)	978 (10.3)	674 (9.7)	1,479 (8.1)	1,259 (10.9)	4,443 (9.6)
≥11	1,251 (6.5)	400 (5.2)	394 (4.1)	244 (3.5)	580 (3.2)	786 (6.8)	1,955 (4.2)
Mean (SD) all	3.72 (7.99)	3.42 (6.96)	3.16 (5.95)	3.07 (4.75)	2.90 (5.89)	3.80 (8.34)	3.20 (6.22)
Est§ (95% CI)	Referent	-0.30 (-0.48 to -0.12)	-0.56 (-0.72 to -0.39)	-0.65 (-0.83 to -0.47)	-0.82 (-0.96 to -0.69)	Referent	-0.60 (-0.74 to -0.47)
aEst† (95% CI)	Referent	-0.32 (-0.50 to -0.15)	-0.58 (-0.74 to -0.42)	-0.67 (-0.86 to -0.49)	-0.87 (-1.00 to -0.73)	Referent	-0.65 (-0.78 to -0.51)
Mean (SD)¶	5.74 (9.32)	5.08 (7.98)	4.50 (6.66)	4.22 (5.12)	4.10 (6.64)	5.90 (9.77)	4.55 (7.00)
Est (95% CI)	Referent	-0.65 (-0.90 to -0.41)	-1.23 (-1.46 to -1.01)	-1.52 (-1.76 to -1.27)	-1.63 (-1.82 to -1.45)	Referent	-1.35 (-1.54 to -1.16)
aEst† (95% CI)	Referent	-0.68 (-0.93 to -0.44)	-1.27 (-1.50 to -1.05)	-1.56 (-1.81 to -1.32)	-1.71 (-1.90 to -1.53)	Referent	-1.41 (-1.60 to -1.22)
Illness during past 2 weeks							
Gastrointestinal	1,086 (5.7)	359 (4.7)	475 (5.0)	309 (4.4)	729 (4.0)	689 (6.0)	2129 (4.6)
PR (95% CI)	Referent	0.83 (0.7 to 0.93)	0.88 (0.7 to 0.98)	0.79 (0.6 to 0.88)	0.70 (0.6 to 0.77)	Referent	0.77 (0.7 to 0.84)
aPR† (95% CI)	Referent	0.83 (0.7 to 0.94)	0.88 (0.7 to 0.98)	0.79 (0.6 to 0.89)	0.72 (0.6 to 0.79)	Referent	0.78 (0.7 to 0.85)
Respiratory	2,625 (13.7)	979 (12.8)	1,222 (12.8)	847 (12.1)	2,235 (12.3)	1,596 (13.8)	5,919 (12.8)
PR (95% CI)	Referent	0.93 (0.8 to 1.00)	0.93 (0.8 to 1.00)	0.88 (0.8 to 0.95)	0.89 (0.8 to 0.94)	Referent	0.93 (0.8 to 0.98)
aPR† (95% CI)	Referent	0.94 (0.8 to 1.01)	0.94 (0.8 to 1.01)	0.89 (0.8 to 0.96)	0.91 (0.8 to 0.96)	Referent	0.94 (0.8 to 0.99)

Abbreviations: aEst = adjusted estimate (from linear regression); aPR = adjusted prevalence ratio; CI = confidence interval; Est = estimate (from linear regression); PR = prevalence ratio; SD = standard deviation.

* FPL represents an indicator used to define the boundary for those eligible for federal aid; FPL is defined by the U.S. Department of Health and Human Services annually each January to adjust for inflation and is proportional to the size of the household. Because the poverty line data includes both income and number of household members, there were more missing values for poverty level; therefore, the numbers in the below FPL and at or above FPL groups do not sum to the number in all income groups.

† Adjusted for age and sex of child, as well as year of data collection.

§ Estimated difference from reference.

¶ Among those missing ≥1 school day only.

81.2% of those living at or above the poverty level. Differences for both gastrointestinal and respiratory illnesses were significant in bivariable analyses (e.g., chi-square tests), but not in final model risk ratios.

When analyzed by the number of days missed, children in the lowest income bracket (<$35,000) missed a mean of 0.3–0.9 more days in the last year compared with children in other income brackets (Table 2). Among only children who missed ≥1 school day, the differences were larger (mean = 0.7–1.7 more days). Similarly, overall, children living below the federal poverty level missed an average of 0.6 more days of school per year than did children in higher income households; among only those who missed ≥1 day of school, the difference increased to 1.4 days.

Discussion

Compared with children from higher income households, those from lower income households were more likely to have had a gastrointestinal or respiratory illness during the 2 weeks preceding the survey. Although children from lower income households were less likely to have missed any days of school during the last year, those who did miss school missed more days than did children from higher income households.

The combination of increased illness prevalence and absenteeism with decreasing income status highlights the need for accessible, affordable resources and interventions at home and school. Multiple barriers faced by children in low-income households could explain these findings, including lack of access to preventive health care (*2*). Although targeted social distancing, such as a requirement for absence from school might be an effective recommended course of action to protect public health (*3*,*4*), low-income parents might not have the opportunities (e.g., paid sick leave from work) to be able to implement this. These circumstances might affect both their children's ability to stay home from school and health-seeking behaviors (*5*). In the long-term, longer periods of absenteeism could be associated with adverse educational outcomes (*6*).

The findings in this report are subject to at least two limitations. First, although NHIS collects health and school absence data generalizable to the U.S. population as a whole, the reasons for school absence are not collected. Second, both health and school absence data are self-reported, making them subject to recall bias, and the data are not consistent in their respective recall timelines (preceding 2 weeks versus preceding year). However, recall of self-reported illness and school absenteeism is likely to be more accurate for the recent past (*7*); thus the association between reporting of recent illness and school absenteeism is likely to be strengthened. In addition, subgroup differences in illness, though small (one percentage point) fell outside of the survey margins of error.

Summary

What is already known about this topic?

Gastrointestinal and respiratory infections are important illnesses that affect U.S. school-aged children. Schools can serve as primary settings of transmission.

What is added by this report?

During 2010–2016, parents of children from low-income households were more likely to report recent childhood gastrointestinal and respiratory illnesses than were higher income parents. Although parents of children from low-income households were less likely to report missing any school, these children tended to miss more school days, on average, when they did miss school.

What are the implications for public health practice?

Public health partners could expand prevention efforts to decrease transmission of gastrointestinal and respiratory illnesses, especially low-cost measures such as promoting hand hygiene education in schools.

From a public health perspective, these findings highlight a need for resources for, and attention to, preventive measures to keep children in school. Beyond practices in the home, schools have opportunities to serve as settings for preventing transmission of communicable diseases. Some school-based programs promoting handwashing, and more generally hand hygiene, have been found to be effective in reducing gastrointestinal and respiratory illnesses and associated absenteeism (*8*). Research suggests that peer support and provision of soap can increase handwashing and reduce absenteeism related to both gastrointestinal and respiratory illnesses (*9*). However, further study of sustained, community-based encouragement of proper hand hygiene practices as effective, low-cost means of preventing such illnesses is needed. Ongoing health promotion activities in schools can increase awareness and understanding of handwashing with soap as an effective and affordable way to prevent transmission of infectious diseases. Increased public awareness of the importance of hand hygiene, as promoted by Global Handwashing Day (observed each year on October 15), is important to promoting public health and reducing the transmission of illness.

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Vital Signs: Epidemiology and Recent Trends in Methicillin-Resistant and in Methicillin-Susceptible *Staphylococcus aureus* Bloodstream Infections — United States

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Abstract

Introduction: *Staphylococcus aureus* is one of the most common pathogens in health care facilities and in the community, and can cause invasive infections, sepsis, and death. Despite progress in preventing methicillin-resistant *S. aureus* (MRSA) infections in health care settings, assessment of the problem in both health care and community settings is needed. Further, the epidemiology of methicillin-susceptible *S. aureus* (MSSA) infections is not well described at the national level.

Methods: Data from the Emerging Infections Program (EIP) MRSA population surveillance (2005–2016) and from the Premier and Cerner Electronic Health Record databases (2012–2017) were analyzed to describe trends in incidence of hospital-onset and community-onset MRSA and MSSA bloodstream infections and to estimate the overall incidence of *S. aureus* bloodstream infections in the United States and associated in-hospital mortality.

Results: In 2017, an estimated 119,247 *S. aureus* bloodstream infections with 19,832 associated deaths occurred. During 2005–2012 rates of hospital-onset MRSA bloodstream infection decreased by 17.1% annually, but the decline slowed during 2013–2016. Community-onset MRSA declined less markedly (6.9% annually during 2005–2016), mostly related to declines in health care–associated infections. Hospital-onset MSSA has not significantly changed ($p = 0.11$), and community-onset MSSA infections have slightly increased (3.9% per year, $p<0.0001$) from 2012 to 2017.

Conclusions and Implications for Public Health Practice: Despite reductions in incidence of MRSA bloodstream infections since 2005, *S. aureus* infections account for significant morbidity and mortality in the United States. To reduce the incidence of these infections further, health care facilities should take steps to fully implement CDC recommendations for prevention of device- and procedure-associated infections and for interruption of transmission. New and novel prevention strategies are also needed.

Introduction

Staphylococcus aureus is a major cause of community- and health care–associated infections (*1*), ranging from superficial skin and soft tissue infections (SSTI) to invasive infections, sepsis, and death. Methicillin-resistant *S. aureus* (MRSA) has long been recognized as a pathogen associated with health care settings; however, in the 1990s, community-associated MRSA infections, causing mostly SSTI, emerged in the United States (*2*). Substantial progress has been achieved in preventing MRSA bloodstream infections in U.S. health care facilities (*3–5*) after widespread introduction of enhanced infection control efforts in acute-care hospitals.

Although the rates of hospital-onset MRSA bloodstream infections have substantially decreased, evidence from the National Healthcare Safety Network (NHSN) and from the Emerging Infections Program (EIP) surveillance system suggests that the decline might have slowed in more recent years (*4*,*6*); the United States is not on track to meet the 2020 goal of the Healthcare-Associated Infection National Action Plan of a 50% reduction in hospital-onset MRSA bloodstream infections from the 2015 baseline (*7*). Moreover, to protect patients, expanded efforts are needed to prevent methicillin-susceptible *S. aureus* (MSSA), which causes approximately half of all health care–associated *S. aureus* infections (*8*). There is little information on the current epidemiology of MSSA infections in the United States, and available data might not be nationally representative (*9–11*).

A critical assessment of recent trends and incidence of both MRSA and MSSA invasive disease in the United States is crucial to informing public health policy and formulating a framework of approaches to further prevent *S. aureus* infections. In this report, recent data from the EIP population surveillance and two large electronic health record (EHR) data sets from over 400 U.S. acute care hospitals were used to update estimates of MRSA and MSSA bloodstream infections, and to estimate associated in-hospital mortality.

Methods

EIP population MRSA surveillance. MRSA bloodstream infection data were obtained from CDC's EIP active laboratory- and population-based surveillance for invasive MRSA in selected counties from six sites* reporting data continually from 2005 to 2016 (population in 2016 = 13 million). A case of MRSA bloodstream infection was defined as isolation of MRSA from a blood culture in a resident of the catchment area, who had not had a positive invasive culture from a normally sterile site in the preceding 30 days. Annual incidence was calculated per 100,000 census population and stratified according to patient epidemiologic exposure, determined through medical record review as 1) hospital-onset if the culture was obtained on or after the fourth day of an inpatient hospitalization; 2) health care–associated community-onset, if the culture was obtained from an outpatient or during the first 3 days of hospitalization in a patient with one of several significant prior health care exposures; and 3) community-associated, otherwise. Community-onset infections comprise health care–associated community-onset and community-associated infections. Further details about the surveillance program can be found elsewhere (*3*). Adjusted annual decreases were modeled using Poisson regression and accounting for changes in the overall population and dialysis population demographics. Postcensus bridged-race census files were used for EIP analyses.

EHR databases. The Premier Healthcare Database (*12*) and Cerner Health Facts EMR (*13*) data were used to identify *S. aureus* bloodstream infections among patients discharged from participating acute care hospitals reporting results of microbiologic cultures with antimicrobial susceptibility testing during January 1, 2012–December 31, 2017. A case was defined as the identification of *S. aureus* in a blood culture with reported antimicrobial sensitivity, without a positive *S. aureus* blood culture in the preceding 14 days. Community-onset and hospital-onset cases were defined as for EIP surveillance. Incidences of MSSA and MRSA were calculated as the number of community-onset cases per 1,000 hospital discharges and the number of hospital-onset cases per 10,000 patient-days. Trends in monthly incidence during 2012–2017 were assessed using generalized estimating equations to fit negative binomial regression models adjusted for seasonality and certain hospital characteristics and accounting for clustering and repeated measures. The outcome variable was the number of *S. aureus* bloodstream infections, and the predictor variable was a continuous time covariate. Adjusted rates are presented as relative annual trends. Deaths associated with *S. aureus* bloodstream infections were defined as deaths or discharges to hospice for patient hospitalizations with documented *S. aureus* bloodstream infections. Differences in annual mortality were assessed using generalized estimating equations binomial models adjusting for all the same characteristics as for incidence. Hospital characteristics were used in a raking-procedure to determine weights to extrapolate the number of discharges included in the sample to match the distribution of discharges for all hospitals from the American Hospital Association survey (*14*). Using these weights, national estimates of cases of *S. aureus* bloodstream infections and deaths associated with *S. aureus* bloodstream infections were extrapolated. All statistical analyses were performed using SAS (version 9.4; SAS Institute).

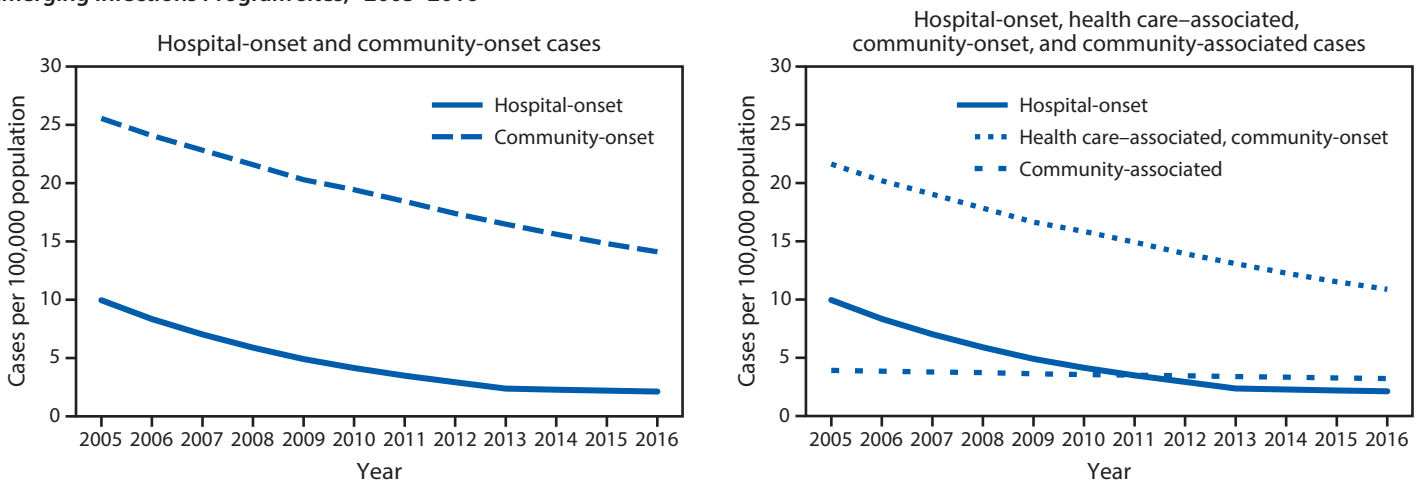
Results

Rates of hospital-onset and community-onset MRSA, EIP surveillance, 2005–2016. From 2005 to 2016, the incidence of hospital-onset and community-onset MRSA bloodstream infection declined 74% and 40%, respectively (Figure 1). The decline in hospital-onset MRSA bloodstream infection rates has slowed in more recent years: adjusted rates decreased by 17.1% per year ($p<0.001$) during 2005–2012 but did not significantly change during 2013–2016 ($p = 0.25$). Adjusted community-onset MRSA bloodstream infection rates declined by 6.9% per year during 2005–2016 ($p<0.001$). Declines in rates of health care–associated community-onset infections accounted for most of the decline in community-onset MRSA bloodstream infections during 2005–2016 (Figure 1). Adjusted health care–associated community-onset bloodstream infection rates declined by 7.8% per year ($p = 0.001$), but community-associated bloodstream infections declined by only 2.5% per year ($p = 0.001$).

Rates of hospital-onset and community-onset MRSA and MSSA and associated mortality, EHR data, 2012–2017. From 2012 to 2017, 447 hospitals contributed data (average per year = 325). During this time, adjusted hospital-onset MRSA bloodstream infection rates declined 7.3% per year ($p<0.0001$) (Figure 2), with no significant change in community-onset MRSA rates ($p = 0.35$). Hospital-onset MSSA rates did not change ($p = 0.11$), and community-onset MSSA rates significantly increased (3.9% per year, $p<0.001$) (Figure 2).

* California (three counties), Connecticut (statewide), Georgia (eight counties), Minnesota (one county), New York (one county), and Tennessee (one county).

FIGURE 1. Adjusted* methicillin-resistant *Staphylococcus aureus* bloodstream infection rates from population based surveillance — six U.S. Emerging Infections Program sites,† 2005–2016



* Adjusted for year and distribution of age, sex, and race among overall and dialysis population. Community-onset infections comprise health care–associated community-onset and community-associated infections.
† California (three counties), Connecticut (statewide), Georgia (eight counties), Minnesota (one county), New York (one county), and Tennessee (one county).

The overall unadjusted in-hospital mortality among patients with *S. aureus* bloodstream infections over the study period was 18%. No significant change was observed from 2012 to 2017, although significant differences were observed by epidemiologic classification: unadjusted MRSA and MSSA mortality rates were higher for hospital-onset cases (29% and 24%, respectively) than for community-onset cases (18% and 14%, respectively) (p<0.001).

Estimated morbidity of *S. aureus* bloodstream infections and in-hospital mortality, EHR data, United States, 2017. Overall, an estimated 119,247 cases of *S. aureus* bloodstream infections and 19,832 associated deaths occurred nationwide in 2017.

Conclusions and Comments

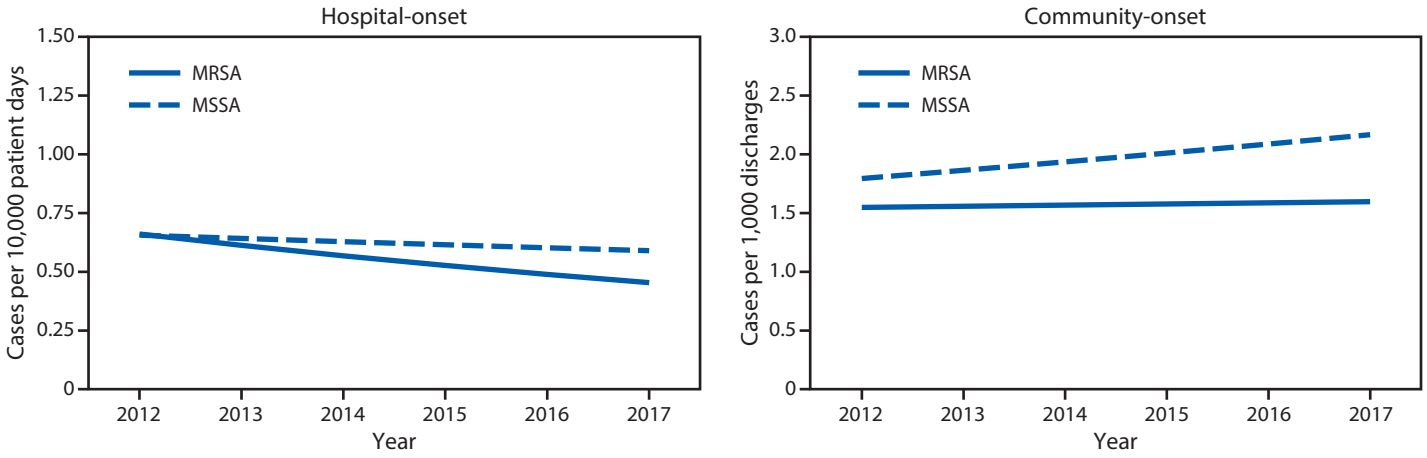
This study identified substantial reductions in hospital-onset MRSA bloodstream infection rates between 2005 and 2012; however, since 2012, the rate of decline has slowed. These trends are consistent with recent data from NHSN (*4*). Less marked declines were noted in rates of community-onset MRSA bloodstream infections compared with those of hospital-onset infections. The detailed epidemiologic information that EIP collects allowed subclassification of community-onset MRSA infections into those with prior health care exposure (health care–associated community-onset), which account for the majority of cases, and those without health care exposure (community-associated). Most of the reduction in MRSA bloodstream infection is attributable to reductions in health care–associated MRSA. Community-associated MRSA infection rates have changed little overall. Hospital-onset MSSA infection rates have not changed since 2012, whereas community-onset-MSSA infection rates might be increasing slightly.

The reasons for the declines in hospital-onset MRSA bloodstream infections might be attributable to a variety of infection control efforts, including improvements in preventing device- and procedure-associated infections (*15*–*17*), as well as efforts to interrupt MRSA transmission in the hospital setting (*5*,*18*). As has been reported previously (*17*), significant national reductions in central-line–associated bloodstream infections occurred during 2001–2009, particularly in those caused by *S. aureus*; these reductions have continued through more recent years (*4*). Meanwhile, evidence from the National Veterans Affairs system suggests that decreasing hospital transmission of MRSA likely also contributed to the observed reductions (*19*,*20*).

National MRSA reductions primarily reflect declines in the incidence of infections caused by USA100 strains, which are predominantly transmitted in health care settings, and, to a lesser extent, USA300 strains, which are predominantly transmitted in the community (*21*). Historically, large shifts in *S. aureus* strain epidemiology have occurred (*22*). Whereas the reasons for some of these shifts might be related to strain virulence and fitness, health care–related interventions are likely to have played a role in the decrease in USA100.

The recent slowing in the reduction in hospital-onset MRSA bloodstream infections and the limited decline in community-associated MRSA and in MSSA infections point to the need for an updated *S. aureus* prevention framework, including greater use of evidence-based practices that can reduce transmission and prevent device- and procedure-associated infections, as well as new and novel approaches. These include strategies to suppress *S. aureus* colonization in patients during periods of high risk for invasive *S. aureus* infection, such as when

FIGURE 2. Adjusted* hospital-onset and community-onset rates of *Staphylococcus aureus* bloodstream infections — Premier and Cerner Hospitals, United States, 2012–2017



Abbreviations: MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-susceptible *Staphylococcus aureus*.
* Modeled relative to observed rates in 2012. Model adjusts for discharge month and year and hospital region, teaching status, bed size, and distributions of patient age, sex and race, in addition to accounting for repeated measures and clustering by facility.

invasive devices are in place, during admission to high-risk hospital units, or perioperatively for certain high-risk surgical procedures. The experience with MRSA suggests that the post-discharge period might also be important for targeting innovative prevention efforts: EIP data suggest that the majority of all MRSA bloodstream infections are health care–associated community-onset, and most occur in the 3 months after hospital discharge (*3*). A recent study suggests that prescribing serial decolonization protocols at the time of hospital discharge could significantly reduce postdischarge *S. aureus* infections (*23*). Suppression of *S. aureus* colonization might play an important role in decreasing transmission, but data to recommend this approach as a replacement for currently recommended strategies to prevent transmission, such as contact precautions, are insufficient (*24*). All hospitals should have strategies in place for preventing *S. aureus* infections; however, the prevention impact might be greatest in those with a particularly high *S. aureus* incidence. A recent review of NHSN data indicated that a relatively small number of hospitals (approximately 200) account for slightly over half of the hospital-onset MRSA incidence in excess of the 2020 goals and could be prioritized for prevention to reduce MRSA bloodstream infections nationally (NHSN, unpublished data).

Community-associated MRSA infections provide a reservoir that contributes to health care–associated disease incidence and fuels transmission both outside and within health care settings. USA300 strains, for example, emerged in the community and spread to health care settings (*25*). Community-associated *S. aureus* infections are not declining, and the ongoing opioid epidemic might be contributing to this trend. Emerging evidence suggests a 16-fold risk for invasive MRSA infection among persons who inject drugs; 9.2% of invasive MRSA cases in 2016 occurred in persons who inject drugs (*26*). Prevention of opioid misuse, increasing access and linkage to medication-assisted treatment for persons with opioid use disorder (*27*), ensuring access to sterile injecting equipment, improving education about safer injection practices and how to recognize early signs of infection, and linking those with an infection to care are needed. Additionally, community-associated *S. aureus* infections are known to disproportionately affect persons in lower socioeconomic strata (*28*); this has implications for the formulation of approaches to enhance prevention. The observed increases in rates of community-onset MSSA infections highlight the need to systematically study the epidemiology of MSSA and develop innovative, evidence-based prevention strategies for this setting. Research for a vaccine or for novel ways to decrease *S. aureus* bioburden should continue.

The incidence of *S. aureus* bloodstream infections and associated deaths is substantial and consistent with estimates using Nationwide Inpatient Sample data (*29*). Mortality was unchanged over the time studied and comparable to what was achieved in the VA hospital system through implementation of improved clinical management of infection (*28*). Appropriate and timely diagnosis and antimicrobial susceptibility-guided treatment of *S. aureus* infections remain key to reducing poor outcomes and preventing sepsis and death (*29*).

The findings in this report are subject to at least two limitations. First, the lack of detailed epidemiologic information on previous health care exposures captured in EHR precluded subclassification of community-onset infections into those with and without previous health care exposures. Second, possible

Summary

What is already known about this topic?

Invasive methicillin-resistant *Staphylococcus aureus* (MRSA) infections have been declining in health care settings; however, the rate of decline has recently slowed.

What is added by this report?

Nearly 120,000 *Staphylococcus aureus* bloodstream infections and 20,000 associated deaths occurred in the United States in 2017. After years of progress, the rate of decline of MRSA bloodstream infections has slowed, whereas bloodstream infections caused by methicillin-susceptible *S. aureus* are increasing slightly in the community (3.9% annually, 2012–2017).

What are the implications for public health practice?

Adherence to CDC recommendations for preventing device- and procedure-associated infections and interrupting transmission, along with innovative, tailored interventions (including decolonization) are needed to further prevent *S. aureus* infections.

variability in clinical or data capture practices across different hospitals might affect the validity of EHR data and trends.

Strengths of this study include the use of multiple data sources; the detailed epidemiologic information provided in the population-based EIP surveillance; the inclusion of two widely used EHR systems representing a large number of U.S. acute-care hospitals; and the use of weights to derive national estimates. As has been previously shown with another infection-related condition (sepsis), clinical criteria using EHR data are immune to temporal variations in coding practices that can be significant (*30*), whereas death-certificate data are an insensitive measure of sepsis-related mortality (*31*).

S. aureus infections account for substantial morbidity in the United States. Despite significant reductions in health care–associated MRSA infections, progress is slowing. MSSA infections have not decreased as much in hospitals and might be increasing in the community. Adherence to CDC recommendations (*32*) for preventing device- and procedure-associated infections and interrupting transmission, along with innovative interventions tailored to the needs of health care facilities (including decolonization) are needed to further prevent *S. aureus* infections.

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Vital Signs: Trends in *Staphylococcus aureus* Infections in Veterans Affairs Medical Centers — United States, 2005–2017

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Abstract

Introduction: By 2007, all Department of Veterans Affairs medical centers (VAMCs) had initiated a multifaceted methicillin-resistant *Staphylococcus aureus* (MRSA) prevention program. MRSA and methicillin-susceptible *S. aureus* (MSSA) infection rates among VAMC inpatients from 2005 to 2017 were assessed.

Methods: Clinical microbiology data from any patient admitted to an acute-care VAMC in the United States from 2005 through 2017 and trends in hospital-acquired MRSA colonization were examined.

Results: *S. aureus* infections decreased by 43% overall during the study period (p<0.001), driven primarily by decreases in MRSA, which decreased by 55% (p<0.001), whereas MSSA decreased by 12% (p = 0.003). Hospital-onset MRSA and MSSA infections decreased by 66% (p<0.001) and 19% (p = 0.02), respectively. Community-onset MRSA infections decreased by 41% (p<0.001), whereas MSSA infections showed no significant decline. Acquisition of MRSA colonization decreased 78% during 2008–2017 (17% annually, p<0.001). MRSA infection rates declined more sharply among patients who had negative admission surveillance MRSA screening tests (annual 9.7% decline) compared with those among patients with positive admission MRSA screening tests (4.2%) (p<0.05).

Conclusions and Implications for Public Health Practice: Significant reductions in *S. aureus* infection following the VAMC intervention were led primarily by decreases in MRSA. Moreover, MRSA infection declines were much larger among patients not carrying MRSA at the time of admission than among those who were. Taken together, these results suggest that decreased MRSA transmission played a substantial role in reducing overall *S. aureus* infections at VAMCs. Recent calls to withdraw infection control interventions designed to prevent MRSA transmission might be premature and inadvisable, at least until more is known about effective control of bacterial pathogen transmission in health care settings. Effective *S. aureus* prevention strategies require a multifaceted approach that includes adherence to current CDC recommendations for preventing not only device- and procedure-associated infections, but also transmission of health care–prevalent strains.

Introduction

Staphylococcus aureus is among the most common causes of health care–associated infections and accounts for significant morbidity and mortality. Beginning in 2005, in response to high rates of methicillin-resistant *S. aureus* (MRSA) infections, the U.S. Department of Veterans Affairs (VA) piloted an MRSA prevention program in 18 VA medical centers (VAMCs). By October 2007, all 153 VAMCs had implemented the MRSA prevention program, which included, among other components, admission screening for nasal MRSA carriage and using contact precautions (i.e., wearing a gown and gloves for all interactions involving contact with the patient or the patient's environment) for patients found to be carriers (*1*). To assess the impact of the intervention, the investigators tracked the incidence of MRSA and methicillin-susceptible *S. aureus* (MSSA) infections at 130 VAMCs from 2005 to 2017 and examined hospital-acquired MRSA colonization based on results of MRSA surveillance tests collected during the same period.

Methods

Clinical data from any patient admitted to VAMCs in the United States from January 1, 2005 through December 31, 2017 were analyzed. Facilities were excluded from the study if they did not provide acute care or if they did not report data to VA's periodic complexity assessment (e.g., the level and type of care provided) (*2*) in all eligible years during the study period. Clinical diagnostic culture and MRSA surveillance test results were extracted from electronic health records as described elsewhere (*3*). Bloodstream infections were defined as isolation of *S. aureus* from blood samples. Nonblood infections were

Summary

What is already known about this topic?

Staphylococcus aureus is an important cause of health care–associated infections and accounts for significant morbidity and mortality.

What is added by this report?

During 2005–2017, U.S. Department of Veterans Affairs medical centers across the United States experienced a sharp decline in *S. aureus* infections following introduction of a multifaceted infection control intervention. Most reductions were explained by decreases in methicillin-resistant *S. aureus* (MRSA). Decreased MRSA transmission likely played a substantial role.

What are the implications for public health practice?

These findings offer important insights informing *S. aureus* prevention strategy. Effective prevention strategies require a multifaceted approach, including efforts to prevent transmission of MRSA as well as efforts directed at infection prevention.

defined as isolation of *S. aureus* from any other sample type, excluding those obtained for surveillance purposes and those obtained within 14 days of a positive blood culture. MRSA isolates from samples collected from the same patient within 365 days were considered duplicates and excluded; MSSA duplicates were defined in the same manner. Infections were classified as hospital-onset when the specimen was obtained >3 days after admission, and as community-onset when the specimen was obtained ≤3 days after admission. Community-onset infection rates and total (combined community-onset and hospital-onset) infection rates were calculated per admission. Hospital-onset infection rates were expressed per 1,000 patient-days-at-risk, excluding days after the patient had met one of the infection definitions. MRSA colonization status at admission was considered positive if the last test within 24 hours after admission was positive. Patients were considered to have acquired MRSA if they had at least one MRSA-positive test (clinical or surveillance) after a negative admission surveillance test. Fluoroquinolone use was measured and defined according to National Healthcare Safety Network methods to assess for potential changes in antimicrobial pressure exerted on *S. aureus* (*4*).

To model rates, trend analyses were performed with generalized estimating equation models clustering by VAMC and using a negative binomial distribution, patient days at risk as the exposure, an autoregressive correlation structure, and robust error estimation. Models were adjusted for major hospital characteristics, including Medicare Relative Risk score, patient volume, resident slots, intensive care unit level, and number of advanced specialty clinical programs (*2*). Proportions were modeled similarly but with a binomial distribution. All percentage changes are based on modeled rates. Statistical analyses were performed using Stata statistical software (release 15; StataCorp, LLC). This study was performed with approval from the University of Utah Institutional Review Board and the VA Salt Lake City Health Care System Research and Development Office.

Results

The analysis included 130 VA hospitals. The overall rate of *S. aureus* infections decreased by 43% during 2005–2017 (4.7% annually, p<0.001) (Table). The reductions were driven primarily by decreases in MRSA infections, which declined by 55% (7.3% annual rate of decrease, p<0.001); MSSA infection rates decreased much more slowly, by 12% (1.2% annually, p = 0.003) (Figure 1). Hospital-onset MRSA infections decreased by 66% (p<0.001), and hospital-onset MSSA infections decreased 19% (p = 0.02); similar reductions were observed in both bloodstream and nonbloodstream infections (Figure 2).

Among community-onset infections, overall MRSA infection rates decreased by 41% (p<0.001), and community-onset MSSA infection rates declined by 0.4% (p = 0.93) (Table) (Figure 3). The decreases in community-onset MRSA bloodstream and nonbloodstream infections were greatest among infections occurring within 30 days of hospital discharge (Table). Decreases in community-onset infections played a substantial role in overall *S. aureus* trends: reduction in community-onset MRSA infections accounted for 48% of the overall MRSA rate decreases, and 40% of decreases in overall *S. aureus* infection rates.

The rate of hospital-acquired MRSA colonization decreased 78% during the study period 6.8 per 1,000 patient-days at risk (2008) to 1.5 per 1,000 patient-days at risk (2017) (16.7% annually, p<0.001). When hospital-onset MRSA infection rates were stratified according to results of admission nasal surveillance tests, MRSA infection rates among patients whose admission screening tests were negative declined by 58% (9.7% annually, p<0.001). In contrast, the reduction among patients with positive admission screening tests was significantly less; MRSA infections decreased 31% (4.2% annually, p<0.001) (p<0.05 compared with patients with a negative admission test). Fluoroquinolone use did not change significantly between 2005 and 2008, but between 2009 and 2017, fluoroquinolone use rates decreased by 44% (annual decrease = 4.8% p<0.001).

Conclusions and Comment

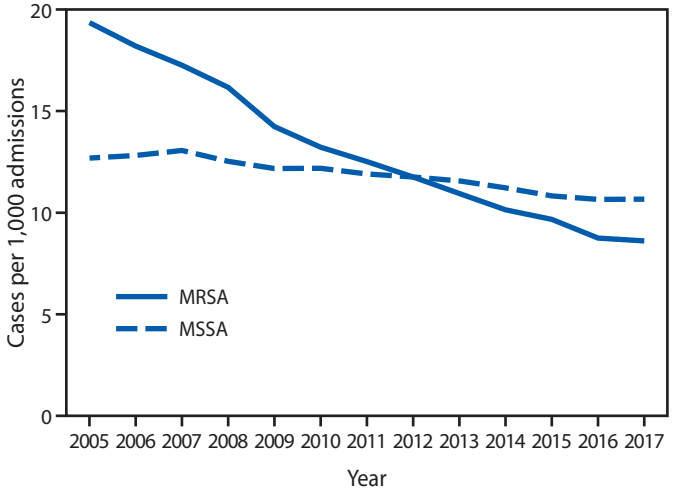
During 2005–2017, following introduction of a system-wide, multifaceted infection control intervention that included admission screening for nasal MRSA carriage and use of contact precautions for MRSA-colonized patients, VAMCs across the United States experienced a sharp decline in *S. aureus* infections among hospitalized patients. Most of the reductions were explained by decreases in MRSA; reductions in MSSA rates

TABLE. Changes in incidence of *Staphylococcus aureus* infections among hospitalized patients — 130 Veterans Affairs medical centers, United States, 2005–2017*

Infection characteristic	Overall change (%)	Average annual change (%)	p-value for trend
All *S. aureus* infections			
Total (MRSA and MSSA)	**-42.5**	**-4.7**	**<0.001**
Total MRSA	-54.6	-7.3	<0.001
Total MSSA	-12.2	-1.2	0.003
Hospital-onset *S. aureus* infections			
All hospital-onset	-70.2	-10.1	<0.001
MRSA	-65.7	-8.9	<0.001
MSSA	-18.7	-1.7	0.017
Bloodstream			
MRSA	-75.7	-11.8	<0.001
MSSA	-23.4	-2.2	0.357
Nonbloodstream			
MRSA	-64.1	-8.5	<0.001
MSSA	-18.8	-1.7	0.012
Community-onset *S. aureus* infections			
All community-onset	-27.5	-2.7	<0.001
MRSA	-40.6	-4.8	<0.001
MSSA	-0.4	-0.04	0.930
Bloodstream			
MRSA			
≤30 days postdischarge	-33.8	-3.8	0.022
31–365 days postdischarge	-15.2	-1.5	0.344
No discharge in last year	-11.1	-1.1	0.518
MSSA			
≤30 days postdischarge	-28.9	-3.1	0.139
31–365 days postdischarge	6.5	0.6	0.800
No discharge in last year	19.7	1.6	0.420
Nonbloodstream			
MRSA			
≤30 days postdischarge	-54.9	-7.2	<0.001
31–365 days postdischarge	-38.0	-4.4	<0.001
No discharge in last year	-36.5	-4.1	<0.001
MSSA			
≤30 days postdischarge	-0.1	-0.01	0.983
31–365 days postdischarge	10.5	0.9	0.159
No discharge in last year	0.6	0.06	0.916

Abbreviations: MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-susceptible *Staphylococcus aureus*.
* Based on multivariate analysis.

FIGURE 1. Rate* of *Staphylococcus aureus* infections among hospitalized patients, by methicillin resistance status — 130 Veterans Affairs medical centers, United States, 2005–2017



Abbreviations: MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-susceptible *Staphylococcus aureus*.
* Unadjusted.

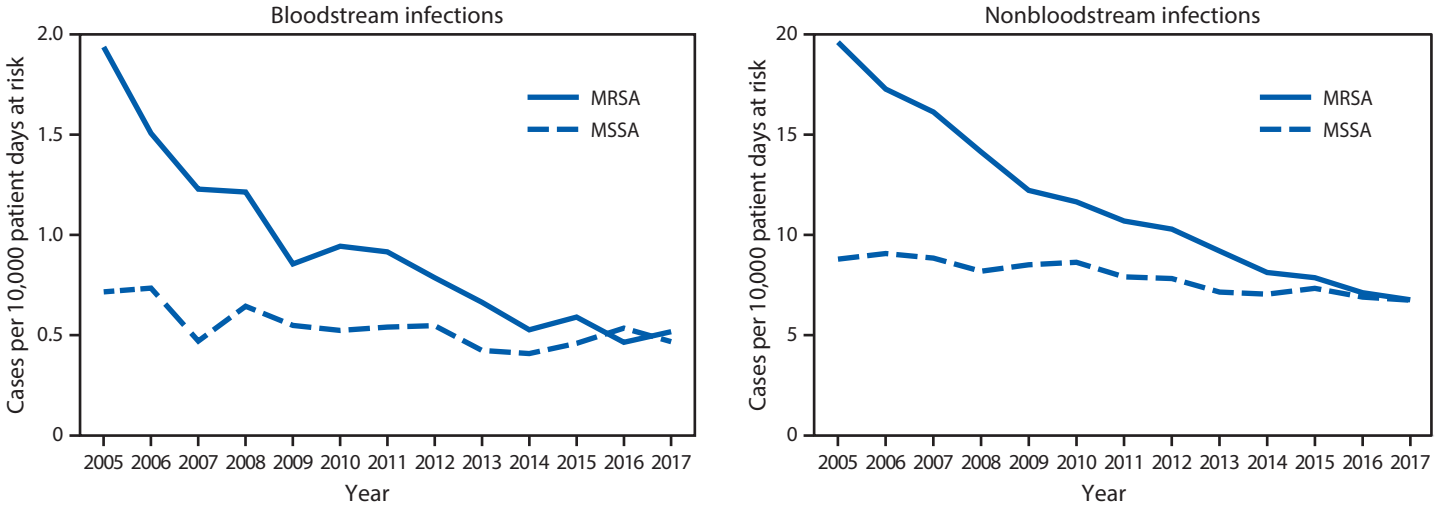
were more modest. Although the precise relationship between the observed trends and infection control interventions are difficult to demonstrate and likely complex, a careful examination of the potential mechanisms that could explain discordant MRSA and MSSA trends provides important insights for *S. aureus* prevention strategies.

One potential explanation for the discordant MSSA and MRSA trends is that the observed trends represent an artifact of differential detection bias, by which MRSA-infected patients would be progressively less likely than would MSSA-infected patients to have cultures obtained over the course of the study period. There is no obvious reason that likelihood of obtaining a diagnostic culture in patients with suspected infection would differ according to a provider's clinical suspicion of MSSA versus MRSA, and there was no change in rate of diagnostic cultures obtained over the study period, nor was there any difference in diagnostic culture rate based on admission MRSA carriage status.

A second potential explanation is that shifts in *S. aureus* epidemiology might have influenced the observed trends. It has been suggested that downward temporal trends in community-associated infections caused by community-associated MRSA strains (e.g., USA300) might explain decreases in health care–associated MRSA (*5*). Although strain data were not available for this analysis, data describing the national MRSA experience do not support this hypothesis. Population-based surveillance data from CDC's Emerging Infections Program show that although rates of health care–associated MRSA infection rates have been declining, community-associated MRSA rates have remained unchanged since 2005 (*6*). In addition, almost all MRSA reductions resulted from decreases in USA100, a strain associated with health care system transmission (*7*). Conversely, only modest reductions were observed in USA300, a strain associated with community transmission. In the absence of replacement by other strains, this suggests that successful interruption of MRSA transmission in health care settings is an important contributor to national trends.

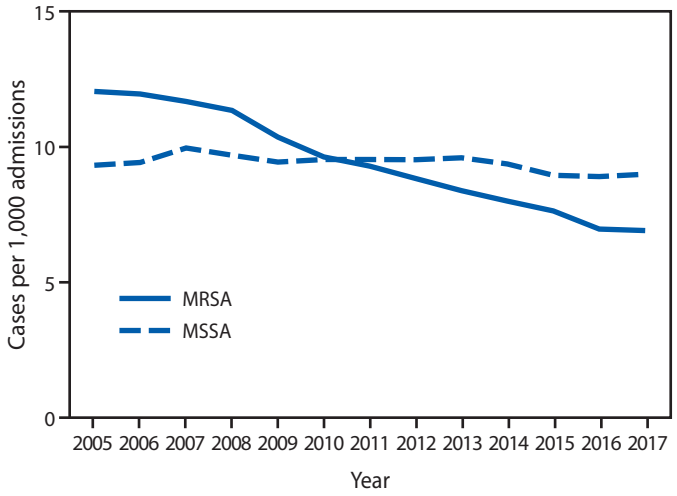
Infection control interventions might produce differential trends in MRSA and MSSA infection rates. Two broad approaches to preventing health care–associated infection include reducing the likelihood of invasive disease given colonization or exposure and decreasing transmission of pathogens (preventing infection by avoiding colonization or

FIGURE 2. Hospital-onset *Staphylococcus aureus* bloodstream and nonbloodstream infection rates,* by methicillin resistance status — 130 Veterans Affairs medical centers, United States, 2005–2017



Abbreviations: MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-susceptible *Staphylococcus aureus*.
* Unadjusted.

FIGURE 3. Community-onset *Staphylococcus aureus* infection rates,* by methicillin resistance status — 130 Veterans Affairs medical centers, United States, 2005–2017



Abbreviations: MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-susceptible *Staphylococcus aureus*.
* Unadjusted.

exposure in the first place). The VA system adopted both of these strategies. Similar to programs elsewhere, the VA system implemented bundled interventions designed to prevent device- and procedure-related infections (e.g., central line–associated bloodstream and surgical site infections). However, if such interventions were primarily responsible for the observed *S. aureus* trends, MSSA and MRSA rates would have been expected to have been affected approximately equally.

Other evidence also suggests decreased MRSA transmission as the primary mechanism for *S. aureus* reductions in VA hospitals. First, the discordance between MRSA and MSSA trends is consistent with mathematical modeling studies of health care transmission. Models predict that a decrease in overall transmission of bacterial pathogens in health care settings will result in disproportionately greater impact on strains having characteristics that provide a selective advantage for health care transmission, such as resistance to multiple antibiotics, including MRSA (*8*,*9*). Thus, the VA trends are consistent with decreased *S. aureus* transmission as the causative mechanism, regardless of whether improvements in infection control practices specifically targeted MRSA. Second, the rate of MRSA acquisition, a direct measure of MRSA transmission, decreased markedly during the course of the study. Third, reductions in hospital-onset MRSA infection were significantly greater among patients who were not carrying MRSA at the time of admission, suggesting that practices preventing acquisition of MRSA colonization had a greater impact than practices preventing progressing to infection among colonized patients. These findings are not consistent with the hypothesis that device- and procedure-associated prevention bundles, which are designed to prevent progression from colonization to infection, were primary drivers of *S. aureus* reduction in VA hospitals. Finally, the striking reductions in MRSA infection rates in the early postdischarge period are consistent with decreased acquisition during inpatient stays.

The mechanisms by which transmission was prevented are difficult to determine with precision, in part because multiple interventions were occurring simultaneously. It is highly plausible that the aggressive and targeted approach to preventing MRSA transmission (i.e., screening for MRSA carriage and implementation of contact precautions for all carriers)

contributed to the pronounced decrease in MRSA infections. However, the discordant MRSA/MSSA trends might also be explained by infection control practices that prevent transmission of all bacterial pathogens, but do not specifically target MRSA, such as hand hygiene. A sustained decline in gram-negative rod bloodstream infections in the VA system after implementation of the MRSA prevention program was also observed (*10*). However, it is likely that contact precautions for MRSA-colonized patients contributed to this trend: another VA study showed that 31% of patients with multidrug-resistant gram-negative bacteria would have been under contact precautions because of a positive MRSA screen (*11*). Changes in antibiotic use could have contributed as well. There is evidence that fluoroquinolone use is associated with increased MRSA colonization (*12*), and the reduction in fluoroquinolone use could contribute to selective reduction in MRSA because it is more commonly fluoroquinolone-resistant than is MSSA. The VA did observe a substantial reduction in fluoroquinolone use, but the fluoroquinolone reductions did not begin until 2009, after substantial MRSA reductions had already occurred.

The findings in this report are subject to at least five limitations. First, the patient population in VAMCs is predominately male, although it is not clear that this characteristic would affect these findings. Second, the models used in this analysis did not include data regarding adherence to infection control practices; including such data might have provided additional insight into which components of the intervention might have had the most impact. Third, information about MSSA colonization was lacking, making it difficult to characterize MSSA transmission dynamics. Fourth, no information on MRSA or MSSA strain characteristics was available. Finally, simple exponential trends improve interpretability but might not always closely reflect trends in complex systems.

The significant reduction in *S. aureus* infection observed across VAMCs, driven primarily by a decrease in MRSA infection rates, offers important insights that can inform national *S. aureus* prevention strategy. Although the causal relationship between specific components of the VA-wide infection control intervention and the reduction in infection rates is difficult to determine with precision, it seems likely that decreased MRSA transmission played a substantial role. These data suggest that recent calls to withdraw infection control interventions (*5*) designed to prevent MRSA transmission, such as use of contact precautions, might be premature and inadvisable, at least until more is known about effective control of bacterial pathogen transmission in health care settings. Adherence to CDC recommendations (*13*) for antimicrobial stewardship, preventing device- and procedure-associated infections and interrupting transmission of health care–prevalent strains (e.g., use of contact precautions for MRSA) continue to be a mainstay of *S. aureus* prevention.

Acknowledgments

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Update on Vaccine-Derived Poliovirus Outbreaks — Democratic Republic of the Congo and Horn of Africa, 2017–2018

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Widespread use of live attenuated (Sabin) oral poliovirus vaccine (OPV) has resulted in marked progress toward global poliomyelitis eradication (*1*). However, in underimmunized populations, extensive person-to-person transmission of Sabin poliovirus can result in genetic reversion to neurovirulence and paralytic vaccine-derived poliovirus (VDPV) disease (*1*). This report updates (as of February 26, 2019) previous reports on circulating VDPV type 2 (cVDPV2) outbreaks during 2017–2018 in the Democratic Republic of the Congo (DRC) and in Somalia, which experienced a concurrent cVDPV type 3 (cVDPV3) outbreak* (*2*,*3*). In DRC, 42 cases have been reported in four cVDPV2 outbreaks; paralysis onset in the most recent case was October 7, 2018 (*2*). Challenges to interrupting transmission have included delays in outbreak-response supplementary immunization activities (SIAs) and difficulty reaching children in all areas. In Somalia, cVDPV2 and cVDPV3 were detected in sewage before the detection of paralytic cases (*3*). Twelve type 2 and type 3 cVDPV cases have been confirmed; the most recent paralysis onset dates were September 2 (cVDPV2) and September 7, 2018 (cVDPV3). The primary challenge to interrupting transmission is the residence of >300,000 children in areas that are inaccessible for vaccination activities. For both countries, longer periods of surveillance are needed before interruption of cVDPV transmission can be inferred.

Vaccine-Derived Polioviruses

VDPV types 1 or 3 are polioviruses that are >1% divergent (≥10 nucleotide differences in the genetic sequence) from the corresponding Sabin OPV strain in the viral protein 1 (VP1) genomic coding region (*1*,*4*). VDPV2s are >0.6% divergent (≥6 nucleotide differences in the VP1 coding region) (*1*,*4*). When polioviruses replicate during transmission, nucleotide substitutions in the viral genome accumulate at approximately 1.1% (10 nucleotides of the VP1 coding region) per year, which can provide the means to determine how long a strain has been circulating. VDPVs are classified as circulating (cVDPVs) when community transmission is demonstrated by genetic linkages of VDPVs isolated from paralytic cases, community contacts, or environmental (sewage) samples (*4*).

2016 Global Switch from Trivalent OPV to Bivalent OPV

The type 2 component of trivalent OPV (tOPV) (containing vaccine virus types 1, 2, and 3) was responsible for >90% of cVDPV cases occurring during 2006–2015 (*5*–*7*). After the declaration of eradication of wild poliovirus type 2 in 2015 (*6*,*7*), a globally synchronized switch from tOPV to bivalent OPV (bOPV) (containing types 1 and 3) occurred in all OPV-using countries by May 1, 2016 (*6*,*7*). A single dose of inactivated poliovirus vaccine (IPV), which includes all three poliovirus serotypes, was introduced into routine immunization schedules in OPV-using countries to mitigate the risk for a gap in immunity to poliovirus type 2 (*6*). Children who seroconvert after IPV administration are protected from paralytic disease but still can contribute to the transmission of poliovirus. Monovalent type 2 OPV (mOPV2) is held in a global stockpile for implementation of outbreak response SIAs for poliovirus type 2 outbreaks after the switch (*8*).

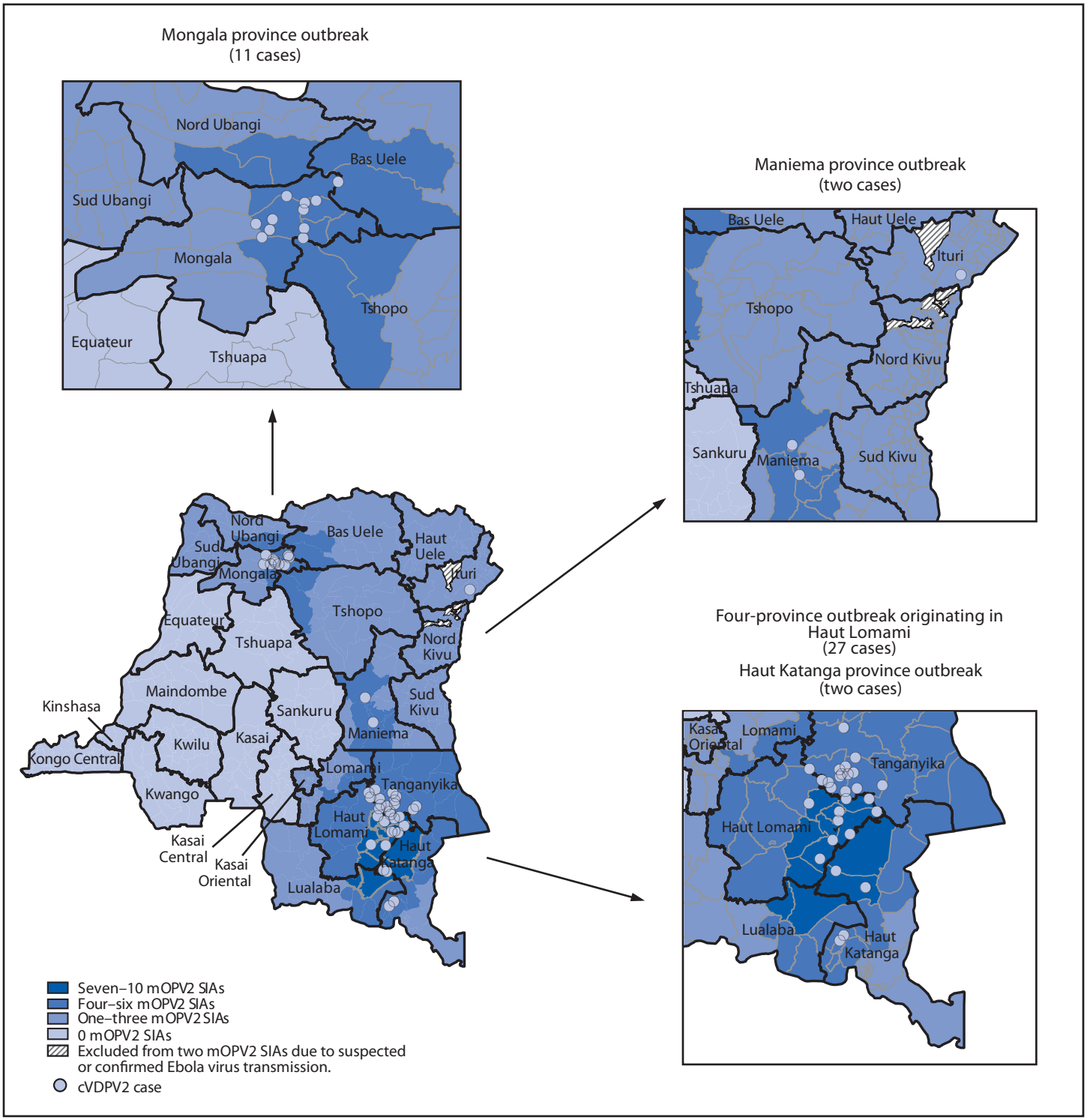
cVDPV2 Outbreaks in the Democratic Republic of the Congo

Maniema province outbreak (two cases): The first patient in this outbreak had paralysis onset on March 26, 2017, and the second had paralysis onset on April 18, 2017 (*2*). Genetic analyses of the cVDPV2 isolates identified a 7-nucleotide difference from the Sabin type 2 strain, suggesting recent emergence. After the onset of the most recent case, four to five mOPV2 supplementary immunization activities (SIAs) were conducted in the health zones (subprovince areas) nearest to the identified cases and two in the remainder of the province (Figure 1).

Four-province outbreak originating in Haut Lomami (27 cases): The first patient had paralysis onset on February 20, 2017, in Haut Lomami province; the VDPV2 isolate from this case had a 15-nucleotide difference from Sabin 2, indicating >1 year of undetected circulation. Subsequent to this case, 26 additional cases with genetically linked cVDPV2 isolates were

* Because of the outbreak in DRC, on July 19, 2017, CDC issued a Level 2 Travel Health Notice recommending that all travelers to the DRC be fully vaccinated against polio. A similar notice was issued for Somalia on July 23, 2018. Before traveling to the DRC or Somalia, adults who completed their routine polio vaccine series as children are advised to receive a single, lifetime adult booster of polio vaccine.

FIGURE 1. Circulating vaccine-derived poliovirus type 2 (cVDPV2) cases, as of February 26, 2019, by location and number of response supplementary immunization activities (SIAs) with monovalent poliovirus vaccine type 2 (mOPV2) — Democratic Republic of the Congo, 2017–2018*



* Each dot represents one confirmed paralytic cVDPV2 case. Dots are randomly positioned within health zones and do not represent exact locations where cases occurred.

identified, with paralysis onset from March 8, 2017, to May 27, 2018, in Haut Lomami province (eight cases), in two adjacent provinces (Haut Katanga [two] and Tanganyika [15]), and in Ituri province in northeastern DRC (one). In response to these cases, up to 10 mOPV2 SIAs were conducted in the outbreak area; three mOPV2 SIAs were conducted in the broader outbreak area after the onset of the most recent case (Figure 1) (*2*). The isolate from the Ituri patient was genetically linked to the Haut Lomami outbreak area; however, no epidemiologic link was established. Up to three mOPV2 SIAs were conducted after the onset of the single case in Ituri province, except in health zones where Ebola virus transmission had been confirmed or suspected in 2018 (*9*).

Mongala province outbreak (11 cases): The first case of paralysis onset associated with this outbreak occurred on April 26, 2018, and the patient's VDPV2 isolate had a 19-nucleotide difference from Sabin 2, indicating nearly 2 years of undetected circulation. Ten additional cases with genetically linked viruses were reported, with paralysis onset during June 14–September 13, 2018. Four mOPV2 SIAs were conducted in health zones with identified cases and two to four in the remainder of Mongala and neighboring provinces; two mOPV2 SIAs have been conducted in the entirety of the outbreak area after the onset of the most recent case (Figure 1).

Haut Katanga province outbreak (two cases): In this outbreak, the first patient had paralysis onset on October 6, 2018, and the second on October 7. The VDPV2 isolates had 7- and 8-nucleotide differences from the Sabin 2 strain, indicating emergence in 2018 after use of mOPV2 for SIAs in response to the Haut Lomami area outbreak, with suboptimal coverage achieved. Two SIAs were conducted after the onset of these cases (Figure 1).

cVDPV2 and cVDPV3 Outbreaks in the Horn of Africa

Environmental surveillance, the testing of sewage samples for polioviruses, detected genetically linked cVDPV2 in samples taken from two different environmental surveillance sites in Banadir province, Somalia, in October 2017 and January 2018 and genetically linked cVDPV3 from two different sites in April 2018. Genetic analyses of the viruses indicated undetected circulation of cVDPV2 for >3 years (36–44-nucleotide differences from Sabin 2) and of cVDPV3 for >1 year (15–17-nucleotide differences from Sabin 3) (*3*). No genetically linked paralytic cVDPV cases were detected until a coinfection with cVDPV2 and cVDPV3 was identified in a patient from the central province of Hiran, with paralysis onset on May 11, 2018 (Figure 2) (*3*). As of January 31, 2019, a total of 12 cVDPV cases had been identified in Somalia: five cVDPV2 cases, six cVDPV3 cases, and the cVDPV2/cVDPV3 coinfection (Figure 2) (Figure 3). The most recent paralysis onsets occurred on September 2 (cVDPV2) and September 7, 2018 (cVDPV3). Three patients resided in districts that were inaccessible for polio vaccination for >5 years, and none had ever received OPV.

Twenty-one sewage samples from environmental surveillance sites in Banadir province tested positive for genetically linked cVDPV2, the most recent collected on October 11, 2018. One sewage sample collected in Kamakunji district, Kenya, in March 2018 tested positive for cVDPV2 genetically linked to strains circulating in Somalia (*3*); however, no cVDPV2 cases were detected in Kenya. Genetically linked cVDPV3 isolates were identified in 12 sewage samples from Banadir province, the most recent collected on August 23, 2018. No cVDPV3 isolates have been detected by environmental or acute flaccid paralysis (AFP) surveillance in Kenya, and neither cVDPV2 nor cVDPV3 has been detected in Ethiopia.

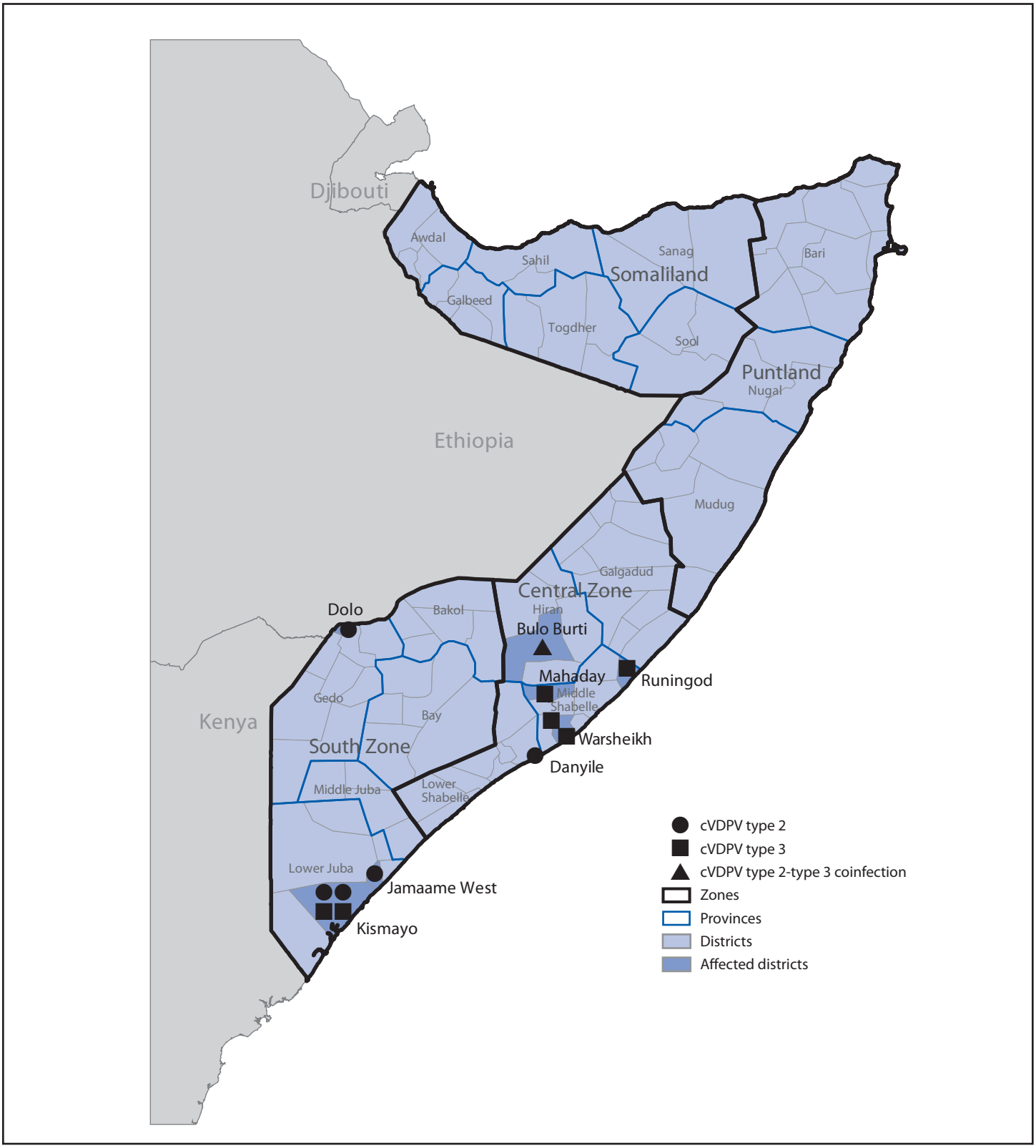
In response to the Horn of Africa cVDPV2 outbreak, six mOPV2 outbreak response SIAs were conducted in Somalia during December 2017–November 2018, including two conducted after the most recent case onset. Two of these SIAs were synchronized with subnational mOPV2 outbreak response SIAs in Kenya and Ethiopia during July–September 2018. Before that, when cVDPV2 was identified by environmental surveillance in Kenya, a focal mOPV2 outbreak response SIA was conducted in Kamakunji district in May 2018.

After cVDPV3 detection in Somalia, three bOPV outbreak response SIAs were conducted there during April–October 2018, two of which were synchronized with subnational bOPV SIAs in Kenya during September–October 2018. Both SIAs were implemented after paralysis onset of the most recent cVDPV3 case in Somalia.

Discussion

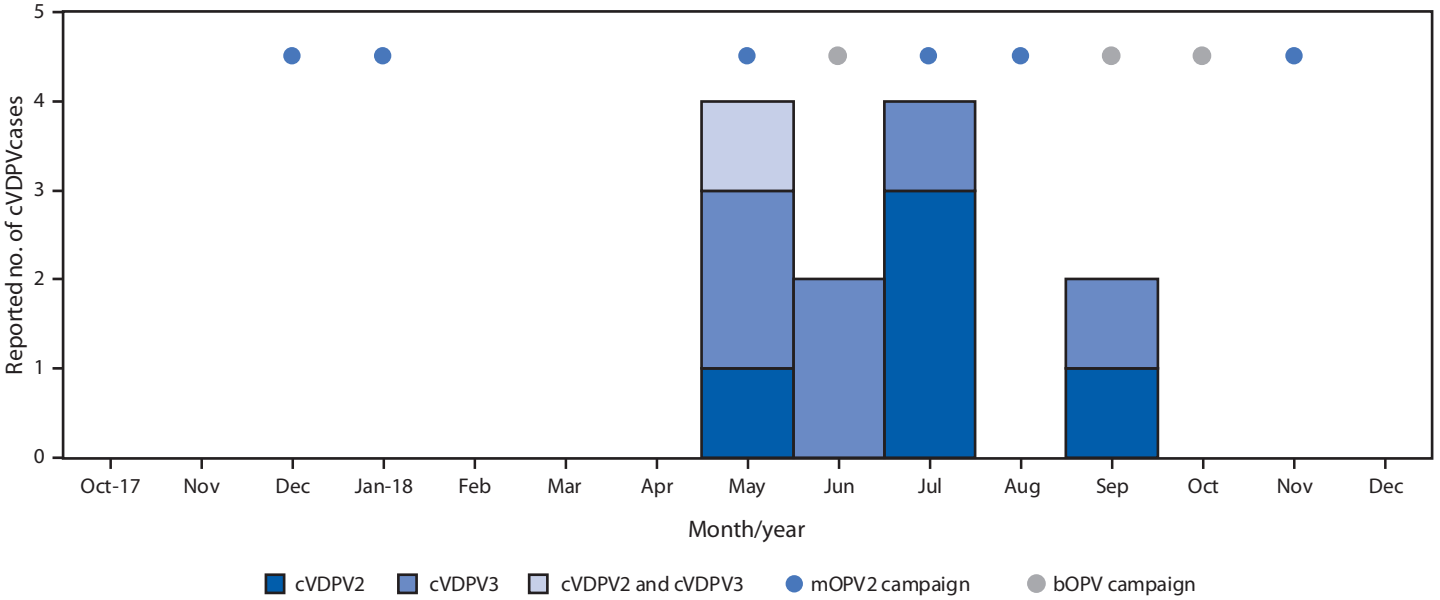
During 2005–2013, multiple cVDPV2 outbreaks occurred in DRC and Somalia (*2*,*10*). Because of chronically low childhood routine immunization coverage in both countries, preventive tOPV SIAs were implemented annually to boost immunity before the tOPV/bOPV switch in 2016 (*2*,*10*). The cVDPV outbreaks during 2017–2018 indicate that children residing in the outbreak-affected areas were not effectively reached with tOPV before the switch (and for type 3, with bOPV after the switch) through childhood routine immunization services or preventive SIAs. After the tOPV/bOPV switch, preventive SIAs using tOPV can no longer be implemented; although IPV can provide protection from paralytic disease to infected children who have received it, low routine immunization coverage precluded IPV serving as a substantive means of preventing cVDPV cases in both countries. In addition to DRC and Somalia, cVDPV2 outbreaks also were

FIGURE 2. Circulating vaccine-derived poliovirus (cVDPV) type 2 and type 3 cases, as of February 26, 2019, by location — Somalia, 2018*



* Each symbol represents one confirmed paralytic cVDPV case. Symbols are randomly positioned within districts and do not represent exact locations where cases occurred.

FIGURE 3. Circulating vaccine-derived poliovirus (cVDPV) cases and outbreak response supplementary immunization activities, by month — Somalia, 2017–2018



Abbreviations: bOPV = bivalent oral poliovirus vaccine (types 1 and 3); cVDPV2 = circulating vaccine-derived poliovirus type 2; cVDPV3 = circulating vaccine-derived poliovirus type 3; mOPV2 = monovalent oral poliovirus vaccine (type 2).

identified during 2017–2018 in Mozambique, Niger, Nigeria, and Syria. Although improving delivery of bOPV through routine immunization services would prevent cVDPV1 or cVDPV3 outbreaks, this would require considerable time, effort, and resources. Preventive bOPV SIAs can raise population immunity more quickly in countries and areas with low routine immunization coverage.

cVDPV2 transmission in the DRC outbreaks might have ceased; however, a longer period of surveillance is needed before interruption of transmission can be inferred. Because of serious limitations in mOPV2 SIA quality (i.e., low population coverage), delays in SIA implementation, and a smaller geographic scope than that needed for some SIAs, many more SIAs were needed to achieve apparent interruption of transmission than are usually required. As well, when SIA coverage in the target population is low, there is a risk that the mOPV2 response SIAs themselves will seed new cVDPV2 outbreaks; in DRC, the Haut Katanga outbreak resulted from suboptimal outbreak response SIAs for the Haut Lomami area outbreak.

In Somalia, AFP surveillance performance indicators have been met, even in insecure areas where community-based surveillance is conducted. However, undetected cVDPV2 and cVDPV3 transmission for approximately 1–3 years indicates high likelihood that the emergence and circulation of VDPVs occurred among unimmunized children residing in inaccessible areas. To extend the reach of the outbreak response as much as possible, outbreak response SIAs included vaccination of children living in inaccessible areas when they were at transit points (e.g., bus stations) and at markets, and rapid response vaccination in a few areas where children were not usually accessible for vaccination. However, >300,000 unimmunized children are estimated to reside in these areas. An extended period of AFP surveillance and environmental surveillance will be needed to indicate that cVDPV transmission has been interrupted in Somalia.

In both countries, if additional response is required, programs need to ensure the quality and reach of timely SIAs. The continued use of aggressive strategies, such as transit-point vaccination, to reach underimmunized populations, should be considered.

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Summary

What is already known about this topic?

Prolonged person-to-person transmission of polio vaccine viruses in underimmunized populations can lead to emergence of outbreaks of paralysis from circulating vaccine-derived poliovirus (cVDPV).

What is added by this report?

During 2017–2018, four cVDPV type 2 outbreaks, with 42 cases to date, occurred in six provinces of the Democratic Republic of the Congo and required multiple response supplementary immunization activities (SIAs). In Somalia, concurrent cVDPV type 2 and cVDPV type 3 outbreaks occurred, first identified by sewage testing months before occurrence of 12 paralytic cases to date.

What are the implications for public health practice?

To promptly interrupt cVDPV transmission, country programs must effectively plan and implement timely response SIAs to optimize their quality and reach.

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All authors have completed and submitted the ICMJE form for disclosure of potential conflicts of interest. No potential conflicts of interest were disclosed.

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Notes from the Field

Tetanus in an Unvaccinated Child — Oregon, 2017

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Tetanus is an acute neuromuscular disease caused by the bacterium *Clostridium tetani*. Bacterial spores found in soil can enter the body through skin disruption, with subsequent onset of clinical illness ranging from 3 to 21 days (usually within 8 days). In 2017, a boy aged 6 years who had received no immunizations sustained a forehead laceration while playing outdoors on a farm; the wound was cleaned and sutured at home. Six days later, he had episodes of crying, jaw clenching, and involuntary upper extremity muscle spasms, followed by arching of the neck and back (opisthotonus) and generalized spasticity. Later that day, at the onset of breathing difficulty, the parents contacted emergency medical services, who air-transported him directly to a tertiary pediatric medical center. The boy subsequently received a diagnosis of tetanus and required approximately 8 weeks of inpatient care, followed by rehabilitation care, before he was able to resume normal activities.

Upon hospital arrival, the child had jaw muscle spasms (trismus). He was alert and requested water but was unable to open his mouth; respiratory distress caused by diaphragmatic and laryngeal spasm necessitated sedation, endotracheal intubation, and mechanical ventilation. Tetanus immune globulin (3,000 units) and diphtheria and tetanus toxoids and acellular pertussis vaccine (DTaP) were administered for presumed tetanus. He was admitted to the pediatric intensive care unit and cared for in a darkened room with ear plugs and minimal stimulation (stimulation increased the intensity of his spasms). Intravenous metronidazole was initiated, and the scalp laceration was irrigated and debrided.

His opisthotonus worsened, and he developed autonomic instability (hypertension, tachycardia, and body temperatures of 97.0°F–104.9°F [36.1°C–40.5°C]). He was treated with multiple continuous intravenous medication infusions to control his pain and blood pressure, and with neuromuscular blockade to manage his muscle spasms. A tracheostomy was placed on hospital day 5 for prolonged ventilator support. Starting on hospital day 35, the patient tolerated a 5-day wean from neuromuscular blockade. On day 44, his ventilator support was discontinued, and he tolerated sips of clear liquids. On day 47, he was transferred to the intermediate care unit. Three days later, he walked 20 feet with assistance. On day 54, his tracheostomy was removed, and 3 days later, he was transferred to a rehabilitation center for 17 days.

The boy required 57 days of inpatient acute care, including 47 days in the intensive care unit. The inpatient charges totaled $811,929 (excluding air transportation, inpatient rehabilitation, and ambulatory follow-up costs). One month after inpatient rehabilitation, he returned to all normal activities, including running and bicycling. Despite extensive review of the risks and benefits of tetanus vaccination by physicians, the family declined the second dose of DTaP and any other recommended immunizations.

This is the first pediatric tetanus case in >30 years in Oregon (unpublished data, Oregon Health Authority, 2018). The diagnosis of tetanus is made based on clinical findings because the bacterium *C. tetani* is difficult to grow from wounds. A wound culture from the child's laceration did not grow *C. tetani*. However, a negative wound culture does not rule out disease. The health care costs to treat this child's preventable disease were approximately 72 times the mean (2012) cost of $11,143 for a U.S. pediatric hospitalization (*1*). A recent report describing adult tetanus cases included hospital charges ranging from $22,229 to $1,024,672 (*2*).

Widespread use of tetanus toxoid–containing vaccines (tetanus toxoid inactivated vaccine or a combination vaccine that contains tetanus toxoid) and tetanus immune globulin for wound management has led to a 95% decline in the number of tetanus cases and a 99% decrease in the number of tetanus-related deaths since the 1940s (*3*). From 2009 to 2015, 197 tetanus cases and 16 tetanus-associated deaths were reported in the United States (*4*). Unvaccinated or inadequately vaccinated persons are at risk for tetanus, irrespective of age, and recovery from tetanus disease does not confer immunity (*5*).

Routine administration of a 5-dose DTaP series is recommended for all eligible children at 2, 4, and 6 months of age, then a dose at 15–18 months of age, and a fifth dose at 4–6 years of age. Booster doses of diphtheria and tetanus toxoids are recommended every 10 years throughout life (*4*). Uninsured or underinsured eligible children may receive vaccines at no cost through the Vaccine For Children program (https://www.cdc.gov/vaccines/programs/vfc/index.html). Resources to assist health care providers in discussing vaccination with their patients, including how to address questions, are available online (https://www.cdc.gov/vaccines/partners/childhood/professionals.html).

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In the report "Update: Recommendations of the Advisory Committee on Immunization Practices for Use of Hepatitis A Vaccine for Postexposure Prophylaxis and for Preexposure Prophylaxis for International Travel," errors occurred in Table 1. The corrected Table 1 is below.

TABLE 1. Recommendations for postexposure prophylaxis and preexposure protection, by age group and risk category

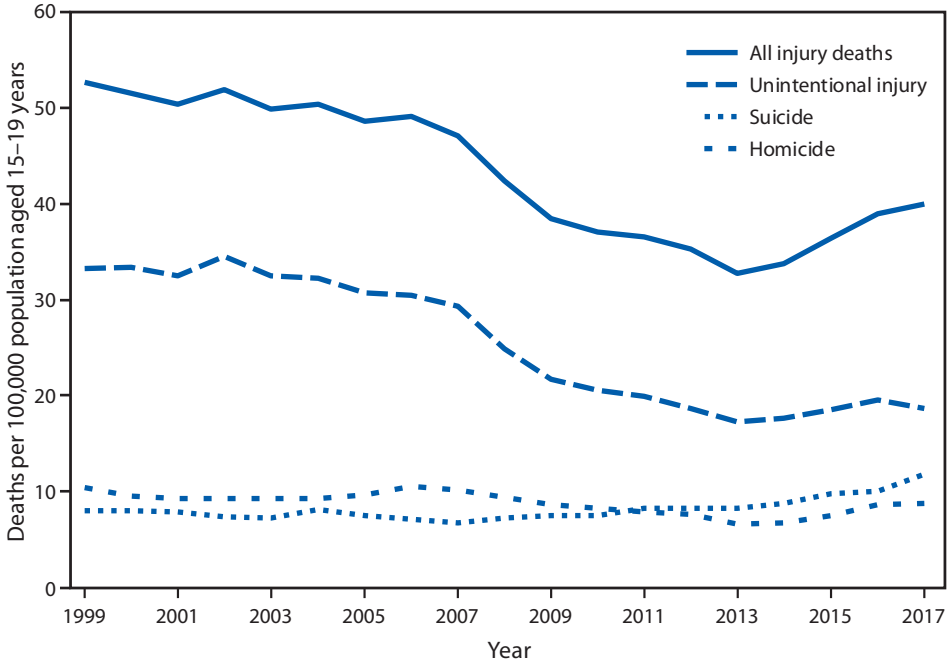
Indication/ Age group	Risk category/ Health status	Hepatitis A vaccine	Immune globulin
Postexposure prophylaxis			
<12 mos	Healthy	No	0.1 mL/**kg**
12 mos–40 yrs	Healthy	1 dose†	None
>40 yrs	Healthy	1 dose†	0.1 mL/kg§
≥12 mos	Immunocompromised or chronic liver disease	1 dose†	0.1 mL/kg¶
≥12 mos	Vaccine contraindicated**	No	0.1 mL/kg
Preexposure protection††			
<6 mos	Healthy	No	0.1–0.2 mL/kg§§
6–11 mos	Healthy	1 dose¶¶	None
12 mos–40 yrs	Healthy	1 dose***	None
>40 yrs	Healthy	1 dose***	0.1–0.2 mL/kg§§,†††
>6 mos	Immunocompromised or chronic liver disease	1 dose***	0.1–0.2 mL/kg§§,†††
>6 mos	Persons who elect not to receive vaccine or for whom vaccine is contraindicated	No	0.1–0.2 mL/kg§§

* Measles, mumps, and rubella vaccine should not be administered for at least 3 months after receipt of immune globulin.
† A second dose is not required for postexposure prophylaxis; however, for long-term immunity, the hepatitis A vaccination series should be completed with a second dose at least 6 months after the first dose.
§ The provider's risk assessment should determine the need for immune globulin administration. If the provider's risk assessment determines that both vaccine and immune globulin are warranted, Hepatitis A vaccine and immune globulin should be administered simultaneously at different anatomic sites.
¶ Vaccine and immune globulin should be administered simultaneously at different anatomic sites.
** Life-threatening allergic reaction to a previous dose of hepatitis A vaccine, or allergy to any vaccine component.
†† Immune globulin should be considered before travel for persons with special risk factors for either hepatitis A virus (HAV) infection or increased risk for complications in the event of exposure to HAV.
§§ 0.1 mL/kg for travel up to 1 month; 0.2 mL/kg for travel up to 2 months, 0.2 mL/kg every 2 months for travel of ≥2 months' duration.
¶¶ This dose should not be counted toward the routine 2-dose series, which should be initiated at age 12 months.
*** For persons not previously vaccinated with HepA vaccine, administer dose as soon as travel is considered, and complete series according to routine schedule.
††† May be administered, based on providers' risk assessment.

QuickStats

FROM THE NATIONAL CENTER FOR HEALTH STATISTICS

Injury Death Rates* for Persons Aged 15–19 Years, by Intent — United States, 1999–2017



* Injury deaths are those identified with *International Classification of Diseases, Tenth Revision* (ICD-10) codes V01–Y36, Y85–Y87, Y89, and U01–U03. Unintentional injury deaths are identified with ICD-10 codes V01–X59 and Y85–Y86; suicide with ICD-10 codes X60–X84, Y87.0, and U03; and homicides with ICD-10 codes X85–Y09, Y87.1, and U01–U02.

The injury death rate for persons aged 15–19 years declined from 52.7 per 100,000 in 1999 to 32.8 in 2013 but then increased to 40.0 in 2017. Homicide, suicide, and unintentional injury rates have all declined since 1999, with suicide rates beginning to increase in 2008 and homicide rates increasing in 2014. There was not a clear pattern for unintentional injury from 2013 to 2017. Throughout the period, the death rate for unintentional injury was higher than for suicide and homicide, but the difference has narrowed over the past decade. In 2017, the death rate for unintentional injury was 18.7, for suicide was 11.8, and for homicide was 8.7.

Source: National Vital Statistics System. Underlying cause of death data, 1999–2017. https://wonder.cdc.gov/ucd-icd10.html.

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For more information on this topic, CDC recommends the following link: https://www.cdc.gov/injury/.

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