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## Incidence of Measles in the United States, 2001–2015

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Through nationwide use of vaccination, endemic measles (ie, a transmission chain lasting 12 months or longer) was eliminated in the United States in 2000.<sup>1</sup> Yet, importations of measles from endemic countries continue to occur, leading to outbreaks.<sup>2</sup> We describe the incidence of measles among US residents and examine temporal trends after elimination.

### Methods

Measles is nationally notifiable and clinician reporting to health departments is mandatory in every state. Cases are investigated and classified according to standard case definitions<sup>3</sup> by state health departments and reported to the US Centers for Disease Control and Prevention (CDC). Reports of all confirmed cases in the United States from January 2001-December 2015 were analyzed, including available information on age, vaccination, and importation status. Age-specific and yearly incidence rates were calculated by dividing the number of cases by corresponding population estimates.<sup>4</sup> Changes in incidence over time were evaluated using negative binomial regression models. Patients were considered vaccinated if they had documented receipt of 1 or more doses of a measles-containing vaccine. Internationally imported cases had an exposure period outside the United States (7–21 days before rash onset) and rash onset within 21 days of entry into the country. Trends in the proportion of cases that were imported and vaccinated were evaluated by Cochran-Armitage tests. Analyses of incidence and vaccination status were restricted to US residents so census data could be used and to assess US-based vaccine recommendations; analyses of importation status were based on all reported cases, including foreign visitors. Analyses were conducted using SAS (SAS Institute), version 9.3. Statistical significance was defined

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**Author Contributions:** Ms Clemmons had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

*Concept and design:* Clemmons, Gastañaduy.

*Acquisition, analysis, or interpretation of data:* All authors.

*Drafting of the manuscript:* Clemmons.

*Critical revision of the manuscript for important intellectual content:* All authors. *Statistical analysis:* Clemmons.

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**Disclaimer:** The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the US Centers for Disease Control and Prevention (CDC).

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as a 2-sided *P* value of less than .05. The CDC determined the study was exempt from review.

## Results

From 2001 through 2015, 1789 measles cases were reported among US residents (median age, 15 years [range, 0–89]; female, 47.1%). Most were unvaccinated (1243 patients [69.5%]) or had unknown vaccination status (316 patients [17.7%]); in those 30 years or older, 48.1% had unknown vaccination status (Table 1). Overall, 535 of 2012 measles cases (26.6%) were imported; 1477 (73.4%) were acquired in the United States.

Measles incidence was 0.39 (95% CI, 0.37–0.41) per million population. Incidence per million population was highest in infants aged 6 to 11 months (5.44 [95% CI, 4.67–6.34]) and toddlers aged 12 to 15 months (5.38 [95% CI, 4.45–6.51]). Measles rates declined with age beginning at 16 months.

The annual number of measles cases varied between 24 and 658, and incidence per million population varied between 0.08 (95% CI, 0.05–0.12) and 2.06 (95% CI, 1.91–2.22) (Table 2). Higher incidence per million population was noted over time, from 0.28 (95% CI, 0.22–0.35) in 2001 to 0.56 (95% CI, 0.48–0.65) in 2015 (*P* < .001). The proportion of cases that were imported and vaccinated also varied by year but decreasing trends were observed. Imported cases ranged between 9.5% and 73.0% of all cases and decreased from 46.6% (95% CI, 37.2%–56.1%) in 2001 to 14.7% (95% CI, 10.0%–20.5%) in 2015 (*P* < .001). Vaccinated patients ranged between 5.5% and 29.6% of US cases and decreased from 29.6% (95% CI, 20.0%–40.8%) in 2001 to 20.2% (95% CI, 14.6%–26.9%) in 2015 (*P* < .001).

## Discussion

The annual incidence of measles in the United States remained extremely low (<1 case/million population), in line with the absence of indigenous transmission<sup>5</sup> and compared with incidence worldwide (40 cases/million population).<sup>6</sup> Relative increases in measles rates were observed over the period. Ten of 13 outbreaks with 20 or more cases occurred after 2010.<sup>1,2</sup> The concurrent increase in incidence and declines in the proportion of imported and vaccinated cases (signifying relative increases in US-acquired and unvaccinated cases) may suggest increased susceptibility and transmission after introductions in certain subpopulations. Given modest changes and year-to-year variability, cautious interpretation is warranted.

The declining incidence with age, the high proportion of unvaccinated cases, and the decline in the proportion of vaccinated cases despite rate increases suggest that failure to vaccinate, rather than failure of vaccine performance, may be the main driver of measles transmission, emphasizing the importance of maintaining high vaccine coverage.

Limitations include lack of verifiable immunization on 48% of adults and the possibility of reporting changes, although sustained surveillance adequacy has been documented.<sup>1</sup> Concerns about susceptibility pockets underscore the need for continued surveillance and rapid containment strategies.

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Vaccination Status of Measles Cases and Crude Measles Incidence Rate (IR) by Age Group in the United States, 2001–2015

**Table 1**

Age Group	No. of Measles Cases <sup>a</sup>	Vaccination Status, No. (%) <sup>b</sup>			Annual IR per Million Population (95% CI)
		Unvaccinated	Vaccinated	Unknown	
0–5 mo	31	31 (100.0)	0	0	1.03 (0.73–1.47)
6–11 mo	163	161 (98.8)	2 (1.2)	0	5.44 (4.67–6.34)
12–15 mo	106	95 (89.6)	7 (6.6)	4 (3.8)	5.38 (4.45–6.51)
16 mo–4 y	214	164 (76.6)	36 (16.8)	14 (6.5)	0.98 (0.86–1.12)
5–17 y	464	406 (87.5)	36 (7.8)	22 (4.7)	0.58 (0.53–0.63)
18–29 y	362	235 (64.9)	67 (18.5)	60 (16.6)	0.48 (0.43–0.53)
30–49 y	366	114 (31.1)	80 (21.9)	172 (47.0)	0.29 (0.26–0.32)
50 y	81	36 (44.4)	2 (2.5)	43 (53.1)	0.06 (0.05–0.07)
<b>Overall<sup>c</sup></b>	<b>1789</b>	<b>1243 (69.5)</b>	<b>230 (12.9)</b>	<b>316 (17.7)</b>	<b>0.39 (0.37–0.41)</b>

<sup>a</sup> Foreign visitors (n = 220) and patients with unknown residency status (n = 3) were excluded, allowing for the use of US census data and to assess US-based vaccine recommendations.

<sup>b</sup> One or more doses of a measles-containing vaccine.

<sup>c</sup> For 2 cases, age was missing, 1 was unvaccinated and 1 had an unknown vaccination status.

**Table 2**  
 Importation and Vaccination Status of Measles Cases and Crude Measles Incidence Rate (IR) by Year in the United States, 2001–2015

Year	No. of Measles Cases <sup>a</sup>	No. Imported Measles Cases <sup>a,b</sup>	Imported Cases, % (95% CI) <sup>a,b</sup>	No. of US-Resident Cases <sup>c</sup>	No. of Vaccinated Cases <sup>c,d</sup>	Vaccinated Patients, % (95% CI) <sup>c,d</sup>	Annual IR per Million Population (95% CI) <sup>e</sup>
2001	116	54	46.6 (37.2–56.1)	81	24	29.6 (20.0–40.8)	0.28 (0.22–0.35)
2002	44	18	40.9 (26.3–56.8)	36	5	13.9 (4.7–29.5)	0.13 (0.09–0.17)
2003	56	24	42.9 (29.7–56.8)	38	9	23.7 (11.4–40.2)	0.13 (0.10–0.18)
2004	37	27	73.0 (55.9–86.2)	24	4	16.7 (4.7–37.4)	0.08 (0.05–0.12)
2005	66	24	36.4 (24.9–49.1)	59	7	11.9 (4.9–22.9)	0.20 (0.15–0.26)
2006	55	31	56.4 (42.3–69.7)	42	11	26.2 (13.9–42.0)	0.14 (0.10–0.19)
2007	43	29	67.4 (51.5–80.9)	31	7	22.6 (9.6–41.1)	0.10 (0.07–0.15)
2008	140	25	17.9 (11.9–25.2)	127	7	5.5 (2.2–11.0)	0.42 (0.35–0.50)
2009	72	21	29.2 (19.1–41.1)	65	8	12.3 (5.5–22.8)	0.21 (0.17–0.27)
2010	63	39	61.9 (48.8–73.9)	47	6	12.8 (4.8–25.7)	0.15 (0.11–0.20)
2011	220	80	36.4 (30.0–43.1)	196	29	14.8 (10.1–20.6)	0.63 (0.55–0.72)
2012	55	21	38.2 (25.4–52.3)	43	11	25.6 (13.5–41.2)	0.14 (0.10–0.18)
2013	187	51	27.3 (21.0–34.3)	164	13	7.9 (4.3–13.2)	0.52 (0.44–0.60)
2014	667	63	9.5 (7.3–11.9)	658	53	8.1 (6.1–10.4)	2.06 (1.91–2.22)
2015	191	28	14.7 (10.0–20.5)	178	36	20.2 (14.6–26.9)	0.56 (0.48–0.65)
<b>Overall</b>	<b>2012</b>	<b>535</b>	<b>26.6 (24.7–28.6)</b>	<b>1789</b>	<b>230</b>	<b>12.8 (11.4–14.5)</b>	<b>0.39 (0.37–0.41)</b>

<sup>a</sup>All measles cases and imported measles cases reported in the United States are included (ie, US residents, foreign visitors, and patients with unknown residency status).

<sup>b</sup>Internationally imported cases had an exposure period outside the United States (7–21 d before rash onset) and rash onset within 21 d of entry into the United States.

<sup>c</sup>Foreign visitors (n = 220) and patients with unknown residency status (n = 3) were excluded, allowing for the use of US census data and to assess US-based vaccine recommendations.

<sup>d</sup>One or more doses of a measles-containing vaccine.