Title

The economic burden of sixteen measles outbreaks on United States public health departments in 2011

Journal

Vaccine, 32(11)

ISSN

0264-410X

Authors

Ortega-Sanchez, Ismael R
Vijayaraghavan, Maya
Barskey, Albert E
et al.

Publication Date

2014-03-01

DOI

10.1016/j.vaccine.2013.10.012

Peer reviewed

Vaccine 32 (2014) 1311–1317

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

The economic burden of sixteen measles outbreaks on United States public health departments in 2011

Ismael R. Ortega-Sanchez*, Maya Vijayaraghavan[1], Albert E. Barskey, Gregory S. Wallace

Centers for Disease Control and Prevention (CDC), National Center for Immunization and Respiratory Diseases, 1600 Clifton Road, Ne MS-A-34, Atlanta, GA 30333, USA

ARTICLE INFO

Article history:
Received 10 April 2013
Received in revised form 28 August 2013
Accepted 2 October 2013
Available online 14 October 2013

Keywords:
Measles outbreak
Costs
Public health

ABSTRACT

Background: Despite vaccination efforts and documentation of elimination of indigenous measles in 2000, the United States (US) experienced a marked increase in imported cases and outbreaks of measles in 2011. Due to the high infectiousness and potential severity of measles, these outbreaks require a vigorous response from public health institutions. The effort and resources required to respond to these outbreaks are likely to impose a significant economic burden on these institutions.
Objective: To estimate the economic burden of measles outbreaks (defined as ≥3 epidemiologically linked cases) on the local and state public health institutions in the US in 2011.
Methods: From the perspective of local and state public health institutions, we estimated personnel time and resources allocated to measles outbreak response in local and state public health departments, and estimated the corresponding costs associated with these outbreaks in the US in 2011. We used cost and resource utilization data from previous studies on measles outbreaks in the US and, relying on outbreak size classification based on a case-day index, we estimated costs incurred by local and state public health institutions.
Results: In 2011, the US experienced 16 outbreaks with 107 confirmed cases. The average duration of an outbreak was 22 days (range: 5–68). The total estimated number of identified contacts to measles cases ranged from 8936 to 17,450, requiring from 42,635 to 83,133 personnel hours. Overall, the total economic burden on local and state public health institutions that dealt with measles outbreaks during 2011 ranged from an estimated $2.7 million to $5.3 million US dollars.
Conclusion: Investigating and responding to measles outbreaks imposes a significant economic burden on local and state health institutions. Such impact is compounded by the duration of the outbreak and the number of potentially susceptible contacts.

1. Introduction

Since the elimination of indigenous measles from the United States (US) was documented in 2000, relatively low numbers of cases per year (average of 71 cases, range 37–140) were reported during this decade [1]. However, in 2011 the country experienced a marked increase in measles cases and outbreaks [2,3]. All initial measles cases in these outbreaks were import-associated [2], defined as meeting one or more of the following criteria, measles cases were imported from other countries, were epidemiologically linked to importations, had viral genetic evidence of an imported genotype, or were epidemiologically linked to an imported virus [2,3]. Outbreaks usually began with susceptible persons infected with measles while staying in countries with endemic circulation and who became ill just prior to or after arriving in the United States [4]. Infected persons may transmit the disease to a number of potentially susceptible contacts in a variety of settings including homes, airplanes or airports [5], schools or daycare centers [4,6,7], university dormitories, refugee camps [8], clinics and hospitals [9,10].

Due to its high infectiousness and the potential severity of complications, a measles outbreak often constitutes a serious public health event entailing a vigorous response from local public

Abbreviations: CDC, the Centers for Disease Control and Prevention; DHHS, Department of Health and Human Services; ID, identification (for outbreaks labels); logs, logarithms; MMWR, Morbidity and Mortality Weekly Report; n/r, not reported; n/a, not applicable; US, the United States.

* Corresponding author. Tel.: +1 404 639 2834; fax: +1 404 639 4960.
E-mail address: IOrtegaSanchez@cdc.gov (I.R. Ortega-Sanchez).
[1] Maya Vijayaraghavan is now with the Asian Development Bank, but work on this manuscript was undertaken while she was with the Centers for Disease Control and Prevention.

0264-410X
http://dx.doi.org/10.1016/j.vaccine.2013.10.012

health departments and can involve multiple states and counties [2,11,12]. A typical response could involve a range of complex activities, i.e., confirmed cases are isolated, case contacts traced and their disease or vaccination history assessed, potentially susceptible individuals tested for immunity and, if required, vaccinated or quarantined [11–13]. As part of the response to the outbreak, public health departments may need to enhance disease surveillance, plan response efforts, coordinate response activities with healthcare providers, other public health officials, the Centers for Disease Control and Prevention (CDC), and also address public concerns and media attention [11–13]. As a result of the amount of effort and resources reallocated to the outbreak response, the economic toll on these public health departments could be significant [11–14]. In this study, we aim to estimate the economic burden of the sixteen measles outbreaks reported in 2011 on local and state public health departments in the US.

2. Methods

Using local and state public health perspectives, we estimated personnel time for public health departments and costs associated with responding to the measles outbreaks (defined as three or more epidemiologically linked cases) reported in the US in 2011. To do this, we computed average cost and resource utilization data (e.g., wages and salaries, number of personnel hours) from previous studies in the US that estimated the economic impact of measles outbreaks on state and local health departments [11–14], and used these data to estimate the personnel time and costs attributable to the response to the measles outbreaks reported in 2011.

2.1. Cost studies on measles outbreaks

From a review of the literature on the economic impact of measles outbreaks in the US [11–14], we collated data on the reallocation of personnel and resources for the outbreak response (including investigation, contact tracking, screening, laboratory work, emergency response and surveillance) as well as associated costs incurred by local and state public health departments; specifically, we retrieved data on the number of cases reported in these outbreaks, the number of contacts (or exposures to measles cases) identified, the number of hours allocated by local and state responders, and the main activities performed during the outbreak investigations and response (Table 1). Particular attention was given to studies that reported number of personnel hours allocated to the response by local and/or state health department and associated personnel costs. Using these data, we estimated both the average number of personnel hours per contact and the average cost per contact. All costs were adjusted for inflation to 2011 US dollars using the Consumer Price Index [15].

2.2. Measles outbreak data in 2011

Data on the number of confirmed measles cases reported in each outbreak and the duration of the outbreak were collected from local and state health department reports for 2011 [2,8,16–20]. The duration of the outbreak was defined as the number of days from the first to the last rash onset date reported and assumed this interval was the minimum period during which an active public health response was in place. Additionally, data on the number of identified contacts for each outbreak were collected retrospectively from the affected local and state public health departments (Table 2). Despite efforts to standardized contacts data collection, sites resorted to either documentation, recall, or both definitions of contacts.

2.3. Outbreak size classification and case-day index

Due to the limitations of collecting contact numbers retrospectively, we utilized an indirect approach to define outbreak size scenarios and estimated personnel hours and costs for these scenarios. Specifically, we relied on the number of confirmed measles cases and outbreak duration to build a case-day index (i.e., case-day index = number of cases *times* number of days) for each outbreak, and then classified the size of the outbreak using this index (Table 2 and Fig. 1A). The rationale behind the case-day index approach is that the magnitude of a public health response to a measles outbreak is usually driven by the number of individuals that have been in direct contact with infective measles cases and by the time and effort it takes to respond these outbreaks. Therefore, the magnitude of an outbreak response tends to be increasingly compounded by the number of cases (and contacts), and by the duration of the outbreak (Fig. 1A).

Table 1
Cases, contacts, personnel hours and costs associated with measles outbreaks.

	Iowa and Michigan, 2004 [11]	Indiana, 2005 [12]	San Diego, California, 2008 [13]	Kentucky, 2010 [14]
Confirmed cases	1	34	12	1
Identified contacts	>1000[e]	500	376	45
Personnel hours				
Local	516	429	1355	n/r[a]
State	1786	1103	390	n/r
Total	2302	1532	1745	387
Hours per contact				
Local	0.5	0.9	3.6	n/a[b]
State	1.8	2.2	1.0	n/a
Total	2.3	3.2	4.6	8.6
Outbreak costs ($)[d]				
Local	44,558	20,427	116,098	n/r
State	137,121	39,404	13,997	n/r
Total	181,679	59,831	130,095	24,569[c]
Cost per contact ($)				
Local	45	41	309	n/a
State	137	79	37	n/a
Total	182	120	346	546[c]

[a] n/r = not reported.
[b] n/a = not applicable.
[c] Includes some federal personnel expenses.
[d] All costs were adjusted to 2011 US dollars using the consumer price index.
[e] Estimates of hours per contact and cost per contact used 1000 as the number of contacts for this outbreak.

Table 2
Description and size classification of 2011 measles outbreaks in the US.

Outbreak ID [Ref.]	Confirmed cases[a]	Duration (days)[a]	Contacts[b]	Contacts per case	Contacts per day	Cases-days index	Size classification[c]
PA1 [2]	6	21	290	48	14	126	Medium
MN1 [2]	22	68	3009	137	44	1496	Large
MI/MN/TX [2]	6	14	140	23	10	84	Medium
UT1 [16]	7	24	12,000	1714	500	168	Medium
FL [2]	3	13	8	3	1	39	Small
KS [2]	6	36	3000	500	83	216	Large
CA [2,8]	3	18	126	42	7	54	Small
PA2 [2]	3	5	35	12	7	15	Small
VA [2]	4	17	295	74	17	68	Medium
NY/MD [19]	5	14	285	57	20	70	Medium
UT2 [16]	6	24	2400	400	100	144	Medium
IN [18]	14	26	780	56	30	364	Large
PA3 [2]	4	16	387	97	24	64	Medium
MN2 [2]	3	12	177	59	15	36	Small
CA/MD/WI/NC [2,17]	9	24	781	87	33	216	Large
NY [2]	6	13	248	41	19	78	Medium
	107	345	23,961				

[a] For each specific outbreak the data of both the number of confirmed measles cases and duration (in days) were taken from several official outbreak reports.
[b] Data on contacts to measles cases per outbreak were obtained from sites retrospectively (in 2012). Although efforts were made to collect the number of contacts to measles cases using a specific epidemiological definition of "contact," these data may still have important biases in the definition, detection, documentation, reporting and recall of "true" contacts.
[c] Outbreak size classification was based exclusively on the two-dimension case-day index to capture the impact of outbreaks based not only on the number of cases but also the duration of the response. Once an outbreak size was re-classified, assumptions on the number of contacts per measles case were assigned based in part on low and high ranges and thresholds observed in contacts data.

Once calculated, the case-day index was then used to classify the size of outbreaks around the 25th and 75th percentiles of its distribution. Then, the number of contacts per measles case was assigned according to the classified size of each outbreak, and based in part on the distribution of reported contacts and in the low and high ranges between size thresholds (Table 2) (See also Appendix Fig. A.1). Specifically, based on thresholds observed in contacts data, outbreaks were defined as small (i.e., case-day index <25th percentile, with an assumed range of 3–25 contacts per case), medium (case index ≥25th and ≤75th percentiles, range of 40–100 contacts per case) or large (>75th percentile, range of 140–250 contacts per case). After calculating the range in the number of contacts per case for each outbreak size scenario we input the estimated average number of personnel hours (4.7 h per contact) and unit costs ($298 per contact) from the reviewed literature (Table 1) to obtain the total number of hours and costs for all measles outbreaks reported in 2011(Table 3).

Table 3
Estimated low and high[a] number of contacts, personnel hours and costs associated with 2011 measles outbreak by classified outbreak size.

Outbreak	Cases-days	Number of contacts		Personnel hours		Costs	
Size/ID	Index	Low	High	Low	High	Low	High
Large							
MN1	1,496	3,080	5,500	14,442	25,790	918,847 $	1,640,798 $
IN	364	1,960	3,500	9,190	16,412	584,721 $	1,044,144 $
CA/MD/WI/NC	216	1,260	2,250	6,348	11,336	421,244 $	752,221 $
KS	216	840	1,500	4,232	7,557	280,829 $	501,481 $
Medium							
UT1	168	280	700	1,313	3,282	83,532 $	208,829 $
UT2	144	240	600	1,125	2,813	71,598 $	178,996 $
PA1	126	240	600	1,125	2,813	71,598 $	178,996 $
MI/MN/TX	84	240	600	1,125	2,813	71,598 $	178,996 $
NY	78	240	600	1,125	2,813	71,598 $	178,996 $
NY/MD	70	200	500	938	2,345	59,665 $	149,163 $
VA	68	160	400	750	1,876	47,732 $	119,331 $
PA3	64	160	400	750	1,876	47,732 $	119,331 $
Small							
CA	54	9	75	42	352	2,685 $	22,375 $
FL	39	9	75	42	352	2,685 $	22,375 $
MN2	36	9	75	42	352	2,685 $	22,375 $
PA2	15	9	75	42	352	2,685 $	22,375 $
Total		8,936	17,450	42,635	83,133	2,741,436 $	5,340,781 $
Median		240	600	1,125	2,813	71,598 $	178,996 $
Mean (overall)		526	1,026	2,508	4,890	161,261 $	314,164 $
Large		1,785	3,188	8,553	15,274	551,410 $	984,661 $
Medium		196	489	917	2,292	58,339 $	145,849 $
Small		9	75	42	352	2,685 $	22,375 $

[a] "Low" and "High" numbers were assumed to range from 3 to 25 contacts per case (in small outbreaks), from 40 to 100 contacts per case (in medium outbreaks), and from 140 to 250 contacts per case (in large outbreaks). Number of hours (average 4.7 h per contact) and unit costs (average $298 per contact) were used to estimate Personnel hours and costs.

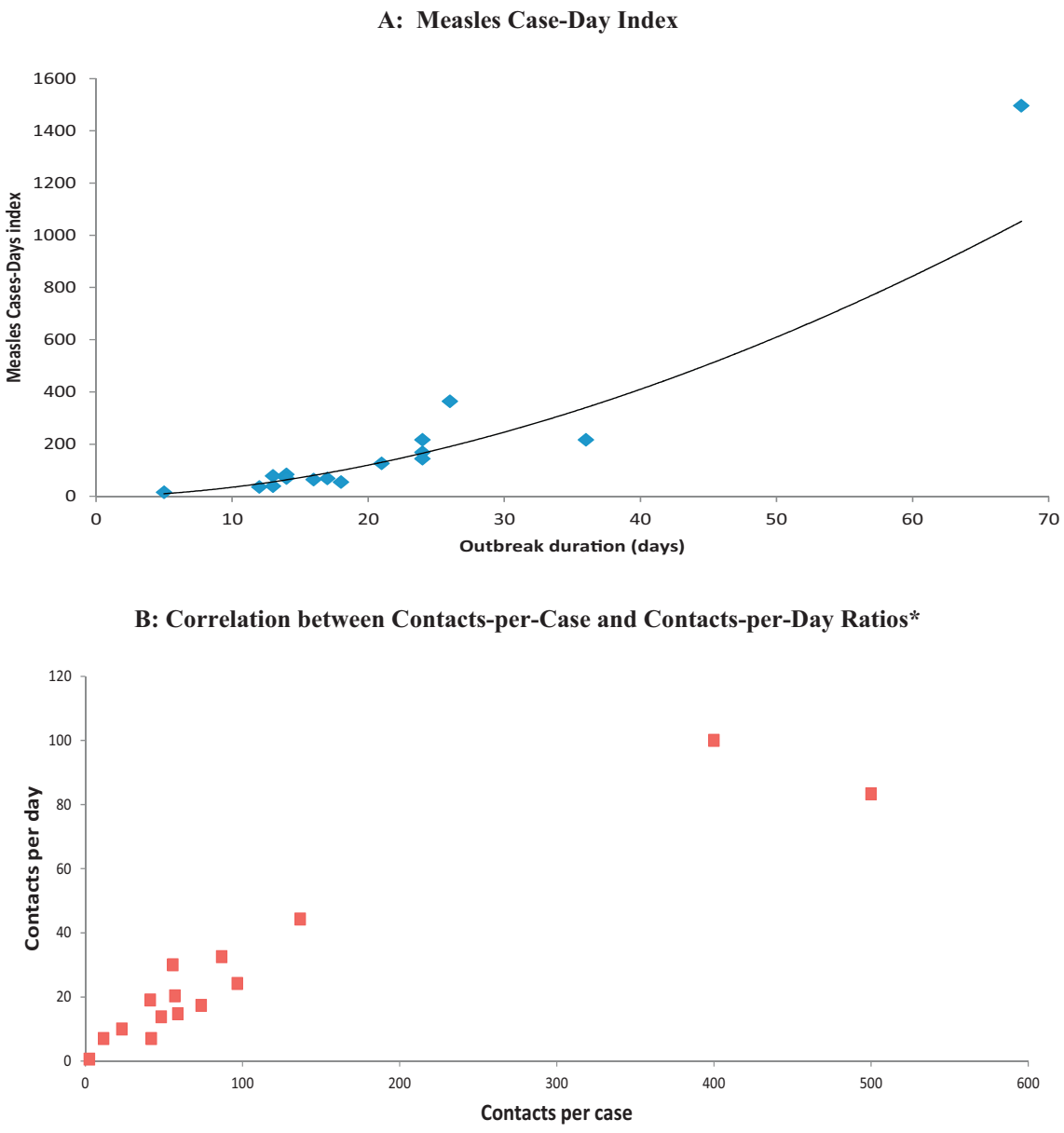

Fig. 1. Outbreak size classification and contacts ratios from 2011 measles outbreaks.
A: Measles case-day index
B: Correlation between contacts-per-case and contacts-per-day ratios*
* Illustrates 15 out of 16 outbreaks. The excluded outbreak (see Table 2) was considered in the estimation of the correlation coefficient ($R^2 = 0.95$).

In order to validate the case-day index approach, we re-classified the outbreaks' size using either the contacts per case ratio or the contacts per day ratio and we observed that the size rankings were very similar to the index approach. Moreover, both ratios show large positive covariance and strong correlation ($R^2 = 0.95$) further validating our compounding hypothesis (Fig. 1B).

3. Results

In 2011, 220 confirmed measles cases were reported in the US including 16 outbreaks that comprised 107 confirmed cases reported from these outbreaks. The median number of cases per outbreak was 6 (range 3–22), and the average outbreak duration was 22 days (median 17.5, range 5–68, Fig. 2). Using diverse epidemiological definitions of contacts and with biases in the detection, documentation and recall of "true" contacts, managers in outbreak sites retrospectively reported a median of 293 identified contacts (range 8–12,000) per outbreak.

Based on the case-day index, 4 (25%) outbreaks were defined as relatively small, 8 (50%) were medium and 4 (25%) were large outbreaks. Using the range of index-attributable contacts to measles cases among these outbreaks, the number of contacts to measles cases ranged from 9 to 75 in small outbreaks, from 160 to 700 in medium size outbreaks, and from 840 to 5500 in relatively large outbreaks.

On average, using the case-day index a range of 526–1026 contacts were attributed to each outbreak in 2011 (median range 240–600 contacts), corresponding to 2508–4890 personnel hours (median range 1125–2813 h) and approximate expenditures of $161,000–$314,000 (median range $72,000–$179,000) associated with the outbreak response(Table 3). With a median duration of 17.5 days per outbreak, an active response costs a median range

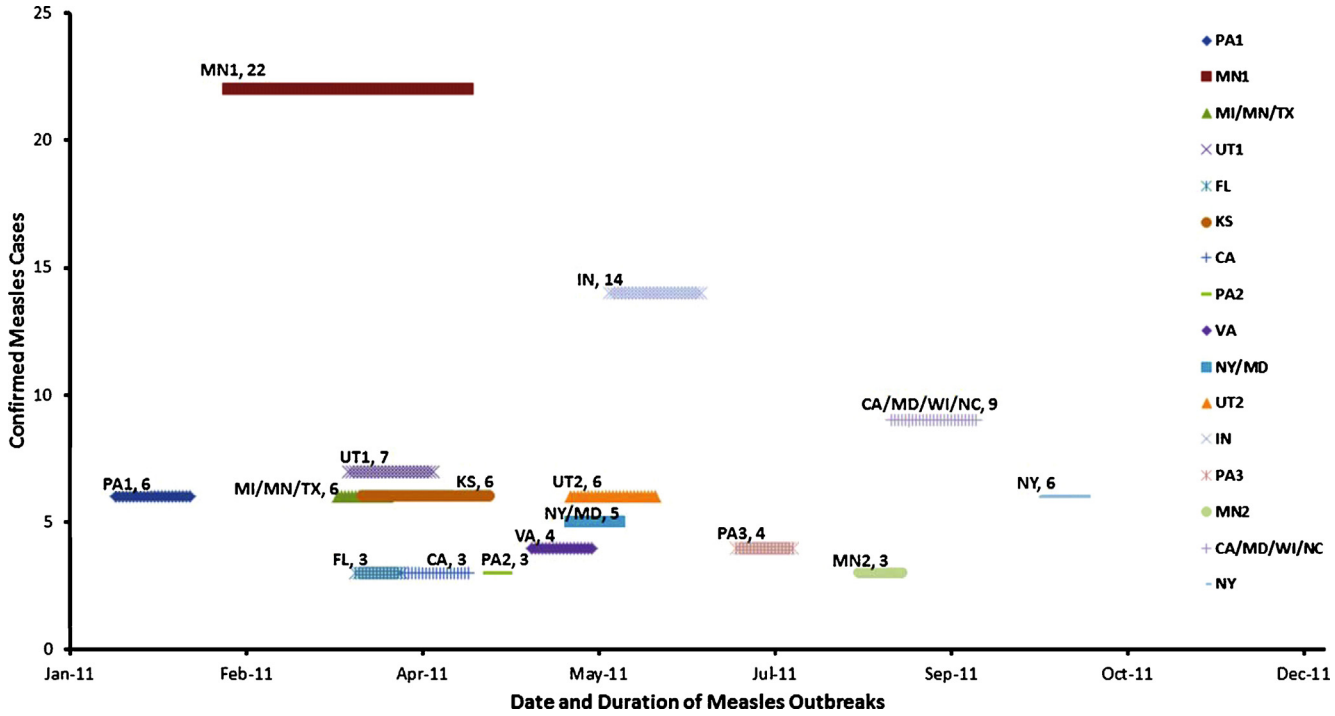

Fig. 2. Measles outbreaks during 2011 in the United States by duration and number of confirmed cases*.
* Letter and numbers in the figure illustrate the outbreak specific label and number of confirmed cases. The length of the symbol repetitions indicates the duration of the outbreak.

of $4091–$10,228 per day. Average costs per outbreak ranged from $2685 to $22,000 for small outbreaks, from $58,000 to $146,000 for medium and from $551,000 to $985,000 for large outbreaks.

For the sixteen outbreaks combined, the estimated total number of individuals identified as contacts to confirmed measles cases ranged from 8936 to 17,450. The estimated total number of personnel hours for the 16 outbreaks ranged from 42,635 to 83,133 (Table 3), and the corresponding total estimated costs for the public response accrued to local and state public health departments ranged from $2.7 million to $5.3 million US dollars.

4. Discussion

The collective responses to each and all the sixteen measles outbreaks had a sizable impact on local and state public health departments. Our estimates show that local and state public health response to measles outbreaks consume substantial personnel hours and could impact other public health priorities as staff is reassigned to outbreak response. At an increased frequency of measles outbreaks, such a diversion of public health resources to outbreaks response could significantly consume public health budgets, divert the health priorities and roles at the local and state levels and further increase the pressure on available resources.

As an illustration of the opportunity costs imposed on public health departments, we estimated that the number of personnel hours responding to these sixteen measles outbreaks would require the full time work of 20–39 public health officers during a year (i.e., assuming 2080 h/year or 40 h/week). Likewise, including cost of other inputs and materials, each public health department that experienced a measles outbreak in 2011 would have incurred a median range cost of $11,933–$29,833 per measles case. These costs, however, are not exclusive of measles outbreaks since about 113 (51% of the 220) measles cases reported in 2011 occurred by definition not in outbreak settings yet they may have demanded a similarly resource-intensive response from local public health departments. A very conservative estimate (i.e., assuming only three contacts per case) of the impact of the 113 non-outbreak measles cases – isolated or fewer than three epidemiologically linked cases – would add approximately 1579 personnel hours and would increase total costs by approximately $100,128.

Measles outbreaks will likely continue to occur in the US mainly because of the persistent risk of imported measles cases derived partly from the increased disease transmission and number of outbreaks in the European region [21]. Such a risk is magnified by the presence of susceptible sub-populations in the US due to lack of vaccination, the variety of potential outbreak settings (hospitals, clinics, airports, cruise ships, etc.), the limited state and local response capabilities, and the lack of awareness of vaccine recommendations in a few susceptible individuals traveling to endemic countries. Beyond the impact on local and state public health departments, responses to measles outbreaks also affect hospitals, clinics [9,22], as well as non-health public departments such as schools, universities and occasionally local police departments enforcing quarantines or supporting control actions [11,13]. Additionally, susceptible individuals and their households face higher health risks derived from potential serious measles complications (i.e., otitis media, pneumonia, encephalitis or death [23]) along with associated medical and productivity lost costs [23,24].

This study has some limitations. The personnel costs used for this study were based on average estimates of data reported in four previous studies published before 2011. Unit costs are likely to vary between departments in various locations, and are dictated by both the variation in wage rates as well as the intensity of the response to the outbreak (e.g., departments with more resources may mount a more expensive but more effective response, while those with fewer resources are unable to respond as quickly or effectively). Finally, the retrospective nature of gathering data on

the number of contacts traced for the outbreaks could have introduced recall bias of reported number of contacts. However, it is uncertain how much or in what direction this bias would have affected the reported number of contacts and our estimates. To improve the validity of future estimates, a plan to collect and analyze data from outbreaks should be put in place and standardized.

In conclusion, staging effective responses to measles outbreaks have a sizable economic impact on local and state public health departments. The costs of measles outbreaks responses are compounded by the duration of outbreaks and the number of potentially susceptible contacts. Outbreak-response estimates not only substantiate the sizable amount of resources and costs allocated by local and state public health departments, but also provide a perspective of what additional resources and capacities might be needed to respond to future outbreaks.

Disclaimer

The findings and conclusions expressed are those of the authors and do not necessarily represent the official views of the Centers for Disease Control and Prevention (CDC) or Department of Health and Human Services (DHHS).

Funding

This research was completed while authors were employees of the US Centers for Disease Control and Prevention (CDC).

Financial disclosure

All, authors, no financial relationships relevant to this article.

Conflict of interest

All authors, no conflict of interest.

Contributor's statement

Dr. Ismael R Ortega-Sanchez: conceptualized and designed the study, carried out the initial analyses, drafted the initial manuscript, and approved the final manuscript as submitted.

Dr. Maya Vijayaraghavan conceptualized the study, reviewed and revised the manuscript, and approved the final manuscript as submitted.

Mr. Albert E Barskey collected the epidemiology data, reviewed and revised the manuscript, and approved the final manuscript as submitted.

Dr. Gregory S Wallace coordinated and supervised data collection, critically reviewed the manuscript, and approved the final manuscript as submitted.

Acknowledgement

We acknowledge the collaboration of Susan Redd and Jane Seward from CDC.

Appendix A. Appendix

See Fig. A.1.

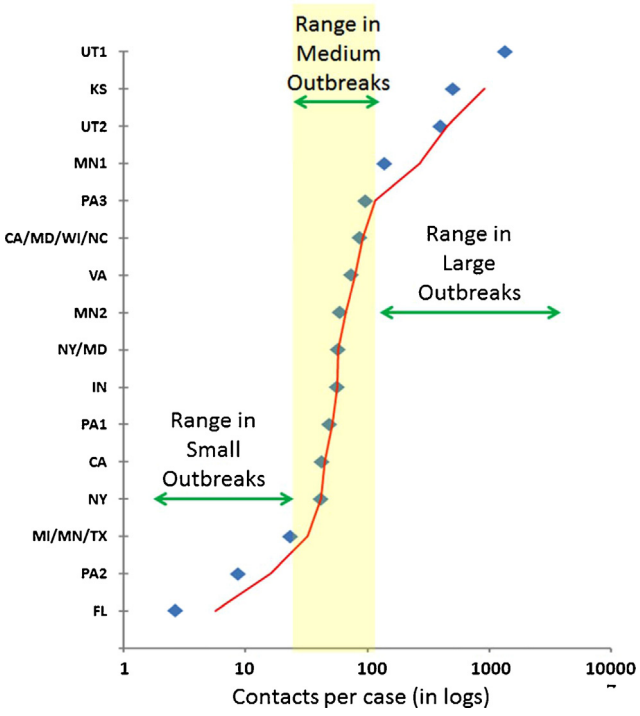

Fig. A.1. Number of reported contacts per case by measles outbreak in 2011*: Definition of thresholds and ranges of contacts per case.
* The red line describes the moving average of reported contacts and helps to illustrate the threshold used to assigned range of contact to outbreaks after their sized was determined by the case-day index.

References

[1] Centers for Disease Control and Prevention (CDC). Summary of notifiable diseases – United States, 2010. MMWR Morb Mortal Wkly Rep 2012;59(53):1–111.
[2] Centers for Disease Control and Prevention (CDC). Measles – United States, 2011. MMWR Morb Mortal Wkly Rep 2012;61:253–7.
[3] Centers for Disease Control and Prevention (CDC). Progress in global measles control, 2000–2010. MMWR Morb Mortal Wkly Rep 2012;61(4):73–8. Erratum in: MMWR Morb Mortal Wkly Rep. 2012 Feb 17;61:110.
[4] Centers for Disease Control and Prevention (CDC). Outbreak of measles – San Diego, California, January–February 2008. MMWR Morb Mortal Wkly Rep 2008;57:203–6.
[5] Lasher LE, Ayers TL, Amornkul PN, Nakata MN, Effler PV. Contacting passengers after exposure to measles on an international flight: implications for responding to new disease threats and bioterrorism. Public Health Rep 2004;119:458–63.
[6] Centers for Disease Control and Prevention (CDC). Measles outbreak in a boarding school – Pennsylvania, 2003. MMWR Morb Mortal Wkly Rep 2004;53:306–9.
[7] Lowe AM. Reemergence of measles. Current operation "vaccination" in our schools. Perspect Infirm 2012;9(2):25–6.
[8] Centers for Disease Control and Prevention (CDC). Measles outbreak associated with an arriving refugee – Los Angeles County, California, August–September 2011. MMWR Morb Mortal Wkly Rep 2012;61:385–9.
[9] Centers for Disease Control and Prevention (CDC). Hospital-associated measles outbreak – Pennsylvania, March–April 2009. MMWR Morb Mortal Wkly Rep 2012;61(2):30–2.
[10] Botelho-Nevers E, Gautret P, Biellik R, Brouqui P. Nosocomial transmission of measles: an updated review. Vaccine 2012;30(27):3996–4001.
[11] Dayan GH, Ortega-Sanchez IR, LeBaron CW, Quinlisk MP, The Iowa Measles Response Team. The cost of containing one case of measles: the economic impact on the public health infrastructure – Iowa 2004. Pediatrics 2005;116(1):e1–4.
[12] Parker AA, Staggs W, Dayan GH, Ortega-Sanchez IR, Rota PA, Lowe L, et al. Implications of a 2005 measles outbreak in Indiana for sustained elimination of measles in the United States. N Engl J Med 2006;355:447–55.
[13] Sugerman DE, Barskey AE, Delea MG, Ortega-Sanchez IR, Bi D, Ralston KJ, et al. Measles outbreak in a highly vaccinated population San Diego 2008: role of the intentionally undervaccinated. Pediatrics 2010;125:747–55.
[14] Coleman MS, Garbat-Welch L, Burke H, Weinberg M, Humbaugh K, Tindall A, et al. Direct costs of a single case of refugee-imported measles in Kentucky. Vaccine 2012;30(2):317–21.
[15] Bureau of Labor Statistics. Consumer price index. http://www.bls.gov/cpi/cpifact8.htm

[16] Centers for Disease Control and Prevention (CDC). Two measles outbreaks after importation – Utah, March–June 2011. MMWR Morb Mortal Wkly Rep 2013;62(12):222–5.
[17] Centers for Disease Control and Prevention (CDC). Notes from the field: measles among U.S. -bound refugees from Malaysia–California, Maryland, North Carolina, and Wisconsin, August–September 2011. MMWR Morb Mortal Wkly Rep 2011;60(37):1281–2.
[18] Centers for Disease Control and Prevention (CDC). Notes from the field: measles outbreak – Indiana, June–July 2011. MMWR Morb Mortal Wkly Rep 2011;60(34):1169.
[19] Centers for Disease Control and Prevention (CDC). Measles – United States, January–May 20, 2011. MMWR Morb Mortal Wkly Rep 2011;60(20):666–8.
[20] Centers for Disease Control and Prevention (CDC). Notes from the field: measles outbreak – Hennepin County, Minnesota, February–March 2011. MMWR Morb Mortal Wkly Rep 2011;60(13):421.
[21] Centers for Disease Control and Prevention (CDC). Increased transmission and outbreaks of measles – European Region, 2011. MMWR Morb Mortal Wkly Rep 2011;60(47):1605–10.
[22] Chen TH, Kutty P, Lowe LE, Hunt EA, Blostein J, Espinoza R, et al. Measles outbreak associated with an international youth sporting event in the United States, 2007. Pediatr Infect Dis J 2010 Sep;29(9):794–800.
[23] Zhou F, Reef S, Massoudi M, Papania MJ, Yusuf HR, Bardenheier B, et al. An economic analysis of the current universal 2-dose measles-mumps-rubella vaccination program in the United States. J Infect Dis 2004;189(1):S131–45.
[24] Zhou F, Santoli J, Messonnier ML, Yusuf HR, Shefer A, et al. Economic evaluation of the 7-vaccine routine childhood immunization schedule in the United States, 2001. Arch Pediatr Adolesc Med 2005 Dec;159(12):1136–44.