Canadian Agency for Drugs and Technologies in Health

Agence canadienne des médicaments et des technologies de la santé

HTA

May 2015

Costs of Contact Tracing Activities Aimed at Reducing the Transmission of Measles in Canada

Supporting Informed Decisions

Cite as: Budden A, Lee KM, Lam P. Costs of Contact Tracing Activities Aimed at Reducing the Transmission of Measles in Canada [Internet]. Ottawa: CADTH; 2015 May. [cited YYYY-MM-DD].

The Canadian Agency for Drugs and Technologies in Health (CADTH) would like to acknowledge Carolyn Spry for assistance with literature searches and Rhonda Boudreau for helping to refine the project scope.

Production of this report is made possible by financial contributions from Health Canada and the governments of Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, Northwest Territories, Nova Scotia, Nunavut, Ontario, Prince Edward Island, Saskatchewan, and Yukon. The Canadian Agency for Drugs and Technologies in Health takes sole responsibility for the final form and content of this report. The views expressed herein do not necessarily represent the views of Health Canada or any provincial or territorial government. CADTH is funded by Canadian federal, provincial, and territorial governments.

About CADTH: CADTH is an independent, not-for-profit organization responsible for providing Canada's health care decision-makers with objective evidence to help make informed decisions about the optimal use of drugs, medical devices, diagnostics, and procedures in our health care system.

Funding: CADTH receives funding from Canada's federal, provincial, and territorial governments, with the exception of Quebec.

Views: The views expressed herein are those of CADTH and do not necessarily reflect the views of our funders.

CP0010 – May 2015

TABLE OF CONTENTS

ABBREVIATIONS

A$	Australian dollars
C$	Canadian dollars
CDC	Centers for Disease Control
CDI	case-day index
IDPH	Iowa Department of Public Health
IMG	immunoglobulin
ISDH	Indiana State Department of Health
KDPH	Kentucky Department of Public Health
MMR	measles, mumps, and rubella
MMWR	Morbidity and Mortality Weekly Reports
PHAC	Public Health Agency of Canada
PHU	public health unit
US$	United States dollars

EXECUTIVE SUMMARY

Background and Context

Measles is a highly communicable infectious disease that is spread through droplets from the nose or throat. Vaccination programs have eliminated indigenous measles in Canada; however, outbreaks continue to occur through importations. Recent outbreaks in Canada and the US have highlighted the importance of immunization for the containment of outbreaks. Contact tracing has been implemented to mitigate the spread of measles by identifying susceptible contacts for treatment and to avoid further spread. The Public Health Agency of Canada (PHAC) is reviewing current activities and exploring new strategies aimed at sustaining measles elimination in Canada, and has requested that CADTH undertake a project estimating the amount of health care resources and costs that should go into contact tracing in response to a case of measles in Canada.

Methods

A review of the published literature was undertaken to identify studies that could inform a cost analysis to estimate the health care resource use associated with contact tracing for a measles outbreak.

Results

Seven primary studies and one review reported disaggregated resource use and/or costs associated with contact tracing, although none were from a Canadian perspective. The primary studies reported a wide range of measles cases, contacts, and associated costs and resource use. As such, it was not considered appropriate to generalize the results of any single population to a wider Canadian population. Although limitations with the review by Ortega-Sanchez et al. were noted, it was deemed an appropriate starting point to undertake an analysis of the estimated costs associated with contact tracing.

A cost analysis was undertaken for the Canadian population from the perspective of a Canadian public health unit, in which costs to the public payer associated with the task of contact tracing, excluding costs associated with the direct treatment of case patients, were the focus. Information from a subset of US studies was used to determine a model scenario that estimated costs and health care resources based on the number of contacts and cases, and information regarding Canadian-specific outbreaks was obtained from an informal literature search and PHAC.

In the base-case analysis, an outbreak in Alberta in 2013 (42 cases; 2,005 contacts) was the basis for estimating costs associated with contact tracing activities, which resulted in an estimate of $297,000. Sensitivity analyses adjusting the costs, resource use, and model scenario had a large effect on the total cost associated with contact tracing (range: $76,267 to $2,078,225), with the number of contacts per case having the largest impact.

Conclusions

The estimated cost of contact tracing activities is likely an underestimate, given the lack of information on the type of activities and extent of effort in Canada. Information on contact tracing activities during measles outbreaks is not typically collected in a standardized manner that can be used to inform decision-making. More detailed capture of activities and costs incurred during outbreaks will allow for more precise estimates of the economic impact of contact tracing activities.

1. BACKGROUND

Measles is a highly communicable infectious disease that is spread through droplets from the nose or throat (e.g., coughing or sneezing).[1] Complications from measles are rare but serious, including blindness, encephalitis, and severe respiratory infections such as pneumonia.[2] There are limited treatments for measles, other than supportive care; however, it is preventable by immunization.[2]

Publicly funded measles vaccine programs have been implemented in Canada since the 1970s,[3,4] with a booster added to routine schedules in 1996 to 1997.[5,6] As a result of a two-dose routine vaccination program, there have been no cases of endemic measles in Canada since 1998. However, importations and outbreaks continue to occur as long as there is travel to countries with disease activity and there are susceptible individuals and communities who are not immunized or are under-immunized.

Recent outbreaks in Canada[5,7-14] and the US[15-18] have highlighted the importance of immunization for the containment of outbreaks. In the Canadian outbreaks, suboptimal vaccination rates may have contributed to the transmission and sustainability of the longer and larger outbreaks.[5,7,8,14] In the US, immunization continues to be a political topic, with several US states considering laws to make it harder for parents to legally opt out of vaccinating their children,[19,20] while anti-vaccine campaigners have made statements linking vaccinations to childhood disorders[21-23] — claims that have not been supported by clinical evidence.[24-26] The issue is also becoming a topic for political discussion in Canada,[27] given the resistance of certain groups toward immunization.[28,29]

Contact tracing has been implemented to mitigate the spread of measles by identifying susceptible contacts for treatment and to avoid further spread. Due to the high secondary attack rate of measles and Canada's commitment to maintaining elimination, the public health response in Canada is typically triggered by one case of measles. Public health professionals take into consideration a variety of factors associated with outbreak control (i.e., number of suspected measles cases, vaccination rates of the outbreak region, long-term immunity). The Public Health Agency of Canada's (PHAC) *Guidelines for the Prevention and Control of Measles Outbreaks in Canada*[30] provides some guidance for communication methods and management of measles outbreaks in Canada. The guidelines provide key recommendations which may need to be adapted by local public health units to match their response and protocols.

Current guidance from PHAC indicates that contact tracing should be undertaken once a case of measles has been identified, to limit secondary spread to avoid or contain an outbreak:[30]

- Case identification and reporting
- Case investigation (upon suspected measles), including data collection (demographic, onset of rash, vaccination history, etc.)
- Contact investigation (collection of epidemiological data on persons in contact with measles cases)
- Management of cases and identified contacts (vaccination, immunoglobulin, or exclusion)
- Communications with other affected jurisdictions (e.g., travellers)
- Notification to community and local health services.

It is unclear what the optimal amount of health care resources are that should go into contact tracing in response to a case of measles in Canada, or whether contact tracing should be undertaken given high vaccination rates in certain areas. The current public health efforts,

especially in areas with high vaccination rates, may be quite large in comparison with the expected benefit.

2. CONTEXT AND POLICY ISSUES

As part of Canada's commitment to maintaining measles elimination, PHAC is reviewing current activities and exploring new initiatives to sustain the gains the country has made in reducing the burden of measles. One of the elements being reviewed is the 2013 PHAC *Guidelines for the Prevention and Control of Measles Outbreaks in Canada*.[30] A focus of the review is to determine sections that need to be updated and include evidence-informed recommendations to assist in preventing or reducing the spread of secondary measles infection. PHAC has requested that CADTH undertake the following project to gain a better understanding of the health care resources, including costs, involved in contact tracing activities to reducing transmission of measles in Canada.

3. RESEARCH OBJECTIVE

The aim of this project is to estimate the costs and/or health care resource use associated with contact tracing in response to a measles outbreak in Canada.

4. METHODS

Published literature was searched to identify studies (economic evaluations and modelling studies) that could inform a cost analysis to estimate the impact on a local health authority, focusing on health care resource use associated with contact tracing for a measles outbreak, excluding costs borne by other health departments. This work is related to, but independent of, the CADTH report on the clinical effectiveness of various public health interventions during a measles outbreak in Canada.[31]

4.1 Literature Search

To identify published economic evaluations of contact tracing in measles outbreaks, a literature search was conducted on key resources including MEDLINE, Embase, PubMed, University of York Centre for Reviews and Dissemination NHS Economic Evaluations Database, Health Economic Evaluations Database, and Canadian and major international health technology agencies that provide economic assessments, as well as a focused Internet search. The main search concepts were measles, contact tracing, isolation and disease outbreaks/importation. A methodological filter was applied to limit retrieval to economic studies. The search, run on September 26, 2014, was limited to English language documents. Retrieval was not limited by date of publication (See Appendix 1: Literature Search for more information on the literature search strategy). PHAC was also consulted, to ensure no studies were missed. The following inclusion criteria were used to identify citations from the formal literature search for an in-depth review:

- Measles outbreak
- Primary study or review of studies
- Examine contact tracing or post-outbreak

- Includes costs or resource use information.

The following were excluded:
- Theoretical papers
- Conference abstracts
- Non-human studies.

Based on the literature search, 541 citations were identified and screened, of which 33 were retrieved for a more detailed review. A detailed review of retrieved articles identified six primary studies that were determined to be appropriate for inclusion, based on reporting disaggregated resource use and/or costs associated with contact tracing: Dayan et al.,[32] Parker et al.,[33] Sugerman et al.,[34] Coleman et al.,[35] Stuart et al.,[36] and Flego et al.[37] One review of studies by Ortega-Sanchez et al.[38] was also determined to be appropriate for inclusion. Bibliographies from retrieved articles were handsearched for relevant references, which identified one further reference by Collier et al.[39] A breakdown of the article selection is provided in Appendix 2.

Studies that presented modelled cost-effectiveness results, or did not report contact tracing resource use/costs or processes, were not included. Thus, several European studies,[40,41] and a systematic review of the literature, were not included in the review.[42] A brief overview of excluded studies is presented in Appendix 3.

4.2 Overview of the Evidence

Based on the review of the literature and references provided by PHAC, eight relevant studies were identified. These studies were cost analyses or studies of economic burden, which captured resource use and costs associated with contact tracing in response to a measles outbreak.[32-39] None of the identified studies was conducted from a Canadian setting or perspective. However, due to the paucity of Canadian data, the information obtained from the studies was reviewed, assessed, and used to inform a cost analysis for the Canadian setting.

A summary of these eight articles — seven primary studies and one review — is presented below (see Appendix 4 for an expanded review of the studies).

The identified primary studies were published between 2004 and 2013, based on five measles outbreaks in the US (Dayan et al.,[32] Parker et al.,[33] Sugerman et al.,[34] Coleman et al.,[35] and Collier et al.[39]) and two outbreaks in Australia (Stuart et al.[36] and Flego et al.[37]). The review study — published in 2014 — incorporated data from four of the US studies to apply to 16 outbreaks that occurred in the US in 2011.[38]

In each of the five primary studies from the US, the cases were imported by unvaccinated individuals travelling from a destination with a recent outbreak of measles. In four of the five US outbreaks reported, there was secondary or tertiary spread of measles.[32-34,39] The US studies generally reported that the greater areas in which the outbreaks occurred had immunization rates at least in line with US national averages (90% to 97%),[33,34,39] although it was also reported that the communities most affected by the outbreak had lower immunization rates.[32-34,39]

The source of the outbreak was not reported or was unknown in the Australian studies; thus, the extent or spread of the outbreak could not be easily defined. Immunization rates were not reported in either Australian study; however, Flego et al.[37] reported that the community in which the majority of the cases occurred was an under-immunized population.

The majority of the studies stated that patients were interviewed to determine demographic characteristics, the likely transmission event, and persons they had potentially exposed.[33,34,37,39] All studies indicated that the contact tracing done was based on guidance from county, state, or provincial health bodies. Contact tracing and containment measures included locating or identifying contacts and exposures through other methods, such as looking at passenger manifests or contacting areas in which measles cases may have been (e.g., schools or health care facilities); interviewing and testing exposed patients; communicating with other health bodies on a local, state, or national level; and administering measles, mumps, and rubella (MMR) vaccine or immunoglobulin (IMG) to exposed patients without evidence of immunity (within 72 hours for MMR; within six days for IMG).

All studies captured personnel time, with most capturing overhead costs, MMR vaccine and IMG costs, and other material costs (phone calls, travel, and public information and education). The main driver of the total costs reported in all studies were those associated with personnel time (wages, salaries, and fringe benefits), ranging from 60% of total costs[32] to 100%.[35] Costs were captured retrospectively in all studies, while Coleman et al. captured some resource use prospectively. The total costs reported in these analyses varied substantially. Normalized to 2014 Canadian dollar (C$) values via the Bank of Canada Inflation Calculator,[43] these ranged from C$10,840[36] to C$226,501.[33]

The review by Ortega-Sanchez et al.[38] includes information from four of the five identified US primary studies.[32-35] Using information from these four studies (Dayan et al., Parker et al., Sugerman et al., and Coleman et al.), the authors created a modelling scenario through which they undertook a primary economic analysis basing the modelled scenario on case information from 16 individually reported measles outbreaks in the US in 2011. The number of cases (range: n = 3 to 22), contacts (range: n = 8 to 12,000), and duration of the outbreak (range: 5 to 68 days) varied substantially. The modelling scenario applied to each outbreak resulted in the creation of a case-day index (CDI; further explained below in the section *Ortega-Sanchez*), which allowed the authors to determine a range of costs for each outbreak, based on the size of the outbreak. The authors reported that the total economic burden on local and state public health institutions that dealt with the 16 identified measles outbreaks during 2011 ranged from an estimated US$2.7 million to US$5.3 million (2015 Canadian dollars: C$2.9 million to C$5.6 million).[43]

4.1.1 Appraisal

a) Primary Studies

Each of the primary studies is subject to limitations. The paper by Coleman et al.[35] included a single case patient who was not in contact with the general community, based on the contact tracing activities that occurred, and thus may not be representative of a broader population. The Australian studies[36,37] could not identify the index patient in their studies, and the study by Stuart et al.[36] relied solely on a retrospective review of clinical information and with estimates for resource use and cost based on the clinical data (number of cases and contacts). The studies by Collier et al., Sugerman et al., Parker et al., and Dayan et al. reported that the findings were limited by a lack of follow-up on potentially exposed patients.[32-34,39] These limitations are likely to have resulted in an underestimate of the costs of contact tracing. Studies also reported limitations associated with the geographic and cost setting of the study (e.g., costs attributable to other county or state health bodies may not have been included, depending upon the perspective of the study). Each of the studies reported costs related to the treatment of case patients and other resource costs that are not typically associated with contact tracing methods.

Given the non-uniform nature of measles outbreaks, and the substantial differences between the populations identified in the primary studies, it is not appropriate to generalize the results of any single population to a wider Canadian population. However, data collected within the studies often reported different resource and cost components; costs and resources may differ between populations; and there may be recall bias due to the retrospective nature of the data capture.

b) Ortega-Sanchez

While the premise used by Ortega-Sanchez et al.[38] is acceptable in pooling data from existing studies, and estimating the cost of contact tracing associated with an outbreak based on the size of the outbreak, there are some limitations with the information and the strategy used by the authors that lead to potential limitations in the results. These include:

- Inclusion of Coleman et al.
- Apparent errors or lack of justification for revised numbers from the primary studies
- Use of a CDI and assumptions based on the CDI.

As noted in the *Primary Studies* section, the paper by Coleman et al.[35] differs from the other included studies in that it includes a single case patient who was not in contact with the general community, based on the contact tracing activities that occurred. The results from the study have a greater potential to be an outlier, given the single case and narrow setting in which the measurement of potential contacts occurred.

Information captured from Coleman et al. appears to differ from that presented by Ortega-Sanchez et al.[38] in their review. The number of contacts for the single case reported by Coleman et al. was 44, while the number of contacts reported by Ortega-Sanchez et al. from this study was 45. This may be due to the inclusion of the case patient as a contact, but it is not stated or necessarily appropriate. Further, the information provided by Ortega-Sanchez for the San Diego outbreak (Sugerman)[34] — both the number of contacts and costs — could not be found in the original publication. While the authors may have determined that the in-hospital and outpatient costs should not be included in the analysis, no transparent rationale was provided regarding the difference in costs, or why the number of contacts was revised from 839[34] to 377.

The use of a CDI, while providing an indication of both the number of cases and length of the outbreak, does not offer a good representation of the potential cost, as it neglected the number of contacts by the case patient, and thus potentially underestimated the breadth of contact tracing activities required. The range of contacts for outbreaks was estimated using the CDI, with the range of values partially based on the distribution of reported contacts from the four studies. However, the ranges appeared to vary substantially from the actual data that were available.

4.1.2 Summary

Although several limitations were noted with the review by Ortega-Sanchez et al.,[38] the article does present a good starting point to undertake an analysis of the estimated costs associated with contact tracing. Three of the four included studies that formed the basis for their analysis of cost and resource use (Dayan et al.,[32] Parker et al.,[33] and Sugerman et al.[34]) were also deemed appropriate for the current analysis. These three articles reported similar methodologies, cost components, and collaboration with Centers for Disease Control (CDC) and/or other jurisdictions, and also reported similar results.

The four remaining studies that were identified above (Coleman et al.,[35] Flego et al.,[37] Stuart et al.,[36] and Collier et al.[39]) were not included as part of the base-case analysis, given limitations identified with the contact tracing methods, outbreak size and setting, and vastly differing costs associated with contact tracing measures. Pooled data from Flego et al., Stuart et al., and Collier et al. are reported in Appendix 7, given the similarities in the reporting categories and results, and used as a model scenario in a sensitivity analysis.

As none of the available studies provided information that was determined to be appropriate or generalizable to the Canadian setting, the authors undertook a cost analysis based on information from the Ortega-Sanchez et al., Dayan et al., Parker et al., and Sugerman et al. studies. The results from Coleman et al.[35] differ substantially from each of the other identified contact tracing papers and thus have not been included in the analysis.

5. ECONOMIC EVALUATION

5.1 Methods

5.1.1 Type of Economic Evaluation

A cost analysis was conducted to estimate the approximate costs and resources associated with a series of hypothetical measles-outbreak situations in Canada.

5.1.2 Target Population

The focus of this review is on a Canadian-specific outbreak population. Given the non-uniform nature of measles outbreaks, and the substantial differences between the populations identified in the primary studies, a population from a published outbreak[7] was identified to inform the base case. However, several other outbreaks were assessed to test the values associated with different outbreak sizes.

5.1.3 Perspective

The analysis assumed the perspective of a Canadian local public health unit. This perspective concentrated only on the costs to the public payer associated with the task of contact tracing, and did not include costs associated with the direct treatment of case patients (e.g., hospitalization, or doses of measles vaccine or immunoglobulin). This analysis includes costs associated with personnel time (including fringe benefits), overhead costs, laboratory costs for testing, travel costs for staff, toll-free phone lines, and other public health information activities.

5.1.4 Scenarios and Data Sources

For this cost analysis, scenarios regarding the resource use and associated costs were estimated based on the literature identified in the literature review.

The analysis consists of two scenarios:

- Model scenario: estimate of health care resources and costs, and number of cases and contacts, based on modelling exercises from published economic analyses
- Outbreak scenario: based on actual historic information from Canadian outbreaks for which case numbers were known.

The model scenario is used to determine the health care resources, costs and, where required, number of contacts to apply to the population in which the outbreak occurs. The results of the

model scenario were applied to the outbreak scenario to generate cost estimates for Canadian outbreaks.

5.1.5 Model Scenario

a) Resource Use

As noted previously, current PHAC guidance identifies six components of contact tracing in measles outbreaks. For this analysis, the costs and resources associated with treatment and management of individual case patients (e.g., hospitalization, outpatient care, vaccine, and IMG) have not been included in this economic analysis, as the literature reports that these are generally not seen to be a part of the contact tracing exercise.

Three studies identified from the review of the literature (see Section 4 and Appendix 4 of this report) were identified as reporting contact tracing resource and cost components similar to the Canadian practice: Dayan et al. (2005), Parker et al. (2006), and Sugerman et al. (2010). These three studies reported the following cost components: wages and salaries, overhead costs, laboratory costs, public information costs, mileage, and other costs. Where these cost components were not explicitly listed in the current study, these values were weighted (based on proportion of total cost and year of assumed cost) and included based on the studies that incorporated that cost component. At most, the studies were missing two of the components, making up < 10% of the total cost. Each of the studies reported that collaboration with CDC and/or other jurisdictions was undertaken. It was assumed this was captured in the total personnel hours and wages and salaries. As per the economic analysis by Ortega-Sanchez et al.,[38] the costs and resource use associated with hospital and outpatient care were excluded, as the screening and tracing measures undertaken at the hospital were extreme and not expected to translate across outbreaks. Although some direct costs were reported to have been included in the analysis by Ortega-Sanchez, the disaggregation in reporting generally allowed exclusion of these costs.

Table 1 shows a summary from the three included studies, reporting the number of personnel hours and cost components.

Table 1: Summary Table of Resource Use From the Included Studies

Report	Dayan et al. (2005)[a32]	Parker et al. (2006)[33]	Sugerman et al. (2010)[34]	Total[b] *Average (range)*
Outbreak year	2004	2005	2008	
Cases	3	34	12	49
Contacts	> 1,000	500	839	> 2,339
Contacts per case	333	15	70	***47.7 (15 to 333)***
Hours	2,525	1,532	1,745	5,802
Hours per case	145.4	841.6	45.1	*118.4 (45.1 to 841.6)*
Hours per contact	2.08	2.52	3.06	***2.48 (2.08 to 3.06)***

[a] For the purposes of estimating the per-contact information for Dayan et al., it was assumed that there were 1,000 contacts.

[b] Results are totals if normal, and average (range) if italicised. Bolding indicates key result, referred to in text.

As indicated in Table 1, the resource and cost information on a per-contact basis appears to be a much more stable indicator of cost across studies than looking at per-case numbers. The summary of the studies indicated that the number of hours per contact was approximately 2.5 hours, with a number of contacts per case of 48. These resource values were used to populate

the cost analysis for the base case modelled outbreak scenario. A similar pattern regarding stability of cost per contact was also seen across other studies that reported costs associated with measles outbreaks, but at a much lower cost and hours per contact (See Appendix 7).[36,37,39]

Costs

Based on the labour force survey administered by Statistics Canada in January 2015, the estimated hourly wage for professional occupations in health is $35.87.[44] An additional 11% has been added to capture fringe benefits on top of wage (10% of total compensation[45] – wages + benefits — thus, 11% of wages); therefore, the total hourly personnel cost was assumed to be $39.82.

Additional costs associated with the production and dissemination of public information, mileage, laboratory costs, overheads, and other costs (such as phone calls) were included on a per-contact basis. As resource and cost information for the aforementioned additional cost components could not be individually determined, data from the Dayan et al., Parker et al., and Sugerman et al. studies were combined and a weighted average was used to estimate a non-wage cost per contact of $49.83. The results are presented in Table 2.

All foreign costs were converted to Canadian dollars at the year of publication using the Bank of Canada converter (see footnote c, Table 2), while cost estimates older than 2014 were adjusted to 2014 Canadian dollars, using the consumer price index inflation calculator from the Bank of Canada. The results of Table 2 indicate that although the cost of contact tracing per case substantially varied between the three studies, the cost of contact tracing per contact is relatively stable (range: $146 to $212). This is especially apparent when looking at the cost per contact if excluding personnel costs (range: $49 to $51).

5.1.6 Outbreak Scenarios

The outbreak scenario is based on actual information from an outbreak for which case numbers were known. CADTH recently undertook a review of the clinical literature regarding measles outbreaks in Canada and identified two studies (Yuan et al. 1994,[46] and Sutcliffe et al. 1996[47]). Yuan et al.[46] and Sutcliffe et al.[47] were undertaken before measles elimination had been achieved in Canada and deemed to not be appropriate to use for the analysis. An article by De Serres et al. 2011[5] reported on a measles outbreak of more than 700 cases in Quebec, resulting from 21 measles importations. Given the size and nature of this outbreak, guidance from PHAC indicated that this outbreak was not representative of expected future outbreaks in Canada.

A review of literature from an informal (Google) search and references provided by PHAC identified several additional Canadian outbreaks that were reported to provide case numbers. The following Canadian outbreaks were identified: news articles reporting on cases in British Columbia from the Vancouver Winter Olympics in 2010,[10,11] as well as two from Ontario: Ottawa in 2014[8,48-51] and Sudbury in 2014.[52,53] This information was reviewed, but given the limited amount of disaggregated cost and resource information provided within the articles, they were not viewed as appropriate for the primary analysis.

Table 2: Summary Table of Resource Use and Costs From the Included Studies				
Report	**Dayan et al. (2005)[a;32]**	**Parker et al. (2006)[33]**	**Sugerman et al. (2010)[34]**	**Total[b]** ***Average (range)***
Outbreak year	2004	2005	2008	
Cases	3	34	12	49
Contacts	> 1,000	500	839	> 2,339
Costs ($)				
Total cost reported	$142,452	$167,685	$124,517	NA[c]
Total cost, revised[d]	$170,471	$73,247	$178,295	$422,013 *($73,247 to $178,295)*
Total cost per case	$56,827	$2,154	$14,858	*$8,613 ($2,154 to $56,827)*
Total cost per contact	$170	$146	$212	***$180 ($146 to $212)***
Revised cost excluding personnel wages	$50,540	$24,527	$41,486	$116,553
Revised cost per contact, excluding personnel wages	$51	$49	$49	***$50 ($49 to $51)***

NA = not applicable.
[a] For the purposes of estimating the per-contact information for Dayan et al.,[32] it was assumed that there were 1,000 contacts.
[b] Results are totals if normal, and average (range) if italicised. Bolding indicates key result, referred to in text.
[c] As the total costs were determined in different years, it is not appropriate or applicable to determine a total cost for reported costs; thus, NA.
[d] Revisions to the cost included inflating the cost from the outbreak or costed year to 2014 (accessed Feb 2015) and estimating cost components not measured from one of the other studies that did capture this information (see Resource Use section above regarding exclusions). Costs are reported in Canadian dollars; they were converted from US to Canadian dollars at the year of publication using the Bank of Canada conversion tool (http://www.bankofcanada.ca/rates/exchange/10-year-converter/)[54] and inflated to 2014 Canadian dollars using the Bank of Canada Inflation Calculator (http://www.bankofcanada.ca/rates/related/inflation-calculator/).[43]

In addition, a report of a measles outbreak in Alberta was also identified as part of the informal review. Kershaw et al.[7] reported on an outbreak of measles in a primarily non-immunized population in Alberta in October 2013. The potential for an outbreak had been identified before the outbreak and planning began in August 2013, including guidelines for measles immunization of health care workers; communication to stakeholders and the public to raise awareness of the risk of measles; an immunization promotion and education initiative; engagement between local public health and church leaders, physicians, and school administrators; and development of a measles assessment centre plan. The index patient had recently returned from the Netherlands and had been in contact with a large number of non-immunized people while infectious. A total of 42 cases were identified during the six-week outbreak; all cases had not been immunized. While the authors stated that contact tracing was undertaken, the actual number of contacts was not reported.

Other non-Canadian literature from the initial literature search was also reviewed. The 16 US measles outbreaks reported by Ortega-Sanchez et al.[38] were also considered for the outbreak scenario, as a means of comparing the results using the revised modelling scenario with the original results of the Ortega-Sanchez et al. review.

Given the vast differences among the size of the outbreaks reviewed, a series of alternate outbreak scenarios were used. After consultation with PHAC, the decision was made to use the outbreak in Alberta in 2013, as reported by Kershaw et al.[7] as the primary analysis.

Alternate scenarios were undertaken based on a variety of reported scenarios:

- Canadian outbreaks identified in the informal literature review:
  - Vancouver[10,11]
  - Ottawa[8,48-51]
- Combination of the three US outbreaks used to determine the modelling scenario[32-34]
- Based on the 16 US measles outbreaks from 2011 identified by Ortega-Sanchez et al.[38]

Scenarios in which only one case patient was identified, such as the abovementioned Sudbury case,[48,53] were not included as these were not outbreaks and thus would have a different profile from the other outbreaks reported.

5.2 Variability and Uncertainty

One of the objectives of this study was to assess the model results given the variability surrounding diverse model scenarios. Therefore, the following sensitivity analyses were undertaken on the outbreak population used for the primary analysis:

- Using the lower and upper ranges for the number of contacts per case from the current modelling scenario (based on the Dayan et al.,[32] Parker et al.,[33] and Sugerman et al.[34] studies)
- Using the lower and upper ranges for the number of hours per contact from the current modelling scenario (based on the Dayan et al.,[32] Parker et al.,[33] and Sugerman et al.[34] studies)
- Using a revised modelling scenario based on pooling data from the Flego et al.[37], Stuart et al.,[36] and Collier et al.[39] articles to determine the information to populate the analysis
- Using a revised modelling scenario based on Coleman et al.,[35] which reflects a single case to reflect potential differences between outbreaks and events with a single case.

5.3 Assumptions and Limitations

Several assumptions have been made regarding the generalizability of US data to the Canadian setting:

- US contact tracing methods are similar to Canadian contact tracing methods.
- US health campaigns (e.g., encouraging vaccination uptake; warning about not immunizing, etc.) are similar to Canadian health campaigns.
- Where cost components were not reported from the model scenario studies, data could be used and weighted (based on proportion of total costs and inflation or deflation based on year of outbreak) from the other model scenario studies that report that information.
- Costs of contact tracing (excluding personnel wages) do not differ between Canada and the US.
- It is appropriate to convert costs from US or Australian dollars to Canadian dollars at the year of assumed cost and inflate to 2014 values to normalize the values.

Certain costs have not been accounted for, aside from those previously described, such as setting up multiple vaccination clinics and mobile vaccination clinics.

The articles by Dayan et al.[32] and Parker et al.[33] report the number of contacts as being approximations, which may underestimate the total number of contacts. Were the actual number

of contacts for these studies higher, the cost per contact and personnel time per contact may be lower than the estimate calculated.

6. RESULTS

6.1 Base-Case Analysis

The modelling scenario indicated that approximately 2.5 hours of personnel time were required per contact for an outbreak, while the average number of contacts per case was approximately 48 (range: 15 to 333; Table 1). This information was used to determine the total number of contacts within the outbreak (where the number of contacts was not known), and to estimate the amount of personnel time undertaken during the outbreak. The cost of personnel time was calculated based on revised Statistics Canada wage information.[55] Non-personnel costs were estimated from the modelling scenario and added to the personnel time costs. Table 3 presents the results using the modelling scenario for the Alberta 2013 measles outbreak scenario reported by Kershaw et al.,[7] which identified 42 case patients. The analysis used estimates from the earlier studies to determine the number of contacts per case patient, as well as personnel hours and associated resources per contact, to determine the expected number of cases, and reported the estimated cost of the outbreak to be $297,908.

Data tables including the calculations for the results are available in Appendix 5.

Table 3: Base-Case Results for Alberta 2013 Outbreak Scenario

Outbreak Scenario	Reported Number of Cases	Estimated Contacts	Estimated Personnel Hours	Estimated Personnel Costs	Estimated Non-Wage Costs	Estimated Total Costs
Alberta[7]	42	2,005[a]	4,973	$198,006	$99,902	$297,908

[a] Calculated based on the modelling scenario, as no information on the number of contacts could be identified from the references.

6.2 Scenario Analyses

The primary analysis is based on a medium-sized outbreak in a non-immunizing population, which was well prepared for the outbreak. Given the parameters of the population, another four outbreak scenarios were identified, to which the base the modelling scenario can be applied. The results can be seen in Table 4. These scenario analyses use either the contact data reported within the articles, or use the number of contacts per case based on the modelling scenario outlined earlier.

As presented in Table 4, the Ortega-Sanchez scenario is an outlier to other studies, in which the estimated number of contacts per case is substantially higher than reported in the Ottawa outbreak, or calculated in the model scenario. As the total cost is estimated based on the number of contacts, the cost per case is substantially higher than in the other scenarios. However, depending on the time between measles infection and identification of measles, followed by initiation of containment and contact tracing procedures, the scenario in which a large number of persons have been in contact with case patients may be more appropriate.

Table 4: Results for the Outbreak Scenario Analyses						
Outbreak Scenario	**Case (Average)**	**Estimated Contacts**	**Estimated Personnel Hours**	**Estimated Personnel Costs**	**Estimated Non-Wage Costs**	**Estimated Total Costs**
Vancouver[10,11]	80	3,819[a]	9,472	$377,154	$190,290	$567,444
Ottawa[8,48-51]	4	200[b,c]	496	$19,753	$ 9,966	$ 29,719
Pooled results from Dayan et al.,[32] Parker et al.,[33] and Sugerman et al.[34] studies	16	780[a]	1,934	$77,002	$38,851	$115,853
US outbreak summary as reported by Ortega-Sanchez et al.[38]	7	1,498[b]	3,715	$147,904	$76,854	$222,528

[a] Calculated based on the model scenario, because either no information on the number of contacts could be identified from the references, or there was uncertainty regarding the number of contacts.
[b] Based on number provided by reference article.
[c] Number of contacts for the Ottawa outbreak is an underestimate. The reference indicated 200 families, but because the size of the family was not known, it was decided that the number of contacts should remain at 200.
Note: Values are rounded to the nearest whole number.

Data tables including the calculations for the results are available in Appendix 6.

6.3 Sensitivity Analyses

Several parameters in the primary modelling scenario required testing. The results of the sensitivity analyses are presented in Table 5. The results indicate substantial variation based on the assumptions used in the modelling scenario; the analysis was most sensitive to the number of contacts per case from the current modelling strategy, and the use of the modelling scenario from Flego et al., Stuart et al., and Collier et al.

Table 5: Results of the Sensitivity Analyses						
Scenario	**Cases**	**Contacts**	**Personnel Hours**	**Personnel Costs**	**Non-wage Costs**	**Total Costs**
Base case	42	2,005[a]	4,973	$198,006	$99,902	$297,908
SA 1	42	630[a]	1,563	$62,221	$31,393	$93,614
		13,986[b]	34,692	$1,381,300	$696,925	$2,078,225
SA 2		2,005[c]	4,170[d]	$166,024	$99,902	$265,927
			6,143[e]	$244,583	$99,902	$344,486
SA 3[f]		2,531	1,630	$64,591	$11,377	$76,267
SA 4		1,848	16,272	$647,900	$8,306	$656,206

SA = sensitivity analysis.
[a] Calculated based on the lower range (15) contact per case from the studies included in the modelling scenario.
[b] Calculated based on the upper range (333) contact per case from the studies included in the modelling scenario.
[c] Calculated based on the modelling scenario, because no information on the number of contacts could be identified from the references.
[d] Calculated based on the lower range (2.08) hours per contact from the studies included in the modelling scenario.
[e] Calculated based on the upper range (3.06) hours per contact from the studies included in the modelling scenario.
[f] Results have been calculated based on the modelling scenario for these studies, which are presented in Appendix 7.
Note: Case number based on the primary outbreak scenario (Alberta).[7]

7. DISCUSSION

The primary objective of this project was to assist PHAC gain a better understanding of the health care resources and costs associated with contact tracing activities, by estimating costs and/or health care resource use associated with contact tracing in response to a measles outbreak. Originally, a summary of existing published studies and reviews was planned, with greater weighting placed on Canadian sources. The review of the literature did not identify any Canadian studies reporting resources and costs. Although a published review of economic analyses that included a modelled analysis of a US population was identified, the analysis was found to have several questionable assumptions. Thus, it was determined that a revised cost analysis would be undertaken.

As stated earlier, no Canadian studies were identified that quantified the costs and resource use associated with contact tracing. Although there have been numerous published articles reporting on measles outbreaks,[5,7,46,47] these articles are limited given their publication date (prior to measles elimination in 1998),[46,47] lack of contact tracing information,[5,46,47] or lack of disaggregated data.[7]

Although there are several factors that could not be included in the analysis, the modelling scenario used appears to provide a relevant estimate of the costs and resources associated with contact tracing during measles outbreaks. The generalizability of these results to the Canadian setting must be done with caution, with decision-makers considering whether the description of scenarios reflect their jurisdiction.

Based on the review of the literature, contact tracing procedures from the identified US studies appear to be similar to those indicated in the guidance provided by PHAC for the Canadian setting. That is, after diagnosis and confirmation of the index patient, the case is reported to the local public health unit, which then begins the process of contact tracing. The activities include interviewing the index patient, checking flight manifests, contacting relevant contacts,

communicating with other jurisdictions that may be affected based on contact tracing, issuance of press releases and public health advisories and enhanced surveillance measures, and potentially establishing toll-free phone lines and mobile immunization units.[30] There was substantial variation in the size of the outbreaks (in both number and geographic area). The driver of cost and resource use appears to be based on personnel time associated with the outbreak.

There are several limitations with the current analysis that could not be incorporated, given the scope of the work. The data components captured were not identical across the included studies, and thus, not all of the costs are likely to have been included. The costs that have been included may vary among settings to which they are being applied. As has been previously indicated in the literature, where secondary and tertiary cases occur, the overall costs are expected to be far greater than when disease is restricted to the single index patient.[35] Flego et al. indicated that the outbreak was largely sustained by the clustering of susceptible people within a single high school.[37] The proportion of persons vaccinated in an area, while important in determining the spread of disease, is also dependent upon the extent of the movement of the case patient(s) and whether the broader region(s) have similar rates of vaccination. Where unvaccinated or susceptible case patients are well integrated into the wider community, this might increase the potential for widespread transmission.[33]

8. CONCLUSIONS AND IMPLICATIONS FOR DECISION- OR POLICY-MAKING

The estimated cost of contact tracing activities is likely an underestimate, given the lack of information on the type of activities and extent of effort in Canada. Information on contact tracing activities during measles outbreaks is not typically collected in a standardized manner that can be used to inform decision-making, and reporting of personnel hours is likely to have been underestimated. The paucity of published data on resource use and outcomes associated with contact tracing in the post-measles elimination era is a significant limitation, given limited resources and processes to capture details of activities that occur during outbreaks, as it would lead to a greater ability to assess the impact of contact tracing methods in Canada. More detailed capture and reporting of activities and costs incurred during outbreaks will allow for more precise estimates of the economic impact of contact tracing activities.

9. REFERENCES

1. Control of communicable diseases manual. 19th ed. Heymann DL. Washington: American Public Health Association; 2008.
2. Measles [Internet]. In: Immunization & vaccines: vaccine-preventable diseases. Ottawa: Public Health Agency of Canada; 2014 May 8 [cited 2015 Feb 9]. Available from: http://www.phac-aspc.gc.ca/im/vpd-mev/measles-rougeole-eng.php.
3. Publicly funded immunization schedules for Ontario - August 2011 [Internet]. Toronto: Ontario Ministry of Health and Long-term Care; 2011. [cited 2015 Feb 18]. Available from: http://www.health.gov.on.ca/en/public/programs/immunization/docs/schedule.pdf
4. King A, Varughese P, De Serres G, Tipples GA, Waters J, Members of the Working Group of Measles Elimination. Measles elimination in Canada. J Infect Dis [Internet]. 2004 [cited 2015 Feb 18];189(Suppl 1):S236-S242. Available from: http://jid.oxfordjournals.org/content/189/Supplement_1/S236.full.pdf+html
5. De Serres G, Markowski F, Toth E, Landry M, Auger D, Mercier M, et al. Largest measles epidemic in North America in a decade--Quebec, Canada, 2011: contribution of susceptibility, serendipity, and superspreading events. J Infect Dis. 2013 Mar 15;207(6):990-8.
6. Canadian immunization guide. Part 1 [Internet]. Ottawa: Public Health Agency of Canada; 2014 Apr. [cited 2015 Feb 18]. Available from: http://www.phac-aspc.gc.ca/publicat/cig-gci/assets/pdf/p01-eng.pdf
7. Kershaw T, Suttorp V, Simmonds K, St.Jean T. Outbreak of measles in a non-immunizing population, Alberta 2013. CCDR [Internet]. 2014 Jun 12 [cited 2015 Feb 19];Volume 40-12. Available from: http://www.phac-aspc.gc.ca/publicat/ccdr-rmtc/14vol40/dr-rm40-12/dr-rm40-12-surv-3-eng.php
8. 2nd case of measles reported in Ottawa [Internet]. Toronto: CBC; 2014 Mar 10. [cited 2015 Feb 17]. Available from: http://www.cbc.ca/news/canada/ottawa/2nd-case-of-measles-reported-in-ottawa-1.2567278
9. Komarnicki J. AHS spent $1.4 million to fight measles outbreak [Internet].Calgary Herald; 2014 Apr 2. [cited 2015 Feb 17]. Available from: http://www2.canada.com/calgaryherald/news/story.html?id=e9bf9013-ff69-4dd5-974b-242ebe380a4e&p=1
10. Sahni V, Naus M. Measles: an unwelcome consequence of the 2010 Winter Olympic Games [Internet]. Vancouver: BC Centre for Disease Control (BCCDC); 2010 Nov 12. [cited 2015 Feb 17]. Available from: http://www.bccdc.ca/NR/rdonlyres/0135E978-A153-40A7-A994-0335A1D2052D/0/VSahniMNaus_MeaslesAnUnwelcomeConsequenceofthe2010WinterOlympicGames.pdf
11. An outbreak of measles in British Columbia, Canada: an unwelcome consequence of the 2010 Winter Olympics [Internet]. Abstract presented at: 48th Annual Meeting of the Infectious Diseases Society of America. 2010 Oct 22; Vancouver. [cited 2015 Feb 17]. Available from: https://idsa.confex.com/idsa/2010/webprogram/Paper4104.html
12. Clarke K. Four measles cases confirmed in Toronto, no known link or source case [Internet].Toronto Star; 2015 Feb 2. [cited 2015 Feb 27]. Available from: http://www.thestar.com/news/gta/2015/02/02/4-measles-cases-confirmed-in-toronto.html
13. Branswell H. Testing shows 4 of Toronto's measles cases are not linked to Disneyland outbreak [Internet]. Toronto: The Canadian Press; 2015 Feb 9. [cited 2015 Feb 27]. Available from: http://www.thecanadianpress.com/english/online/OnlineFullStory.aspx?filename=DOR-MNN-CP.23083ee577634761b32d68de1d5031b1.CPKEY2008111310&newsitemid=31830083&languageid=1

14. Maki A. Measles outbreak prompts officials to issue national plea for vaccination [Internet]. Toronto: The Globe and Mail; 2014 Mar 14. [cited 2015 Feb 27]. Available from: http://www.theglobeandmail.com/news/british-columbia/health-officials-urge-immunization-amid-measles-outbreak/article17495864/

15. U.S. multi-state measles outbreak December 28, 2014 - February 20, 2015. Atlanta (GA): Centers for Disease Control and Prevention (CDC); 2015 Feb 9.

16. CDC Health Alert Network. U.S. multi-state measles outbreak, December 2014-January 2015 [Internet]. Atlanta (GA): Centers for Disease Control and Prevention; 2015 Jan 23. [cited 2015 Feb 27]. Available from: http://emergency.cdc.gov/HAN/han00376.asp CDCHAN-00376.

17. Lupkin S, Neporent L. Measles continue to spread, reaching 154 cases in 17 states [Internet]. New York: ABC News; 2015 Feb 23. [cited 2015 Feb 27]. Available from: http://abcnews.go.com/Health/measles-continue-spread-reaching-154-cases-17-states/story?id=29169273

18. CCTV America [Internet]. CDC: 84 cases of measles in US, 67 linked to Disneyland in California; 2015 Jan 30 [cited 2015 Feb 27]. Available from: http://www.cctv-america.com/2015/01/30/cdc-84-cases-of-measles-in-us-67-linked-to-disneyland-in-california

19. Johnson EM, Sebens S. Lawmakers want tougher vaccine exemptions amid measles outbreak. Reuters [Internet]. 2015 Feb 5 [cited 2015 Feb 27]. Available from: http://www.reuters.com/article/2015/02/06/us-usa-measles-laws-idUSKBN0LA02N20150206

20. Yahoo Health Editors. [Internet]. Yahoo! Health. States move for tougher vaccine rules as measles epidemic grows; 2015 Feb 6 [cited 2015 Feb 27]. Available from: https://www.yahoo.com/health/states-move-for-tougher-vaccine-exemptions-as-110249980202.html

21. Peters JW, Pérez-Peña R. Measles outbreak proves delicate issue to G.O.P. field [Internet].The New York Times; 2015 Feb 2. [cited 2015 Feb 27]. Available from: http://www.nytimes.com/2015/02/03/us/politics/measles-proves-delicate-issue-to-gop-field.html?_r=0

22. Downs M. Autism-vaccine link: evidence doesn't dispel doubts [Internet]. In: WebMD special report: autism-searching for answers. New York: WebMD; 2008 Mar 21 [cited 2015 Feb 27]. Available from: http://www.webmd.com/brain/autism/searching-for-answers/vaccines-autism.

23. El Akkad O. Why more U.S. parents are refusing to have their children vaccinated [Internet]. Toronto: The Globe and Mail; 2015 Feb 4. [cited 2015 Feb 27]. Available from: http://www.theglobeandmail.com/news/world/why-more-us-parents-are-refusing-to-have-their-children-vaccinated/article22789241/

24. Vaccines do not cause autism [Internet]. In: Vaccine Safety. Atlanta (GA): Centers for Disease Control and Prevention (CDC); 2015 Mar 17 [cited 2015 May 1]. Available from: http://www.cdc.gov/vaccinesafety/concerns/autism/.

25. Does the MMR vaccine cause autism? [Internet].Immunize Canada; 2013 Dec 11. [cited 2015 Feb 27]. Available from: http://immunize.ca/en/publications-resources/questions/autism.aspx

26. Strauss B, Bigham M. Does measles-mumps-rubella vaccination cause inflammatory bowel disease and autism? BC Med J [Internet]. 2001 Nov [cited 2015 Feb 27];43(9):504-9. Available from: http://www.bcmj.org/article/does-measles-mumps-rubella-vaccination-cause-inflammatory-bowel-disease-and-autism

27. Payton L. Stephen Harper tells parents to listen to scientists about vaccines [Internet]. Toronto: CBC; 2015 Feb 25. [cited 2015 Feb 27]. Available from: http://www.cbc.ca/news/politics/stephen-harper-tells-parents-to-listen-to-scientists-about-vaccines-1.2972483

28. Southwick R. One in five Albertans believes vaccines can cause autism: poll [Internet]. Edmonton Journal: 2015 Feb 6. [cited 2015 Feb 27]. Available from: http://www.edmontonjournal.com/five+Albertans+believes+vaccines+cause+autism+poll/10791854/story.html

29. Armstrong J. 20% still think vaccines could cause autism: poll [Internet]. Toronto: Global News; 2015 Feb 6. [cited 2015 Feb 27]. Available from: http://globalnews.ca/news/1816542/20-still-think-vaccines-could-cause-autism-poll/

30. Guidelines for the prevention and control of measles outbreaks in Canada [Internet]. Ottawa: Public Health Agency of Canada; 2013 Oct. (Canada Communicable Disease Report CCDR). Volume 39, ACS-3. [cited 2015 Feb 17]. Available from: http://www.phac-aspc.gc.ca/publicat/ccdr-rmtc/13vol39/acs-dcc-3/assets/pdf/meas-roug-eng.pdf

31. Foerster V, Perras C, Spry C, Weeks L. Public health interventions to reduce secondary spread of measles [Internet]. Ottawa: CADTH; 2015 May. (CADTH rapid response report: systematic review). [cited 2015 May 5]. Available from: https://www.cadth.ca/public-health-interventions-reduce-secondary-spread-measles

32. Dayan GH, Ortega-Sánchez IR, LeBaron CW, Quinlisk MP, Iowa Measles Response Team. The cost of containing one case of measles: the economic impact on the public health infrastructure--Iowa, 2004. Pediatrics [Internet]. 2005 Jul [cited 2014 Oct 8];116(1):e1-e4. Available from: http://pediatrics.aappublications.org/content/116/1/e1.full.pdf+html

33. Parker AA, Staggs W, Dayan GH, Ortega-Sánchez 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 [Internet]. 2006 Aug 3 [cited 2014 Oct 8];355(5):447-55. Available from: http://www.nejm.org/doi/pdf/10.1056/NEJMoa060775

34. 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 Apr;125(4):747-55.

35. 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 Jan 5;30(2):317-21.

36. Stuart RL, Bradford J, Leszkiewicz P, Wilson J, Gillespie EE. The costs of containing measles within a health care service. Healthc Infect. 2010;15(2):43-6.

37. Flego KL, Belshaw DA, Sheppeard V, Weston KM. Impacts of a measles outbreak in Western Sydney on public health resources. Commun Dis Intell Q Rep [Internet]. 2013 Sep [cited 2014 Oct 16];37(3):E240-E245. Available from: http://www.health.gov.au/internet/main/publishing.nsf/Content/cda-cdi3703-pdf-cnt.htm/$FILE/cdi3703g.pdf

38. Ortega-Sánchez IR, Vijayaraghavan M, Barskey AE, Wallace GS. The economic burden of sixteen measles outbreaks on United States public health departments in 2011. Vaccine. 2014 Mar 5;32(11):1311-7.

39. Collier MG, Cierzniewski A, Duszynski T, Munson C, Wenger M, Beard B, et al. Measles outbreak associated with international travel, Indiana, 2011. J Pediat Infect Dis Soc. 2013;2(2):110-8.

40. Wichmann O, Siedler A, Sagebiel D, Hellenbrand W, Santibanez S, Mankertz A, et al. Further efforts needed to achieve measles elimination in Germany: results of an outbreak investigation. Bull World Health Organ [Internet]. 2009 Feb [cited 2014 Oct 8];87(2):108-15. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2636188

41. Carabin H, Edmunds WJ, Kou U, van den Hof S, Nguyen VH. The average cost of measles cases and adverse events following vaccination in industrialised countries. BMC Public Health [Internet]. 2002 Sep 19 [cited 2015 May 1];2:22. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC128813

42. Thompson KM, Odahowski CL. Systematic review of health economic analyses of measles and rubella immunization interventions. Risk Anal. 2014 Dec 24.

43. Bank of Canada [Internet]. Ottawa: Bank of Canada. Inflation calculator; 2012 Available from: http://www.bankofcanada.ca/rates/related/inflation-calculator/

44. Table 282-0069 - Labour force survey estimates (LFS), wages of employees by type of work, National Occupational Classification for Statistics (NOC-S), sex and age group, unadjusted for seasonality [Internet]. In: CANSIM. Ottawa: Statistics Canada; 2015 Feb 6 [cited 2015 Feb 12]. Available from: http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=2820069&paSer=&pattern=&stByVal=1&p1=1&p2=37&tabMode=dataTable&csid.

45. Conference Board of Canada. Benefits benchmarking 2012. Ottawa: Conference Board of Canada; 2012.

46. Yuan L. Measles outbreak in 31 schools: risk factors for vaccine failure and evaluation of a selective revaccination strategy. CMAJ [Internet]. 1994 Apr 1 [cited 2015 Feb 17];150(7):1093-8. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1486406

47. Sutcliffe PA, Rea E. Outbreak of measles in a highly vaccinated secondary school population. CMAJ [Internet]. 1996 Nov 15 [cited 2015 Feb 17];155(10):1407-13. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1335111

48. Greenway T. Measles outbreak causes Ottawa Public Health to run early deficit [Internet]. Ottawa: Metro News; 2014 May 6. [cited 2015 Feb 17]. Available from: http://metronews.ca/news/ottawa/1024794/measles-outbreak-causes-ottawa-public-health-to-run-early-deficit/

49. St. Stephen students without measles immunization asked to stay home [Internet]. Toronto: CBC; 2014 Mar 7. [cited 2015 Feb 17]. Available from: http://www.cbc.ca/news/canada/ottawa/st-stephen-students-without-measles-immunization-asked-to-stay-home-1.2564004

50. Measles case reminder of need to vaccinate, doctors say [Internet]. Toronto: CBC; 2014 Mar 6. [cited 2015 Feb 17]. Available from: http://www.cbc.ca/news/canada/ottawa/measles-case-reminder-of-need-to-vaccinate-doctors-say-1.2562997

51. Duffy A. Public health officials search for 200 families exposed to measles virus [Internet].Ottawa Citizen; 2014 Mar 6. [cited 2015 Feb 17]. Available from: http://ottawacitizen.com/news/local-news/public-health-officials-search-for-200-families-exposed-to-measles-virus

52. Advisory alert - measles update - May 2, 2014 [Internet]. Sudbury (ON): Sudbury & District Health Unit; 2014 May 2. [cited 2015 Feb 17]. Available from: http://www.sdhu.com/content/resources/doc.asp?folder=25544&parent=12&lang=0&doc=13615

53. Health unit still probing Sudbury measles case [Internet]. Sudbury Star; 2014 May 3 [cited 2015 Feb 17]. Available from: http://www.thesudburystar.com/2014/05/03/health-unit-still-probing-sudbury-measles-case

54. 10-year currency converter [Internet]. Ottawa: Bank of Canada; 2015. Available from: http://www.bankofcanada.ca/rates/exchange/10-year-converter/

55. CANSIM database [Internet]. Ottawa: Statistics Canada. Table 282-00695. Labour force survey estimates (LFS), wages of employees by type of work, National Occupational Classification for Statistics (NOC-S), sex and age group, unadjusted for seasonality; 2015 Feb 5 [cited 2015 Feb 27]. Available from: http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=2820069&paSer=&pattern=&stByVal=1&p1=1&p2=37&tabMode=dataTable&csid

APPENDIX 1: LITERATURE SEARCH

OVERVIEW	
Interface:	Ovid
Databases:	Embase 1974 to 2014 September 25 Ovid MEDLINE Daily and Ovid MEDLINE 1946 to 2014 September 25 Ovid MEDLINE In-Process & Other Non-Indexed Citations 1946 to 2014 September 25 **Note:** Subject headings have been customized for each database. Duplicates between databases were removed in Ovid.
Date of Search:	September 25, 2014
Study Types:	economic studies
Limits:	English language

SYNTAX GUIDE	
/	At the end of a phrase, searches the phrase as a subject heading
MeSH	Medical Subject Heading
exp	Explode a subject heading
*	Before a word, indicates that the marked subject heading is a primary topic; or, after a word, a truncation symbol (wildcard) to retrieve plurals or varying endings
ADJ	Requires words are adjacent to each other (in any order)
ADJ#	Adjacency within # number of words (in any order)
.ti	Title
.ab	Abstract
pmez	Ovid code for MEDLINE database
oemezd	Ovid code for Embase database

MULTI-DATABASE STRATEGY

Line #	Search strategy
1	Measles/ or Measles virus/ or exp Measles vaccine/
2	(measle* or rubeola or morbillivirus or morbilli).ti,ab.
3	or/1-2
4	Contact tracing/
5	(contact* adj4 (trac* or identif* or detect* or exam* or name* or case* or control or infection* or infected or pattern* or casual or intimate or information or investigation* or passenger* or household* or follow up or followed up or immunocompromised or immune-compromised or high risk or case-patient)).ti,ab.
6	contacts.ti,ab. or contact*.ti. or time to contact.ti,ab. or susceptible.ti. or susceptibles.ti,ab.
7	(susceptible adj3 (individual* or contact* or case* or person* or people or adult* or women or men or child* or employee* or student* or subgroup* or sub-group* or infant* or adolescen* or teen* or youth or youths or population* or communit*)).ti,ab.
8	(suspected adj3 (patient* or case* or contact*)).ti,ab.
9	(measle* adj2 (exposed or exposure)).ti,ab.
10	(unimmuniz* or unimmunis* or underimmuniz* or underimmunis* or under-immuniz* or under-immunis* or unvaccinat* or undervaccinat* or under-vaccinat* or non-vaccinat* or nonvaccinat* or un-vaccinat* or unvaccinat* or un-immuniz* or un-immunis*).ti,ab.

MULTI-DATABASE STRATEGY	
Line #	**Search strategy**
11	("not" adj2 vaccinated).ti,ab.
12	(fail* adj4 vaccinat*).ti,ab.
13	(secondary adj2 (spread or attack* or transmission*)).ti,ab.
14	(case adj (finding or detect* or identif*)).ti,ab.
15	or/4-14
16	Hospitals, Isolation/ or Patient isolation/ or Patient isolators/ or Quarantine/ or isolation.ti.
17	Isolat*.ti,ab. and (Cross Infection/ or exp Disease Transmission, infectious/ or exp Disease outbreaks/ or exp Communicable Diseases/ or Infection Control/)
18	(Isolat* and (cross infection or nosocomial* or infection control or outbreak* or hospital acquired or healthcare associated or health care associated or hospital associated or communicable)).ti,ab.
19	(isolat* and (import* adj4 (case or cases or virus or disease))).ti,ab.
20	((Isolator* or isolation or isolating or isolate or isolated or segregat* or containment) adj3 (patient* or ward* or unit* or room* or precaution* or pre-caution* or preemptive or pre-emptive or contact* or practice* or measure or measures or facility or facilities or period* or strateg*)).ti,ab.
21	(quarantin* or quarantain* or cohorting or cohort nursing or superisolation or isolette* or droplet precaution* or reverse isolation).ti,ab.
22	or/16-21
23	exp Disease outbreaks/
24	(outbreak* or importation* or secondary spread or secondary transmission*).ti,ab.
25	((epidemic* or pandemic*) adj4 measle*).ti,ab.
26	or/23-25
27	((target* or outbreak*) adj3 (response* or campaign* or strateg*)).ti,ab.
28	((target* or outbreak*) adj (vaccinat* or immuniz* or immunis* or inoculat*)).ti,ab.
29	or/27-28
30	3 and (15 or 22 or 26 or 29)
31	30 use pmez
32	exp Measles/ or Measles vaccination/ or Measles vaccine/
33	(measle* or rubeola or morbillivirus or morbilli).ti,ab.
34	or/32-33
35	Contact examination/ or Susceptible population/
36	(contact* adj4 (trac* or identif* or detect* or exam* or name* or case* or control or infection* or infected or pattern* or casual or intimate or information or investigation* or passenger* or household* or follow up or followed up or immunocompromised or immune-compromised or high risk or case-patient)).ti,ab.
37	contacts.ti,ab. or contact*.ti. or time to contact.ti,ab. or susceptible.ti. or susceptibles.ti,ab.
38	(susceptible adj3 (individual* or contact* or case* or person* or people or adult* or women or men or child* or employee* or student* or subgroup* or sub-group* or infant* or adolescen* or teen* or youth or youths or population* or communit*)).ti,ab.
39	(suspected adj3 (patient* or case* or contact*)).ti,ab.
40	(measle* adj2 (exposed or exposure)).ti,ab.
41	(unimmuniz* or unimmunis* or underimmuniz* or underimmunis* or under-immuniz* or under-immunis* or unvaccinat* or undervaccinat* or under-vaccinat* or non-vaccinat* or nonvaccinat* or un-vaccinat* or unvaccinat* or un-immuniz* or un-immunis*).ti,ab.
42	("not" adj2 vaccinated).ti,ab.
43	(fail* adj4 vaccinat*).ti,ab.

MULTI-DATABASE STRATEGY	
Line #	**Search strategy**
44	(secondary adj2 (spread or attack* or transmission*)).ti,ab.
45	(case adj (finding or detect* or identif*)).ti,ab.
46	or/35-45
47	Isolation.ti.
48	isolat*.ti,ab. and (Cross Infection/ or Hospital Infection/ or exp Disease Transmission/ or Infection control/ or Import disease/)
49	(Isolat* and (cross infection or nosocomial* or infection control or outbreak* or hospital acquired or healthcare associated or health care associated or hospital associated or communicable)).ti,ab.
50	(isolat* and (import* adj4 (case or cases or virus or disease))).ti,ab.
51	((Isolator* or isolation or isolating or isolate or isolated or segregat* or containment) adj3 (patient* or ward* or unit* or room* or precaution* or pre-caution* or preemptive or pre-emptive or contact* or practice* or measure or measures or facility or facilities or period* or strateg*)).ti,ab.
52	(quarantin* or quarantain* or cohorting or cohort nursing or superisolation or isolette* or droplet precaution* or reverse isolation).ti,ab.
53	or/48-52
54	Import disease/ or Epidemic/ or Pandemic/
55	(outbreak* or importation* or secondary spread or secondary transmission*).ti,ab.
56	((epidemic* or pandemic*) adj4 measle*).ti,ab.
57	or/54-56
58	((target* or outbreak*) adj3 (response* or campaign* or strateg*)).ti,ab.
59	((target* or outbreak*) adj (vaccinat* or immuniz* or immunis* or inoculat*)).ti,ab.
60	or/58-59
61	34 and (46 or 53 or 57 or 60)
62	61 use oemezd
63	Economics/
64	exp "Costs and Cost Analysis"/
65	Economics, Nursing/
66	Economics, Medical/
67	Economics, Pharmaceutical/
68	exp Economics, Hospital/
69	Economics, Dental/
70	exp "Fees and Charges"/
71	exp Budgets/
72	budget*.ti,ab.
73	(economic* or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic* or pharmaco-economic* or expenditure or expenditures or expense or expenses or financial or finance or finances or financed).ti.
74	(economic* or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic* or pharmaco-economic* or expenditure or expenditures or expense or expenses or financial or finance or finances or financed).ab. /freq=2
75	(cost* adj2 (effective* or utilit* or benefit* or minimi* or analy* or outcome or outcomes)).ab.
76	(value adj2 (money or monetary)).ti,ab.
77	exp models, economic/
78	economic model*.ti,ab.
79	markov chains/

MULTI-DATABASE STRATEGY	
Line #	**Search strategy**
80	markov.ti,ab.
81	monte carlo method/
82	monte carlo.ti,ab.
83	exp Decision Theory/
84	(decision* adj2 (tree* or analy* or model*)).ti,ab.
85	or/63-84
86	Economics/
87	Cost/
88	exp Health Economics/
89	Budget/
90	budget*.ti,ab.
91	(economic* or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic* or pharmaco-economic* or expenditure or expenditures or expense or expenses or financial or finance or finances or financed).ti.
92	(economic* or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic* or pharmaco-economic* or expenditure or expenditures or expense or expenses or financial or finance or finances or financed).ab. /freq=2
93	(cost* adj2 (effective* or utilit* or benefit* or minimi* or analy* or outcome or outcomes)).ab.
94	(value adj2 (money or monetary)).ti,ab.
95	Statistical Model/
96	economic model*.ti,ab.
97	Probability/
98	markov.ti,ab.
99	monte carlo method/
100	monte carlo.ti,ab.
101	Decision Theory/
102	Decision Tree/
103	(decision* adj2 (tree* or analy* or model*)).ti,ab.
104	or/86-103
105	(31 and 85) or (62 and 104)
106	limit 105 to english language
107	remove duplicates from 106

OTHER DATABASES	
PubMed	Same MeSH, keywords, limits, and study types used as per MEDLINE search, with appropriate syntax used.

Grey Literature

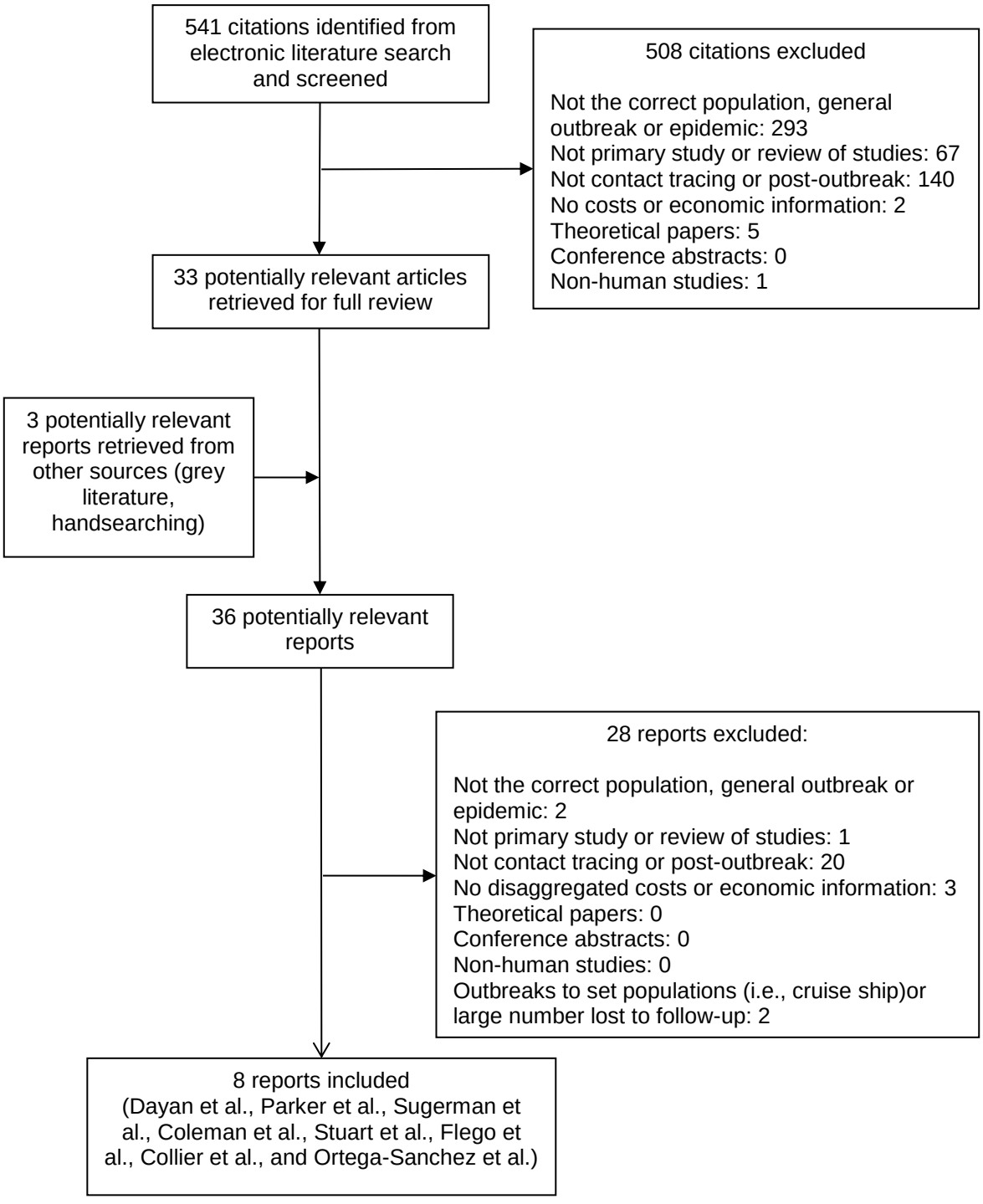
Dates for Search:	September 29 – October 1, 2014
Keywords:	Measles, outbreak, epidemic, pandemic, contact tracing, isolation, outbreak response
Limits:	English language

The following websites and databases were searched:

- University of York Centre for Reviews and Dissemination NHS Economic Evaluations Database
- Health Economic Evaluations Database
- Canadian Institute of Health Economics
- Ontario Case Costing Initiative, Ontario Ministry of Health and Long-Term Care
- Public Health Agency of Canada, Economic Burden of Illness in Canada
- Toronto Health Economics and Technology Assessment Collaborative
- National Centre for Pharmacoeconomics (Ireland)
- Health Economics Research Unit, University of Aberdeen
- Federal Reserve Bank of St. Louis, Economic Research Division.

The above was followed by a focused Internet search.

APPENDIX 2: SELECTION OF INCLUDED STUDIES



APPENDIX 3: SUMMARY OF EXCLUDED STUDIES

Citation	Reason for Exclusion
Althouse et al. Proceedings of the National Academy of Sciences of the United States of America 2010; 107(Suppl 1): 1696-701	Not the correct population, general outbreak or epidemic
Becker et al. Aust N Z J Public Health 2005; 29(1): 58-63	Does not present disaggregated costs or economic information
Bonačić Marinović et al. Emerging Infectious Diseases 2012; 18(9): 1405-1413	Study does not include contact tracing or was not done post-outbreak
Boxall et al. European communicable disease bulletin 2008; 13(16)	Study does not include contact tracing or was not done post-outbreak
Carabin et al. BMC Public Health 2002; 2:22	Study does not include contact tracing or was not done post-outbreak
Haraoui et al. American Journal of Tropical Medicine and Hygiene. 2011; 85(6 (Suppl 1)): 395	Study does not include contact tracing or was not done post-outbreak
Helmecke et al. American Journal of Infection Control 2013; 41(6 (Suppl)): S136-S137	No disaggregated costs or economic information
Helmecke et al. Am J Infect Control 2014;42(8):911-5	Outbreaks to set populations (i.e., cruise ship) or large number lost to follow-up
JAMA 1997;278(17):1396-7	Not a primary study or review of studies
JAMA 1998;279(21):1685-6	Study does not include contact tracing or was not done post-outbreak
Kelly et al. Med J Aust 2002;176(2):50-1	Study does not include contact tracing or was not done post-outbreak
Knol et al. European communicable disease bulletin 2013; 18(36):ii	Study does not include contact tracing or was not done post-outbreak
Kutty et al. Human Vaccines and Immunotherapeutics 2014; 10(5): 1373-81	Not in the correct population, general outbreak or epidemic
Lernout et al. European communicable disease bulletin 2009; 14(2)	Study does not include contact tracing or was not done post-outbreak
Minetti et al. Am J Epidemiol 2014;179(2):245-51	Study does not include contact tracing or was not done post-outbreak
Mitruka et al. Journal of Travel Medicine 2012;19(4):233-7	Outbreaks to set populations (i.e., cruise ship) or large number lost to follow-up
Morbidity and Mortality Weekly Reports 1997; Morbidity(11):242-6	Study does not include contact tracing or was not done post-outbreak
Morbidity and Mortality Weekly Reports 1997; Morbidity(49):1159-63	Study does not include contact tracing or was not done post-outbreak
Morbidity and Mortality Weekly Reports 1998; Morbidity(14):273-6	Study does not include contact tracing or was not done post-outbreak
O'Donnell et al. American Journal of Infection Control 2010; 38 (5): E4	Does not present disaggregated costs or economic information
Parent et al. European communicable disease bulletin 2009; 14(6)	Study does not include contact tracing or was not done post-outbreak

Citation	Reason for Exclusion
Pelletier et al. Vaccine 1998;16(9-10):989-96	Study does not include contact tracing or was not done post-outbreak
Shiell et al. Aust N Z J Public Health 1998;22(1):126-32	Study does not include contact tracing or was not done post-outbreak
van Velzen et al. European communicable disease bulletin 2008; 13(31)	Study does not include contact tracing or was not done post-outbreak
Wadl et al. BMC Public Health 2011; 11: 474	Study does not include contact tracing or was not done post-outbreak
Wallace et al. Vaccine 2014;32(35):4505-14	Study does not include contact tracing or was not done post-outbreak
Weekly epidemiological record / Health Section of the Secretariat of the League of Nations 1994;69(48):360-2	Study does not include contact tracing or was not done post-outbreak
Wichman et al. Bull World Health Organ 2009;87(2):108-15	Study does not include contact tracing or was not done post-outbreak

APPENDIX 4: SUMMARY OF STUDIES FROM ECONOMIC LITERATURE SEARCH

Dayan et al. (2004)
Dayan et al.[32] reported on a measles outbreak from Iowa in 2004, examining the costs associated with the measles-containment efforts (direct costs of the disease were not measured). This outbreak resulted from a case imported from India, in which six members of a larger group of college students from Iowa who were susceptible to measles contracted measles while there. One student (the case patient) ignored Iowa Department of Public Health (IDPH) recommendations to stay in India during the infectious or incubation period and returned to Iowa earlier than recommended. The travel involved connections through two major airports, during which time the case patient developed symptoms. Shortly after returning to Iowa, the patient presented to a physician and the case of measles was confirmed. An intensive measles-containment strategy was implemented. While Iowa has a statewide average of 97% vaccination, the local community had a high proportion of non-medical exemptions, with only 59% of students in the area being vaccinated.

The containment activities undertaken by IDPH included subpoenaing flight manifests, contacting Iowa-resident passengers regarding post-exposure prophylaxis, communicating with other states concerning non-Iowa resident passengers, issuing press releases, issuing health advisories to alert physicians and enhance surveillance, collaborating with the Centers for Disease Control and Prevention (CDC), establishing special measles vaccination clinics, and setting up a toll-free measles information phone line.

The spread was limited to two secondary cases; one unvaccinated close contact of the case patient and an appropriately vaccinated person who had sat next to the case patient on a plane for two hours. No third-generation cases were reported. Contact tracing on the secondary cases indicated that more than 1,000 people were exposed. Three vaccination clinics were held for these contacts. Seven people refused post-exposure vaccination and had to be quarantined; some required intervention from law enforcement. Approximately 2,500 hours of personnel time were reported, based on written chronological reports and retrospective interviews. Table 6 reports a breakdown of the personnel hours by activity and jurisdiction, along with the associated costs.

Table 6: Estimated Resources and Costs Reported by Dayan et al. 2004							
	IDPH	**Linn County**	**Jefferson County**	**Johnson County**	**University of Iowa Hospitals/ Clinics**	**Public Health Laboratory for Iowa**	**Total**
Personnel time per activity							
Investigation	327.3	30.7	9.3	241.7	27.0	115.0	750.9
Emergency response	840.0	127.9	80.0	329.5	202.0		1,579.5
Other	59.0	32.2				33.0	124.2
Total hours	1,226.3	190.8	89.5	571.3	299.0	148.0	2,524.8
Materials							
Phone calls	1,700.0		45.0		280.0		2,025.0
MMR vaccine doses	1,550.0	33.0	33.0	32.0			1,550.0
IMG doses	450.0	80.0		19.0			450.0
Miles	2,173.0	70.0					2,243.0
Estimated costs							
Personnel (incl. fringe benefits)	$46,185	$6,507	$1,773	$17,647	$8,561	$4,620	$85,292
Overheads	$15,125	$1,500		$2,739		$2,171	$21,535
Public information	$858	$13	$440				$1,311
MMR vaccine and IMG	$28,964						$28,963
Others			$90	$144		$4,501	$4,734
Miles	$596	$20					$616
Total costs	**$91,727**	**$8,040**	**$2,302**	**$20,529**	**$8,561**	**$11,292**	**$142,452**

IDPH = Iowa Department of Public Health; IMG = immunoglobulin; MMR = measles, mumps, rubella.
Note: Costs are reported in US$
Adapted from: Dayan et al. 2004.[32]

Parker et al. (2006)

Parker et al.[33] reported on a measles outbreak from Indiana, USA, in 2005. In May 2005, an unvaccinated person travelled back to Indiana from Romania after having unknowingly acquired measles. The study consisted of investigating transmission patterns, vaccination rates, and costs of containment activities, including time spent by personnel, materials, and direct costs related to containing the measles virus for the study period. The vaccination rate in Indiana was reported to be 92% in 2004, including 98% of kindergarteners and sixth-graders, but was higher in the two counties that comprised the majority of case patients (94%) in this study (98% of kindergarteners and nearly 100% of sixth-graders, respectively).

Information regarding time and materials required to undertake contact tracing activities was collected through a survey of public health officers and infection-control personnel. Personnel costs were calculated by multiplying a person's gross wage by the time they spent on the measles outbreak. Overhead costs and fringe benefits were calculated to be a proportion of the person's wages. Unit costs were obtained for other expenses (e.g., vaccines or miles). Direct medical costs for the treatment of cases were not included.

The authors reported that there were more than 500 contacts during the outbreak, although an actual number was not specified. The majority of these contacts were from a large gathering that the case patient attended shortly after returning to Indiana. Two weeks after the gathering, the Indiana State Department of Health (ISDH) was notified that a child who had attended the gathering had been hospitalized with measles in another state, which led to action by the ISDH.

Three generations of cases occurred during the outbreak, in which 66 individuals were suspected of having measles, of whom 34 were confirmed cases or epidemiologically linked to a laboratory-confirmed case. Only two of the confirmed cases had evidence of vaccination. Thirty-two cases were located within the two Indiana counties; one was located in a third Indiana county, and one in Illinois. Nineteen cases were infected by the index patient (second generation), and 13 were infected by a second-generation case (third generation). Although 20 patients were infectious and interacted with the community prior to the public health authorities being made aware of the cases and instituting containment measures, no known transmission occurred in the community outside the gathering, with the exception of one hospital worker, who had received one measles vaccination. Cases and contacts who declined prophylactic vaccination were asked to be voluntarily quarantined for up to four days after the onset of symptoms (i.e., rash) and 18 days after being exposed. No legal action was required to enforce containment measures.

Containment activities involved approximately 3,650 person-hours, 4,800 telephone calls, 5,500 miles driven, and 550 lab specimens tested. The costs of containment were calculated to be US$167,685 (Table 7).

Table 7: Estimated Resources and Costs Reported by Parker et al. 2006

	Indiana State Department of Health	Illinois State Health Department	County Health Departments	Hospital A	Outpatient Care	Total
No. personnel directly involved	18	2	9	66	4	99
Time spent per activity (hr)						
Investigation	298		53	422	13	786
Emergency response	535	74	374	1,078	19	2,080
Laboratory work	135			481		616
Other	61		2	96	33	192
Total	1,029	74	429	2,077	65	3,674
Materials or activities						
No. phone calls	1,422	11	1,630	1,581	167	4,811
Doses of MMR vaccine			141	317	7	465
Doses of IMG			5	210	1	216
No. specimen collection kits	51	3		508	15	577
Travel (miles)	5,298	127	129			5,554
Estimated costs						
Wages and salaries	$21,972	$1,813	$12,284	$70,948	$1,575	$108,592
Overheads	$5,339	$440	$2,985	$21,284	$383	$30,431
MMR vaccine and IMG			$2,372	$19,185	$135	$21,692
Mileage	$1,536	$37	$37			$1,610
Other	$3,074		$56	$2,230		$5,360
Total costs	**$31,921**	**$2,290**	**$17,734**	**$113,647**	**$2,093**	**$167,685**

IMG = immunoglobulin; MMR = measles, mumps, rubella.
Note: Costs are reported in US$
Adapted from: Parker et al. 2006.[33]

Sugerman et al. (2010)

Sugerman et al.[34] reported on a measles outbreak from San Diego in 2008. Measles transmission patterns, vaccination rates, outbreak costs, and beliefs or characteristics of parents who decline vaccination for their children were examined as part of this study. This outbreak resulted from an intentionally unvaccinated juvenile unknowingly infected with measles returning from Switzerland to San Diego. Contact tracing activities appear to have consisted of interviewing cases to determine the likely transmission event and persons they potentially exposed, and checking records for immunization status. Other containment measures appear to have been implemented, although it is not clear what these were.

In total, 839 persons were identified as having been exposed to measles, resulting in 12 cases being identified (10 lab confirmed, two epidemiologically linked), linked over three generations. The index patient transmitted measles to eight contacts, including two immediate family members. The index patient visited multiple health care facilities prior to being diagnosed with measles, which may have amplified the spread of disease. By the time the tests on the index patient confirmed measles, four of the eight secondary cases were infectious. A further three contacts were infected (third generation). These new cases were all isolated or quarantined so that no further transmission occurred. Of the 839 exposed persons, 13% did not have documented proof of measles immunization. A total of 1,745 person-hours were reported to have been spent on investigation and containment measures, at a public sector cost of US$124,517 (Table 8).

Table 8: Estimated Resources and Costs Reported by Sugerman et al. 2008

	San Diego County Health and Human Services Agency	California Department of Public Health	Total
Personnel directly involved	31	10	41
Time spent per activity			
Investigation	399	11	410
Emergency response	479	136	615
Laboratory work	81	241	322
Vaccination	32	0	32
Other	366	2	368
Total time	1,355	390	1745
Percentage of overtime	15.9	6.1	15.7
Selected materials			
MMR vaccine (doses)	5	0	5
Travel (miles)	273	0	273
Estimated costs			
Wages and salaries	$92,552	$8,039	$100,591
Overhead	$17,766	$608	$18,375
Laboratory	$501	$4,750	$5,251
MMR vaccine	$163	$0	$163
Mileage	$138	$0	$138
Total costs	**$111,120**	**$13,397**	**$124,517**

MMR = measles, mumps, rubella.
Note: Costs are reported in US$
Adapted from: Sugerman et al. 2010[34]

Coleman et al. (2012)

Coleman et al.[35] undertook an analysis to estimate the medical and public health costs incurred in responding to a case of measles in Kentucky. They estimated the costs of directly documented labour involved in both caring for the index case and conducting the event response. The case patient was diagnosed with measles shortly after immigrating to the US from India. Health workers determined that the case patient exhibited no rash upon entry to the US, although was unwell on the flight. The Kentucky Department of Public Health (KDPH) implemented contact tracing and vaccination of contacts. KDPH coordinated the activities of its own personnel, as well as two CDC quarantine stations, the Kentucky Office for Refugees, a district health department, a metropolitan health department, and local medical practices. Response activities included issuing information; coordinating care and travel for family, as well as medical care and interpreter services; conducting contact interviews; acquiring vaccines; treating patients; setting up meetings and phone calls; and creating reports.

Contact tracing activities resulted in the interview of 44 contacts, most of whom were staff at health care facilities. Immunoglobulin or vaccine was administered to 16 contacts and two family members, due to a lack of recorded confirmation of measles immunity. No additional cases were identified. A total of 387 personnel hours were recorded. Using the Kentucky state based hourly wage plus benefits (assumed to be 30% of the wage added to the base hourly wage), the personnel costs were US$11,881. The authors reported a further US$11,934 associated with hospital treatment and physician visits for the index patient, vaccine and immunoglobulin (IMG) doses, travel costs, and immunologic screening tests. Disaggregated costs are presented in Table 9.

Table 9: Estimated Resources and Costs Reported by Coleman et al. 2012					
	Labour Hours	**Kentucky State Hourly Wage**	**Kentucky State Hourly Wage + Benefits**	**Total Cost (Kentucky Labour Costs)**	**Total Cost (National Labour Costs)**
CDC	20	$53.72	$69.84	$1,397	$1,397
Quarantine stations	4	$53.72	$69.84	$279	$279
Refugee case worker	87.7	$19.82	$25.77	$2,260	$2,650
Nursing supervisor	2.5	$27.94	$36.32	$91	$104
Physician time	2.33	$94.53	$122.63	$286	$235
Standard nurse time	16.91	$25.57	$33.24	$562	$601
Medical support staff	9.6	$13.03	$16.93	$163	$181
Lab time	1	$21.33	$27.73	$28	$30
Regional epidemiologist	37.5	$25.41	$33.03	$1,239	$1,522
County PHD	134.65	$19.82	$25.77	$3,469	$4,068
State refugee coordinator	16	$25.79	$33.53	$536	$612
State PHD	52.75	$19.82	$25.77	$1,359	$1,594
Hospital interpreter	2.5	$65.40	$85.02	$213	$213
Personnel costs	**387.44**			**$11,881**	**$13,485**
				Costs	
Hospital treatment for index patient				$9,431	
Physician visits				$294	
Vaccine and IMG				$1,765	
Mileage				$205	
Immunologic screening tests				$240	
Non-personnel costs				**$11,935**	
Totals costs				**$23,816**	**$25,420**

CDC = Centers for Disease Control; IMG = immunoglobulin; PHD = public health department.
Note: Costs are reported in US$
Adapted from: Coleman et al. 2012.[35]

Ortega-Sanchez et al. (2014) — Review

Ortega-Sanchez et al.[38] conducted a review seeking to estimate the economic burden of measles in the United States of America (US) in 2011. The authors took information from 16 measles outbreaks reported in the US in 2011 (Table 10). The information for cases and contacts from these outbreaks was sourced from various Centers for Disease Control (CDC) Morbidity and Mortality Weekly Reports. The authors reported that sites did not have standardized methods of data collection, so contacts were reported based on both documentation and recall.

Table 10: Information on United States Measles Cases, 2011									
Outbreak	**Cases**	**Duration**	**Contacts**	**CDI**	**Outbreak**	**Cases**	**Duration**	**Contacts**	**CDI**
PA1	6	21	290	126	VA	4	17	295	68
MN1	22	68	3,009	1,496	NY/MD	5	14	285	70
MI/MN/TX	6	14	140	84	UT2	6	24	2,400	144
UT1	7	24	12,000	168	IN	14	26	780	364
FL	3	13	8	39	PA3	4	16	387	64
KS	6	36	3,000	216	MN2	3	12	177	36
CA	3	18	126	54	CA/MD/WI/NC	9	24	781	216
PA2	3	5	35	15	NY	6	13	248	78

CA = California; CDI = case-day index; FL = Florida; IN = Indiana; KS = Kansas; MD = Maryland; MI = Michigan; MN = Minnesota; NC = North Carolina; NY = New York; PA = Pennsylvania; TX = Texas; UT = Utah; VA = Virginia; WI = Wisconsin.
Note: "Outbreak" refers to state in which outbreak occurred. Numbering in the "Outbreak" column indicates multiple outbreaks within the state.
Adapted from: Ortega-Sanchez et al. 2014[38]

Resource utilization and average costs were determined from four studies that had estimated the economic impact of measles on health departments in the US. These four studies were described previously in this section of the document, but a summary table has been reproduced in Table 11.

Table 11: Summary Table of Resources and Costs from Measles Outbreaks in the United States					
	Iowa and Michigan, 2004 (Dayan et al.)	**Indiana, 2005 (Parker et al.)**	**San Diego, 2008 (Sugerman et al.)**	**Kentucky, 2010 (Coleman et al.)**	**Average**
Confirmed cases	1	34	12	1	12
Identified contacts	> 1,000	500	376	45	480
Personnel hours					
Local	516	429	1,355	NR	615[a]
State	1,786	1,103	390	NR	877[a]
Total	2,302	1,532	1,745	387	1,492
Hours per contact					
Local	0.5	0.9	3.6	NA	2.33[a]
State	1.8	2.2	1.0	NA	2.34[a]
Total	2.3	3.2	4.6	8.6	4.68
Outbreak costs					
Local	$44,558	$20,427	$116,098	NR	$48,264[a]
State	$137,121	$39,404	$13,997	NR	$50,780[a]
Total	$181,679	$59,831	$130,095	$24,569	$99,044
Cost per contact					
Local	$45	$41	$309	NA	$182 [a]
State	$137	$79	$37	NA	$117[a]
Total	$182	$120	$346	$546	$299

NA = not applicable; NR = not reported.
[a] Local and state hours and costs for Coleman were derived from total hours and weighted based on proportional spread from Dayan et al., Parker et al., and Sugerman et al.
Note: Costs are reported in US$
Adapted from: Ortega-Sanchez et al. 2014[38]

The 16 outbreaks that were included in the review reported 107 confirmed cases, with a median of six cases per outbreak (range: 3 to 22) and an average outbreak duration of 22 days (range: 5 to 68). A median of 293 contacts per outbreak were reported retrospectively (range: 8 to 12,000). These data were used to estimate the number of personnel hours per contact and average cost per contact.

Ortega-Sanchez et al. used an indirect approach to define outbreak size based on the duration of outbreak multiplied by the number of measles cases, to arrive at a case-day index (CDI) (Table 10). The authors' rationale for using a CDI approach is based on the assumption that the magnitude of a public health response is driven by the number of individuals in direct contact with infective measles cases and by the time and effort it takes to respond these outbreaks. The CDI was then used to classify the size of the outbreaks around the quartiles of their distribution, stratifying the 16 outbreaks into four small outbreaks (CDI: 15 to 54), eight medium-sized outbreaks (CDI: 64 to 168), and four large outbreaks (CDI: 216 to 1,496). The number of contacts per case was then assumed based on the size of the outbreak (small: 3 to 25; medium: 40 to 100; large: 140 to 250).

The authors provided a range of contacts based on the size of the outbreak, then assumed a total of 4.7 personnel hours per contact and a cost of US$298 per contact based on the prior literature (Table 11) to determine the ranges for the outbreaks in the US in 2011. Ortega-Sanchez et al.[38] stated that they validated the case-day approach by reclassifying the outbreak by contacts per day; the rankings were similar, with both ratios showing strong correlation (R^2 = 0.95).

Using the CDI and revised determinants for contacts, the estimated number of contacts, range of costs for outbreaks, and estimated number of personnel hours are reported in Table 12. The estimated costs for public response to local and state public health departments were estimated to range from US$2.7 million to US$5.3 million.

Table 12: Estimated Resources and Costs Associated With 2011 US Measles Outbreaks Reported by Ortega-Sanchez et al. 2014				
Outbreak	**Case-Day Index**	**Number of Contacts**	**Personnel Hours**	**Costs**
Large				
MN1	1,496	3,080 to 5,500	14,442 to 25,790	$918,847 to $1,640,798
IN	364	1,960 to 3,500	9,190 to 16,412	$584,721 to $1,044,144
CA/MD/WI/NC	216	1,260 to 2,250	6,438 to 11,336	$421,244 to $752,221
KS	216	840 to 1,500	4,232 to 7,557	$280,829 to $501,481
Medium				
UT1	168	280 to 700	1,313 to 3,282	$83,532 to $208,829
UT2	144	240 to 600	1,125 to 2,813	$71,598 to $178,996
PA1	126	240 to 600	1,125 to 2,813	$71,598 to $178,996
MI/MN/TX	84	240 to 600	1,125 to 2,813	$71,598 to $178,996
NY	78	240 to 600	1,125 to 2,813	$71,598 to $178,996
NY/MD	70	200 to 500	938 to 2,345	$59,665 to $149,163
VA	68	160 to 400	750 to 1,876	$47,732 to $119,331
PA3	64	160 to 400	750 to 1,876	$47,732 to $119,331
Small				
CA	54	9 to 75	42 to 352	$2,685 to $22,375
FL	39	9 to 75	42 to 352	$2,685 to $22,375
MN2	36	9 to 75	42 to 352	$2,685 to $22,375
PA2	15	9 to 75	42 to 352	$2,685 to $22,375
Total		**8,936 to 17,450**	**42,635 to 83,133**	**$2,741,436 to $5,340,781**
Mean (overall)		526 to 1,026	2,508 to 4,890	$161,261 to $314,164
Mean (large)		1,785 to 3,188	8,553 to 15,274	$551,410 to $984,661
Mean (medium)		196 to 489	917 to 2,292	$58,339 to $145,849
Mean (small)		9 to 75	42 to 352	$2,685 to $22,375

CA = California; FL = Florida; IN = Indiana; KS = Kansas; MD = Maryland; MI = Michigan; MN = Minnesota; NC = North Carolina; NY = New York; PA = Pennsylvania; TX = Texas; UT = Utah; VA = Virginia; WI = Wisconsin.
Note: "Outbreak" refers to state in which outbreak occurred. Numbering in the "Outbreak" column indicates multiple outbreaks within the state.
Note: Costs are reported in US$
Adapted from: Ortega-Sanchez et al. 2014.[38]

Stuart et al. (2010)

Stuart et al.[36] reported the economic impact of measles-containment efforts in a single health service in Victoria, Australia. Cases retrospectively identified from January 2009 to March 2009 were reviewed and included, although not in a sequenced manner (i.e., there was no identification of an index patient). Infection control measures were identified and resources required to implement measles control were measured. Contact tracing methods were based on guidelines set out by the Department of Human Services, Victoria, and recommendations to susceptible persons were based on those of the National Health and Medical Research Council. Twelve episodes covering 17 confirmed measles cases were reported during the study period. In one episode, measles was not identified until a week after presentation; thus, formal contact tracing did not occur for this episode. The contact tracing measures identified 871 contacts requiring follow-up (0 to 262 per episode), 506 of whom required follow-up.

Costs included within the analysis were nursing time, phone calls, and vaccine administration. Personnel time was based on the time required to complete contact tracing activities, provide vaccinations, and educate staff. It was estimated that for a single measles contact, 10 minutes of personnel time was required per contact, which included time for developing a contact list, finding contact details, and making phone calls and call-backs. The hourly rate for personnel was A$45 (which included on-costs), while additional costs included phone calls, vaccine and

immunoglobulin administration, and education. Costs associated with general practitioner attendances or hospitalizations were not included. More than 150 hours of personnel time within the health service were reported to have been expended during the outbreak. The estimated cost of contact tracing time was $6,532; additional related costs included A$600 for phone calls, and A$360 for educational activities. Other costs attributed within the study were $300 for time to vaccinate contacts, A$1,722 for vaccine costs, and A$825 for readmission and immunoglobulin administration. While this provides some information on costs, the authors stated that they were not able to follow up all contacts to ascertain whether other cases had occurred within the community.

Flego et al. (2013)

Flego et al.[37] reported the impact of a measles outbreak on public health unit (PHU) resources in New South Wales, Australia, in February 2011. No source of the outbreak was identified. The authors reported that a review of case-investigation records was undertaken based on a series of forms completed for each case during the outbreak. Contact tracing was performed as per New South Wales Health Guidelines, and records of these measures were reviewed. Contact tracing included conducting interviews of the case patient; contacting any health care facilities to which the case patients had presented, to determine staff and patients who were exposed; and contacting those exposed, to determine their measles vaccination status. Data were prospectively gathered on the time spent by PHU staff on contact tracing activities and arranging testing. Staff costs were determined based on the top rate for their award level. A log of communications was kept and costed according to the rate stated to be charged by the local health district. Pathology costs were actual costs billed by the laboratory for tests ordered. Hospital medical records were reviewed to determine whether any unreached contacts had visited any hospitals. The cost of following up one contact was estimated by dividing the costs for following up contacts of the case by the number of contacts followed up. The total cost of follow-up was estimated by multiplying the per contact cost by the total number of contacts, and adding the cost of staffing a vaccination clinic that was part of the outbreak response.

The initially identified case patient had not travelled recently and no source case was identified. Shortly afterward, another case of measles was notified in a child with whom the original case patient had had some social contact, but not within the timelines required to transmit measles. Two additional patients were notified at this time, neither with any epidemiological connection to either of the other patients. During the next five weeks, a further 22 cases of confirmed measles were reported, of which three were acquired overseas. In total, 26 cases were reported in this outbreak, with all case patients residing within the same local government area in New South Wales. Seven patients required admission to hospital for more than one day, and a further 10 were managed within a hospital emergency department. In total, 1,395 contacts were identified and managed by PHU staff. Of these, 169 potentially susceptible contacts were identified and prophylactically treated; 79 received immunoglobulin, and 90 were recommended to receive the measles vaccine. There were no secondary cases among the contacts given post-exposure prophylactic treatment.

The authors reported that a case study was undertaken to determine the cost of contact tracing, which estimated the cost per contact to be A$2,433. Thus, the authors concluded that the total cost to the PHU of contact management for the outbreak was A$48,000. Given the number of cases and cost per case, it is not apparent as to how the authors arrived at this cost.

The authors discussed the results of the study by Dayan et al., indicating that additional costs were captured (e.g., overhead costs, vaccine and immunoglobulin costs, transport costs, and costs associated with the public health campaign) in comparison to their study, but even when

these were excluded from the analysis, Dayan et al. still determined a total cost of US$78,734 for the three cases and more than 1,000 contacts. The authors hypothesize that while no direct comparison can be made, previous study results suggest that the figure of A$48,000 may be an underestimation.

Collier et al. (2013)

Collier et al.[39] reported on case-finding measures after five epidemiologically linked measles cases were reported by an emergency physician in Indiana. The authors describe the epidemiologic characteristics of the outbreak and containment measures used to stop measles transmission in the surrounding community.

The index patient, identified through subsequent contact investigation, had travelled to Indonesia while unvaccinated. Case patients were interviewed to identify additional cases and exposure settings. Persons were considered contacts if they were in the same exposure setting at the same time and for up to two hours after an infectious patient left the setting. Containment measures included active surveillance and case-finding among contacts using Indiana's Public Health Emergency Surveillance System. Community members were informed of potential exposure through local media releases, and providers were notified through the Indiana Health Alert Network, the ISDH health care provider email distribution system.

Potential areas of exposure included workplace and social settings. The Indiana health department attempted to contact all exposed persons. People within the same household or close contacts of case patients, who did not have presumptive immunity (i.e., no record of vaccination), were offered measles, mumps, and rubella (MMR) vaccine or immunoglobulin (IMG). Unvaccinated persons were voluntarily quarantined at home until 21 days after their most recent exposure (although this was not verified, due to resource limitations). A mandatory quarantine was imposed if voluntary quarantine was refused. Persons within the workplace had to prove immunity; otherwise they received vaccinations or were excluded. As the index patient had travelled via plane while infectious, relevant airlines released passenger manifests and limited demographic information to the CDC, which allowed the CDC to follow up with potential contacts. The case patients had also entered health care settings in an infectious state, thus exposing health care workers and patients to measles. The health care facilities directly followed up with contacts thought to have been exposed.

From a total of 38 suspected cases, 14 case patients were identified. Contact tracing methods identified 868 persons as having been exposed to measles. Six hundred and forty-four patients (74%) had presumptive immunity or self-reported vaccination, while 153 were lost to follow-up. That left a further 71 contacts without evidence of measles immunity. Of these contacts, 44 were vaccinated through health department efforts, nine were too young for vaccination, 12 developed measles disease, and six were not vaccinated.

The authors reported that resource costs accrued by the state health department during the investigation totalled approximately US$35,172, portioned as US$2,005 for travel-related expenses, US$835 for measles vaccinations, US$30,418 in salaries for personnel diverted to outbreak-related activities, and US$1,914 in laboratory supplies. Direct costs related to the case patient care were not included. The methodology and calculations for these figures were not provided. A total of 960 personnel hours were expended on the investigation and control efforts. The authors noted several limitations, including the lack of follow-up information, the uncertainty regarding the capture of community exposure, and the use of retrospective data collection for the economic assessment.

APPENDIX 5: DATA TABLES FOR THE PRIMARY ANALYSIS

Table 13: Calculations for the Base-Case Results for Alberta 2013 Outbreak Scenario	
Number of cases	42 cases
Number of contacts	42 cases × 47.7 = 2,005 contacts
Number of personnel hours	2,005 contacts × 2.48 hours = 4,973 hours
Cost of personnel (wages or salaries)	4,973 hours × $39.82 = $198,006
Cost of other resources	2,005 contacts × $49.83 = $99,902
Total costs associated with outbreak	$297,908

Note: values may not calculate exactly due to rounding

APPENDIX 6: DATA TABLES FOR THE SCENARIO ANALYSES

Table 14: Results for the Individual Outbreaks, Based on the Base Modelling Scenario (Scenarios 1 and 2)

Scenario	Case	Contacts	Personnel Hours	Personnel Costs	Non-wage Costs	Total Costs
Vancouver	80	3,819[a]	9,472	$377,154	$190,290	$567,444
Ottawa	4	> 200[b]	496	$19,753	$9,966	$29,719

[a] Calculated based on the modelling scenario, as no information on the number of contacts could be identified from the references.
[b] Based on number provided by reference article. Note: the number of contacts for the Ottawa outbreak is an underestimate, as the reference indicated 200 families, but because the size of the family was not known, it was decided that the number of contacts should remain at 200, with the caveat that this is an underestimate.

Table 15: Calculations for Outbreak Scenario 3, Based on Averages From the Dayan, Parker, and Sugerman Studies

Number of cases	16 cases
Number of contacts	780 contacts
Number of personnel hours	780 contacts × 2.48 hours = 1,934 hours
Cost of personnel (wages or salaries)	1,934 hours × $39.82 = $77,002
Cost of other resources	780 contacts × $49.83 = $38,851
Total costs associated with outbreak	$115,853

Note: values may not calculate exactly due to rounding

Table 16: Results for the Individual Outbreaks, Based on the Base Modelling Scenario (Scenario 3)

Scenario	Case	Contacts	Personnel Hours	Personnel Costs	Non-Wage Costs	Total Costs
Dayan et al.	3	1,000[a]	2,481	$98,763	$49,930	$148,593
Parker et al.	34	500[a]	1,240	$49,382	$24,915	$74,297
Sugerman et al.	12	839[a]	2,081	$82,862	$41,808	$124,670

[a] Based on number provided by reference article. Note: the number of contacts for the Ottawa outbreak is an underestimate, as the reference indicated 200 families, but because the size of the family was not known, it was decided that the number of contacts should remain at 200, with the caveat that this is an underestimate.

Table 17: Calculations for Outbreak Scenario 4, Based on Averages From the US 2011 Measles Outbreaks Reported in Ortega-Sanchez et al.

Number of cases	7 cases
Number of contacts	1,498 cases
Number of personnel hours	1,498 contacts × 2.48 hours = 3,715 hours
Cost of personnel (wages or salaries)	3,715 hours × $39.82 = $147,904
Cost of other resources	1,498 contacts × $49.83 = $74,622
Total costs associated with outbreak	$222,528

Note: values may not calculate exactly due to rounding

APPENDIX 7: POOLED DATA FROM THE FLEGO ET AL., STUART ET AL., AND COLLIER ET AL. STUDIES

Table 18 below reports a summary from the Flego et al.,[37] Stuart et al.,[36] and Collier et al.[39] studies; providing the number of personnel hours and cost components. Data from these three studies were pooled to estimate outbreak characteristics and total costs reported by the studies in a manner similar to the base modelling scenario.

Table 18: Summary Table of Resource Use From a Secondary Set of Included Studies

Report	Flego et al. (2013)[a,37]	Stuart et al. (2010)[36]	Collier et al. (2013)[39]	Total[b] *Average (Range)*
Outbreak year	2011	2009	2011	
Cases	26	12	14	52
Contacts	1395	871	868	3,134
Contacts per case	54	73	62	***60.3 (54 to 73)***
Hours	911	150	960	2,021
Hours per case	35.1	12.5	68.6	*38.7 (12.5 to 68.6)*
Hours per contact	0.65	0.17	1.11	***0.64 (0.17 to 1.11)***
Costs ($)				
Total cost reported	~$48,000[a]	$10,339	$35,172	NA[c]
Total cost, revised[d]	$51,811[e]	$8,169	$35,266	$96,246
Total cost per case	$1,993	$681	$2,590	*$1,755 ($681 to $2,590)*
Total cost per contact	$37	$9	$42	***$29 ($9 to $42)***
Revised cost excluding personnel wages	$4,851	$1,006	$4,139	$9,996
Revised cost per contact, excluding personnel wages	$3.48	$1.16	$4.77	***$3.13 ($1.16 to $4.77)***

NA = not applicable.
[a] The cost and resource use information reported by Flego et al. were for one patient who had 45 contacts. The cost and resource use information was extrapolated on a per-contact basis, as recommended by Flego et al., to the broader population.
[b] Results are totals if normal, and average (range) if italicised. Bolding indicates key result, referred to in text.
[c] As the total costs were determined in different years, it is not appropriate or applicable to determine a total cost for reported costs; thus, NA.
[d] Revisions to the cost included inflating the cost from the outbreak or costed year to 2014, and estimating cost components not measured from one of the other studies that did capture this information (see earlier Resource Use section regarding exclusions). Costs are reported in Canadian dollars; they were converted from US to Canadian dollars at the year of publication using the Bank of Canada conversion tool (http://www.bankofcanada.ca/rates/exchange/10-year-converter/)[54] and inflated to 2014 Canadian dollars using the Bank of Canada Inflation Calculator (http://www.bankofcanada.ca/rates/related/inflation-calculator/).[43]
[e] Assumptions were made regarding extraneous one-off costs.