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Note from the editors: *Eurosurveillance* - an authoritative information source on infectious diseases

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After a break over the festive season, the *Eurosurveillance* editors present the first issue of the journal in 2015. It features two rapid communications and a news item about Ebola virus disease (EVD), a disease which, since 2014, has caused worldwide concern. The EVD outbreak in Guinea, Liberia and Sierra Leone is the third event classified as a 'Public Health Emergency of International Concern (PHEIC)' by the World Health Organization [1]. Since mid-2014, numerous healthcare workers (HCW), epidemiologists and other emergency specialists have volunteered to work, often under difficult circumstances and risking their health or even lives on the ground to stop Ebola where it is most needed. They deserve our highest respect for their efforts and work. While the outbreak has unfortunately not yet been controlled and suffering goes on in the affected countries, there have been success stories from Nigeria and Mali where concerted actions were able to limit and halt the spread of the disease [2,3]. In Nigeria this was possible due to a close collaboration between mainly the public health and medical sectors, and using structures already in place to fight polio.

While the main burden of EVD is of course in West Africa, few cases have arisen outside the affected area through secondary transmission during healthcare for medically evacuated patients, or through individuals becoming symptomatic after having left West Africa [4,5]. One of the rapid communications in this issue describes the public health measures following the secondary Ebola transmission to an HCW in Spain in late 2014 such as contact tracing and monitoring of 232 individuals [6]. Another rapid communication presents an SMS-based system developed in Australia that should allow active tracing and monitoring of potentially exposed persons and require less resources than the traditional ways of monitoring [7].

The importance of the EVD outbreak matches the number of publications on the subject. A PubMed search using keywords [Guinea] OR [Liberia] OR [Sierra Leone] OR [Nigeria] OR [West Africa] OR [Western Africa] OR/ AND [Ebolavirus] OR [Haemorrhagic Fever, Ebola] OR [Ebola Haemorrhagic Fever] OR [ebolavirus*] OR [ebola] OR [evd] and limited to publications after 1 February 2014, retrieved 285 entries on 7 January 2015, many of them commentaries and editorials reflecting the situation, its challenges and potential solutions. *Eurosurveillance* has contributed with 13 articles published by the end of December 2014, mainly rapid communications as well aseditorials and letters. They are available from a **dedicated space** on our website.

At the beginning of a new year we provide feedback on the past year. In 2014, we received on average 72 submissions per month and published 288 items: 68 rapid communications, 137 regular articles, and 83 in other categories (editorials, letters and news). The geographical focus of submitted as well as published articles was Europe, however, we received publications from well over 60 countries worldwide and published a number of papers from countries outside of Europe that were of relevance for public health overall and Europe in particular.

Besides our traditional focus on human immunodeficiency virus (HIV) and tuberculosis (TB) on World AIDS day and World TB day respectively, we published a special issue on polio in February to cover the introduction and silent transmission of wild poliovirus type-1 over several months in 2013 in Israel. Other dedicated issues focused on the serious and increasing threat of vector-borne diseases (April), the potential transmissibility and evolution of avian influenza A viruses (June) and chikungunya in the Caribbean and its impact on Europe (July).

In mid-2014, when the annual impact factors were released by Thompson Reuters, soon followed by the SCOPUS-based SCImago Journal Ranks, we were glad to see that despite a lower impact factor than in previous years (2014: 4.65), *Eurosurveillance* remained among the top 10 journals in the category of infectious diseases and that it was in the first quarter of journals in four categories (medicine general, virology, public health, environmental and occupational health) in SCImago. The Google Scholar metrics were equally favourable with the journal listed on rank 4 and 10 among journals in the categories epidemiology and communicable diseases. On the social media channel

Twitter the number of followers keeps increasing and they use the information we provide in their tweets and/or comment on our content.

The beginning of a new year is also the moment when we like to express our gratitude to all our supporters. We are grateful to our reviewers and – as every year - publish a **list** with the names of the experts who have helped us: once again more than 500 individuals kindly dedicated their time to provide us with written guidance. There are also many supporters and colleagues out there who assist us with input whenever we ask them to share their views and discuss ideas with us; they remain unnamed here but we thank them wholeheartedly nonetheless. A special thanks goes to our editorial board members, associate editors and editorial advisors in the countries, who have continued to support us actively and enthusiastically over the years. We rely on their constructive feedback and encouragement. We are also grateful for the continued funding, logistic support and encouragement we receive from our publisher the European Centre for Disease Prevention and Control (ECDC) and its Director who grant us the editorial freedom [8] that has been crucial to establish *Eurosurveillance* as a credible and well respected source for authoritative scientific information.

Last but not least we note with pleasure that the results from the recently published ECDC external evaluation [9] which has demonstrated that a large proportion of public health decision makers consider the journal highly useful. Having the interest of our readers and contributors in mind, we aim to remain an attractive platform for the public health and scientific community working in the wider field of infectious diseases and look forward to doing this jointly with all our supporters and contributors in the years to come.

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First secondary case of Ebola outside Africa: epidemiological characteristics and contact monitoring, Spain, September to November 2014

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On 6 October 2014, a case of Ebola virus disease (EVD) acquired outside Africa was detected in Madrid in a healthcare worker who had attended to a repatriated Spanish missionary and used proper personal protective equipment. The patient presented with fever <38.6 °C without other EVD-compatible symptoms in the days before diagnosis. No case of EVD was identified in the 232 contacts investigated. The experience has led to the modification of national protocols.

Introduction

The current Ebola virus disease (EVD) epidemic affecting countries in West Africa is the largest ever registered outbreak of this disease [1]. Ongoing intensive transmission in the community and in healthcare facilities associated with weak health systems including limited human and material resources hinder adequate outbreak control and case management. Healthcare workers (HCW) in these areas have been significantly affected during this epidemic [2-5].

On 7 August 2014, the Spanish government decided to repatriate a Spanish missionary healthcare worker at the St. Joseph's hospital in Monrovia (Liberia) who had tested positive for Ebola virus. On arrival, the person was admitted to the infectious diseases isolation unit at the reference hospital (La Paz-Carlos III Hospital Complex in Madrid). The patient remained hospitalised until his death on 12 August. On 22 September, a second Spanish missionary healthcare worker who had worked at a hospital in Lunsar (Sierra Leone) and who was also suffering from Ebola virus infection was repatriated under the same procedure. This patient was admitted to the same reference hospital where he died on 25 September. One of the HCW who was caring for the second repatriated Ebola case was diagnosed with EVD on 6 October. This was the first secondary case of this disease outside Africa.

In this paper we describe the epidemiological characteristics and public health control measures adopted after the identification of this first transmission outside the epidemic area. The information and lessons learnt in Spain may contribute to improving preparedness and response guidelines and protocols in non-affected countries. The risk of transmission of Ebola virus to healthcare professionals associated with repatriated patients needs to be reassessed and considered for future surveillance and control measures in these settings [5-7].

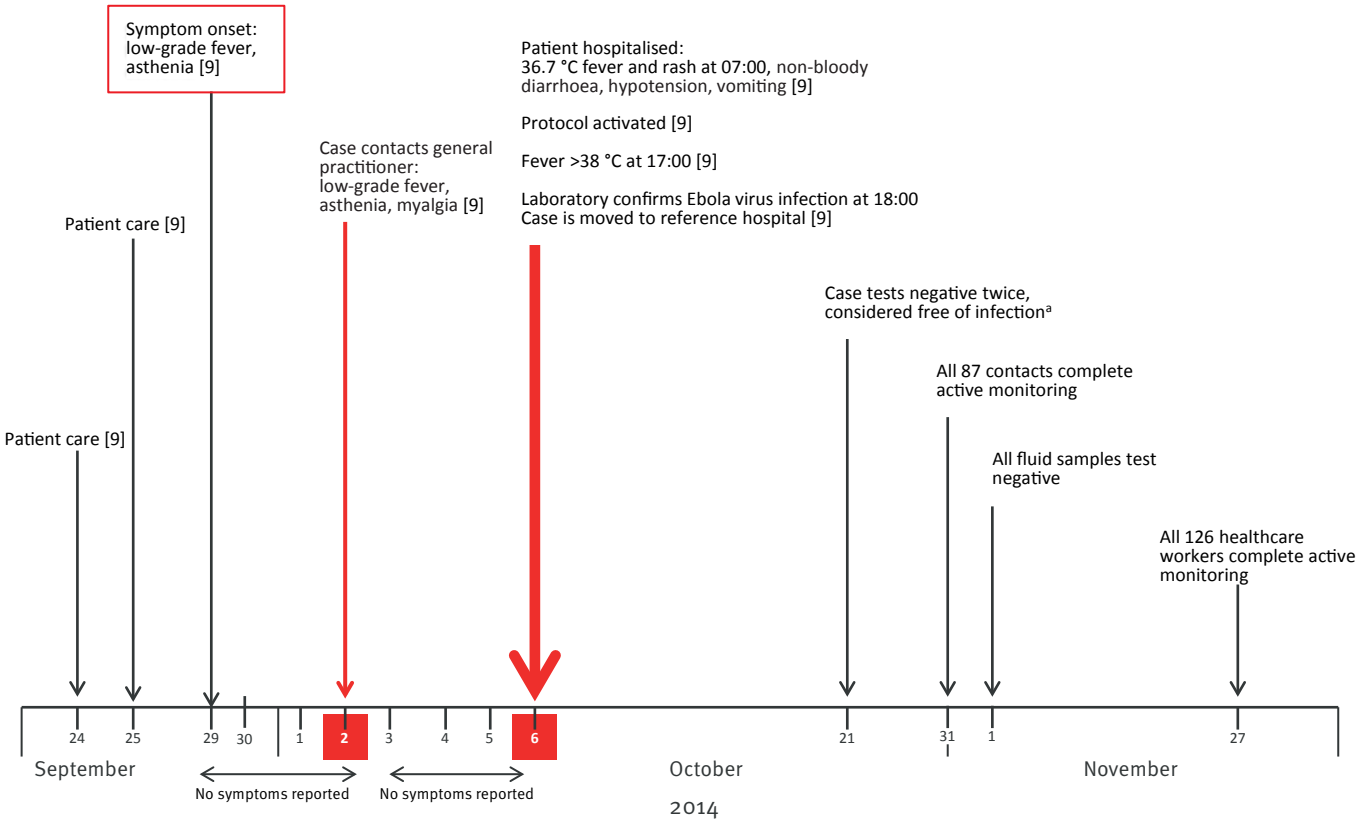
Epidemiological investigation and contact monitoring

Case description

The secondary case of EVD diagnosed in Spain on 6 October was one of the 117 HCW who had participated in the care of the two repatriated EVD cases. The HCW completed the 21-day monitoring period after caring for the first case on 30 August. On 21 and 25 September, she was exposed to the second patient and presumably contaminated fomites. She was classified as a low-risk contact and was therefore self-monitoring for symptoms, in accordance with the protocol [8]. The HCW had used appropriate personal protective equipment (PPE), i.e. waterproof long-sleeved clothing covering the feet, waterproof footwear, hood, face mask or goggles, double layer of gloves, and FP3 respirator [8], and she did not recall any incident during its use.

Figure 1

Timeline of events for secondary Ebola case, Madrid, 24 September–27 November 2014



[a] Culture results for all body fluids taken on 21 October were negative

Following the established procedures for HCW caring for EVD patients [8], the hospital recommended self-monitoring for 21 days from 25 September onwards. According to these procedures, the HCW was supposed to inform the monitoring official at the hospital in case of fever ›38.6 °C and any of the symptoms of the disease: severe headache, vomiting, diarrhoea, abdominal pain or bleeding. On the following day, 26 September, she was off duty. She contacted the monitoring official for the first time on 2 October.

Symptoms started on 29 September. She presented malaise and low-grade fever ‹38 °C. The grade fever remained at this level for three days and increased to 38 °C in the three following days [9]. Figure 1 shows the evolution and timeline of events.

On 6 October at 04:00, she called the public health officials to report a temperature of 37.3°C, general malaise, nausea and cough. These symptoms led the public health officer to request medical evaluation at home and to refer her to the closest hospital. On admission at 07:00, she had a temperature of 36.7 °C, blood pressure of 90/60 mm Hg, 95% oxygen saturation measured by means of pulse oximetry, and a maculopapular rash. She reported that she had not received antipyretic agents [9]. At 08:00 on 6 October, the hospital contacted the public health services and they decided to classify the case as under investigation for EVD and send blood samples to the national reference laboratory. The patient's condition worsened in the following hours [9] and at 18:00, the reference laboratory confirmed the diagnosis of EVD. The patient was transferred to the reference hospital under strict isolation measures. The patient received antiviral treatment and convalescent serum from a recovered Ebola patient. On 21 October, the case tested EVD-negative in two samples taken 48 hours apart and, according to protocols, was considered free of Ebola virus infection on 1 November when a PCR test of all body fluid samples yielded negative results. The isolation measures were suspended on the same day, and the patient was finally discharged on 5 November 2014.

Contact monitoring

The epidemiological investigation began at the time of diagnosis. Information on the patient's possible exposure was requested and contact identification, risk classification and monitoring began at the same time. A committee of experts was established for the classification of contacts. High- and low-risk classification criteria and the action taken for each group are

Table 1

Classification of contacts and public health measures adopted for the secondary Ebola case, Madrid, 6 October–27 November 2014

CLASSIFICATION OF CONTACTS	PUBLIC HEALTH MESURES FOR CONTACTS
Low-risk contact	
A person who, with appropriate PPE and without incidences in the use of PPE, had direct contact with a confirmed case, with his/her body fluids or any material that has potentially been contaminated in the course of healthcare;	Active monitoring: professionals responsible for monitoring contacts have daily contact with the monitored individual, measure his/her axillary temperature twice a day and record the presence of any symptom;
A person who has stayed in a closed physical space in which there could have been fomites with biological remains from the case and who does not comply with high-risk contact criteria (e.g. seats in the waiting room, the same surgery, the same ambulance, etc	The identity of contacts for monitoring is sent to health centres and hospitals (alerts in electronic clinical records) for early detection in case they consult for Ebola-related symptoms. The Blood Donors Centres of the Madrid Region also receive electronic alerts in the clinical records to avoid any incident related to possible blood donations by these individuals.
High-risk contact	
Close contact (distance <1 m), without appropriate PPE or with incidences in the use of PPE, with a confirmed case who was coughing, vomiting, bleeding or had diarrhoea;	Quarantine is indicated. In order to facilitate the compliance with the quarantine, hospital quarantine is offered to these contacts. All contacts included in this group (15 people) agreed to be admitted voluntarily.
Unprotected sexual relation with a confirmed case three months after the onset of symptoms;	
Direct contact with clothing, bedclothes or fomites contaminated with the blood, urine or body fluids of a confirmed case, without appropriate PPE or with incidences in the use of PPE;	
Percutaneous wound (e.g. needle-stick injury) or mucosal exposure to body fluids, tissues or laboratory samples of a confirmed case;	
Healthcare given to a case or handling of his/her samples, without the appropriate PPE or with incidences in the use of PPE.	

Table 2

Number of contacts of the secondary Ebola case by exposure place, relationship with case and risk category (high risk contacts in brackets), Madrid, Spain, 29 September–27 November 2014 (n=232)

Relation with case/ place of exposure	Cleaner	Patient/ patient's aid	Spouse	HCW	Dog sacrifice	Ambulance technicians	Other	**Total**
Transport by ambulance[a]	4	12	0	3	0	10	0	**29**
Primary care	2 (1)	22	0	4 (1)	0	0	0	**28 (2)**
Home	8[b]	0	1 (1)	1 (1)	6	0	1	**17 (2)**
Hospital	2	0	0	7 (7)	0	0	3 (1)	**12 (8)**
Other activities	0	0	0	2	0	0	7 (3)	**9 (3)**
Subtotal	16 (1)	34	1 (1)	17 (9)	6	10	11 (4)	**95 (15)**
HCW at reference hospital	11	0	0	113	0	0	2	**126**
Reference laboratory	0	0	0	0	0	0	11	**11**
Total contacts	27 (1)	34	1 (1)	130 (9)	6	10	24 (4)	**232 (15)**

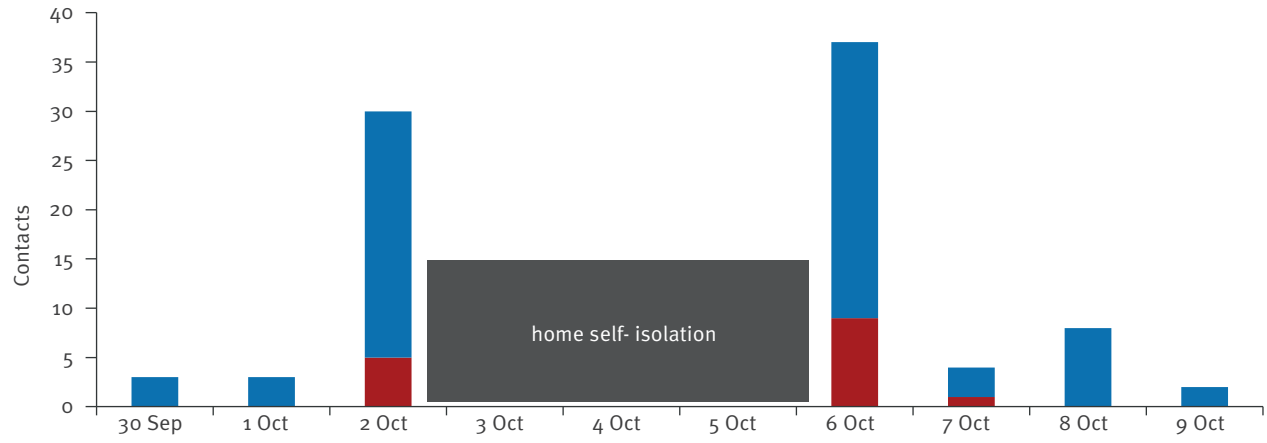
HCW: healthcare worker who attended to the secondary case.

[a] Two ambulances: from home to first hospital and from first hospital to reference hospital.

[b] The home cleaning was performed on the day after the patient was discharged from hospital.

Figure 2

Number of contacts of the secondary Ebola case, by exposure date and risk category[a], Madrid, Spain, 29 September–9 October 2014 (n=87)



	30 Sep	1 Oct	2 Oct	3 Oct	4 Oct	5 Oct	6 Oct	7 Oct	8 Oct	9 Oct
Low risk	3	3	25	0	0	0	28	3	8	2
High risk	0	0	5	0	0	0	9	1	0	0

[a] Excluded healthcare workers at the reference hospital, laboratory workers and home cleaners.

presented in Table 1. These actions were adapted from those established in the current protocol [8]. The first epidemiological information was provided by a family member of the patient at the hospital and was completed with available health and administrative records and the locations the patient reported to have visited from onset of symptoms until hospitalisation.

A total of 232 contacts were identified, of whom 15 were classified as high-risk and 217 as low-risk (Table 2). Most contacts, excluding HCW at reference hospital, occurred on the day of diagnosis at the hospital where the diagnosis was established (Figure 2). The 15 contacts classified as high-risk were informed of the risks associated with their contact with the case and were recommended a quarantine, at a hospital facility if possible. All of them voluntarily agreed to undergo hospital quarantine for 21 days after the last exposure day.

One of the low-risk contacts presented fever during the monitoring, but EVD was ruled out.

A total of 126 hospital employees were in contact with the patient during her stay at the hospital. Follow-up ended on 27 November, 21 days after the final exposure of the hospital cleaning staff. By that time, none of the contacts monitored had presented EVD.

Discussion

Action protocols are based on the evidence obtained in the outbreak in Africa [9-11]. Early detection of cases for minimising the probability of transmission is the key aim of contact monitoring. However, when the first secondary case was diagnosed in Spain, the case definition provided in the existing national protocol and in most international protocols (European Centre for Disease Prevention and Control [12], United States (US) Centers for Disease Control and Prevention [13,14]) required a fever of ›38.6 °C and symptoms compatible with the disease. This definition was not sensitive enough to detect this case in the first stages of disease. The non-specific clinical presentation of Ebola also makes early case detection difficult. This situation was also observed in the two secondary cases diagnosed a few days later in the US [15-17].

We would like to draw attention to the 'paucisymptomatic' presentation of EVD in infected contacts closely monitored after exposure to confirmed cases outside of the epidemic area in Africa not described up to now.

The public health measures applied immediately to the contacts of the secondary case in Madrid included active monitoring of low-risk contacts and quarantine for high-risk contacts. All contacts accepted these measures. However, in the future it may be necessary to apply the quarantine to more people or to contacts who refuse to be quarantined. In our opinion, it is necessary to develop procedures and laws which would establish and help apply the quarantine.

The experience with the repatriated cases in several non-epidemic countries and the secondary transmissions identified in Spain and in the US have resulted in proposals to modify existing protocols. These proposals [18] include increased sensitivity of the case

definitions for persons under investigation in order to detect possible cases in the initial phases of the disease, particularly for contacts of confirmed cases, and a revision of contact classification and monitoring measures.

The Spanish experience highlights that the generation of secondary cases among HCW caring for repatriated EVD patients represents the currently main risk for Europe as has happened also in US [8,13-15]. The risk is very low, however it can not be excluded [19].

Despite the existence of preparedness and response plans, trained professional teams, 24/7 alert systems and contingency plans for control and response of communicable diseases in both hospitals, the number of exposed contacts among HCW was high. After the secondary case was diagnosed, training and assessment was reinforced for all healthcare professionals involved in the treatment and care of EVD and a committee was set up to classify incidents. This alert shows the need for constant updating and training of professionals in the use of PPE and strict application of donning and doffing procedures in order to minimise the risks. Hence it is necessary to provide adequate risk communication and create awareness in HCW who care for these patients.

Despite the rapid activation of the protocols and control measures, this first case of secondary transmission of EVD outside Africa has represented an unprecedented challenge for the health services and public health authorities in Spain [9,12-14] and has highlighted the need to strengthen continuous preparation and training in order to respond properly to this type of emergency.

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Conflict of interest

None declared.

Authors' contributions

Jenaro Astray and Mª Ángeles López wrote the first draft of the manuscript. Mª Ángeles López managed the Ebola outbreak alert system, Jenaro Astray coordinated the Ebola response team of the Community of Madrid and acted as a liaison to the reference hospital, Maria Ordobás was responsible for contact monitoring, Felicitas Dominguez managed the alert information system, Carmen Álvarez and Manuel Martínez led the Ebola Crisis Committee. Carmen Amela, Mª José Sierra and Fernando Simón coordinated the Ebola response at the national level, and Carmen Amela also participated in the regional Ebola response team. Josep Jansa and Diamantis Plachouras participated in the contact classification and assessment. The working group participated in the fieldwork, conducting epidemiological survey, classifying cases and contact monitoring. All authors critically read and revised the drafts of the manuscripts.

Members of the working group of the Ebola outbreak investigation team of Madrid

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EbolaTracks: an automated SMS system for monitoring persons potentially exposed to Ebola virus disease

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We report development and implementation of a short message service (SMS)-based system to facilitate active monitoring of persons potentially exposed to Ebola virus disease (EVD), whether returning from EVD-affected countries, or contacts of local cases, should they occur. The system solicits information on symptoms and temperature twice daily. We demonstrated proof-of-concept; however this system would likely be even more useful where there are many local contacts to confirmed EVD cases or travellers from EVD-affected countries.

Background

The 2014–2015 Ebola virus disease (EVD) outbreak in West Africa is the largest in history, with widespread and ongoing transmission occurring in Guinea, Liberia, and Sierra Leone [1]. In addition, four countries (Mali, Nigeria, Senegal, and the United States of America (US)) have had EVD cases imported from West Africa. Moreover aid and healthcare workers (HCW) who developed EVD in West Africa have been evacuated by air for treatment in the US and several European countries [2]. One or more secondary cases have occurred in Mali, Nigeria, Spain and the US [2]. Internationally, public health authorities recommend surveillance of contacts of people with Ebola virus infection for 21 days following their last potential exposure so they can be promptly isolated and treated if they develop illness, minimising opportunities for further spread [3-6]. Depending on an individual risk assessment, and with some variation between countries, passive or active monitoring is recommended for HCWs, household and community contacts of persons with EVD, and in some instances, for travellers from EVD-affected countries irrespective of a specific exposure history.

Limited experience outside West Africa to date demonstrates that monitoring contacts of persons with EVD requires 'substantial time, resources, and coordination between local health jurisdictions' and that the number of persons requiring follow-up can quickly escalate [7]. Short message services (SMS) technology has been effectively used in a variety of public health and medical monitoring programmes [8-13]. Given our prior success in using SMS to conduct vaccine safety surveillance [14], we sought to develop an SMS-based system to streamline active monitoring of persons potentially exposed to EVD. Here we describe an automated SMS system implemented by the Department of Health in Western Australia (WA Health) to actively monitor travellers returning from EVD-affected countries, and contacts of any locally diagnosed EVD cases in WA (should the need arise).

Description of the system

The 'EbolaTracks SMS system' is designed to facilitate active monitoring of EVD contacts for 21 days following their last possible exposure to Ebola virus. As there have been no EVD cases diagnosed in WA, the system has thus far focused on monitoring persons who have travelled from the EVD-affected countries Guinea, Liberia, and Sierra Leone. These travellers, potentially exposed to EVD, are identified by federal authorities at Perth International Airport and their contact details and travel history are recorded. WA Health then provides these individuals with an EbolaTracks monitoring pack, which includes information about EVD, an explanation of the purpose of the system and its operation, a digital thermometer, instructions on how to take and report temperature by SMS to WA Health, and a mobile phone with one month's credit if they do not have their own. Based on reported exposures, travellers (or potentially local contacts) are classified as casual, low, or high risk, according to Australian criteria [6]. Participants are also categorised according to exposure type as HCW, household contacts, or 'other', which includes travellers from EVD-affected countries and local contacts in settings such as public transport. Those enrolled into the system are either manually entered as individual records or batch imported via a spreadsheet (in the case of larger volumes). The enrolment details include everything captured on the enrolment form (i.e. demographics, date of last possible exposure, contact details and information about risk).

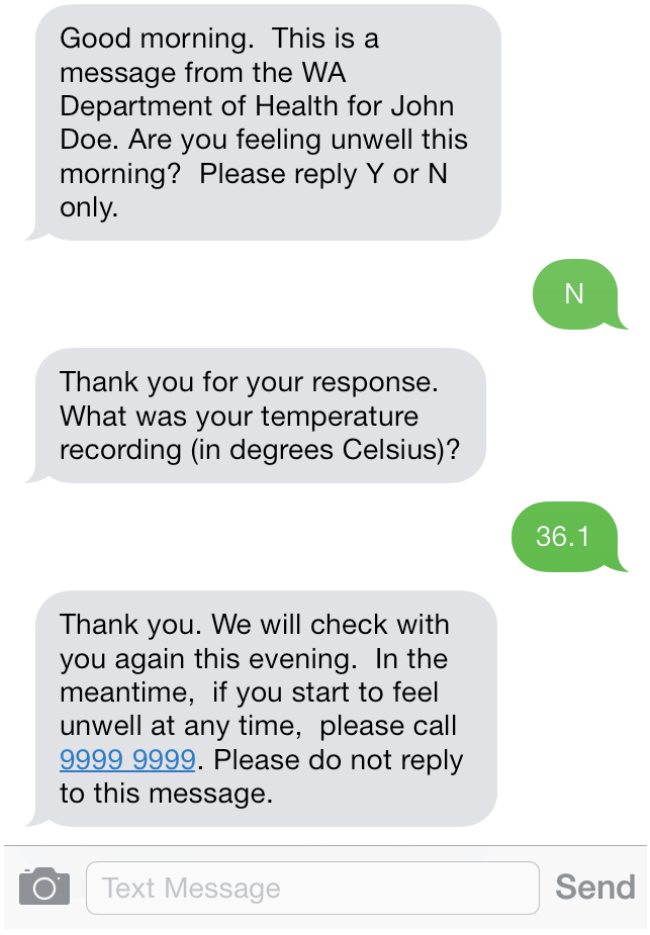
The EbolaTracks software was developed using the database programme FileMaker and runs on the Microsoft Windows 7 operating system. The SMS

functionality utilises an SMS gateway to send and receive messages via mobile telephone networks. Persons under surveillance are requested to take their temperature twice daily between the hours of 8 and 9AM and again between 5 and 6PM.

EbolaTracks participants are contacted twice daily by SMS, at 9AM and 6PM respectively. At each of those times, the system sends two consecutive SMSs. The first SMS asks if the participant is feeling unwell and requests a 'Y' (for yes) or 'N' (for no) response by SMS. Should the participant's response differ from the 'Y' or 'N' format requested, the software can convert ca 50 commonly used variations, such as 'Yes' or 'No', and can appropriately parse answers that include spaces and/or punctuation. Following the first SMS and response, a second SMS asks the participant to report their temperature, recorded in degree Celsius (Figure). In interpreting the participant's SMS response with their temperature, the software will filter out all characters except numbers, full stops and commas.

Figure

An example of the text messages sent from EbolaTracks each morning with responses from a fictitious participant



'John Doe' is a fictional name and '9999-9999' is not the actual telephone number provided.

Table

Individuals undergoing 21 day health monitoring using EbolaTracks, Western Australia, 21 November 2014–5 January 2015 (n=22)

Residence[a]	Date of last potential exposure to Ebola virus	Monitoring completion date[b]	Risk type[6]	Risk Level [6]
Urban	16/11/2014	06/12/2014	Other	Casual
Urban	19/11/2014	10/12/2014	Healthcare worker	Low
Rural	29/11/2014	19/12/2014	Other	Casual
Urban	29/11/2014	19/12/2014	Other	Casual
Urban	29/11/2014	19/12/2014	Other	Casual
Urban	30/11/2014	20/12/2014	Healthcare worker	Low
Urban	01/12/2014	21/12/2014	Other	Casual
Urban	03/12/2014	23/12/2014	Other	Casual
Urban	06/12/2014	27/12/2014	Other	Casual
Urban	10/12/2014	30/12/2014	Other	Casual
Rural	10/12/2014	17/12/2014	Other	Casual
Rural	10/12/2014	30/12/2014	Other	Casual
Urban	16/12/2014	04/01/2015	Other	Casual
Urban	17/12/2014	02/01/2015	Other	Casual
Urban	18/12/2014	06/01/2015	Other	Casual
Urban	18/12/2014	08/01/2015	Other	Casual
Urban	18/12/2014	08/01/2015	Other	Casual
Urban	18/12/2014	08/01/2015	Other	Casual
Urban	19/12/2014	09/01/2015	Other	Casual
Urban	21/12/2014	11/01/2015	Other	Casual
Rural	21/12/2014	11/01/2015	Other	Casual
Urban	25/12/2014	15/01/2015	Other	Casual

[a] Urban means residing within a greater metropolitan area, with access to a tertiary hospital with capacity to test for and treat patients with Ebola virus disease; rural means residing outside a metropolitan area.

[b] The monitoring completion date indicates either the end of the 21 day monitoring period or the day the individual left Western Australia.

For any participants who report feeling unwell or a temperature ≥ 37.5°C, EbolaTracks automatically sends both an SMS and an email alert to an on-call medical officer, who then telephones the individual to assess their condition and determine appropriate management. In addition, if an individual does not respond within an hour, EbolaTracks generates an SMS and email alert to the on-call officer, who then contacts the person to check their condition and to ensure that they are monitoring their temperature. Any SMS responses that cannot be interpreted by the programme are considered non-responses during automated processing and the on-call officer is notified. The on-call officer can review these responses, interpret and manipulate them manually, or may contact the participant if further clarification is needed.

Once enrolled, the automated system will send and receive SMS messages for all active records. Each

participant is included in the process until they reach 21 days after the date of last possible exposure to EVD or they depart WA.

Users of the software have the opportunity to monitor the automated process running in real-time and view the responses as they are received. All historical responses can be reviewed at any time. If no alerts are generated, it means all people currently under surveillance have answered both messages and all have reported being well and afebrile, and no further action is required.

The database used to send and receive SMS messages to/from persons who have been potentially exposed to EVD is maintained on a password protected/secure server within the WA Health Department. Any mobile telephone numbers used are verified with the contact before enrolment in EbolaTracks, and the ensuing SMS communications are subject to the same level of security as voice calls on commercial telephone networks.

Experience using EbolaTracks

EbolaTracks became operational on 21 November 2014. Twenty-two individuals who have arrived in WA from EVD-affected countries have been enrolled as of 5 January 2015 and 14 of these participants have successfully completed active monitoring (Table). The average age of participants was 46 years (range: 28–68 years; 18 men and 4 women), whereby three returned from Guinea, three from Liberia, and 16 from Sierra Leone.

To date, the system has sent a total of 1,108 messages soliciting symptom information, of which 1,008 (91%) received a return SMS; the remaining 100 outgoing EbolaTracks messages received no reply or were uninterpretable and required telephone follow-up by the Department of Health to confirm that the participants remained well and afebrile. Of the 1,008 responses received, 1,007 replies indicated the individuals were well and afebrile; one participant reported an elevated temperature. At the end of December, this non-HCW who had returned from one of the EVD-affected countries six days prior, replied by SMS with a temperature of 37.7°C. This response generated an alert to the on-call medical officer who subsequently interviewed the traveller. Repeated measurements confirmed a low-grade fever but the individual was otherwise asymptomatic at the time of the call. They were advised to stay at home until further notice, and a programme of regular follow-up was established which included more frequent temperature monitoring and regular contact with the medical officer. The low-grade fever resolved within a day and the individual remains well.

Discussion

Interrupting chains of human-to-human transmission is the highest priority for preventing the spread of EVD. Early identification, isolation and testing of suspected cases is essential, both for providing optimal care to patients and for preventing further transmission [4]. Our experience suggests that an SMS-based symptom monitoring system can assist in these goals by facilitating active monitoring of potentially exposed individuals while conserving staff resources. In addition, we found EbolaTracks was relatively straight-forward to develop and implement, built over a 19 day period using a contracted systems designer for a cost of approximately €17,000.

A strength of EbolaTracks is that this system can accommodate large numbers of both potentially exposed incoming travellers from EVD-affected countries and HCWs, household and community contacts exposed to a domestic EVD case. Furthermore, it is easily scalable; while we have demonstrated proof-of-concept in WA, this SMS-based monitoring would likely be even more useful where there are a large volume of contacts to follow-up, for example, in European countries or the US which receive many more travellers from EVD-affected areas than does Australia – or when actively monitoring numerous healthcare and community contacts of an imported or local secondary case. By reducing the resources required to perform active monitoring of contacts, SMS-based systems permit expansion of active monitoring to situations now reliant on passive self-monitoring, thus improving public confidence in EVD control strategies. In our setting at least, an additional positive attribute is that the SMS approach is highly acceptable to participants as it provides potential benefits to them, with minimum imposition or inconvenience.

The potential value of using SMS systems for active monitoring of Ebola contacts is not limited to industrialised countries; mobile phone use is widespread in many parts of Africa and any country with a moderate to high level of mobile phone coverage ought to be able to benefit from this approach [15]. SMS has already successfully been integrated into the public health response to EVD in Nigeria and Senegal. In Nigeria, HCW used a real-time reporting application to upload laboratory test results and receive SMS information on individuals being monitored for EVD symptoms [16], and the United Nations Children's Fund (UNICEF) developed a cascade SMS system to educate people about Ebola virus transmission and prevention [17]. In Senegal, the Ministry of Health sent 4 million SMS messages to the public, warning of the dangers of EVD and how to prevent it as part of a coordinated public awareness campaign [18]. These examples highlight that SMS has already been successfully integrated into the public health response to the EVD outbreak, and our application extends this to automated, active monitoring of persons potentially exposed to EVD.

There are limitations of the SMS-based approach to monitoring EVD contacts. First, SMS monitoring cannot supplant the potential advantages of direct visual inspection recommended for high risk contacts as the lack of fever and illness is not independently verified. Thus, subject to resources, it may be preferable to

monitor persons at very high risk in-person, or potentially using video calls. Second, the system must be adequately explained to participants so that the number of uninterpretable responses and delayed responses requiring follow-up can be minimised. Third, not everybody will have a mobile phone or be able to use one; in our setting, we will provide an inexpensive mobile phone with time-limited credit to contacts who do not already have one, but so far this has not been necessary. Finally, we must acknowledge that some contacts to Ebola cases may be disinclined to self-report illness if they subsequently become unwell. We believe, however, that disincentives to self-reporting can be overcome by ensuring timely access to appropriate diagnostics and prompt provision of high quality medical care, should it be necessary.

As long as the current epidemic continues in West Africa, active monitoring of individuals travelling from EVD-affected countries, particularly those with documented exposures (such as HCW), remains a cornerstone of public health strategies to facilitate early identification of imported cases and prevent local transmission, in both developing and developed countries [19]. In WA, EbolaTracks has proven useful and efficient for monitoring travellers arriving from West Africa. While the future course of the current epidemic is unknown, large numbers of potential exposures stemming from air travel, use of public transport, and healthcare provided to an imported case are not inconceivable, as has occurred in the US [7]. In our assessment, SMS-based fever and symptom monitoring systems could be valuable tools for implementing large-scale active monitoring of contacts exposed to EVD and other serious infectious diseases.

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Conflict of interest

None declared.

Authors' contributions

PE conceived the concept. LT and AR worked with the programmer on the system development and performed data collection and analysis. All authors contributed to development of system methods and protocols. All authors discussed the results, edited and commented on the manuscript draft. All authors read and approved the final manuscript.

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Assessing the risk of measles resurgence in a highly vaccinated population: Belgium anno 2013

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Despite long-standing two-dose measles-mumps-rubella (MMR) vaccination, measles outbreaks still occur in highly vaccinated European populations. For instance, large measles outbreaks occurred in France (2008–13), the United Kingdom (2012–13) and the Netherlands (2012). Based on a multicohort model approach, using spatial serological survey data, MMR vaccination coverage data and data on social contacts, we found effective reproduction numbers significantly higher than 1 for measles in Belgium. This indicates that at one of the expected re-introductions, a measles outbreak is likely to spread, especially when it occurs during school term. The predicted average effective reproduction number increased over a 30-year time span from 1.3 to 2.2 and from 1.9 to 3.2 for basic reproduction numbers of 12 and 18, respectively. The expected relative measles incidence was highest in infants under one year of age, in adolescents and young adults. In conclusion, gradually increasing proportions of susceptible adolescents and young adults provide through their highly active social life an avenue for measles to resurge in large outbreaks upon re-introduction in Belgium, especially during school terms. Infants form an important vulnerable group during future measles outbreaks.

Introduction

A large-scale measles outbreak in France started in 2008, with more than 20,000 reported measles cases by 2013 (see e.g. [1]). In 2012 and 2013, large-scale measles outbreaks have also been reported in the Netherlands [2] and the United Kingdom (UK) [3,4]. To date, no large measles outbreaks have been reported in Belgium since the start of the two-dose vaccination programme in 1995, although some small outbreaks occurred in specific subpopulations. In 2007 and 2008, an outbreak was reported in orthodox Jewish communities [5]. In 2011, a measles outbreak started in a day-care centre and spread to anthroposophic schools, where vaccination coverage was low [6]. It is of interest to determine whether a potential for a resurgence of measles in Belgium still exists. Typically, serological data are used to determine the age-specific susceptibility profile of the population of interest. However, proper quantification of the risk of a possible resurgence based solely on such serological data is only possible if these data are recently collected and if the probability of transmission can be assumed to be independent of age.

Since there are no such recent serological data for Belgium, we apply a newly developed multicohort model [7] that allows using available serological data not necessarily collected at the calendar time of interest. In this approach, the serological data are combined with data on vaccination coverage and data on social contacts. These data are supplemented by estimates of the duration of maternal immunity and of primary and secondary vaccine failure, which were obtained from extensive literature reviews with meta-analysis.

Methods

We first present the data sources that we relied on, and then briefly introduce the cohort model as proposed in [7].

Data sources

Serological data

We used serological data on measles from 2006 in Belgium. Details about data collection and testing can be found in [8]. Briefly, residual samples were collected using a multi-tiered approach to reach a sufficient number of serum samples (n = 3,884). To obtain a geographically well-distributed sample, 15 diagnostic laboratories were involved that were spread over

the country's 10 provinces. They were allocated fixed numbers of samples per age group according to a two-stage stratified survey with probability proportional to size with the regions (Flanders, Wallonia, Brussels capital region) in a first stage and the provinces in a second stage. To avoid election of immunosuppressed subjects by using residual samples, specific selection criteria were communicated to the laboratories [8]. For each sample, the birth date, sampling date, sex and postal code of the place of residence were provided by the collecting laboratories. For those samples with missing postal code, the laboratory's postal code was used instead. Samples were analysed with commercial ELISA (Enzygnost, Siemens, Germany). Equivocal results were considered positive.

Vaccination coverage

Vaccination coverage estimates for Belgium for both recommended measles-mumps-rubella (MMR) doses were taken from [9-18].

Waning of maternally acquired immunity

Newborns are initially protected through maternal antibodies. We used estimates as reported by several authors [19-22].

Primary and secondary vaccine failure

An extensive literature search in PubMed and Thomson Reuters Web of Knowledge was conducted to obtain estimates for the seroconversion (as a proxy of primary vaccine failure) and exponential waning rates (as a proxy of secondary vaccine failure). Seropositivity for anti-measles IgG was used as a proxy for natural infection or vaccine-induced protection, and seronegativity as a proxy for susceptibility. A proportion of persons who do not have detectable measles antibody may have a level of protection via cellular immunity, but this proportion remains unknown [23] and could thus not be taken into account in our model. Random-effects meta-analyses were carried out to obtain overall estimates. Overviews of the studies included in the meta-analyses are available in the supplementary material (http://ibiostat.be/online-resources)*.

Social contact data

We used social contact data from Belgium collected in the European study POLYMOD [24] to estimate the age-specific relative incidence of a resurgence of measles. We used social contact data from holiday and school-term periods as reported by [25].

Basic reproduction numbers

In the absence of pre-vaccination serological data, our method relies on assuming a specific value for the basic reproduction number R_0 for measles. We rely on estimates of R_0 for measles as reported by [26], ranging from 12 to 18.

Cohort model

The model we applied was introduced in [7] as a multicohort model that used the most recently available serological information on mumps in a highly vaccinated population such as in Belgium in 2006 to quantify the risk of mumps outbreaks in 2012. While referring to [7] for further methodological details, we can briefly describe the multicohort model according to a three step procedure: (i) modelling the serological data in 2006, (ii) deriving the spatial age-dependent susceptibility profile for 2013 using a cohort model and (iii) using social contact data and the inferred next generation matrix to obtain estimates of the effective reproduction number and the age-dependent relative incidence. In the current analysis, we assume that serological status (seropositivity for anti-measles IgG) is a perfect marker for immunity. Susceptibility therefore refers to seronegativity for anti-measles IgG, seroconversion refers to changing from seronegative to seropositive and waning of immunity refers to IgG antibody decay. We will come back to these assumptions in the discussion.

A model for the serological data in 2006

We used a generalised additive model to estimate measles seroprevalence as a function of age a, sex g and spatial location (x,y). The generalised additive model with complementary log-log link function [27] can be formulated as follows:

$$(1) \qquad cloglog\big(\pi(a,x,y,g)\big) = f(a,x,y,g),$$

where $\pi(a,x,y,g)$ represents the proportion of seropositives of age a with spatial coordinates (x,y) and sex g, and f is a smooth function. Generalised additive models, extending the well-known generalised linear models, allow for spatial interpolation through the use of scatterplot smoothers resulting in the estimation of a smooth susceptibility profile at the municipality-level. Submodels of model (1), including some or all of the available covariate information (i.e. age, sex and spatial location) were considered and results of fitting these models are presented together with a comparison based on the Akaike information criterion (AIC). The model with the smallest AIC value was retained for the estimation of the age-specific seronegativity to measles in Belgium. The smooth function f was decomposed in smooth components $s_i(\cdot)$, $i=1,2$ which were fitted using one-dimensional cubic splines and two-dimensional thin-plate regression splines, respectively, and/or components $te(\cdot,\cdot)$ referring to tensor product thin-plate regression splines allowing for differential smoothing along the two dimensions. As a result, using this approach, geographical estimates of the susceptibility profile in 2006 are obtained by averaging data points with their neighbours.

Geographically and age-dependent susceptibility profiles in 2013

Briefly, denote $s_b(a)$ the proportion of susceptible individuals of age a born in year b. Note that the calendar time can be calculated as $t=b+a$. The multicohort model was based on the following set of equations:

$$(2)\quad 1-s_b(a)=e^{-\eta\times a}\times\left(1-s_b(0)\right)\text{ if }0\leq a<1,$$
$$1-s_b(a)=e^{-\gamma_1\times(a-1)}\times\rho v_1\text{ if }1\leq a<12,$$
$$1-s_b(a)=e^{-\gamma_2\times(a-12)}\times\rho v_2\text{ if }12\leq a.$$

Here ρ represents the seroconversion rate, y_1 and y_2 the decay rates of vaccine-induced immunity related to dose 1 and 2, $s_b(o)$ is the proportion of susceptible newborns (informed by the fraction of susceptible women of childbearing age) and n the rate at which maternal antibodies decay (3.87 year^{-1}, see [7]). Given that our interest was in calculating the age-dependent proportion of susceptible individuals at calendar time 2013, we needed to adapt and apply the aforementioned cohort model in the following way: Firstly, for individuals 20 years and older (who were 13 years or older in 2006) we needed to take vaccine and naturally induced immunity into account. We did this by combining the estimated proportion of susceptible persons in the 2006 serological data with estimates of the vaccination coverage (MMR second dose) over time. The age-dependent proportion of susceptible persons was estimated by using a generalised additive model with a radial spline for age. To propagate this estimate to future years we took into account waning vaccine-induced immunity (multiplication with $e^{-y2\times(a-ao)}$, with a_o the age in the year 2006) and relied on lifelong immunity following natural infection. Secondly, for individuals younger than 20 years, we could not use the 2006 serological data to estimate the proportion susceptible because a second MMR dose had been offered to these children afterwards and we needed to rely entirely on the more recent vaccination coverage data. We could then use equation set (2) to determine the age-dependent proportion of susceptibles. Note that we also adapted equation set (2) to account for groups of individuals that received the first dose only.

The reproduction number and age-dependent relative incidence

The basic/effective reproduction number is the expected number of secondary cases produced by a typical infected individual during their entire infectious period when introduced into a completely/partially susceptible population. The basic/effective reproduction number determines the spread of the virus in the population: if it is lower than 1, the virus will stop spreading; if it is higher than 1, the virus will spread. Based on the age-dependent susceptibility profile, social contact data and a literature-based estimated range for R_0, we calculated the effective reproduction number R, and the age-specific relative incidence of re-emerging measles outbreaks in Belgium. We used social contact data from holiday and school-term periods to infer the effective reproduction number in each of those periods. Note that we did not use spatially adjusted contact patterns given that sufficient information to obtain regional contact patterns was not available. As a result, contact patterns were assumed spatially invariant.

Table 1

Generalised additive models fitted to seroprevalence data on measles infection with corresponding AIC values, Belgium, 2006

Model	Linear predictor	AIC
(1)	*te(x,y,a,by=g)+te(x,y,by=1-g)*	1,098.42
(2)	*te(x,y,a)*	1,091.86
(3)	s_1 *(a)+te(x,y)*	1,085.68
(4)	s_1 *(a)+*s_2 *(x,y)*	1,085.66
(5)	s_1 *(a)*	1,126.24

AIC: Akaike information criterion.

a is age, *x*, *y* are spatial coordinates and *g* is sex (0/1 – female/male).

Uncertainty

Uncertainty was taken into account by applying a parametric bootstrap which enabled us to calculate 95% confidence intervals (CI) for the effective reproduction number using contact patterns from both holiday and school-term period and assuming R_0 equal to either 12 or 18 (using school-term period contact patterns). Furthermore, uncertainty related to vaccination coverage was taken into account by resampling vaccination coverage information from the available 95% CIs through the specification of underlying normal distributions with corresponding percentiles, from which random samples were drawn. An interpolating spline model was used to obtain a smooth susceptibility profile as well as 95% CIs.

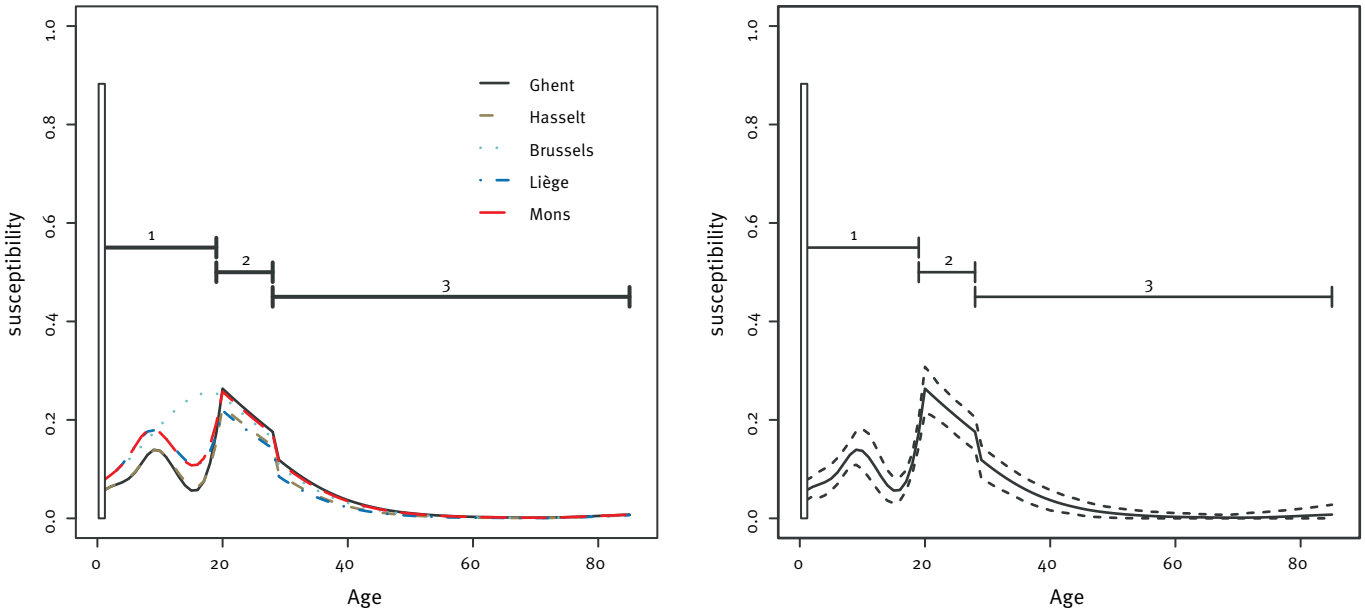
Results

Table 1 summarises the result of modelling the serological data for 2006. The generalised linear model consisting of an additive decomposition of age and spatial coordinates was the preferred model based on AIC (1,085.66). The second best model has a slightly higher AIC (1,085.68) and used a tensor-product spline (*te*) which yielded differential smoothing for the spatial coordinates *x* and *y* as compared with the best model ($s(\cdot,\cdot)$). Other models resulted in substantially higher (i.e. comparatively worse) AIC values.

Our random-effects meta-analyses resulted in an estimated ρ or seroconversion rate of 0.977 (95% CI: 0.959 – 0.990) and estimated γ_1 and γ_2, the exponential waning rates of 0.007 (95% CI: 0.003–0.018) after the first ($d=1$) and of 0.008 (95% CI: 0.004–0.020) after the second ($d=2$) dose of the trivalent MMR vaccine. Based on these results, a common γ or waning rate for

Figure 1

Age-specific susceptibility to measles infection, Belgium, 2013



Left panel: estimated susceptibility in five Belgian cities.

Right panel: Estimated susceptibility (solid line) and 95% confidence limits (dashed lines) for Ghent.

The susceptibility curve is based on (i) coverage information assuming waning of vaccine-induced immunity; (ii) coverage information, serology and assuming waning of vaccine-induced immunity; and (iii) serology assuming lifelong natural immunity. The bar on the left hand side represents the proportion of susceptible infants younger than one year.

Table 2

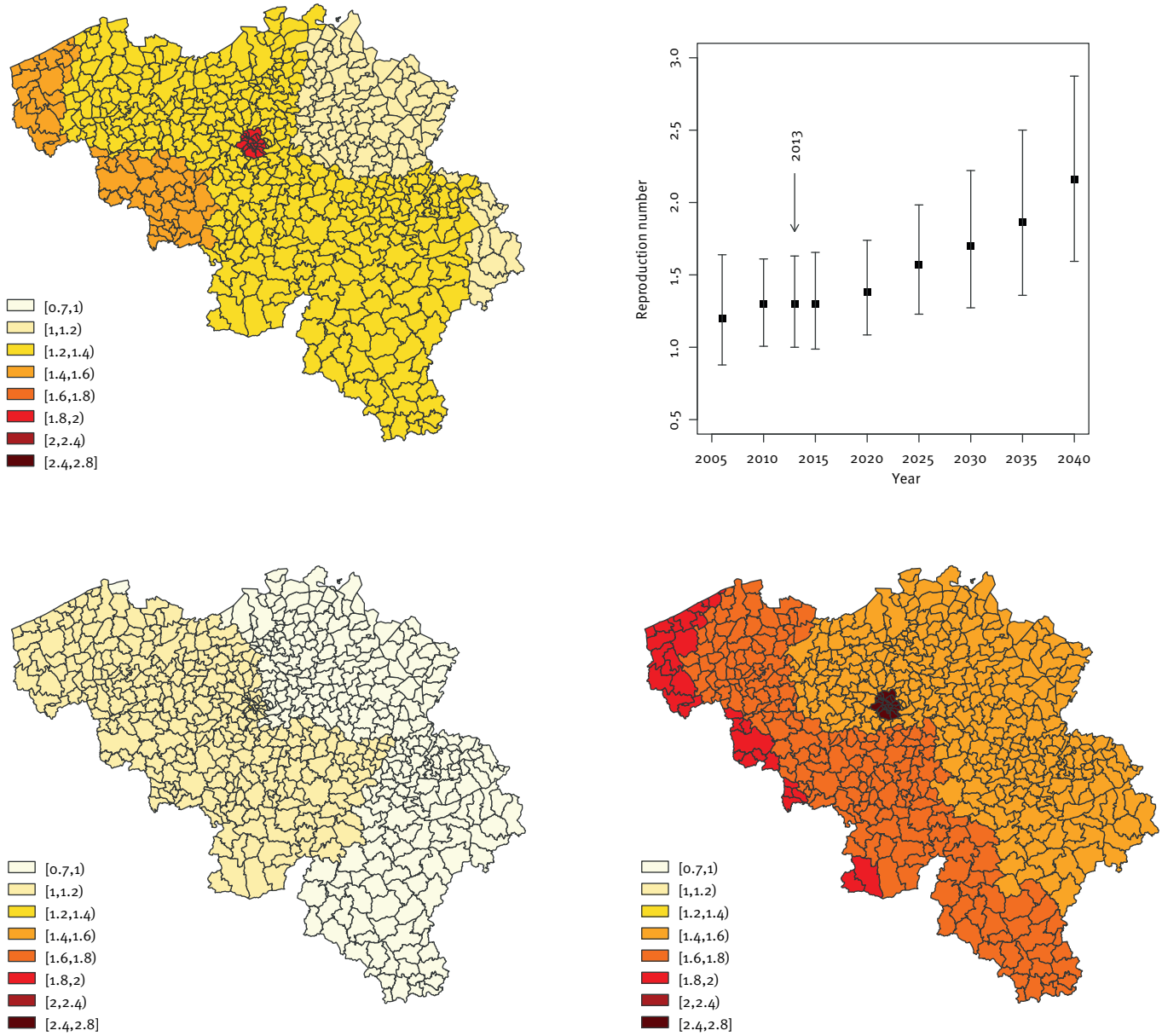
Estimated vaccination coverages for MMR in per region and 95% confidence intervals when available, Belgium survey years 1995–2012

Year and Region	MMR first dose		MMR second dose	
	Estimated coverage in %	95% CI	Estimated coverage in %	95% CI
1995				
Brussels	68.1	NA	NA	NA
1999				
Flanders	83.4	80.3–86.5	NA	NA
Wallonia	82.4	NA	NA	NA
2000				
Brussels	74.5	70.1–78.9	NA	NA
2003				
Wallonia	82.5	NA	NA	NA
2005				
Flanders	94.0	92.6–95.3	83.6	81.4–85.8
2006				
Brussels	91.1	88.7–93.6	70.5	NA
Wallonia	89.0	86.3–91.8	70.5	NA
2008				
Flanders	96.6	95.2–97.6	90.6	89.0–92.2
2009				
Wallonia	92.4	90.2–94.6	75.5	NA
2012				
Brussels	94.1	92.1–96.1	NA	NA
Flanders	96.6	95.1–97.6	92.5	90.9–94.1
Wallonia	94.4	92.4–96.4	NA	NA

CI: confidence interval; MMR: measles-mumps-rubella vaccine; NA: not applicable.

Figure 2

Time-specific estimated effective reproduction numbers for measles: spatial average and averaged 95% CI, Belgium, 2013



Upper left panel: Estimated effective reproduction numbers for a school-term period and Ro = 12 for Belgium in 2013. Upper right panel: Time-specific estimated effective reproduction numbers for Belgium: spatial average and averaged 95% CI. Bottom panels: 95% confidence limits for effective reproduction numbers for a school-term period and Ro = 12 for Belgium in 2013.

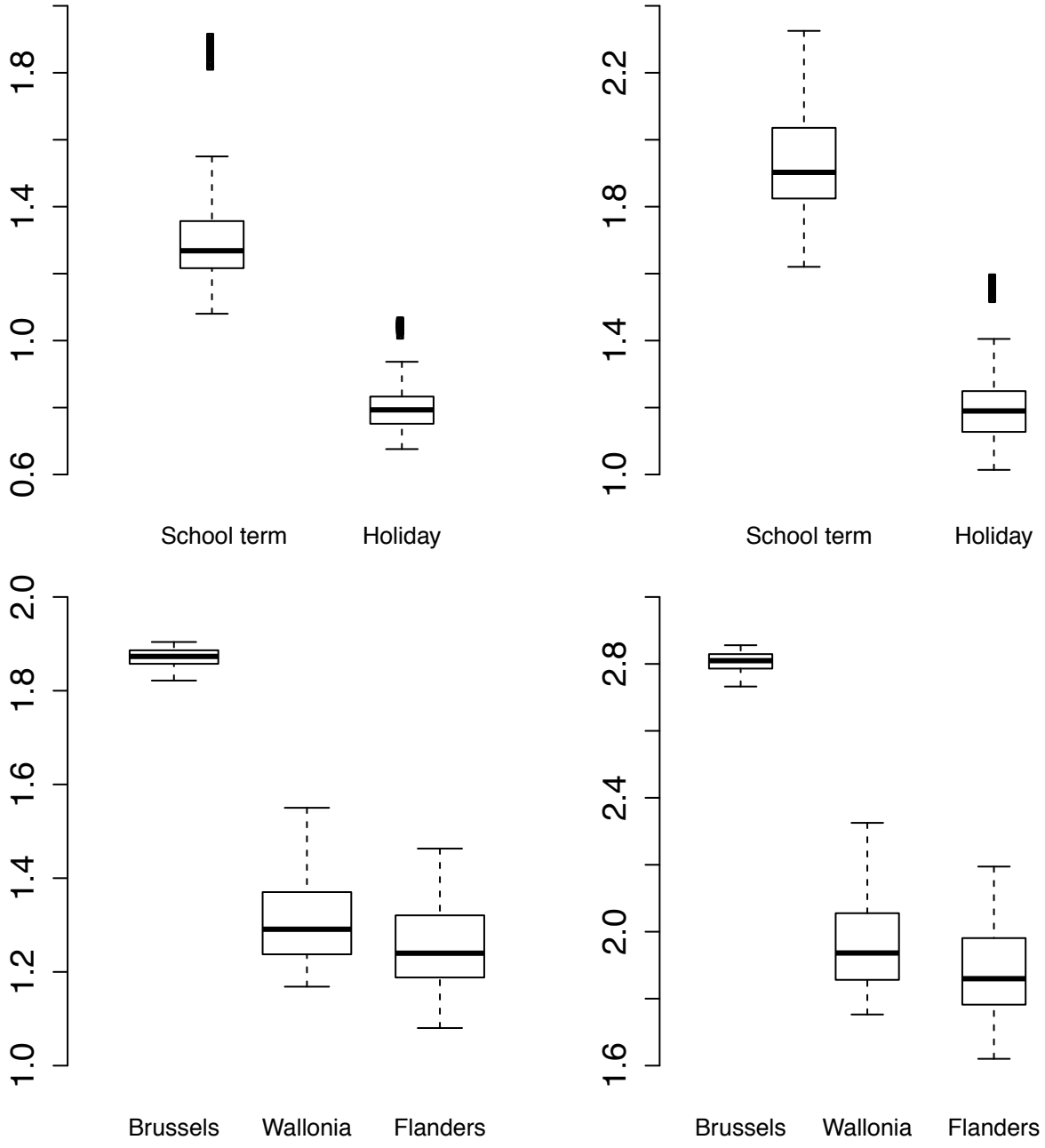
doses 1 and 2, equal to 0.008 (95% CI: 0.005–0.014), was assumed.

Figure 1 (left panel) shows the age-specific susceptibility profile in 2013 for five Belgian cities. The susceptibility curve was based on different data sources and assumptions: (i) coverage information summarised in Table 2, and waning of vaccine-induced immunity; (ii) coverage information, serology and waning of vaccine-induced immunity; and (iii) serology with lifelong natural immunity. Susceptibility among adolescents was high but decreased after vaccination at 12 months and 12 years of age. The susceptibility curve for Brussels was somewhat distinct from those for Ghent, Hasselt, Liège and Mons as a result of limited historical information on vaccination coverages in Brussels (Table 2). Figure 1 (right panel) shows the age-specific susceptibility profile for Ghent together with 95% CI.

The spatial pattern of effective reproduction numbers for Belgium during a school-term period in 2013 and assuming $R_0=12$ is shown in the upper left panel of

Figure 3

Boxplots of the spatial distribution of effective reproduction numbers for measles infection assuming $R_0 = 12$ (left column) and $R_0 = 18$ (right column), Belgium, 2013



Differences between school-term and holiday periods (upper row) and differences between the three Belgian regions (bottom row) in 2013.

Figure 2. The corresponding 95% CI are shown in the two bottom panels of Figure 2. In the upper right panel of Figure 2, the corresponding averaged 95% CI and average effective reproduction number are shown over time for $R_0 = 12$. The temporal change in the effective reproduction number already exceeded the epidemiological threshold in 2006, if non-significantly, whereas for 2010, the reproduction number had an estimated value which was significantly above 1. After 2010, the predicted average effective reproduction number increased over a 30-year time span from ca 1.3 to 2.2. Results for $R_0 = 18$ yielded a similar spatial pattern with effective reproduction numbers ranging from ca 1.6 to 2.4 with an average of ca 1.9 (Figure 3, upper right panel, first box plot). The predicted average effective reproduction number increased over 30 years from 1.9 to 3.2 (not shown).

Figure 3 shows boxplots of location-specific effective reproduction numbers for a school-term period and a holiday period in the upper left panel ($R_0 = 12$) and upper right panel ($R_0 = 18$). These results clearly demonstrated a substantial reduction in outbreak risk during holiday periods and a decrease of the majority of

effective reproduction numbers below 1 when $R_0 = 12$. The bottom left panel and the bottom right panel of Figure 3 show substantial differences between the Brussels capital region and the two other regions in Belgium that are mainly due to a lower vaccination coverage (and more limited historical information) in the Brussels capital region and to a lesser extent also due to differences in observed seropositivity between the different regions.

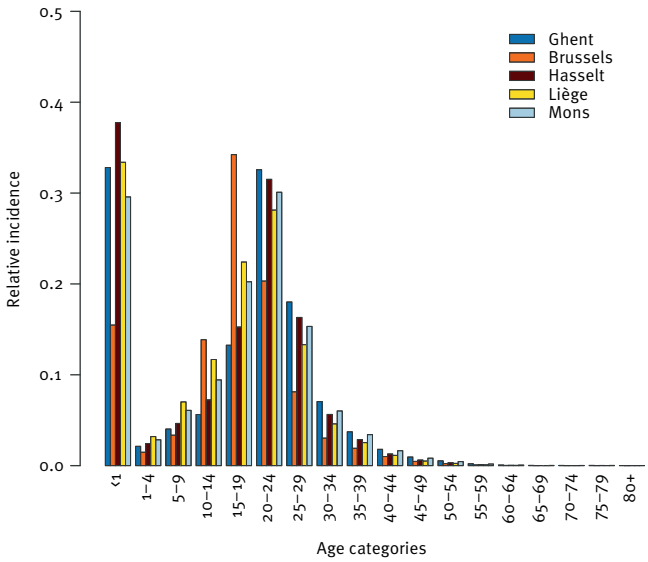
Figure 4 shows the expected age-specific relative incidence of a measles epidemic upon re-introduction of measles in the Belgian population for five different cities: Brussels, Ghent, Hasselt, Liège and Mons in a school-term period. A large proportion of new cases is expected to occur in infants younger than one year because of rapid waning of maternal antibodies [21,22]. The peak incidence for people older than one year is expected in the age category 20 to 24 years, except for Brussels where the peak incidence is expected in the age category 15 to 19 years. Note that because of a higher expected absolute incidence in the age categories 15 to 19 and 20 to 24 years in Brussels compared with the other four cities, the relative incidence for infants younger than one year was estimated lower in Brussels compared with the other four cities. This observation and the peak incidence at 15 to 19 and 20 to 24 years resulted from an increased susceptibility in 2013 of the age categories 15 to 19 and 20 to 24 years in Brussels and the other cities, respectively and a higher frequency of social contact in the 15 to 19 year-olds [24,28]. Taking both susceptibility and contact intensity into account is important to explain the relatively high expected incidence in the 15 to 19 year age category for all five cities, whereas the susceptibility in 2013 in this age category was estimated lower than in the age category 20 to 30 years, due to vaccination in the intermittent years (Figure 1).

Discussion

Using a simple multicohort model [7], we were able to estimate current spatially-explicit age-dependent measles outbreak risk using seroprevalence data, vaccine coverage data and social contact data from Belgium. Our main findings can be summarised as follows: (i) outbreak risk (effective reproduction number > 1) exists all over the country, at least in school-term periods, so imported infections have the potential to spread; (ii) higher risk exists in school-term periods than in holiday periods, implying an increase in risk every time school starts compared with the corresponding preceding holiday period; (iii) at highest risk are infants under one year of age, adolescents and young adults; (iv) spatial heterogeneity in outbreak risk is observed but should not be overinterpreted given that considerable uncertainty exists; (v) propagating predictions based on the most-recently observed vaccination coverages shows that the effective reproduction number is expected to increase over the next few decades.

Figure 4

Predicted age-specific relative incidence for newly emerging measles outbreaks in five Belgian cities: Brussels, Ghent, Hasselt, Liège and Mons, 2013



Despite recent large measles outbreaks in the Netherlands, France and the UK, all neigh- bouring countries of Belgium, no new measles outbreaks have been reported since the small local epidemic in 2011 in Belgium. Only 39 isolated cases were reported in 2013, corresponding to an incidence of 3.5 per million inhabitants (personal communication: Martine Sabbe, Scientific Institute of Public Health, Brussels, January 2014). However, even within the Netherlands, the outbreak did not spread to the wider community. Instead it affected mostly the Dutch Bible Belt, which consists of a large cluster of families with low vaccination coverage (from < 80% to 90–95% [29]), inspired by their religious beliefs. The epidemic had not (yet) spread to the surrounding highly vaccinated regions, including the Belgian–Dutch border. In addition, with effective reproduction numbers slightly above 1, potential outbreaks go extinct very rapidly. For example, assuming homogeneous mixing and an effective reproduction number equal to 1.3 would result in ca 62% of outbreaks going extinct with a final size smaller than n=10 [30].

School outbreaks of measles have been reported very often, and seasonal variation with a clear impact of school holidays has been demonstrated in the period before mass vaccination against measles was launched [31,32]. In those days, mainly children were at risk for measles outbreaks. The projected outbreak risk in Belgium increases as a result of simultaneous processes involving two large subgroups of the population. On the one hand, vaccine-induced immunity among vaccinated people wanes as they age over time. On the other hand, the generally older subgroup of incomplete or unvaccinated people, many of whom acquired long-lasting immunity following natural

infection, grows older, and thus on average has fewer social contacts and a higher probability of all-cause death over time. That means that the proportion of the population that is naturally protected from measles is gradually dying out. These processes imply that the overall susceptibility and outbreak risk increase over time. This risk is highest in the part of the population that typically constitutes the engine of airborne transmission through their social contacts at childcare, school, and within and between households. In order to achieve the European measles elimination goal, public health authorities in a number of countries are undertaking campaigns to raise MMR second dose coverage in adolescents which is currently still below the 95% target needed for elimination (see Table 2). Young adults are, however, harder to reach in such campaigns, and sporadic preventive health services in Belgium are often limited to working or student populations. Suboptimally vaccinated cohorts of young adults could thus delay the impact of elimination efforts. A catch-up campaign focusing all young adults is necessary to achieve elimination in the short term.

Our analysis showed that using a relatively simple model [7] and data that are commonly available for most European countries, the outbreak risk for measles can be estimated and age groups in which the risk is highest can be identified. Our method differs from the one used for the analysis of Australian serosurvey data in 2012 [33] by accounting for secondary vaccine failure and using social contact data while acknowledging spatial heterogeneity in susceptibility and vaccination coverage. Our study has several limitations: Firstly, we relied on antibody seropositivity as a proxy for immunological protection against measles infection based on an ELISA test [23]. The ELISA used to detect measles antibodies (Enzygnost, Siemens, Germany) was, as most diagnostic tests, more specific than sensitive (100% and 99.6%, respectively, as reported by the manufacturer), which may have overestimated susceptibility at the population level. Moreover, ELISA results do not perfectly correlate with the more sensitive plaque reduction neutralisation values (›120) which were used in few other existing studies to relate circulating antibodies to clinical protection from measles, e.g. [34]. Antibodies are the main but not the only mechanism of immunological protection. For instance, long-lasting immunity after natural measles infection in patients with deficient humoral immunity (primary agammaglobulinaemia) has been demonstrated, indicating that the cellular immune system alone is capable of preventing measles. Therefore, again, susceptibility might be overestimated if based on antibody titres only. On the other hand, in the current study, equivocal results were classified as positive and therefore could result in underestimating susceptibility at the population level. However, the age and spatial patterns are likely to have remained unaffected by this. Secondly, the spatial resolution of various data we used was limited. Nevertheless, the analysis of the serological data clearly indicated spatial heterogeneous serological profiles. Coverage data (and their spatial resolution) were not available to the same extent in each region, and the spatial distribution of our social contact data was not detailed enough due to sample size restrictions, limiting spatial estimates of susceptibility. Thirdly, susceptibility was only allowed to change over time as a result of waning of vaccine-induced immunity, and therefore, very rarely, decreases in susceptibility caused by sporadic infections over the years are ignored. Finally, our method relied on several inputs such as a realistic estimate of the basic reproduction number R_0 in the study population and estimates for the waning rates after vaccination for which uncertainty was accounted for in the parametric bootstrap approach.

Although the demographic structure of a population is of importance in the estimation of the effective reproduction number and varies over time, we did not use a dynamic model in which population and infectious disease dynamics were modelled simultaneously. Our method was based on a cohort model, which could be adjusted for different population structures; this is deemed necessary especially if the serological survey sampling occurs long before the time point of interest. Therefore, prediction of the effective reproduction number over time relied on observed population sizes and predicted population sizes for future years according to a demographic model for Belgium (data not shown). The proposed methodology can be extended to include diagnostic test uncertainty, which was not pursued here because of a specificity and sensitivity close to 100%. It can also be used as an informative pilot for the design of studies to document serological profiles, social contacts and vaccination coverage in populations with the aim to improve outbreak risk assessments.

Our model has partly been validated by (i) the mumps outbreak in 2012 in Flanders for which, in hindsight, our estimates are in line with the observed incidence [35], (ii) a small measles outbreak in a day care centre in the province of Antwerp for which the incidence was in line with the predicted relative incidence [36]. Indeed, young infants remain at increased risk for measles since maternal antibodies are waning rapidly during the first months of life. Almost all cases in that outbreak occurred in infants too young to be vaccinated with the first MMR dose. These cases can be prevented by vaccination strategies targeting the other susceptible age groups in society. The currently available measles vaccines are not effective enough when routinely used in infants younger than one year.

Current vaccination campaigns focus on improving vaccination coverage especially for the second dose of MMR at its recommended age (10 to 13 years). In Flanders, schools and vaccinating physicians have been encouraged in 2013 and 2014 to promote MMR2 and reduce missed vaccination opportunities, and

further actions to better reach underserved populations are foreseen.

Given the high relevance of our results for public health, the competent authorities were informed about our work and a press release based on the findings of this study has been released at the start of the 2013/14 campaign mentioned above. In that press release we advised people aged 20 to 30 years to check their vaccination status and take action if it was incomplete. Official recommendations for catch-up vaccination with MMR have been updated and include adults up to birth year 1971, but to date, no national or regional campaigns have been undertaken to increase coverage in this age group.

*Note

Supplementary information made available by the authors on an independent website is not edited by *Eurosurveillance*, and *Eurosurveillance* is not responsible for the content. The material can be accessed at: http://ibiostat.be/online-resources/.

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Conflict of interest

None declared.

Authors' contributions

NH, SA and ES performed the analyses. HT, EL, TL and KVK provided the data for the analyses and contributed together with NG, HG, PVD and PB to the analyses and their interpretation.
NH, SA and PB wrote the initial draft of the manuscript after which all authors contributed to drafting the final manuscript. All authors read and approved the final manuscript.

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European Union SHIPSAN ACT Joint Action: Preparedness for the response to Ebola virus disease in the maritime transport sector

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The European Union (EU) SHIPSAN ACT Joint Action has published a '**Questions and Answers**' (Q&A) section about Ebola virus disease in the maritime transport sector on its website.

The aim of the Q&A is to provide clarifications useful for public health authorities, for port workers and for the shipping industry with regards to:

- Personal protective equipment for port health officers going aboard a ship, which has come from an affected area, without having ill persons on board
- Response measures by competent authority when a ship arrives from an affected country with a traveller presenting clinical criteria compatible with Ebola virus disease
- Transportation of a patient, meeting the criteria for the person under investigation or probable case, from the ship to the medical facility
- Actions by the competent authority in the event of a patient meeting the criteria for the person under investigation or probable case on board a ship
- Actions by the competent authority in the event of a traveller on board a ship meeting the criteria for a confirmed case of Ebola virus disease
- Waste management (sewage) on ships
- Ships visiting ports in affected countries
- Recommendatio ns to the captain of a ship departing from affected areas and going to an EU port
- Plan for event management of a suspected case of EVD on board ships
- Recommendation for port-workers in EU ports, dealing with cargo from affected areas

An algorithm is also provided, outlining two response phases: (i) phase one describes the decision making of the public health competent authorities in response to an event of a suspected case of Ebola virus disease on board ships and (ii) phase two describes the response of public health competent authorities to an event of a confirmed case of Ebola virus disease on board ships.

The above information can be used by the competent authorities in the development of contingency plans according to the International Health Regulations [1] in conjunction with European Centre for Disease Prevention and Control [2] and World Health Organization [3] guidelines.

The EU SHIPSAN ACT is a European Joint Action funded by the European Commission under the Health Programme (2008-2013) [4]. It deals with the impact on maritime transport of health threats due to biological, chemical and radiological agents, including communicable diseases and supports the implementation of International Health Regulations 2005.

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