Early-warning health and process indicators for sentinel surveillance in Madagascar 2007-2011

Soatiana Rajatonirina[1], Fanjasoa Rakotomanana[1], Laurence Randrianasolo[1], Norosoa Harline Razanajatovo[2], Soa Fy Andriamandimby[2], Lisette Ravolomanana[3], Armand Eugène Randrianarivo-Solofoniaina[4], Jean-Marc Reynes[5], Patrice Piola[1], Alyssa Finlay-Vickers[6], Jean-Michel Heraud[2], Vincent Richard [7]

1. Unité d'Epidémiologie, Institut Pasteur de Madagascar, Antananarivo, Madagascar

2. Unité de Virologie, Institut Pasteur de Madagascar, Antananarivo, Madagascar

3. Directions des Urgences et de la Lutte contre les Maladies Négligées (DULMN), Ministère de la Santé Publique, Antananarivo, Madagascar

4. Direction de la Veille Sanitaire et de la Surveillance Epidémiologique (DVSSE), Ministère de la Santé Publique, Antananarivo, Madagascar

5. Unité de Virologie, Institut Pasteur de Madagascar. Present address: Unité de Biologie des Infections Virales Emergentes / Institut Pasteur de Lyon

6. Malaria Branch, Division of Parasitic Diseases US Centers for Disease Control and Prevention, President's Malaria Initiative, Madagascar

7. Unité d'épidémiologie, Institut Pasteur de Dakar, Dakar, Sénégal

Abstract

Background: Epidemics pose major threats in resource-poor countries, and surveillance tools for their early detection and response are often inadequate. In 2007, a sentinel surveillance system was established in Madagascar, with the aim of rapidly identifying potential epidemics of febrile or diarrhoeal syndromes and issuing alerts. We present the health and process indicators for the five years during which this system was constructed, showing the spatiotemporal trends, early-warning sign detection capability and process evaluation through timely analyses of high-quality data.

Methods: The Malagasy sentinel surveillance network is currently based on data for fever and diarrhoeal syndromes collected from 34 primary health centres and reported daily via the transmission of short messages from mobile telephones. Data are analysed daily at the Institut Pasteur de Madagascar to make it possible to issue alerts more rapidly, and integrated process indicators (timeliness, data quality) are used to monitor the system.

Results: From 2007 to 2011, 917,798 visits were reported. Febrile syndromes accounted for about 11% of visits annually, but the trends observed differed between years and sentinel sites. From 2007 to 2011, 21 epidemic alerts were confirmed. However, delays in data transmission were observed (88% transmitted within 24 hours in 2008; 67% in 2011) and the percentage of forms transmitted each week for validity control decreased from 99.9% in 2007 to 63.5% in 2011.

Conclusion: A sentinel surveillance scheme should take into account both epidemiological and process indicators. It must also be governed by the main purpose of the surveillance and by local factors, such as the motivation of healthcare workers and telecommunication infrastructure. Permanent evaluation indicators are required for regular improvement of the system.

Keywords: Sentinel surveillance, Madagascar, early warning, mobile phone.

Correspondence: vrichard@pasteur.sn

DOI: 10.5210/ojphi.v6i3.5400

Introduction

The concept of surveillance was developed principally for control of the transmission of infections and for the early detection of outbreaks. The main elements of surveillance methods have been described elsewhere. Surveillance is a continuous, systematic process of descriptive information collection, validation, analysis, interpretation, and dissemination for use in planning, and in the implementation and evaluation of public health policies and strategies for the prevention and control of diseases or disease outbreaks [1-3]. The public health problems approached in this way, including acute and chronic diseases and environmental hazards, are diverse, necessitating the development of tools for the timely monitoring of disease trends. Furthermore, surveillance systems must be evaluated regularly, to ensure that they provide valuable information in an efficient manner [4,5].

Efficient disease surveillance systems are the key to the timely detection of early-warning signs potentially signalling the occurrence of disease outbreaks or epidemics. The World Health Organisation (WHO) has highlighted the importance of improving national epidemic surveillance capacities [6,7]. Recently developed innovative tools, such as mobile telephone technology and electronic systems, have facilitated the improvement of surveillance systems, by reducing data processing [8]. However, these systems are mostly implemented in high-income countries [9], as most developing countries are faced with logistic and budgetary constraints, resulting in low-quality surveillance systems based on pen-and-paper methods. In many cases, these low-tech systems provide health institutions with inadequate support, resulting in frequent "health crises" [10]. Moreover, the healthcare infrastructure, laboratory diagnostic capacity, skills and number of physicians in these countries are generally insufficient to deal with emerging diseases likely to cause epidemics. Consequently, delays in raising the alarm often limit the possibility of an effective early response to new, emerging public health problems.

The need for an efficient sentinel surveillance network in Madagascar was highlighted by worldwide infectious disease threats to public health, such as severe acute respiratory syndrome (SARS) in 2003, avian influenza A H5N1 in 2005 and the Chikungunya epidemics observed in the Indian Ocean region in 2006. In addition, the 2005 International Health Regulations stressed the importance of commitment to the goal of global security and asked all member states to establish and implement effective surveillance and response systems, making it possible to detect and contain public health threats of national and international importance. As a result, the government of Madagascar, in partnership with the Institut Pasteur de Madagascar, established 13 fever sentinel sites in 2007, expanding the network to 34 sites by 2011, to improve the timely detection and management of febrile disease outbreaks. Two key attributes of the sentinel surveillance system are monitored continuously: timeliness and data quality. This system was designed to identify outbreaks for which public health interventions may be required early enough for such interventions to be effective.

We report here the indicators, for 2007 to 2011, of the syndromic sentinel surveillance network, presenting spatiotemporal trends, alert detection capability and evaluations of the process on the basis of timeliness and quality data.

Methods

The sentinel surveillance network in Madagascar has been described elsewhere [11,12]. Briefly, it includes primary healthcare centres (sentinel sites) from across the country (Figure 1) and is managed by a national steering committee. The network was expanded from 13 influenza-like illness (ILI) sentinel sites in 2007 to 34 sentinel sites in 2011, with the aim of improving geographic coverage and representativeness of the country as a whole (4 sites are located in Antananarivo) (Figure 1). The sentinel surveillance system makes use of syndromic indicators to monitor the occurrence of selected diseases of importance for the country. The main criterion for the inclusion of cases or patients is fever or diarrhoea. For patients with fever, additional screening criteria (based on syndromic case definitions) are used to identify specific syndromes: malaria, ILI, dengue-like syndromes. Standard WHO case definitions are used, to ensure comparability [11,12]. Malaria diagnosis requires biologic confirmation with a positive rapid diagnostic test in patients with fever syndromes.

Cases and patients at the participating sites are identified by trained healthcare personnel participating in the surveillance network on a voluntary basis. One of the key features of the system is the timely transmission of syndromic data, on a daily basis, by coded short message service (SMS) messages sent from mobile phones. Upon reception at the IPM, the data transmitted in this manner are input daily into a specifically designed MS Access® database and analysed as soon as possible after the patients' initial visit. This results in a turnaround time of 24 hours, from data collection to reception at the IPM, even for data sent from the most remote areas of the country. The data received by SMS include: sentinel site code, date of data collection, total number of outpatient consultations, total number of confirmed malaria cases, total number of ILI cases, total number of dengue-like cases, total number of diarrhoea cases, and the number of consultations by age group. The age groups were those commonly used by the Ministry of Health in Madagascar: less than 1 year, 1-4 years, 5-14 years, 15-24 years, 25 years and over.

Surveillance data are analysed and presented in easy-to-interpret tables and graphs providing the number of cases for each syndrome monitored. In addition, daily and weekly baselines (mean number of cases in the corresponding period of previous years) are calculated for each syndrome and plotted against current observations, to identify early signs of outbreaks triggering alerts. The information is disseminated on a weekly and monthly basis to healthcare staff involved in the network and to the staff of the Ministry of Health (MoH) in Madagascar.

Ethics clearance

The surveillance protocol was approved by the MoH and the National Ethics Committee of Madagascar.

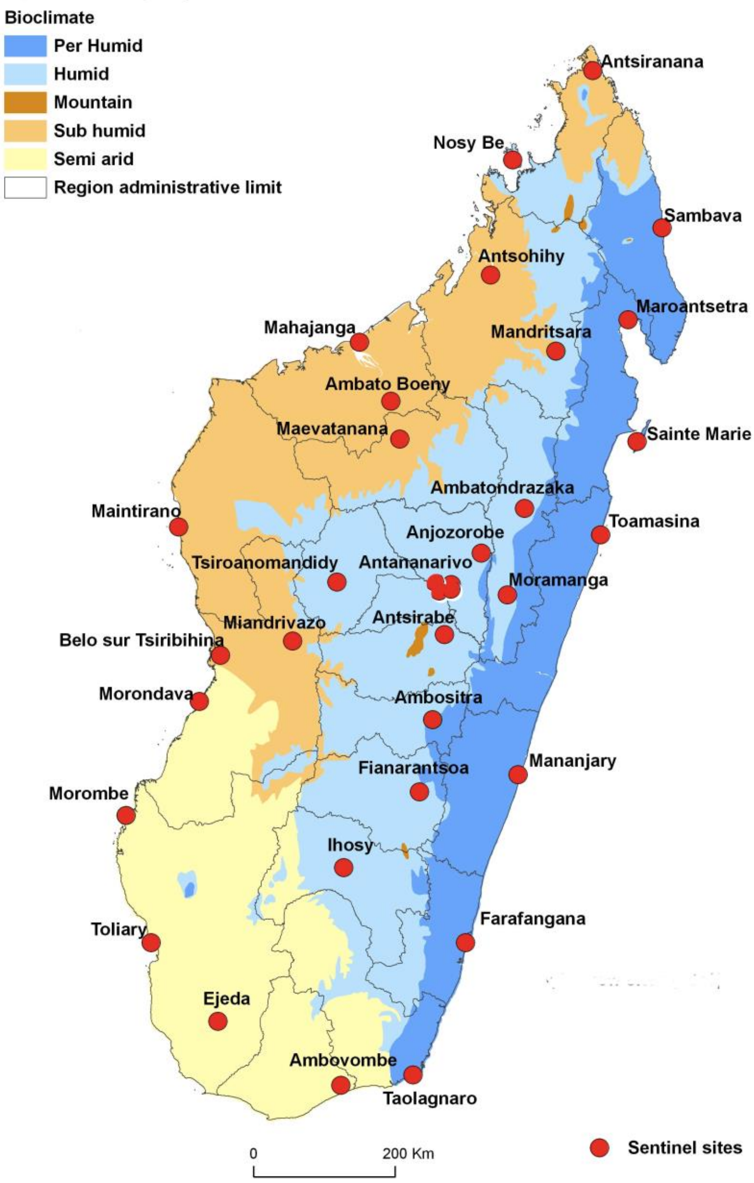

Figure1: Surrounding climate and location of the health centres participating in the sentinel surveillance system in Madagascar

Results

Description of the epidemiological indicators

From January 2007 to December 2011, the data collected on a daily basis corresponded to 917,798 visits (Table 1). The age distribution of the patients concerned, as a function of the total numbers of visits and febrile syndromes, is indicated in Table 1. In total, 102,200 cases (11.1%) of fever were reported. Fever syndromes accounted for 12.1% of visits in 2007, 12.2% in 2008, 11.8% in 2009, 10.8% in 2010 and 10.0% in 2011 (p<0.01, Table 2).

Table 1: Annual distribution of visits by age group, according to SMS data

Age group	All visits (*n*=917,798)									
	2007		**2008**		**2009**		**2010**		**2011**	
	n	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)
<1 year	7,663	(9.6)	13,794	(10.0)	22,748	(10.4)	24,405	(10.8)	28,607	(11.2)
1-4 years	12,564	(15.7)	20,967	(15.2)	35,652	(16.3)	38,074	(16.8)	44,382	(17.4)
5-14 years	10,092	(12.6)	17,836	(13.0)	34,911	(15.9)	32,230	(14.2)	37,695	(14.8)
15-24 years	16,096	(20.2)	27,569	(20.1)	39,421	(18.0)	42,254	(18.7)	49,340	(19.3)
≥25 years	33,456	(41.9)	57,356	(41.7)	86,259	(39.4)	89,196	(39.4)	95,231	(37.3)
Total	79,871	(8.7)	137,522	(15.0)	218,991	(23.9)	226,159	(24.6)	255,255	(27.8)

ILI accounted for 14.7% of fever cases in 2007, 8.5% in 2008, 21.3% in 2009, 20.2% in 2010 and 32.8% in 2011 (p<0.01), according to the data transmitted by SMS (Table 3). Dengue-like syndromes (Table 3) accounted for 18.6% of fever cases in 2007, 8.7% in 2008, 10.2% in 2009, 11.5% in 2010 and 4.2% in 2011 (p<0.01). Confirmed cases of malaria (Table 3) accounted for 12.0% of fever cases in 2007, 8.3% in 2008, 10.6% in 2009, 16.8% in 2010 and 12.4% in 2011 (p<0.01). From January 2008 to December 2011, 40,510 cases (4.8%) of diarrhoea were reported in the 837,881 visits (Table 3). Diarrhoea cases accounted for 3.1% of visits in 2008, 4.9% in 2009, 5.5% in 2010 and 5.1% in 2011 (p<0.01).

The epidemiological characteristics of groups with fever-related syndromes, such as those with ILI, identified by the sentinel surveillance system, were investigated by the plotting of daily count data on a graph (Figure 2). Daily and weekly counts, as a function of the regional pattern, were also plotted and analysed for each sentinel centre (data not shown). Figure 2 shows a peak in the number of daily visits in November 2009 corresponding to an increase in the number of febrile syndromes and ILI cases.

A plot of the distribution of febrile and other syndromes over the various years (Figures 2-5) showed that ILI was the dominant cause of fever in most of the country, from 2009 onwards. A subanalysis of the longitudinal data, using only the first 13 sentinel sites established in 2007-2011, yielded similar trends (Figure 4).

Table 2: Process indicators by sentinel site and year

		2007				2008				2009				2010				2011			
Sentinel site	Opening date	Fever	Forms	Forms / Fever %	SMS delay %	Fever	Forms	Forms / Fever %	SMS delay %	Fever	Forms	Forms / Fever %	SMS delay %	Fever	Forms	Forms / Fever %	SMS Delay %	Fever	Forms	Forms / Fever %	SMS Delay %
Ambatondrazaka	2009-05-11	--	--	--	--	--				297	200	67.3	37	211	185	87.7	38	276	154	55.8	25
Ambato Boeny	2010-09-01	--	--	--	--	--				--	--	--	--	363	53	14.6	51	1094	4	0.4	28
Ambovombe	2009-06-02	--	--	--	--	--				111	111	100.0	34	171	53	31.0	53	190	73	38.4	45
Ambositra	2011-08-25	--	--	--	--	--				--	--	--	--	--	--	--	--	212	195	92.0	6
AntananarivoBHK	2009-01-26	--	--	--	--	--				412	412	100.0	18	331	180	54.4	22	273	124	45.4	39
Antananarivo CDA	2009-04-01	--	--	--	--	--				132	111	84.1	18	240	172	71.7	23	308	198	64.3	43
Antananarivo MJR	2009-02-02	--	--	--	--	--				441	144	32.7	24	292	215	73.6	2	480	235	49.0	7
Antananarivo TSL	2009-02-09	--	--	--	--	--				143	134	93.7	26	44	44	100.0	25	38	28	73.7	10
Antsirabe	2008-09-08	--	--	--	--	258	256	99.2	20	1304	1304	100.0	7	576	550	95.5	4	1025	653	63.7	4
Antsiranana	2007-04-19	1652	1650	99.8	NA	2215	2215	100.0	10	2579	2148	83.3	5	1995	1968	98.6	10	1577	1252	79.4	11
Antsohihy	2007-05-02	263	263	100.0	NA	1172	1172	100.0	19	611	565	92.5	29	585	558	95.4	35	248	180	72.6	23
Anjozorobe	2010-07-29	--	--	--	--	--	--	--	--	--	--		--	49	38	77.6	45	158	153	96.8	38
Belo sur Tsiribina	2010-10-11	--	--	--	--	--	--	--	--	--	--		--	183	182	99.5	48	529	419	79.2	50
Ejeda	2007-12-10	5	5	100.0	NA	63	63	100.0	12	76	76	100.0	10	113	113	100.0	20	137	137	100.0	24
Farafangana	2007-06-07	473	473	100.0	NA	929	929	100.0	6	970	961	99.1	8	1102	925	83.9	14	1710	1609	94.1	17
Fianarantsoa	2008-08-04	--	--	--	--	250	250	100.0	9	427	427	100.0	10	162	145	89.5	11	302	186	61.6	11
Ihosy	2007-12-10	71	71	100.0	NA	793	793	100.0	9	552	525	95.1	16	350	350	100.0	19	745	538	72.2	11
Maevatanana	2007-04-23	1639	1639	100.0	NA	1906	1906	100.0	9	2736	2223	81.3	5	3414	3311	97.0	20	2582	1668	64.6	29
Mahajanga	2007-04-23	519	518	99.8	NA	597	467	78.2	10	851	829	97.4	8	943	922	97.8	11	891	730	81.9	20
Maintirano	2010-07-19	--	--	--	--	--	--	--	--	--	--	--	--	354	311	87.9	25	675	467	69.2	50
Mananjara	2010-02-18	--	--	--	--	--	--	--	--	--	--	--	--	853	822	96.4	27	409	299	73.1	35
Mandritsara	2011-09-26	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	391	391	100.0	37
Maroantsetra	2010-09-02	--	--	--	--	--	--	--	--	--	--	--	--	158	158	100.0	18	433	240	55.4	28
Miandrivaza	2010-05-07	--	--	--	--	--	--	--	--	--	--	--	--	875	875	100.0	37	582	493	84.7	46
Moramanga	2007-04-12	1436	1436	100.0	NA	2227	2196	98.6	18	3213	2964	92.3	15	1454	1396	96.0	23	1730	1010	58.4	20
Morombe	2011-09-12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	158	130	82.3	21
Morondava	2007-04-10	623	623	100.0	NA	1163	1163	100.0	5	1182	1182	100.0	8	707	707	100.0	21	617	426	69.0	37
Nosy Be	2009-06-02	--	--	--	--	--	--	--	--	2402	18	0.7	28	2645	1100	41.6	54	2542	791	31.1	68
Sainte Marie	2010-03-04	--	--	--	--	--	--	--	--	--	--	--	--	71	35	49.3	46	61	6	9.8	41
Sambava	2009-01-21	--	--	--	--	--	--	--	--	1125	574	51.0	25	1515	279	18.4	40	934	242	25.9	50
Taolagnara	2007-04-24	407	407	100.0	NA	709	709	100.0	15	742	636	85.7	17	464	427	92.0	23	383	320	83.6	35
Toamasina	2007-04-16	1140	1140	100.0	NA	2602	2602	100.0	14	3803	2727	71.7	11	2428	2159	88.9	24	2116	1713	81.0	24
Tsiroanamandidy	2007-04-30	1056	1056	100.0	NA	1152	1152	100.0	13	1199	1199	100.0	36	1093	1048	95.9	48	1024	602	58.8	45
Tulear	2007-04-30	352	352	100.0	NA	706	706	100.0	15	576	499	86.6	26	714	711	99.6	25	653	494	75.7	33
Total		9,636	9,633	99.9		16,742	16,579	99.0		25,884	19,969	77.1		24,455	19,992	81.7		25,483	16,160	63.4	

Fever= number of febrile syndrome cases declared by SMS, Forms= number of fever forms received, % forms = percentage of forms for patients with febrile syndromes, NA=not available

Table 3: Number of declared syndromes by sentinel site and year

		2007				2008				2009				2010				2011			
Sentinel site	Opening date	ILI	DLS	Malr	Diarr	ILI	DLS	Malr	Diarr	ILI	DLS	Malr	Diarr	ILI	DLS	Malr	Diarr	ILI	DLS	Malr	Diarr
Ambatondrazaka	2009-05-11	--	--	--	--	--	--	--	--	129	19	7	337	39	4	7	160	122	1	7	234
Ambato Boeny	2010-09-01	--	--	--	--	--	--	--	--	--	--	--	--	195	1	156	156	828	18	197	491
Ambovombe	2009-06-02	--	--	--	--	--	--	--	--	4	0	7	61	3	2	16	114	6	0	9	137
Ambositra	2011-08-25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	68	12	8	118
AntananarivoBHK	2009-01-26	--	--	--	--	--	--	--	--	381	0	6	1365	160	9	4	1093	193	4	9	826
Antananarivo CDA	2009-04-01	--	--	--	--	--	--	--	--	34	0	3	298	68	7	3	393	67	6	2	216
Antananarivo MJR	2009-02-02	--	--	--	--	--	--	--	--	289	2	2	255	185	4	5	188	239	2	11	175
Antananarivo TSL	2009-02-09	--	--	--	--	--	--	--	--	125	0	2	396	41	0	0	569	29	0	2	513
Antsirabe	2008-09-08	--	--	--	--	150	22	8	288	860	12	7	539	311	1	2	535	765	1	7	467
Antsiranana	2007-04-19	236	678	10	--	121	201	3	274	471	180	30	1136	394	210	54	1050	130	115	28	985
Antsohihy	2007-05-02	6	22	10	--	0	0	14	1	1	1	40	4	4	9	215	128	64	31	34	179
Anjozorobe	2010-07-29	--	--	--	--	--	--	--	--	--	--		--	36	4	4	24	141	0	4	53
Belo sur Tsiribina	2010-10-11	--	--	--	--	--	--	--	--	--	--		--	52	33	68	82	159	97	63	483
Ejeda	2007-12-10	0	0	0	--	5	3	7	43	0	4	3	36	0	0	7	39	0	0	30	56
Farafangana	2007-06-07	285	33	23	--	424	45	83	169	289	27	174	322	379	230	59	375	485	37	661	414
Fianarantsoa	2008-08-04	--	--	--	--	13	0	0	113	37	0	12	212	24	2	1	193	70	0	14	178
Ihosy	2007-12-10	0	12	7	--	11	90	63	253	30	63	47	219	72	8	37	131	303	10	33	189
Maevatanana	2007-04-23	127	152	628	--	76	60	644	620	472	146	1158	805	269	126	1681	1301	96	11	631	1173
Mahajanga	2007-04-23	25	142	50	--	11	56	13	505	98	37	30	285	163	23	56	324	381	41	20	293
Maintirano	2010-07-19	--	--	--	--	--	--	--	--	--	--	--	--	97	0	128	106	346	0	109	248
Mananjara	2010-02-18	--	--	--	--	--	--	--	--	--	--	--	--	143	441	6	888	0	115	67	782
Mandritsara	2011-09-26	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	90	0	20	212
Maroantsetra	2010-09-02	--	--	--	--	--	--	--	--	--	--	--	--	96	20	18	93	363	2	30	468
Miandrivazo	2010-05-07	--	--	--	--	--	--	--	--	--	--	--	--	266	0	265	142	263	0	39	218
Moramanga	2007-04-12	222	12	59	--	2196	9	77	557	2964	63	66	881	203	30	30	667	573	42	55	628
Morombe	2011-09-12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	61	0	21	48
Morondava	2007-04-10	153	82	139	--	176	15	39	284	117	27	16	575	25	1	62	545	23	0	27	497
Nosy Be	2009-06-02	--	--	--	--	--	--	--	--	18	205	99	501	783	321	306	991	983	147	135	902
Sainte Marie	2010-03-04	--	--	--	--	--	--	--	--	--	--	--	--	32	10	25	5	30	5	25	60
Sambava	2009-01-21	--	--	--	--	--	--	--	--	331	16	120	487	306	52	220	272	464	20	44	218
Taolagnara	2007-04-24	29	15	8	--	34	32	9	249	93	6	29	331	54	1	90	168	57	2	49	105
Toamasina	2007-04-16	53	583	64	--	123	847	315	267	272	1683	782	352	194	1072	468	237	111	260	734	160
Tsiroanamandidy	2007-04-30	250	15	150		200	12	112	276	299	99	94	583	249	109	104	693	570	51	42	545
Tulear	2007-04-30	34	43	13		17	74	1	395	23	62	3	731	105	80	7	734	266	25	3	838
Total		1,418	1,789	1,161	--	1,420	1,466	1,388	4,294	5,503	2,652	2,736	10,711	4,948	2,810	4,104	12,396	8,346	1,055	3,171	13,109

ILI= number of influenza-like illness cases, DLS=number of dengue-like syndromes, Malaria=number of confirmed malaria confirmed cases, Diarr=number of diarrhoea cases declared by SMS

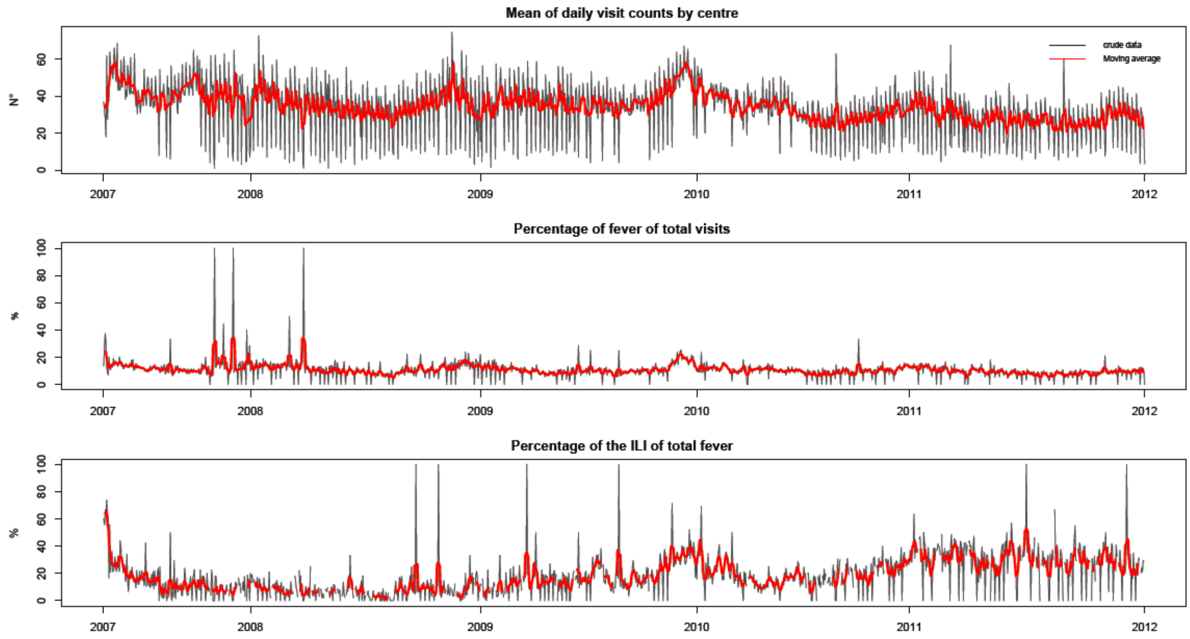

Figure 2: Mean daily visit counts, by centre, in the sentinel surveillance system in Madagascar and daily sentinel surveillance time series plots (%) of fever, total visits and the ILI cases among total fever cases, with the moving average (over 10 days – red curve) for daily visit counts, April 14, 2007 – December 31, 2011.

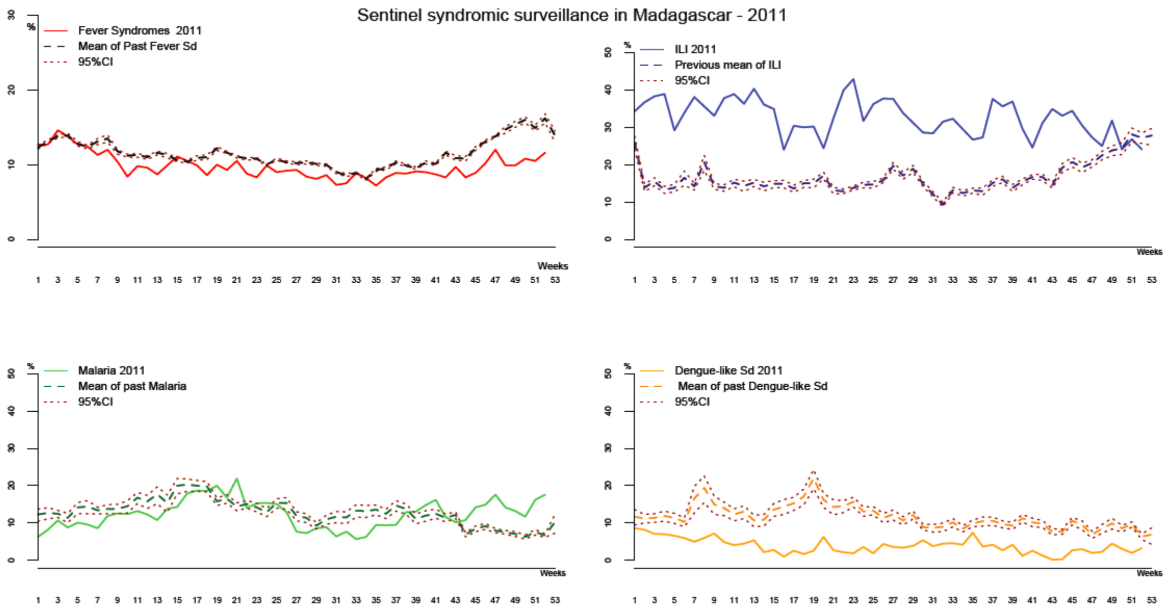

Figure 3: Weekly syndromic data from all sentinel centres in 2011.

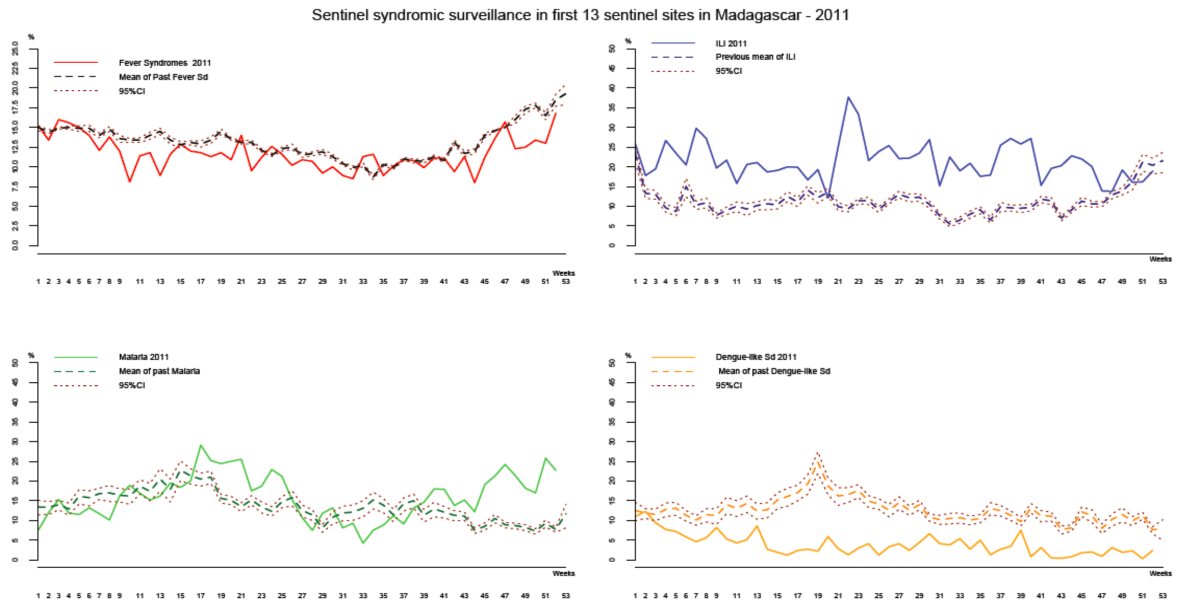

Figure 4: Weekly syndromic data from the first 13 sentinel centres in 2011

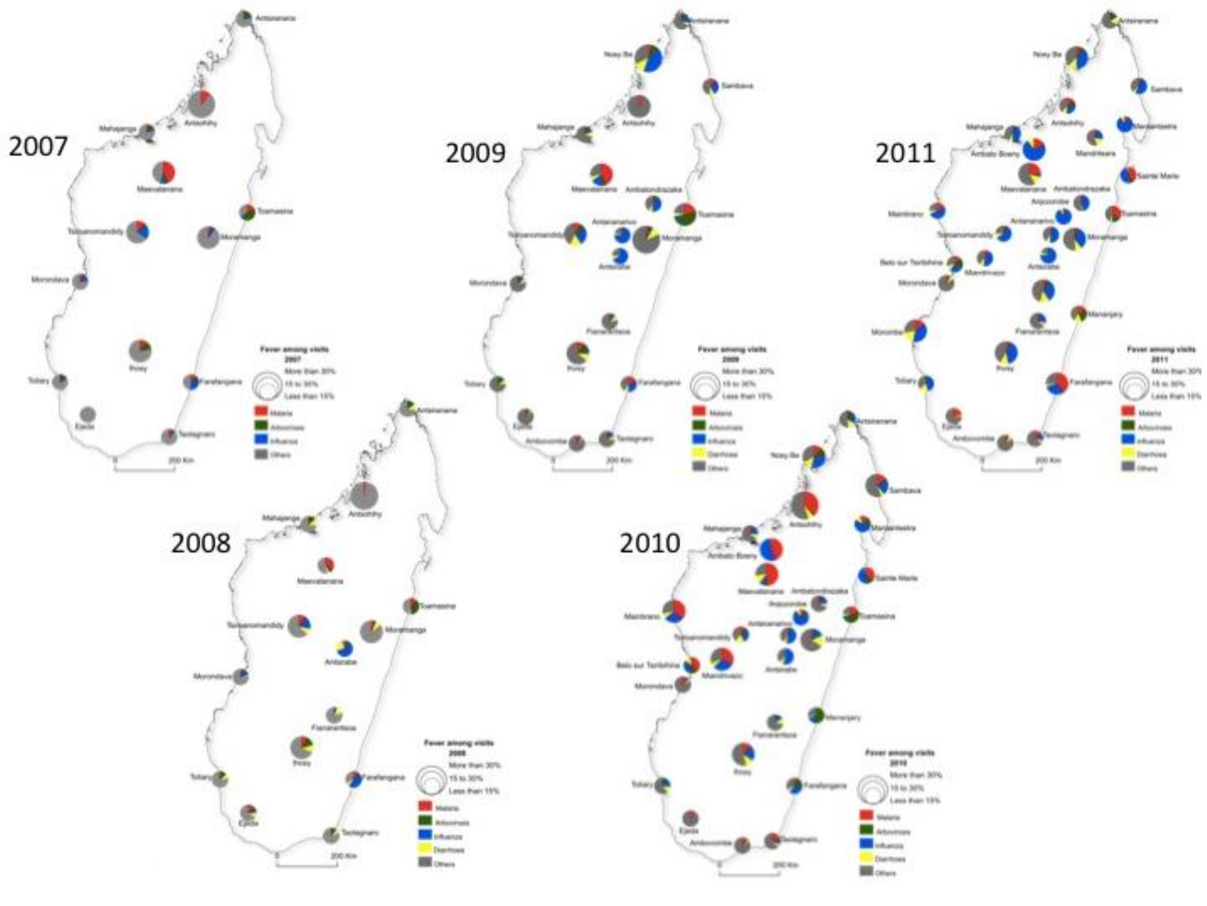

Figure 5: Annual percentage of fever-related syndromes, by centre, based on data collected from sentinel centres by SMS, from 2007 to 2011.

Alerts

From 2007 to 2011, 21 alerts resulting from syndromic surveillance were confirmed by biological surveillance and led to a response and epidemiological investigations to assess the risk.

In October 2008, in Morondava, on the west coast of Madagascar, an increase in the percentage of febrile syndromes and the percentage of ILI cases was recorded. Samples were requested and influenza virus A (H3N2) was detected.

In January 2009, an increase in the percentage of febrile syndromes and in the number of confirmed malaria cases was identified, leading to an investigation of factors potentially associated with an increase in malaria transmission.

In 2010, excess cases of dengue-like syndromes were declared in Mananjary health district, which is located on the southeast coast. The Chikungunya virus was identified and the epidemic confirmed.

None of these events were detected by the routine surveillance system. However, there was no organised response to any of these outbreaks because the MoH lacked the means to deal with these large events.

Process indicators

Relevant process indicators have been identified for the monitoring of the network. These indicators are presented in Table 2 and concern principally the data transmission and data validation processes.

Overall, 85% of the data were transmitted within the 24-hour time frame. This indicator was introduced in 2008. The percentage of data for which transmission was delayed increased from 2008 (12.3%) to 2011 (32.6%), and considerable differences between sentinel sites were observed for this indicator (Table 3).

As previously described [11,12], an individual fever form had to be completed and sent to the IPM for each declared case of febrile syndrome. The fever forms were used to validate the syndrome data transmitted by SMS. Specific forms relating to fever were completed for 82,333 of the patients presenting fever (80.6%). In 2007, 99.9% of the febrile syndromes were documented on a fever form, but this percentage had fallen to 63.4% by 2011.

The sex ratio (male/female) for those with febrile syndromes was 0.88. Age was known for 81,981 patients (99.5%), and the mean age of the patients was 12.5 years (CI 95%: [12.4-12.7]). The age-group distribution is presented in Table 4. ILI, defined on the basis of the symptoms noted on the fever forms (fever and cough, or fever and sore throat), accounted for 49.4% (40,709) of all cases of febrile illness, but significant differences in these percentages ($p<0.01$) were found between years: 49.2% (4,739/9,633) in 2007, 53.6% (8,884/16,579) in 2008, 55.6% (11,102/19,969) in 2009, 42.8% (8,563/19,992) in 2010 and 45.9% (7,421/16,160) in 2011.

Table 4: Annual distribution of febrile illnesses by age group, according to data from individual fever forms

Age group	**Febrile syndromes** (81,981 data available from 82,222 individuals forms)									
	2007		**2008**		**2009**		**2010**		**2011**	
	n	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)
<1 year	1,601	(16.6)	2,887	(17.1)	2,916	(14.5)	2,923	(14.4)	2,375	(14.7)
1-4 years	3,122	(32.3)	5,391	(31.9)	5,396	(26.9)	6,096	(30.0)	4,864	(30.1)
5-14 years	1,775	(18.4)	3,110	(18.4)	4,905	(24.4)	4,529	(22.3)	3,743	(23.1)
15-24 years	1,156	(12.0)	2,177	(12.9)	3,057	(15.2)	2,983	(14.7)	2,253	(13.9)
≥25 years	1,837	(19.0)	3,145	(18.6)	3,563	(17.7)	3,542	(17.4)	2,635	(16.3)
Total	9,491	(11.6)	16,710	(20.4)	19,837	(24.2)	20,073	(24.5)	15870	(19.3)

Discussion

The sentinel surveillance system in Madagascar has two key functions: it provides an early warning of potential threats to public health and it can be used to manage public health programmes, by providing data for malaria indicators, for example. It can rapidly detect unexpected increases in the incidence of fever or diarrhoea syndromes and the biological surveillance associated with the syndromic surveillance programme can then identify the causes of these syndromes.

This system has been described in terms of the methods used [11] and in relation to aspects of influenza surveillance [12,13], such as the spread of the influenza A(H1N1)pdm09 virus [14,15]. During the influenza A(H1N1)pdm09 pandemic, the circulation of this virus in Madagascar was detected and the spread of the virus was followed from October 2009 to March 2010 [14]. We have already highlighted the weaknesses of the routine disease surveillance system in Madagascar, which is based on passive collection and limited capacities for diagnosis outside the capital city. None of the early-warning signs was identified by routine surveillance. Routine surveillance is useful for monitoring long-term programmes, but inappropriate for the timely detection of aberrant patterns. By contrast, syndrome-based near-real time surveillance can detect unusual events more rapidly [15-18]. This timeliness is a key element of the surveillance system and should be evaluated periodically [19].

The evaluation of surveillance systems should promote the most effective use of public health resources, by ensuring that surveillance systems operate efficiently [20]. The sentinel system in Madagascar was clearly simple and rapid, but we found that some process indicators tended to decline over time, due to high staff turnover. The decrease in the number of fever forms received annually, between 2007 and 2011, is one of the weaknesses of this system. The increase in the number of sentinel sites increased the workload of central staff managing the different activities. A lack of co-ordination hindered the training of new healthcare workers entering the network, and changes in practices were discovered only during supervision in the field. Challenges resulting from high staff turnover have also been identified in other countries [6,8]. The indicators used for the continuous assessment of the sentinel network in Madagascar are useful for a rapid, basic internal evaluation, but an external evaluation approach is also required, using CDC guidelines [21], for example, and including economic indicators as an integral part of the surveillance evaluation process [4].

The choice of methods used in the sentinel surveillance system in Madagascar was based on the capabilities of the volunteer healthcare providers and the financial resources available. The Madagascan network has grown over the years and its expansion is probably now limited by the human resources required to manage the network and data analysis. We have found that progressive step-by-step implementation is best, with assessment of the various processes, evaluations of network management capacity and the training of healthcare workers, to make the processes more acceptable.

Despite the results obtained to date, the sustainability of this system remains unclear, although data transmission costs amount to only about 2 US dollars per sentinel site per month. The Madagascan network has been supported by funding from various sources over the years, focusing on different health topics. Self-sustainability is another challenge, as already described [8], and has already been identified as a weakness of this network. We therefore need to focus on the first steps of surveillance system implementation and all system changes. Initial funds targeted arbovirosis, because of the spread of Chikungunya epidemics in Indian Ocean countries in 2006, and influenza, due to the threat posed by avian flu. However, the steering committee subsequently decided to include other diseases associated with febrile syndromes. This policy has been tremendously successful, making it possible for the network to provide epidemiological information not only about arboviruses, but also about malaria and influenza, throughout the country. In 2008, the first human case of Rift Valley fever was detected, by this network, at Taolognaro (in the south of the country), a site used for both syndromic and biological surveillance. For malaria, the network has monitored the shift from control to elimination following the strengthening of malaria prevention and control measures. The usefulness of sentinel networks for influenza detection is well documented and was assessed in the last pandemic period in 2009 [15]. Funding for work on these diseases has improved geographical coverage and made it possible to extend the network over the last five years. This network has become an additional tool for public health decision-making. The syndromic surveillance has been shown to be an effective approach to surveillance and, thanks to the availability of large mobile phone networks throughout Madagascar, the cost of real-time data transmission is low. This surveillance method may also facilitate compliance with the revised International Health Regulations for low-income countries and the aim of the Global Outbreak Alert and Response Network (GOARN) [22].

Limitations

However, the rapidity with which the system can identify unexpected events, which is seen as an advantage [23], must be weighed against delays in the response. For instance, the time required to conduct investigations and retrieve diagnostic and epidemiological information might negate the advantage of rapid data acquisition, particularly in developing countries, in which it can be hard to find the resources necessary for investigations.

The lack of historical data made it difficult to interpret the syndromic trends at each sentinel centre. One of the challenges in our system is determining epidemiological baselines for each centre, to facilitate the development of better statistical methods and more sensitive alert thresholds, as suggested by several authors [24-28]. Indeed, five years after the establishment of this network, large amounts of data are already available and data analysis methods have identified trends for ILI, malaria and dengue-like syndromes in areas of Madagascar with different climates. We now need to develop spatiotemporal models to increase the sensitivity of the alert detection process. However, limited geographical coverage and limited resources may prevent the detection of some epidemic events by this network.

Conclusion

It is clear that the greatest advantage of this system is the ease with which it can be implemented, thanks to the availability of mobile phones and mobile phone networks. Furthermore the quality of the homogeneous data collected will make it possible to improve the system relative to its principal objective: identifying epidemic events early. We recommend this solution for other African countries, because it performs very well and provides rapid benefits in terms of public health decision-making.

Financial support

This work was made feasible by the setting up of a sentinel network supported by WHO Geneva (APW/Ref. OD/AP-08-02451), the French Ministry of Health, the Madagascan Ministry of Health through “projet CRESAN” (crédit IDA – 3302-1-MAG (CRESAN-2)), the US Centers for Disease Control and Prevention (Cooperative Agreement Number: U51/IP000327-01), the US Department of Health and Human Service (Grant Number 6 IDSEP060001-01-01) via the International Network of Pasteur Institutes and the President’s Malaria Initiative program (USAIDS). We would like to thank Kathleen Victoir and Marc Jouan from the International Network of Pasteur Institutes.

Competing interests

The authors have no competing interests to declare.

Acknowledgements

We thank all the staff from the Madagascan National Influenza Centre for influenza testing (Julia Guillebaud, Arnaud Orelle, Girard Razafitrimo and Vololoniaina Raharinosy), and the National Laboratory for Arbovirus (Jean Théophile Rafisandrantantsoa, Jean-Pierre Ravalohery and Josette Razainirina) for all laboratory tests.

We would like to express our gratitude to Dr Yolande Nirina Raoelina, who was one of the key people involved in setting up the sentinel network, and all the staff from the MoH. We are deeply indebted to all the doctors and nurses involved in sentinel surveillance on a daily basis in Madagascar.

References

1. Heymann (editor). Control of Communicable Diseases Manual. 18th éd. USA: APHA; 2004.
2. Last JM. A dictionary of epidemiology. 4th éd. Oxford University Press; 2001.
3. Eylenbosch WJ, Noah NG. Surveillance in Health and Disease. Oxford University Press; 1988.
4. Drewe JA, Hoinville LJ, Cook AJC, Floyd T, Stärk KDC. 2012. Evaluation of animal and public health surveillance systems: a systematic review. *Epidemiol Infect*. 140(4), 575-90. PubMed http://dx.doi.org/10.1017/S0950268811002160
5. Huaman MA, Araujo-Castillo RV, Soto G, Neyra JM, Quispe JA, et al. 2009. Impact of two interventions on timeliness and data quality of an electronic disease surveillance

system in a resource limited setting (Peru): a prospective evaluation. *BMC Med Inform Decis Mak*. 9, 16. PubMed http://dx.doi.org/10.1186/1472-6947-9-16

6. Chretien J-P, Lewis SH. Electronic public health surveillance in developing settings: meeting summary. BMC Proc. 2008;2 Suppl 3:S1.
7. Ijaz K, Kasowski E, Arthur RR, Angulo FJ, Dowell SF. 2012. International Health Regulations--What Gets Measured Gets Done. *Emerg Infect Dis*. 18(7), 1054-57. PubMed http://dx.doi.org/10.3201/eid1807.120487
8. Soto G, Araujo-Castillo RV, Neyra J, Fernandez M, Leturia C, et al. Challenges in the implementation of an electronic surveillance system in a resource-limited setting: Alerta, in Peru. BMC Proc. 2008;2 Suppl 3:S4.
9. Chretien J-P, Burkom HS, Sedyaningsih ER, Larasati RP, Lescano AG, et al. 2008. Syndromic surveillance: adapting innovations to developing settings. *PLoS Med*. 5(3), e72. PubMed http://dx.doi.org/10.1371/journal.pmed.0050072
10. Raviglione MC, Gupta R, Dye CM, Espinal MA. 2001. The burden of drug-resistant tuberculosis and mechanisms for its control. *Ann N Y Acad Sci*. 953, 88-97. PubMed http://dx.doi.org/10.1111/j.1749-6632.2001.tb11364.x
11. Randrianasolo L, Raoelina Y, Ratsitorahina M, Ravolomanana L, Andriamandimby S, et al. 2010. Sentinel surveillance system for early outbreak detection in Madagascar. *BMC Public Health*. 10, 31. PubMed http://dx.doi.org/10.1186/1471-2458-10-31
12. Rajatonirina S, Heraud J-M, Randrianasolo L, Orelle A, Razanajatovo NH, et al. 2012. Short message service sentinel surveillance of influenza-like illness in Madagascar, 2008-2012. *Bull World Health Organ*. 90(5), 385-89. PubMed http://dx.doi.org/10.2471/BLT.11.097816
13. Razanajatovo NH, Richard V, Hoffmann J, Reynes J-M, Razafitrimo GM, et al. 2011. Viral etiology of influenza-like illnesses in antananarivo, madagascar, july 2008 to june 2009. *PLoS ONE*. 6(3), e17579. PubMed http://dx.doi.org/10.1371/journal.pone.0017579
14. Rajatonirina S, Heraud J-M, Orelle A, Randrianasolo L, Razanajatovo N, et al. 2012. The Spread of Influenza A(H1N1)pdm09 Virus in Madagascar Described by a Sentinel Surveillance Network. *PLoS ONE*. 7(5), e37067. PubMed http://dx.doi.org/10.1371/journal.pone.0037067
15. Orelle A, Razanajatovo NH, Rajatonirina S, Hoffmann J, Randrianasolo L, et al. 2012. Epidemiological and virological characterization of 2009 pandemic influenza A virus subtype H1N1 in Madagascar. *J Infect Dis*. 206(Suppl 1), S140-47. PubMed http://dx.doi.org/10.1093/infdis/jis533
16. Buehler JW, Berkelman RL, Hartley DM, Peters CJ. 2003. Syndromic surveillance and bioterrorism-related epidemics. *Emerg Infect Dis*. 9(10), 1197-204. PubMed http://dx.doi.org/10.3201/eid0910.030231
17. Lewis MD, Pavlin JA, Mansfield JL, O'Brien S, Boomsma LG, et al. 2002. Disease outbreak detection system using syndromic data in the greater Washington DC area. *Am J Prev Med*. 23(3), 180-86. PubMed http://dx.doi.org/10.1016/S0749-3797(02)00490-7
18. Miller B, Kassenborg H, Dunsmuir W, Griffith J, Hadidi M, et al. 2004. Syndromic surveillance for influenzalike illness in ambulatory care network. *Emerg Infect Dis*. 10(10), 1806-11. PubMed http://dx.doi.org/10.3201/eid1010.030789

19. Jajosky RA, Groseclose SL. 2004. Evaluation of reporting timeliness of public health surveillance systems for infectious diseases. *BMC Public Health*. 4(1), 29. PubMed http://dx.doi.org/10.1186/1471-2458-4-29

20. CDC. 1988. Guidelines for evaluating surveillance systems. *MMWR Morb Mortal Wkly Rep*. 37(S-5), 1-18. PubMed

21. German RR, Lee LM, Horan JM, Milstein RL, Pertowski CA, Waller MN. Updated guidelines for evaluating public health surveillance systems: recommendations from the Guidelines Working Group. MMWR Recomm Rep. 27 juill 2001;50(RR-13):1-35; quiz CE1-7.

22. Heymann DL, Rodier GR. 2001. Hot spots in a wired world: WHO surveillance of emerging and re-emerging infectious diseases. *Lancet Infect Dis*. 1(5), 345-53. PubMed http://dx.doi.org/10.1016/S1473-3099(01)00148-7

23. Wu T-SJ, Shih F-YF, Yen M-Y, Wu J-SJ, Lu S-W, et al. 2008. Establishing a nationwide emergency department-based syndromic surveillance system for better public health responses in Taiwan. *BMC Public Health*. 8, 18. PubMed http://dx.doi.org/10.1186/1471-2458-8-18

24. Flahault A, Blanchon T, Dorléans Y, Toubiana L, Vibert JF, et al. 2006. Virtual surveillance of communicable diseases: a 20-year experience in France. *Stat Methods Med Res*. 15(5), 413-21. PubMed

25. Viboud C, Boëlle P-Y, Carrat F, Valleron A-J, Flahault A. 2003. Prediction of the spread of influenza epidemics by the method of analogues. *Am J Epidemiol*. 158(10), 996-1006. PubMed http://dx.doi.org/10.1093/aje/kwg239

26. Costagliola D, Flahault A, Galinec D, Garnerin P, Menares J, et al. 1991. A routine tool for detection and assessment of epidemics of influenza-like syndromes in France. *Am J Public Health*. 81(1), 97-99. PubMed http://dx.doi.org/10.2105/AJPH.81.1.97

27. Pelat C, Boëlle P-Y, Cowling BJ, Carrat F, Flahault A, et al. 2007. Online detection and quantification of epidemics. *BMC Med Inform Decis Mak*. 7, 29. PubMed http://dx.doi.org/10.1186/1472-6947-7-29

28. Saltyte Benth J, Hofoss D. 2008. Modelling and prediction of weekly incidence of influenza A specimens in England and Wales. *Epidemiol Infect*. 136(12), 1658-66. PubMed http://dx.doi.org/10.1017/S0950268808000307