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INFECTIOUS DISEASES

A 5-year comparison of performance of sentinel and mandatory notification surveillance systems for measles in Switzerland

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Abstract A sensitive, specific and timely surveillance is necessary to monitor progress towards measles elimination. We evaluated the performance of sentinel and mandatory-based surveillance systems for measles in Switzerland during a 5-year period by comparing 145 sentinel and 740 mandatory notified cases. The higher proportion of physicians who reported at least one case per year in the sentinel system suggests underreporting in the recently introduced mandatory surveillance for measles. Accordingly, the latter reported 2–36-fold lower estimates for incidence rates than the sentinel surveillance. However, these estimates were only 0.6–12-fold lower when we considered confirmed cases alone, which indicates a higher specificity of the mandatory surveillance system. In contrast, the sentinel network, which covers 3.5% of all outpatient consultations, detected only weakly and late a major national measles epidemic in 2003 and completely missed 2 of 10 cantonal outbreaks. Despite its better timeliness and greater sensitivity in case detection, the sentinel system, in the current situation of low incidence, is insufficient to perform measles control and to monitor progress towards elimination.

Keywords Mandatory notification · Measles · Sensitivity · Sentinel surveillance · Specificity · Timeliness

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Abbreviations

CI	Confidence interval
FMH	Swiss Medical Association
FOPH	Federal Office of Public Health
MNS	Mandatory notification system
OR	Odds ratio
SSSN	Swiss Sentinel Surveillance Network
WHO	World Health Organization

Introduction

Measles has been targeted for elimination by year 2010 by the World Health Organization (WHO) Regional Office for Europe [1, 2]. A powerful case-based surveillance system including laboratory data is necessary to assess the progress towards this goal [3, 4]. In most Western European countries, measles surveillance is currently based on mandatory notification of cases by physicians, and often also by laboratories. Some countries, such as France, have relied exclusively until recently on sentinel systems for measles surveillance [5]. Other countries use both systems in parallel (Italy, Germany and Switzerland) [6–10]. Each system has its strengths and weaknesses. The mandatory notification is theoretically exhaustive while a sentinel surveillance system is based on a limited sample of physicians, which raises concerns about its representativeness, and about the reliability of nationwide incidence estimates extrapolated from reported cases [11]. In a situation close to measles elimination, it is essential to investigate all cases and prevent further transmission. Sentinel surveillance could then fail to detect isolated cases and even outbreaks. However, the information provided by sentinel systems is usually considered to be timelier and more complete, due to better compliance of voluntarily reporting physicians [6]. On the other hand, the mandatory notification systems often shows significant underreporting, with incidence rates several times lower than in sentinel systems [12–15].

Several countries have recently tried to improve measles surveillance by replacing one system by another or adding a new system to the one in place. In France because of major underreporting, the mandatory notification for measles was replaced by sentinel surveillance in 1985. However, with the current low measles incidence, the sensitivity of this new system has become insufficient and mandatory notification was recently reintroduced [16]. In Italy a paediatric sentinel network for measles was introduced in 2000 in addition to mandatory notification, which is characterized by an important underreporting. In Germany a sentinel system for measles was launched in 1999 followed by statutory surveillance in 2001 [15]. With declining incidence of measles, the trend is to reinforce mandatory notification, including laboratory reports. Nevertheless sentinel systems could still be useful in countries where reporting compliance is insufficient.

Two systems currently exist for measles surveillance in Switzerland: the Swiss Sentinel Surveillance Network (SSSN) and the mandatory notification system (MNS). The SSSN was launched by the Federal Office of Public Health (FOPH) and the Fakultäre Instanz für Arztmedizin in 1986. It is also used to monitor other diseases such as rubella, mumps, whooping-cough or influenza [17]. The FOPH recommends to the sentinel physicians to confirm all suspected measles cases by laboratory testing. Although two national measles epidemics were detected through the SSSN in 1987 and in 1997, with 10,500 and 6,400 extrapolated cases respectively, incidence shows a decreasing trend since 1986 [18]. With only 73 cases reported in 1998, and 35 cases in 1999, concerns rose about the sensitivity of the system to detect cases. In addition to the SSSN, a case-based mandatory notification of measles for physicians and laboratories was thus introduced in March 1999.

To our knowledge, a detailed comparison over several years of the performance of these two types of surveillance systems for measles has never been published [19, 20]. The aim of this study was to review the 1999–2003 measles surveillance data to compare the performance of the sentinel and the mandatory surveillance systems, and in particular to evaluate if the SSSN still provides reliable information for public health.

Methods

The Swiss Sentinel Surveillance Network (SSSN)

The SSSN consisted of a yearly average of 230 primary care physicians between 1999 and 2003. They were recruited in order to represent as good as possible the distribution of physicians by area (six sentinel regions) and specialty (GPs, specialists in internal medicine and paediatricians) observed among the physicians of the Swiss Medical Association (FMH). Physicians were recruited annually by advertisements in the Bulletin of the FOPH, and direct contacts or mailings made by a representative of the SSSN in each region. Compared to the FMH members, the representativeness of the SSSN members was good with respect to region, speciality (with around 14% of the total paediatricians were voluntarily overrepresented), sex and age. The physicians' attitude towards MMR vaccination and their making use of alternative medicine are not taken into account for recruitment. SSSN physicians covered approximately 3.5% of the total consultations taking place in Swiss private practices (about 5% for the paediatricians), and covered 25 of the 26 cantons. They voluntarily report clinical measles cases to the FOPH by mail on a weekly basis. As soon as the latter receives this first brief report, it requests physicians to deliver additional data on exposure, clinical symptoms, laboratory results, vaccination status, complications and hospitalization. In addition, the SSSN physicians report the total number of consultations carried out during the week, which is used as a denominator.

The mandatory notification system (MNS)

Clinically compatible measles cases must be notified within a week to the cantonal health officer by means of a short form report. The notifying physician is then asked for more details using another form similar to the SSSN complementary form. The cantonal health officer transmits a copy of all physicians' reports to the FOPH. Moreover, all positive measles tests performed by laboratories must be notified simultaneously to the FOPH and the cantonal health officer.

Case definitions and classification

The SSSN measles case definition—a generalized maculopapular rash of at least 3 days duration, and a temperature ≥38°C, and cough or coryza or conjunctivitis—is more specific than the MNS, which does not specify limits for duration or fever. For the purpose of this study the MNS case classification was used to compare both surveillance systems. A confirmed case is either a case with a positive laboratory result (whichever material and test used) and with at least one of the five measles MNS case definition criteria or a case fulfilling this case definition with an epidemiological link with another (confirmed or not) measles case. Outbreaks during the 2003 epidemic were defined as clusters of at least eight cases living in the same canton and beginning between January and July.

Statistical analysis

All measles cases reported by physicians and laboratories with onset between March 1999 and December 2003 were included in the analyses. Although sentinel physicians were expected to notify cases only in the SSSN, 48 SSSN cases (33.1%) were also reported in the MNS. This was mainly due to the notification by the laboratories of positive measles patients cared for by sentinel physicians. These cases were regarded as SSSN cases only. Since the performance of surveillance systems and characteristics of the cases can vary according to the incidence of the disease, we stratified most of the analyses in two periods: an inter-epidemic period (1999–2002) and an epidemic year (2003).

We calculated the relative sensitivity of SSSN and MNS by comparing estimates of incidence rates per 100,000 population according to both systems. We extrapolated SSSN measles cases to the whole country by comparing the number of SSSN consultations—stratified by the patients' sex and age, the physicians' region and type of practice—with similarly stratified total consultations carried out in Switzerland, according to health insurance data. We also evaluated the relative sensitivity of both systems by comparing the number of cases (i) per reporting physician (any physician reporting at least one case), and (ii) per potentially reporting physician (any physician belonging to SSSN or seeing measles cases outside SSSN, respectively).

While sensitivity is essential to surveillance, accuracy and timeliness of reporting are crucial for a rapid intervention to prevent the spread of the disease, particularly at the beginning of an outbreak [21, 22]. Timeliness was estimated in both surveillance systems using four indicators: the time in days between the onset of measles symptoms and the registration by the FOPH of (i) the first of any report (initial, complementary or laboratory notification), (ii) the initial report, (iii) the complementary notification, and (iv) the laboratory report (for MNS only). These data were only available in 2003 for the SSSN cases. Accuracy was estimated in both systems using two indicators: the proportion of (i) confirmed cases, and (ii) laboratory confirmed cases.

To compare the characteristics of cases in both surveillance systems we calculated unadjusted odds ratios (OR) and 95% confidence intervals (CI) of cases being reported in the mandatory versus sentinel (reference) system, for the following variables: age, sex, region, being a confirmed case, laboratory test performed, vaccination status, complications or hospitalization, time elapsed since the onset of disease and its first registration. Using the same variables, logistic regression models were built to adjust for possible confounding factors and to identify factors associated with measles cases reported in the MNS using the SSSN as a reference. Because of the interacting role of the epidemic variable, two separate models were proposed for the inter-epidemic period and the epidemic year respectively.

SPSS 11.5, STATA 8.0 and EpiInfo 6.04d statistical packages were used for analyses. The χ^2 test or the Fisher's exact test were used to analyse differences between proportions, and the χ^2 for linear trend to test trends in proportions. P values less than 0.05 were considered statistically significant.

Results

Availability of reports

A complementary form was available for most of SSSN (96.6%) and MNS (94.6%) cases (Table 1). Only a minority of MNS cases were notified via an initial (17.3%) or a laboratory (29.1%) report. During the inter-epidemic period the proportion of MNS cases with an initial, and respectively a laboratory report was higher as compared to the epidemic year ($P = 0.002$ and $P < 0.001$). The opposite was observed for the complementary reports ($P < 0.001$).

For the 5-year period, 62.8% of MNS cases were exclusively reported through one notification: usually a complementary form, rarely a laboratory form, and hardly ever an initial form. Significantly more cases were announced only through one notification during the epidemic period (68.4%) as compared to the inter-epidemic period (41.9%) ($P < 0.001$). Among MNS cases, 15.9% were notified by at least an initial and a complementary report, 24.9% by at least a complementary and a laboratory report, and only 3.8% by the three notification types together.

Number of reported cases and incidence rates

One hundred forty-five SSSN and 740 MNS measles cases were reported between 1999 and 2003 (Table 2). In the first 2 years after MNS was launched, sentinel physicians reported a similar or even higher (non extrapolated) number of cases than the MNS. Moreover, the estimated incidence rates after extrapolation were 5.2 (2.3–36.0)-fold higher in SSSN compared to MNS, depending on the year. However, the estimated incidence rates were only 2.5 (0.6–11.6)-fold higher in SSSN when the analysis was

Table 1 Cases of measles reported by mandatory notification and sentinel surveillance systems, by type of notification reports and inter-epidemic (1999–2002) and epidemic period (2003)

Time period	Type of notification	Mandatory notification				Sentinel surveillance			
		Total		Reported only by		Total		Reported only by	
		n	(%)[a]	*n*	(%)[b]	*n*	(%)[a]	*n*	(%)[b]
1999–2002	Reported cases	155				94			
	Initial report	40	25.8	3	1.9	94	100.0	5	5.3
	Complementary report	129	83.2	39	25.2	89	94.7	0	0.0
	Laboratory report	79	51.0	23	14.8	na	na	na	na
2003	Reported cases	585				51			
	Initial report	88	15.0	6	1.0	51	100.0	0	0.0
	Complementary report	571	97.6	387	66.2	51	100.0	0	0.0
	Laboratory report	136	23.2	7	1.2	na	na	na	na
Total	Reported cases	740				145			
	Initial report	128	17.3	9	1.2	145	100.0	5	3.4
	Complementary report	700	94.6	426	57.6	140	96.6	0	0.0
	Laboratory report	215	29.1	30	4.1	na	na	na	na

na, non applicable

[a] Proportion of reported cases notified by type of notification

[b] Proportion of reported cases notified exclusively by one type of notification

Table 2 Comparison of measles cases reported by mandatory and sentinel notification surveillance systems, by case classification and year; Switzerland, 1999–2003

Case classification	Year	Mandatory notification		Sentinel surveillance			
		n (reported)	IR[a] (1)	*n* (reported)	*n* (extrapolated)	IR[a] (2)	(2)/(1)
All reported cases	1999	33	0.5	29	767	10.7	23.2
	2000	16	0.2	24	576	8.0	36.0
	2001	57	0.8	22	696	9.6	12.2
	2002	49	0.7	19	495	6.8	10.1
	2003	585	8.0	51	1,336	18.2	2.3
	Total	740	2.0	145	3,870	10.7	5.2
Confirmed cases	1999	25	0.3	11	291	4.1	11.6
	2000	12	0.2	2	48	0.7	4.0
	2001	46	0.6	6	190	2.6	4.1
	2002	43	0.6	1	26	0.4	0.6
	2003	376	5.1	26	681	9.3	1.8
	Total	502	1.4	46	1,236	3.4	2.5

[a] IR: incidence rate (per 100,000 population)

restricted to confirmed cases. These differences in incidence rates decreased over time.

In both surveillance systems the number of reported cases strongly increased during the 2003 epidemic year: compared to 2002, the incidence rate was multiplied by 2.7 in the SSSN and by 11.9 in the MNS. Moreover a case was more likely to be reported in the MNS versus the SSSN (OR 6.96, 95% CI 4.66–10.41, $P < 0.001$) in 2003 compared to inter-epidemic years.

Number of cases per physician

The proportion of physicians who reported at least one case was 4.1–65.5-fold higher in SSSN compared to MNS between 1999 and 2003 (Table 3). However, the number of cases notified per reporting physician was similar in both systems. Nevertheless, the number of cases per physician included in each system was 2.9–59.5-fold higher in the SSSN depending on the year. During the epidemic period

Table 3 Total number of physicians, number of physicians who reported cases, and number of cases per physician in the mandatory notification surveillance as compared to the sentinel system; Switzerland, 1999–2003

Surveillance system	Year	Total no. of physicians[a]	No. of physicians reporting cases	Percentage of reporting physicians	No. of cases reported by physicians	No. of cases per reporting physician	No. of cases per physician in the surveillance system
Mandatory notification	1999	7,200	25	0.3	31	1.24	<0.01
	2000	7,200	10	0.1	12	1.20	<0.01
	2001	7,200	32	0.4	50	1.56	0.01
	2002	7,200	28	0.4	39	1.39	0.01
	2003	7,200	219	3.0	578	2.64	0.08
Sentinel	1999	233	19	8.2	29	1.53	0.12
	2000	242	22	9.1	24	1.09	0.10
	2001	226	13	5.8	22	1.69	0.10
	2002	223	17	7.6	19	1.12	0.09
	2003	224	28	12.5	51	1.82	0.23

[a] The number of potential reporters in the MNS for the whole Switzerland was estimated using the total of hospital-based and general practitioners, internists and paediatricians in private practice, based on 2001 data

the proportion of reporting physicians, the number of cases per reporting physician and per physician in the two surveillance systems increased considerably more in the MNS compared to the SSSN.

Timeliness

During the 4 initial years of the mandatory notification of measles, the first report of a case arrived to the FOPH on average more than 1 month after symptom onset (Table 4). This delay decreased to 3 weeks during the 2003 epidemic. In the SSSN, the time remained stable at 2 weeks. In 2003, cases reported within 14 days after symptom onset were less likely to be reported by the MNS (OR 0.31, 95% CI 0.16–0.61, $P < 0.001$) (Table 5).

In the MNS in 2003, the average delay between measles symptoms onset and registration by the FOPH was 16.8 days for laboratory reports (median 14.0), 22.0 days for physician's initial reports (median 13.0) and 27.3 days for complementary notifications (median 20.0). Except for laboratory reports (mean 15.9, median 15.0 days), these delays were much longer during the years 1999–2002, with a mean of 38.8 days for initial reports (median 30.0) and of 53.9 days for the complementary notifications (median 39.0). Unexpectedly, among cases with both initial and complementary reports 30.5% of the latter were received at the same time as initial reports and 6.8% before them.

Among MNS cases with a laboratory and a complementary report, 77.7% were first notified through a laboratory report, with a median delay of 14.0 days between both reports. The opposite was observed among 9.8% of the cases (median 14.0 days) and both reports arrived together in 12.5% of the situations. Complementary reports for cases with a laboratory notification were received later after the symptom onset (median 27.0 days) than those without a laboratory notification (22.0 days).

For eight cantonal outbreaks detected by both surveillance systems in 2003, the first report was always received

Table 4 Timeliness of reporting to the Federal Office of Public Health in the mandatory notification surveillance (1999–2002 and 2003) and the sentinel (2003) systems

	Number of days between symptom onset and first registration of the case[a]			Number of days between symptom onset and registration of complementary information		
	Mandatory notification		Sentinel	Mandatory notification		Sentinel
	1999–2002	2003	2003	1999–2002	2003	2003
N	116	491	47	115	491	46
Mean	32.7	21.0	14.3	53.9	27.3	31.2
Percentile 25	15.0	11.0	10.0	30.0	13.0	19.0
Percentile 50	25.0	16.0	12.0	39.0	20.0	28.5
Percentile 75	37.0	26.0	15.0	67.0	31.0	38.0

[a] For any type of notification (initial, mandatory or laboratory report)

Table 5 Distribution of measles cases among mandatory notification (MNS) and sentinel surveillance (SSSN) systems by demographic, epidemiological, and system characteristics; stratified by epidemiological period

	Inter-epidemic years (1999–2002)						Epidemic year (2003)					
	MNS		SSSN				MNS		SSSN			
	n	(%)	*n*	(%)	OR (95% CI)	*P* value	*n*	(%)	*n*	(%)	OR (95% CI)	*P* value
Total[a]	155		94				585		51			
Sex												
Male	83	(54.2)	53	(56.4)	0.92 (0.53–1.59)	0.793	302	(52.0)	32	(62.7)	0.64 (0.34–1.20)	0.147
Female	70	(45.8)	41	(43.6)			279	(48.0)	19	(37.3)		
Age												
≥16 years	58	(37.7)	12	(12.8)	4.10 (1.99–8.73)	<0.001	122	(21.0)	10	(19.6)	1.09 (0.51–2.39)	1.000
<16 years	96	(62.3)	82	(87.2)			459	(79.0)	41	(80.4)		
Region[b]												
West	16	(10.3)	9	(9.6)	1.09 (0.43–2.80)	1.000	246	(42.1)	11	(21.6)	2.64 (1.28–5.58)	0.004
Central West	8	(5.2)	16	(17.0)	0.27 (0.10–0.69)	0.003	104	(17.8)	10	(19.6)	0.89 (0.41–1.95)	0.706
North	15	(9.7)	15	(16.0)	0.56 (0.25–1.30)	0.162	13	(2.2)	3	(5.9)	0.36 (0.09–1.67)	0.129
Center	38	(24.5)	15	(16.0)	1.71 (0.84–3.50)	0.150	128	(21.9)	8	(15.7)	1.51 (0.66–3.56)	0.374
East	68	(43.9)	36	(38.3)	1.26 (0.72–2.20)	0.428	76	(13.0)	13	(25.5)	0.44 (0.21–0.91)	0.020
Southeast	10	(6.5)	3	(3.2)	2.09 (0.51–9.86)	0.381	18	(3.1)	6	(11.8)	0.24 (0.08–0.77)	0.009
Case classification												
Confirmed	126	(81.3)	20	(21.3)	16.08 (8.13–32.15)	<0.001	376	(64.3)	26	(51.0)	1.73 (0.94–3.19)	0.069
Non confirmed	29	(18.7)	74	(78.7)			209	(35.7)	25	(49.0)		
Laboratory test performed												
Yes	107	(69.0)	52	(55.3)	1.80 (1.02–3.17)	0.031	167	(28.5)	37	(72.5)	0.15 (0.08–0.30)	<0.001
No	48	(31.0)	42	(44.7)			418	(71.5)	14	(27.5)		
Vaccination status												
Vaccinated	18	(11.6)	37	(39.4)	0.26 (0.13–0.54)	<0.001	62	(10.6)	15	(29.4)	0.27 (0.13–0.56)	<0.001
Unknown	52	(33.5)	11	(11.7)	2.56 (1.15–5.77)	0.012	61	(10.4)	6	(11.8)	0.66 (0.26–2.02)	0.422
Unvaccinated	85	(54.8)	46	(48.9)			462	(79.0)	30	(58.8)		
Hospitalization or complication												
Yes	38	(29.5)	4	(4.5)	8.87 (2.98–35.39)	<0.001	91	(15.9)	4	(7.8)	2.23 (0.78–8.71)	0.155
No	91	(70.5)	85	(95.5)			480	(84.1)	47	(92.2)		
Time between symptoms onset and registration of the first report												
<14 days	26	(22.4)	–	–	–		186	(37.9)	31	(66.0)	0.31 (0.16–0.61)	<0.001
≥14 days	90	(77.6)	–	–			305	(62.1)	16	(34.0)		

The SSSN was used as reference for the odds ratio

OR, odds ratio; CI, confidence interval (95%)

[a] Due to missing values the total for categories can be smaller

[b] Odds ratios were calculated with six dummy variables opposing successively each region to all other regions

by the FOPH later in the SSSN as compared to the MNS (median delay 31 days, range 3–73).

Sex, age and residence of patients

There was no difference in reporting by both surveillance systems according to the sex of the patients (Table 5). Adults were significantly more likely to be reported by MNS, but only during inter-epidemic years. At the regional level, the geographical patterns of cases were different in the SSSN and the MNS during both the inter-epidemic period and the epidemic year. The SSSN reported cases from 17 cantons during the inter-epidemic period and from 13 cantons in 2003. The corresponding figures for the MNS were 20 and 20, respectively.

Outbreak detection

The SSSN totally failed to detect 2 of 10 cantonal outbreaks during the 2003 epidemic, with 61 and 56 MNS cases, respectively. Four other cantonal outbreaks were weakly detected by the sentinel surveillance (only one SSSN case or a very low ratio of SSSN cases compared to MNS cases). For the canton of Schwyz, 2 SSSN and 118 MNS cases were reported. This ratio was 1/48, 1/22 and 1/8 for the cantons of Geneva, Vaud and Lucerne, respectively. Only four outbreaks were clearly detected by both systems (Valais, Sankt Gallen, Bern, and Ticino). Nevertheless, the SSSN also reported a few (rarely confirmed) cases in small cantons without any MNS cases: ten cases in three cantons in 1999–2002, and four in two cantons in 2003.

Case classification

Clinical information was available for all SSSN cases with a complementary report, but only 29.3% of which fulfilled the SSSN clinical case definition and 76.4% the MNS one. Clinical data were available for 94.7% of MNS cases with a complementary report, of which 82.1% fulfilled the MNS case definition. For both systems the proportion of cases corresponding to the clinical definition was significantly higher during the epidemic year (data not shown). The proportion of SSSN confirmed cases was also higher during the epidemic year compared to the inter-epidemic period ($P < 0.001$), while the proportion of confirmed cases was lower in the MNS during the epidemic year ($P < 0.001$) (Table 5). Inter-epidemic cases reported in the MNS compared to SSSN were more likely to be confirmed (OR 16.08, 95% CI 8.13–32.15, $P < 0.001$). This difference was not observed during the epidemic year.

Laboratory results

During the inter-epidemic period MNS cases were more likely to receive a laboratory investigation than SSSN cases (OR 1.80, 95% CI 1.02–3.17, $P = 0.031$) (Table 5). But the proportion of MNS cases with a laboratory investigation decreased from 81.6% in 1999 to 31.5% in 2003 ($P < 0.001$, data not shown), whereas this proportion increased from 48.3% to 72.5% among SSSN cases ($P = 0.009$). In 2003 MNS cases were thus less likely to be confirmed by a laboratory test than SSSN cases (OR 0.15, 95% CI 0.08–0.30, $P < 0.001$).

Positive results among SSSN cases with laboratory declined between 1999 (57.1%) and 2002 (7.7%), and strongly increased during the 2003 epidemic (56.8%). A total of 53 negative cases were reported by SSSN physicians (36.6% of all cases). On the opposite, the proportion of positive results among cases with laboratory was constantly very high in MNS, because negative cases were hardly ever notified by MNS physicians (six cases corresponding to 0.8% of overall cases). For the whole period, the proportion of positive tests among MNS cases was thus higher than among SSSN (OR 66.38, 95% CI 25.53–198.71, $P < 0.001$, data not shown). Overall, during the inter-epidemic period, MNS cases were more likely to be laboratory confirmed than SSSN (OR 11.00, 95% CI 5.46–22.48, $P < 0.001$, data not shown). The opposite was observed for the epidemic year (OR 0.54, 95% CI 0.29–1.02, $P = 0.039$). Four genotypes were identified among MNS cases (D4, D5, D7 and D8) and only two (D5 and D7) among SSSN cases in 2003.

Vaccination status

During both epidemic and inter-epidemic years, vaccinated cases were about 4-fold more likely than unvaccinated cases to be reported in the SSSN compared to MNS ($P < 0.001$) (Table 5). If tested, SSSN unvaccinated cases were significantly more likely to be laboratory positive than vaccinated one (60.4% vs. 12.1%, $P < 0.001$). No difference was observed among MNS cases.

Complications or hospitalization

Compared to SSSN measles cases, MNS cases were more likely to have had complications or to have been hospitalized during the inter-epidemic years (OR 8.87, 95% CI 2.98–35.39, $P < 0.001$). This association was no more significant during the epidemic year.

Logistic regression analysis

Logistic regression using multiple factors to compare the characteristics of the MNS versus the SSSN cases confirmed for inter-epidemic years the significant differences observed in univariate analyses for age, case classification, vaccination status and severity (Table 6). Cases reported in the MNS were more likely to be adults (OR 3.04, 95% CI 1.10–8.44, $P = 0.032$), confirmed (OR 11.57, 95% CI 5.06–26.45, $P < 0.001$), and with complications or hospitalization (OR 6.93, 95% CI 1.74–27.66, $P = 0.006$), but less likely to be vaccinated (OR 0.40, 95% CI 0.16–0.97, $P = < 0.001$).

For the epidemic year, the multiple analysis also confirmed that the availability of a laboratory test was lower in the MNS (OR 0.05, 95% CI 0.02–0.14, $P < 0.001$). MNS cases were more likely to be confirmed (OR 5.78, 95% CI 2.38–14.02, $P < 0.001$) than in the univariate analysis ($P < 0.069$). A similar pattern was found in an additional

Table 6 Variables associated with reporting measles cases in the mandatory notification compared to the sentinel surveillance system (reference) by logistic regression analysis, for inter-epidemic and epidemic years respectively

	Inter-epidemic years (1999–2002)			Epidemic year (2003)		
	OR	95% CI	*P* value	OR	95% CI	*P* value
Sex						
Female	1.00			1.00		
Male	1.36	0.62–3.00	0.445	0.62	0.31–1.22	0.163
Age						
<16 years	1.00			1.00		
≥16 years	3.04	1.10–8.44	0.032	1.84	0.74–4.54	0.187
Region[a]						
West	na	na	na	8.10	2.25–29.12	0.001
Central West	0.20	0.03–1.27	0.088	4.80	1.22–18.96	0.025
North	0.29	0.06–1.36	0.117	1.69	0.28–10.04	0.566
Center	1.78	0.45–6.97	0.410	4.15	1.05–16.40	0.042
East	0.95	0.28–3.25	0.934	2.50	0.69–9.06	0.162
Southeast	4.49	0.66–30.67	0.126	na	na	na
Case classification						
Non confirmed	1.00			1.00		
Confirmed	11.57	5.06–26.45	<0.001	5.78	2.38–14.02	<0.001
Laboratory test performed						
No	1.00			1.00		
Yes	0.57	0.24–1.36	0.205	0.05	0.02–0.14	<0.001
Vaccination status						
Unvaccinated	1.00			1.00		
Vaccinated	0.40	0.16–0.97	<0.001	0.58	0.25–1.33	0.199
Unknown	1.31	0.37–4.66	0.679	0.73	0.24–2.17	0.567
Hospitalization or complications						
No	1.00			1.00		
Yes	6.93	1.74–27.66	0.006	3.07	0.93–10.08	0.065

na, non applicable

[a] Odds ratios were calculated with six dummy variables opposing successively each region to all other regions

model including the timeliness variable (data not shown), in which MNS cases were less likely to be reported within the first 2 weeks after disease onset (OR 0.36, 95% CI 0.17–0.75, $P = 0.007$).

Discussion

Although the nature of the collected information was very similar in both Swiss sentinel and mandatory surveillance systems, each system presented relative strengths and weaknesses, which are summarized in Table 7.

Performance of a surveillance system depends largely on its design and actual operation. The source and completeness of the information as well as the pathways and the reporting times distinguish in part both Swiss measles surveillance systems. The SSSN is an active surveillance system including a zero reporting of cases and reminders, constituted of motivated voluntary enrolled physicians. These specificities result in a high regularity of reporting (94.5% of weekly reports were received as compared to 86% in the German Measles Sentinel [8]), and as compared to MNS, in a higher sensitivity in case detection.

Reporting sentinel and mandatory physicians have notified a similar number of cases per physician. However, proportionally far more sentinel physicians reported at least one measles case per year, suggesting that a large amount of mandatory physicians do not notify this disease. Estimated incidence rates were thus 2–36-fold higher in SSSN depending on the year. However this ratio decreased over time, due in part to the increasing awareness of laboratories and physicians of the inclusion of measles into the mandatory surveillance, and in part to the 2003 epidemic, which the SSSN only weakly detected [23]. German and

Table 7 Strengths and weaknesses of the Swiss Sentinel Surveillance Network compared to the mandatory notification system for measles

	Mandatory notification system	Sentinel surveillance system
Strengths	Better sensitivity for outbreaks detection	Semi-active surveillance system (zero reporting, reminders)
	Faster (but not fast enough) reporting of the beginning of outbreaks	High weekly reporting rate
	Higher proportion of laboratory confirmed cases	Better sensitivity for cases detection
	Higher proportion of confirmed cases	Timelier for case reporting
	Identification of more measles genotypes	Higher proportion of cases with a laboratory investigation
		Reporting of cases with a negative laboratory result
Weaknesses	Underreporting of cases, with a reporting bias in favour of laboratory confirmed and severe cases	Usually failed to detect even important outbreaks (and if not, lately)
	Almost no notification of cases with a negative laboratory result	Lower specificity (lower proportion of confirmed and laboratory confirmed cases, higher proportion of cases not corresponding to the case definition, and of vaccinated cases)
	Lower proportion of cases with a laboratory investigation	Under-representation of physicians reluctant to vaccine against measles
	Less timely for case reporting	Exclusion of hospitals and clinics
		Questionable reliability of estimates of incidence rates
		Identification of less genotypes

Italian measles sentinel systems are also more sensitive than mandatory systems, with incidence rates ratios of 2 and 4, respectively [6, 15]. It is commonly recognized that passively reported measles cases represent the tip of the iceberg of measles incidence [24, 25].

While SSSN physicians clearly know that they have to report measles because they personally receive specific instructions and weekly reporting forms mentioning measles, anecdotic information shows that other physicians often ignore that measles notification is mandatory. In the MNS, underreporting seems higher among laboratories than physicians, in spite of the former frequently using electronic routines for reporting and of having a longer reporting tradition (for laboratories, notification of aggregated positive measles cases was introduced in 1988) [23]. Among laboratory confirmed cases reported by physicians 40 (22.4%) were not reported by laboratories whereas physicians had not notified 30 (14.0%) cases reported by laboratories. The apparently lower reporting compliance of the latter results primarily from the design of the reporting system: no reminder is sent to laboratories which miss to report confirmed cases already notified by physicians, whereas a complementary report is requested from physicians by the cantonal health officer, who has received a laboratory notification. In fact, many physicians are not used to spontaneously report clinical measles cases, neither through an initial nor a complementary reporting form, but wait to be asked for it. This was confirmed by the longer median delay in receiving complementary reports if cases were also notified by a laboratory. Consequently, (i) a majority of cases were not notified by an initial reporting form, (ii) most laboratory reports were received by health authorities before the complementary reports, (iii) only a few laboratory negative cases were reported by physicians, (iv) physicians wouldn't have notified up to three quarters of 166 confirmed cases if the laboratories had not reported them initially, and finally and more importantly for disease control (v) a large proportion of clinical cases without laboratory remains probably unreported.

The sensitivity of measles cases detection is clearly lower in the MNS compared to the SSSN although it should be more complete due to the double notification of physicians and laboratories, and the inclusion of cases diagnosed in hospitals only (14.5% of MNS cases), which are not covered by the SSSN [23]. The higher proportion of MNS patients with complications or requiring a hospitalization is concordant with its lower sensitivity. The propensity of mandatory surveillance to preferentially report the most severe cases was also observed in Germany, where 11% of notified cases were hospitalized as compared to 2% among sentinel cases [15].

Whereas the SSSN was more sensitive to detect measles cases and hence in estimating real incidence, the MNS was far more sensitive to detect outbreaks. During the 2003 epidemic the number of reported cases increased more and faster in the MNS than in the SSSN, which almost failed to detect the epidemic. Most of the 2003 cantonal outbreaks were either not identified by the SSSN, or only weakly and late. Sporadic and sometimes unconfirmed SSSN cases often failed to draw attention, even if the extrapolated incidences were similar to those calculated with the MNS data. The low ability of sentinel systems to detect even large measles outbreaks was also observed in Germany and France [15, 26]. Like in Switzerland, this was due to the low proportion of physicians included in such systems, leaving large sectors and populations uncovered. Probably more importantly for Switzerland, the SSSN fails to represent the minority of alternative physicians who are reluctant to immunize against measles, and thus insufficiently covers the main population at risk. Most patients were indeed unvaccinated, particularly in the MNS. In one canton about three quarters of the 173 MNS cases were reported by homeopaths during the 2003 epidemic [27]. The lack of SSSN sensitivity to detect outbreaks explains why the geographical patterns of cases were so different in both systems, particularly during the 2003 epidemic. The current inability of the SSSN to accurately detect and monitor most outbreaks constitutes a serious limitation for outbreak control.

The better sensitivity of the SSSN to detect cases is partly counterbalanced by a low specificity. Less than one third of the cases fulfilled the SSSN measles case definition, which ought to be the prerequisite for reporting. In fact, a majority of the other cases should be regarded as unclassifiable cases rather than non-clinical cases, because physicians often did not state the patient's body temperature and could not document the duration of the rash at the time of reporting (usually the first patient visit). Using the MNS case definition, the proportion of cases fulfilling the criteria was identical in both systems. Due to a far higher proportion of MNS cases epidemiologically linked with another case, and to a strong reporting bias favouring laboratory confirmed cases in the MNS, SSSN cases were far less likely to be classified as confirmed, above all during inter-epidemic years. Moreover, the higher proportion of vaccinated measles cases in SSSN suggests also its weaker specificity. The low case detection sensitivity of the MNS in comparison to the SSSN may thus partly be a consequence of an overestimation of cases by the latter. Besides, the difference between the incidence estimates in both systems is reduced by half if only the confirmed cases are considered.

The reliability of SSSN extrapolations may be questionable. First, Swiss physicians do not serve a well defined population. Therefore, extrapolations of sentinel cases to the whole population may not be accurate in spite of weighting by main characteristics of patients and physicians [28]. Second, as vaccination coverage of children in sentinel practices is probably higher than the national vaccination coverage, SSSN extrapolated estimates could underestimates disease incidence [6]. Third, the lower specificity of the SSSN tends on the opposite to overestimate the incidence by including numerous non cases. As disease incidence declines these estimates become less and less valid.

Like in Italy, the Swiss sentinel system was timelier at the case level than the MNS, due to motivated participants and direct reporting to the FOPH [6]. Nevertheless, because of its limited coverage SSSN detected the beginning of outbreaks later in comparison to MNS (or not at all). Moreover, and although the reporting delay was shortened in the MNS during the 2003 epidemic as a result of the FOPH communication efforts [9, 29], it was usually too long to plan effective interventions.

The strong increase in the number of cases during the epidemic year was accompanied in both surveillance systems by a modification in reporting routines. For example, reporting was timelier during the epidemic year and more MNS physicians reported directly with the complementary form. Moreover, proportionally less MNS cases were tested, mandatory physicians being accustomed to test only the first cases of each outbreak. Also, far more SSSN cases tested positive, and proportionally more MNS cases were reported by hospitals rather than private practices.

In conclusion, currently operational sentinel and mandatory surveillance systems for measles in Switzerland have significant limitations. They both lack timeliness, whereas sentinel surveillance also lacks specificity and sensitivity to detect outbreaks. The mandatory system suffers from significant underreporting despite its theoretical exhaustiveness and its better ability to detect outbreaks. Due to its low coverage, SSSN is inappropriate to decisively help measles elimination at this state and to assess progress towards this goal. The MNS must improve reporting to allow the accurate monitoring of eradication, and ameliorate its timeliness to permit meaningful public health interventions.

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References

1. WHO regional Office for Europe. Health21—the health for all policy for the WHO European Region. Copenhagen: WHO regional Office for Europe; 1999.
2. World Health Organization and Regional Office for Europe. Strategic plan for measles and congenital rubella infection in the European region of WHO. Copenhagen: World Health Organization and Regional Office for Europe; 2003.
3. Featherstone D, Brown D, Sanders R. Development of the global measles laboratory network. J Infect Dis 2003;187(Suppl 1):S264–9.
4. Hanon FX, Spika JJ, Wassilak SS, Emiroglu N. WHO European Region's strategy for elimination of measles and congenital rubella infection. Euro Surveill 2003;8:129–38.

5. Bonmarin I, Levy-Bruhl D. Measles in France: the epidemiological impact of suboptimal immunisation coverage. Euro Surveill 2002;7:55–60.
6. Ciofi Degli Atti ML, Salmaso S, Bella A, Arigliani R, Gangemi M, Chiamenti G, et al. Pediatric sentinel surveillance of vaccine-preventable diseases in Italy. Pediatr Infect Dis J 2002;21:763–8.
7. Gabutti G, Rota MC, Salmaso S, Bruzzone BM, Bella A, Crovari P. Epidemiology of measles, mumps and rubella in Italy. Epidemiol Infect 2002;129:543–50.
8. Tischer A, Santibanez S, Siedler A, Heider A, Hengel H. Laboratory investigations are indispensable to monitor the progress of measles elimination-results of the German Measles Sentinel 1999–2003. J Clin Virol 2004;31:165–78.
9. Richard JL, Boubaker K, Doutaz M, Schubiger G. Obligatorische Meldepflicht für Masern in der Schweiz: starker Anstieg der Anzahl Fälle im Früjahr 2003/Déclaration obligatoire de la rougeole en Suisse: forte augmentation du nombre de cas au printemps 2003. Schweizerische Ärztezeitung/Bulletin des médecins suisses 2003;84:1439–50.
10. Matter HC, Flückiger H, Pfiffner D, Cloetta J, Stürchler D. Sentinella Arbeitsgemeinschaft. Zehn Jahre Monitoring durch Impfung verhütbarer Krankheiten im Schweizerischen Sentinella System/Système suisse Sentinella: Dix ans de surveillance des maladies vaccinales. Bull BAG/OFSP 1997;38:8–10.
11. Harcourt SE, Edwards DE, Fleming DM, Smith RL, Smith GE. How representative is the population covered by the RCGP spotter practice scheme? Using geographical information systems to assess. J Public Health 2004;26:88–94.
12. Ciofi Degli Atti ML, Arigliani R, Calia V, Carbonari P, Cobianchi F, D'Argenio P. Sentinel pediatric surveillance in Italy: results from 2000. BEN 2001;14. http://www.epicentro.iss.it/ben/precedenti/maggio/2_en.htm.
13. Ciofi Degli Atti ML, Salmaso S. Measles increase in Italy. Eurosurveillance weekly 2002;6.
14. Ciofi Degli Atti ML, Fabi F, Salmaso S. Centers for Disease Control and Prevention (CDC). Measles epidemic attributed to inadequate vaccination coverage—Campania, Italy, 2002. MMWR Morb Mortal Wkly Rep 2003;52:1044–7.
15. Hellenbrand W, Siedler A, Tischer A, Meyer C, Reiter S, Rasch G, et al. Progress toward measles elimination in Germany. J Infect Dis 2003;187(Suppl 1):S208–16.
16. Brücker G. Rougeole: déclaration obligatoire et nouvelles mesures vaccinales. Bull Epidemiol Hebd 2005;41–42:205–12.
17. Matter HC, Cloetta J, Zimmermann H. Sentinella Arbeitsgemeinschaft. Measles, mumps, and rubella: monitoring in Switzerland through a sentinel network, 1986–94. J Epidemiol Community Health 1995;49(Suppl 1):4–8.
18. Paget JW, Zimmermann H, Vorkauf H. Sentinella Arbeitsgemeinschaft. A national measles epidemic in Switzerland in 1997: consequences for the elimination of measles by the year 1997. Euro Surveill 2000;5:17–20.
19. Clarkson JA, Fine PEM. The efficiency of measles and pertussis notification in England and Wales. Int J Epidemiol 1985;14:153–68.
20. Siedler A. Masern-Surveillance mit zwei Erfassungssystemen. Epidemiol Bull 2001;295–8.
21. Jajosky RA, Groseclose SL. Evaluation of reporting timeliness of public health surveillance systems for infectious diseases. BMC Public Health 2004;4:29. doi 10.1186/1471-2458-4-29.
22. Jansson A, Arneborn M, Skarlund K, Ekdahl K. Timeliness of case reporting in the Swedish statutory surveillance of communicable diseases 1998–2002. Scand J Infect Dis 2004;36:865–72.
23. Jansson A, Arneborn M, Ekdahl K. Sensitivity of the Swedish statutory surveillance system for communicable diseases 1998–2002, assessed by the capture-recapture method. Epidemiol Infect 2005;133:401–7.
24. Papania MJ, Strebel PM. Measles surveillance: the importance of finding the tip of the iceberg. Lancet 2005;365:100–1.
25. Trottier H, Carabin H, Philippe P. Proportion des déclarations de cas de rougeole, de coqueluche, de rubéole et d'oreillons aux systèmes de surveillance. Evaluation des études pour les pays industrialisés. Rev Epidemiol Sante Publique 2006;54:27–39.
26. Six C, Franke F, Mantey K, Zandotti C, Freymuth F, Wild F, Parent du Châtelet I, Malfait P. Measles outbreak in the Provence—Alpes—Côte d'Azur region, France, January–July 2003. Euro Surveill 2005;10:46–8.
27. Schmidt K, Ernst E. MMR vaccination advice over the Internet. Vaccine 2003;21:1044–7.
28. Schlaud M, Brenner MH, Hoopmann M, Schwartz FW. Approaches to the denominator in practice-based epidemiology: a critical overview. J Epidemiol Community Health 1998;52(Suppl 1):13S–9S.
29. Richard JL, Zimmermann HP. Recent increase in measles in children and teenagers in Switzerland. Eurosurveillance weekly 2003;7.