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Measles outbreak linked to a minority group in Austria, 2008

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SUMMARY

We report on a measles outbreak originating in an anthroposophic community in Austria, 2008. A total of 394 (94·9 %) cases fulfilled the outbreak case definition including 168 cases affiliated to the anthroposophic community. The source case was a school pupil from Switzerland. The Austrian outbreak strain was genotype D5, indistinguishable from the Swiss outbreak strain. A school-based retrospective cohort study in the anthroposophic school demonstrated a vaccine effectiveness of 97·3 % in pupils who had received a single dose of measles-containing vaccine and 100 % in those who had received two doses. The vaccination coverage of the cases in the anthroposophic community was 0·6 %. Of the 226 outbreak cases not belonging to the anthroposophic community, the 10–24 years age group was the most affected. Our findings underline the epidemiological significance of suboptimal vaccination coverage in anthroposophic communities and in older age groups of the general population in facilitating measles virus circulation. The findings of this outbreak investigation suggest that the WHO European Region is unlikely to achieve its 2010 target for measles and rubella elimination.

Key words: Immunization (vaccination), measles (rubeola), outbreaks.

INTRODUCTION

The World Health Organization set the year 2010 as the target for elimination of measles in the European Region [1]. In Austria (population 8·3 million) in 2002 the incidence was 0·22/100 000 and the notification of measles became mandatory. The following year the incidence peaked at 1·2/100 000 as the result of an outbreak in an Austrian refugee camp [2]. Between 2004 and 2007 Austria was considered as a low-moderate incidence country according to the criteria of EUVAC.NET (< 1/100 000 population per year) [3].

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A bivalent measles-mumps (MM) vaccine (one-dose regimen at age 15 months) had been introduced in Austria in 1974 as part of the national childhood immunization programme and had been replaced in 1994 by a trivalent measles, mumps and rubella (MMR) vaccine (two-dose regimen with the first dose at 15 months and the second dose at age 6 years) [4]. Proof of vaccination against measles is not mandatory for school entrance in Austria. The official estimate of the average measles vaccine coverage with at least one dose for the birth cohorts 1997–2007 was 84% [5]. No data were available on the age group-specific measles seroprevalence of the Austrian population [6].

Outbreak background

In the second week of March 2008 (calendar week 11), a cluster of nine laboratory-confirmed measles cases in pupils of an anthroposophic school in Salzburg city (city population ~150 000) was reported to the public health authority in Salzburg province (province population: ~526 000). Salzburg city, which is separated by a river from a neighbouring city in the German province of Bavaria, is the administrative capital of the province Salzburg. The Federal state of Austria consists of nine provinces. In the third week of March 2008 (calendar week 12) another 35 measles cases occurred in pupils (with Austrian residence) of the anthroposophic school. The school closed on 17 March for the Easter holiday and was kept closed by public order until 5 April. In week 3 of March the neighbouring German province of Bavaria also reported a cluster of 30 measles cases (mutually exclusive to the cases notified in Salzburg province) in pupils attending the anthroposophic school in Salzburg city but residing in Bavaria. In week 4 of March (calendar week 13) the cumulative number of Austrian measles cases reported from Salzburg province totalled 90 and another four high schools in Salzburg city were also affected. The review of historical data on measles for Salzburg province yielded three cases of measles reported in 2007 and no case in the first 2 months of 2008.

The objectives of the outbreak investigation were to describe the measles outbreak in Austria by time, place and person, to identify the outbreak source, to ascertain vaccination coverage in the outbreak cases, to identify possible target groups for vaccination campaigns and to estimate vaccine effectiveness in the pupils at the anthroposophic school.

METHODS

Data collection

Beginning on 25 March 2008, all Austrian cases of measles which occurred between 1 March and 12 July had to be reported to the Austrian Agency for Health and Food Safety (AGES) by the relevant district public health authorities. Data on name, residence, results of serological testing and, if available, on the date of rash onset were provided for each case via an electronic case record. All measles cases were questioned (for those aged <16 years their parents substituted) via telephone or were visited by outbreak investigators for an interview. The questionnaire covered demographic characteristics (age, sex, residence), clinical signs (macular-papular rash, fever, conjunctivitis, cough, coryza), date of rash onset, hospitalization, complications (pneumonia, meningitis, encephalitis, otitis media), name of attended school or kindergarten, affiliation with an anthroposophic community, history of stay in Salzburg province, history of an epidemiological link to a known measles case by human-to-human transmission and history of travel within 3 weeks prior to rash onset. The number of vaccine doses received, and the date(s) of vaccine administration, were determined from vaccination records. Reasons for non-vaccination were obtained from parents of unvaccinated cases by presenting a series of response options within the interview (parents rejected measles immunization [open-ended question to elicit reasons], physicians advised against vaccination, parents forgot vaccination).

A confirmed outbreak case was defined as a person who (1) resided in Austria, (2) fell ill after 1 March 2008 with a generalized macular-papular rash with fever accompanied by at least one of the following clinical signs: cough, coryza, or conjunctivitis and (3) stayed in Salzburg province within 7–21 days prior to rash onset or had an epidemiological link to an outbreak case from Salzburg province within 7–21 days prior to rash onset.

A possible outbreak case was defined as a person who (1) resided in Austria, (2) fell ill with clinical signs of measles (as for a confirmed case) after 1 March 2008, (3) did not fulfil criterion no. 3 of a confirmed outbreak case and (4) in whom no other source of exposure was known.

A non-outbreak case of measles was defined as a person who (1) resided in Austria, (2) fell ill with clinical signs of measles (as for a confirmed case) after 1 March 2008, (3) did not fulfil criterion no. 3 of a confirmed outbreak case and (4) in whom another source of infection was present (e.g. travel to a country with high measles endemicity). The outbreak was described by time, place and person including confirmed and possible outbreak cases.

Analytical epidemiological investigation

The outbreak investigators conducted a school-based retrospective cohort study in the 340 pupils of the affected anthroposophic school in Salzburg city, including also those who lived in neighbouring Bavaria. Teachers and school employees were not included in the study population. The study population was interviewed by face-to-face interview using a standardized questionnaire covering demographic characteristics, history of measles before and after 1 March 2008 and measles vaccination status. In-depth interviews were held with the cases of this study population to identify the source of the outbreak. A positive measles history before 1 March was confirmed by serological testing. The disease status for measles was defined as illness after 1 March 2008 with a generalized macular-papular rash with fever accompanied with at least one of the following clinical signs: cough, coryza, or conjunctivitis. The vaccination status, including the number of measles-containing vaccine (MCV) doses and the date(s) of the dose(s) received were determined from pupils' vaccination records.

Vaccine effectiveness (V_E) was estimated as

$$V_E(\%) = [1-(AR_V/AR_U)] \times 100,$$

where AR_V is the attack rate in vaccinated pupils, AR_U the attack rate in unvaccinated pupils and AR_V/AR_U the relative risk.

The 95% confidence interval (CI) for V_E was calculated as

$$1-\text{the upper limit of the 95\% CI of } AR_V/AR_U \times 100$$

and

$$1-\text{the lower limit of the 95\% CI of } AR_V/AR_U \times 100\ [7].$$

The V_E estimate was stratified by age groups (5–9, 10–14, 15–20 years). Epi-Info version 3.3.2 (CDC, USA) and Stata version 10 (StataCorp LP, USA) were used for data entry and analyses. Proportions were compared using the χ^2 test.

Laboratory investigation

Infection was defined as laboratory confirmed if at least one of the following three laboratory criteria was fulfilled: detection of measles virus-specific IgM, detection of measles virus RNA, isolation of measles virus from a clinical specimen [8]. Initially, serological tests for measles virus-specific IgM and IgG antibodies were performed by local laboratories. From 25 March clinical specimens (throat swabs, samples of serum, oral fluid and urine) from confirmed and possible outbreak cases were sent to the Austrian National Reference Centre for Measles by local physicians, hospitals and local laboratories for serological confirmation of measles infection, for measles virus detection and genotyping. Measles virus RNA in clinical specimens was detected as described by El Mubarak *et al.* [9] and genotyping was performed as described by Santibanez *et al.* [10].

RESULTS

Outbreak description

A total of 415 cases of measles with rash onset between 1 March, 2008 and 12 July (4·5 months) were notified from six of the nine Austrian provinces. Of the 415 cases, 394 (94·9%) fulfilled the definition of an outbreak case. Of these outbreak cases 267 (67·8%) fulfilled the definition of a confirmed outbreak case, and 127 (32·2%) the definition of a possible outbreak case. Of the 394 outbreak cases, 154 were tested and laboratory confirmed (Table 1): 74 measles patients of the 267 confirmed outbreak cases (27·7%) and 80 measles patients of the 127 possible outbreak cases (63%) (Table 1).

The remaining 21/415 measles cases were not associated with the outbreak: they had either recently visited a foreign country or had contact with a measles case that had recently travelled abroad. Source countries were Switzerland, Germany, Spain, and India.

Out of the 394 outbreak cases, 123 (31·2%) attended two anthroposophic institutions in Salzburg city: a kindergarten (7/123) and a school (116/123). Additional in-depth interviews with pupils at the school indicated that a visiting pupil from an anthroposophic school in Switzerland was the probable source case. During a school trip, he and some fellow pupils had visited the anthroposophic school in Salzburg city between 2 and 8 March. He became ill with measles on 7 March, a week before the

Table 1. *Outbreak measles cases by age-group, province of occurrence, and laboratory testing, Austria 2008*

Case characteristics	n (%) ($N=394$)
Age distribution (yr)	
0–4	30 (7·6)
5–9	60 (15·2)
10–14	115 (29·2)
15–19	90 (22·8)
20–24	42 (10·7)
25–29	21 (5·3)
30–34	21 (5·3)
35–39	12 (3)
40–44	2 (0·5)
45–49	1 (0·3)
Province of occurrence	
Salzburg	233 (56·9)
Upper Austria	131 (33·2)
Lower Austria	4 (1)
Vienna	19 (4·8)
Tyrol	4 (1)
Vorarlberg	3 (0·8)
Cases laboratory tested	154 (39)
Measles virus-specific IgM detection in	n/N cases tested (%)
Serum	123/128 (96)
Oral fluid	24/25 (96)
Measles virus RNA detection in	n/N cases tested (%)
Serum	50/77 (65)
Oral fluid	30/31 (97)

occurrence of the first two Austrian outbreak cases at the school in Salzburg city on 13 March. The measles virus RNA of specimens partially sequenced from 16 Austrian outbreak cases was genotype D5.

The highest reported number of cases (83 cases) was registered in calendar week 12 (17–23 March). Of the 394 outbreak cases, 194 (49%) occurred in the first 4 weeks of the outbreak (13 March–6 April, calendar weeks 11–14). Of these 194 early cases, 178 (92%) occurred in Salzburg province (of which 168 cases were connected to the anthroposophic community), 12 (6%) in the province of Upper Austria, two in Vienna and one case each in the two western provinces Vorarlberg and Tyrol. In the following 9 weeks of the outbreak (7 April–13 July, calendar weeks 15–28) another 200 measles cases occurred: 119 (59·5%) in Upper Austria, 55 (27·5%) in Salzburg province, three in Lower Austria and 18 in Vienna (the two eastern provinces, together 10·5%) and two in Vorarlberg and three in Tyrol (together 2·5%). Figure 1 shows the outbreak cases by day of rash onset and province of occurrence. Figure 2 depicts the regional distribution of cases by province and health districts within the first 4 weeks of the outbreak (13 March–6 April, calendar weeks 11–14) and within the following nine outbreak weeks (7 April–13 July, calendar weeks 15–28).

In total, 19/394 outbreak cases developed complications (4·8%). Otitis media as complication of measles occurred in 13/394 outbreak cases (3·3%). Pneumonia occurred in seven cases (1·8%). No case of meningitis or encephalitis due to measles was documented. Forty-two cases (10·7%) were hospitalized.

Table 1 shows the distribution of the outbreak cases by 5-year age groups. The median age of outbreak cases was 14 years (minimum 9 months, maximum 49 years), one case was <1 year old. The male-to-female ratio was 1·5:1. In the age groups most affected, i.e. those aged 10–14 and 15–19 years, the male-to-female ratios were 1·2:1 and 1·1:1, respectively. Outbreak cases were stratified into two groups (group A and group B) for analysis of the age distribution of cases within the anthroposophic community and in the general population. Group A included cases of pupils attending anthroposophic institutions, together with cases of their family members and friends, who share a similar belief system (group A, $n_A=168$); group B included the outbreak cases of the general population (group B, $n_B=226$). Figure 3 shows that the age distribution of outbreak cases stratified by these two groups varied substantially. In group B (cases not related to the anthroposophic community), the 10–14, 15–19 and 20–24 years age groups were the three most affected groups, which resulted in an incidence of 8·3/100 000 persons of the general population aged 10–24 years compared with 5·4/100 000 persons aged <10 years and 0·95/100 000 persons aged >24 years. In group A, the anthroposophic community cases, the >24 years age group was not affected.

Vaccination status in the outbreak cases

The measles vaccination status was known in 386 (98%) of the 394 outbreak cases. Twenty- five (6·5%) cases had been vaccinated with at least one MCV dose before 2008; of these, two cases had received a two-dose regimen (2/386, 0·5%). Stratification of the cases into group A (anthroposophic community; $n_A=168$) and group B (general population; $n_B=226$, vaccination status known in 218) revealed that the proportion of cases vaccinated with at least one MCV dose before 2008 in group A (PCV_A) was 0·6%

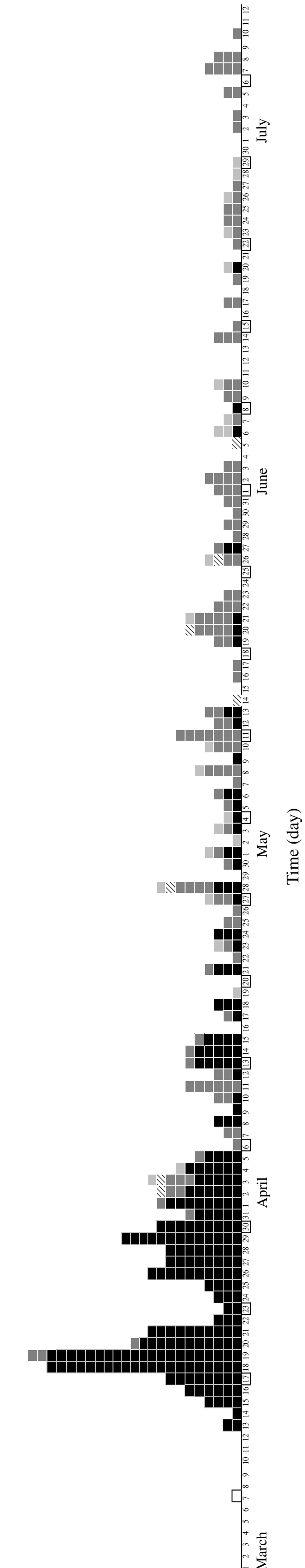

Fig. 1. Measles outbreak cases in Austria by date of rash onset and by province 1 March to 12 July 2008 ($n = 394$). ■, Outbreak cases in Salzburg ($n = 233$); ■, outbreak cases in Upper Austria ($n = 131$); □, outbreak cases in Lower Austria and Vienna ($n = 23$); ▨, outbreak cases in Vorarlberg and Tyrol ($n = 7$); □ the source case.

(1/168) and in group B (PCV_B) was 11% (24/218). Table 2 shows the proportion of vaccinated cases in groups A and B, displayed by age group and number of doses received. In group B the age group-specific vaccine coverage with at least one MCV dose ranged between 10·8% and 18·9% in the 5-year age groups from 5–9 years to 30–34 years, with a maximum of 18·9% in the 20–24 years group; cases in the 0–5 and 35–49 years groups had a negative vaccination history. In group A only one case had a positive vaccination history and she belonged to the 10–14 years age group. Information on reasons for negative vaccination status was available for 198/361 unvaccinated cases (including possible and confirmed outbreak cases). In group A (anthroposophic community cases), information was ascertained for 113/167 (67·7%) unvaccinated cases: in two (1·8%) cases the family doctors had advised against MMR vaccination, in another 106 (94%) the parents rejected measles vaccination (in 18 cases the parents were strictly against all vaccination), and in the other five cases the parents forgot vaccination. In group B (cases not related to the anthroposophic community), information was available for 85/194 (43%) unvaccinated cases: in 41 cases (48·2%) parental forgetfulness was cited, in one case the family doctor had advised against MMR vaccination, in another 32 cases (37·6%) the parents rejected measles vaccination, and in the other 11 cases the parents preferred not to answer this question.

School-based retrospective cohort study

The anthroposophic school comprised 13 classes: one class per grade plus one class for pupils with disabilities. Data on vaccination status, including vaccination dates and number of doses received, were available for all 340 pupils. The median age was 12 years (interquartile range: 10–15 years; minimum 6 years, maximum 20 years); 150 pupils (44·1%) were boys. Measles cases occurred in all grades with attack rates of 41% (30/73), 54·9% (73/133), 54·2% (45/83) and 40% (2/5) in the age groups 5–9 years, 10–14 years, 15–19 years, and 20–24 years, respectively. Excluding pupils with a positive measles history before 1 March 2008 (46/340, 13·5%), the proportion of the remaining 294 pupils vaccinated before 2008 with at least one MCV dose was 34·4% ($n = 101$): single dose 16% ($n = 47$), two doses 18·4% ($n = 54$). The attack rate in the 294 pupils was 51·02% ($n = 150$; 116 Austrian cases, 34 German cases). In unvaccinated

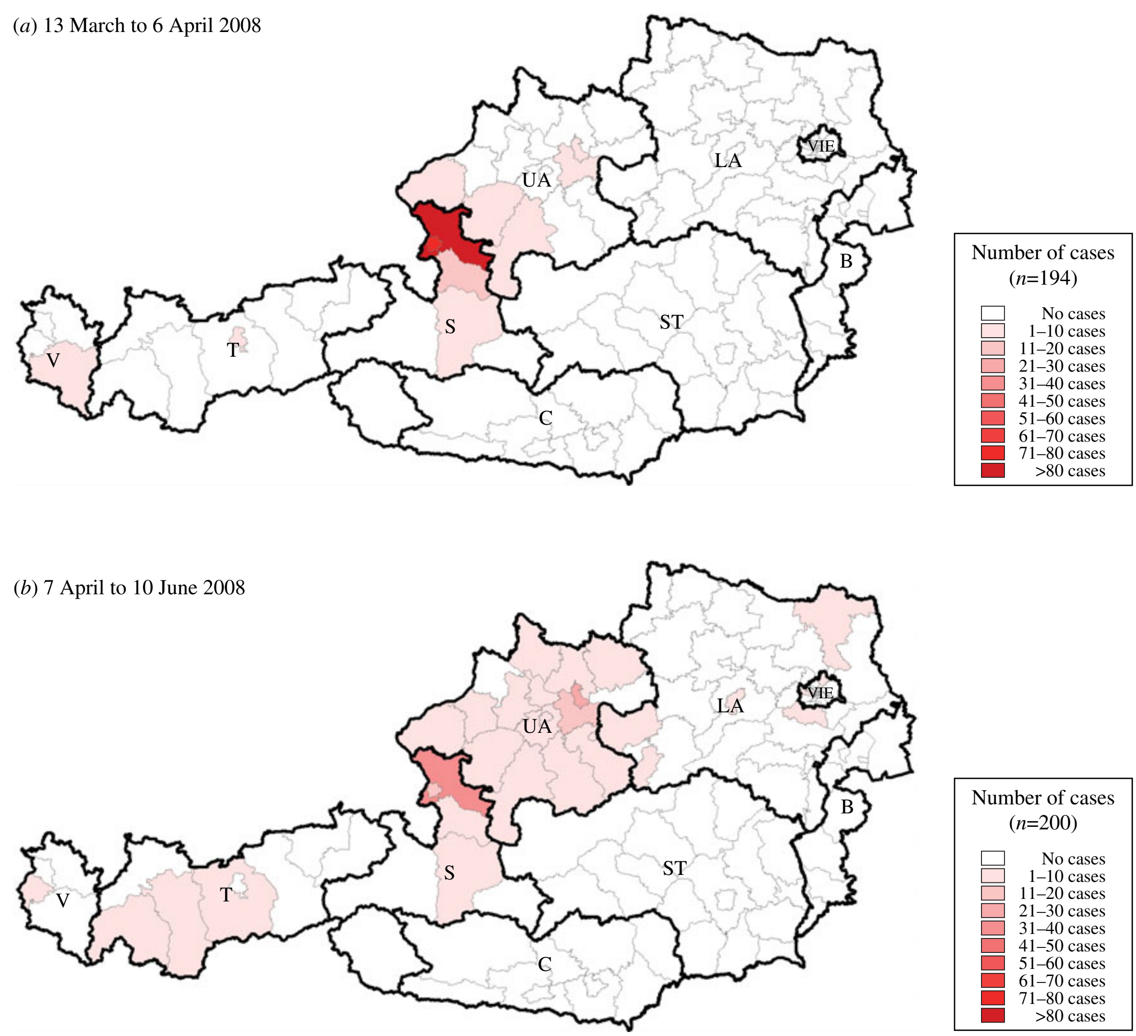

Fig. 2. Austrian outbreak cases by province and health district of residence occurring from (*a*) calendar weeks 11–14 ($n=194$) and (*b*) calendar weeks 15–28 ($n=200$). V, Vorarlberg; T, Tyrol; S, Salzburg; UA, Upper Austria; LA, Lower Austria; VIE, Vienna; B, Burgenland; ST, Styria, C, Carynthia.

pupils the attack rate was 77·2% (149/193) and in those vaccinated with a single MCV dose 2·1% (1/47). None of the 54 pupils with a vaccination history of two MCV doses developed measles. This yielded a V_E of 97·3% (95% CI 80·81–99·6) in pupils who had received a single dose of MCV and a V_E of 100% in those with two doses (Table 3). There was no significant difference in the age group-specific V_E estimates observed: 5–9 years ($V_E/100=1$, 95% CI 0·93–1), 10–14 years ($V_E/100=0{\cdot}99$, 95% CI 0·94–1), 15–20 years ($V_E/100=1$, 95% CI 0·94–1).

Outbreak response

A MMR post-exposure prophylaxis was offered free of charge to susceptible contacts of outbreak cases. The anthroposophic school in Salzburg city closed for a 1-week holiday and was kept closed by public order until 5 April after 96% (118/123) of the outbreak cases in the pupils of this school had already occurred. As soon as other schools were affected (week 4 of March), the following recommendations of the Austrian National Immunization Advisory Board were implemented in all child-care centres, kindergartens and schools operated by Salzburg province: ascertainment of the vaccination status of the attendees (based on vaccination records) and vaccination of susceptible attendees with MMR vaccine free of charge; susceptible individuals who refused vaccination were excluded from the institutions for 3 weeks following a possible infectious contact. All privately operated kindergartens and schools were advised

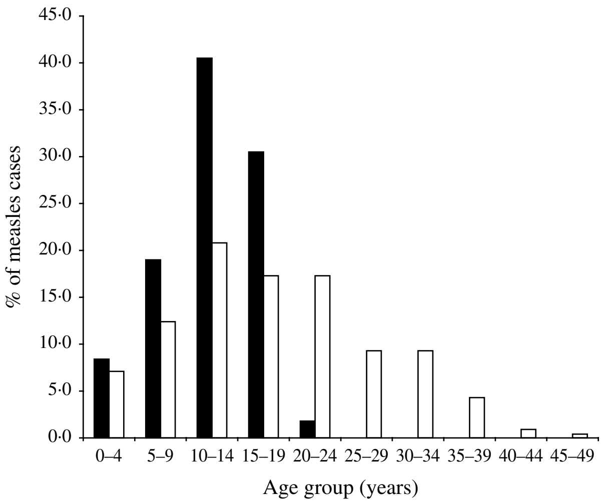

Fig. 3. Austrian outbreak cases by age group stratified by affiliation to the anthroposophic community (■; $n=168$) and not related to the anthroposophic community (□; $n=226$).

to implement these measures similarly. When the anthroposophic school in Salzburg city reopened, permission to attend was given only to those pupils who had serological evidence of a positive measles history or who had received at least one dose of MCV. Pupils who had not received post-exposure prophylaxis were excluded from school for 3 weeks following the last contact with an outbreak case. Outbreak-case family members with a negative measles history and who refused measles vaccination were advised to avoid community facilities for 3 weeks following the last possible infectious contact. Between 20 June and 12 July (calendar weeks 25–28) no further measles case were registered in Salzburg province.

Between January and June 2008 the public health service of Salzburg province administered a total of 13 408 MMR vaccine doses; 4788 first doses, with 31% of those administered to the 10–19 years age group. In comparison, 2242 first doses, with 0·8% of those given to the 10–19 years age group were administered in the first 6 months of 2007. In Upper Austria the total number doses administered in the same periods were 19 413 and 16 140 (no data on age groups vaccinated and number of first doses were available).

Between 12 July and the end of December 2008 another 20 measles cases were reported in Austria: 12 from Upper Austria, two each from Tyrol and Vienna, one each from the provinces of Salzburg and Vorarlberg, and two in the province Steyr, not affected by the outbreak.

DISCUSSION

Of 415 Austrian cases of measles reported between 10 March and 13 July 2008 (calendar weeks 11–28), 394 (including 127 possible outbreak cases) were related to the described measles outbreak originating in the anthroposophic school in Salzburg city. The measles virus entered a pupil population with a proportion of measles susceptibles of 56·7% and spread rapidly in this school population resulting in an attack rate of 51% after the first week. The outbreak extended to the neighbouring German federal state of Bavaria through cases in German pupils attending this anthroposophic school in Salzburg city. After the Austrian outbreak slowed down in the pupil population at the end of the first week of the outbreak, the second wave of spread occurred in pupils' household members and in parallel in the general population, primarily in the provinces of Salzburg and Upper Austria. Four other Austrian provinces were only marginally affected. The measles spread in the anthroposophic community in the province Salzburg finally slowed down in week 4 of the outbreak after the proportion of susceptibles in this community in Salzburg province was reduced. Four Norwegian cases of measles and at least three cases in the German state of Baden-Württemberg were also epidemiologically linked to the outbreak through family relationships to the anthroposophic community in Salzburg city [11]. The measles outbreak was probably initiated by a measles case in a pupil from an anthroposophic school in Switzerland, who visited the anthroposophic school in Salzburg city 1 week before the Austrian outbreak began. Since November 2006, Switzerland has experienced the largest measles outbreak registered in the country since 1999 [12]. The measles virus strain isolated in Switzerland and the Austrian outbreak strain were both genotype D5 [12].

The school-based retrospective cohort study in the anthroposophic school in Salzburg demonstrated high V_E: 97·3% in pupils vaccinated with a single MCV dose and 100% in pupils who received two doses before 2008. This high V_E is consistent with findings of previous studies of recent school outbreaks [13–16]. In a school-based retrospective cohort study during the initial phase of the measles outbreak in the state of North Rhine-Westphalia, Germany in 2006, Wichmann *et al.* demonstrated a V_E of 98·1% in students with one MCV dose and a V_E of 99·4% with two doses [13].

Table 2. *Proportion of measles outbreak cases vaccinated with measles-containing vaccine before 2008 by age group and number of vaccine doses received*

Age group (years)	Cases total (n)	PCV_{total}, n (%) At least 1 dose	1 dose	2 doses	Cases group A (n)	PCV_A, n (%) At least 1 dose	1 dose	2 doses	Cases group B (n)	PCV_B, n (%) At least 1 dose	1 dose	2 doses
0–4	30	0	0	0	14	0	0	0	16	0	0	0
5–9	60	4 (6·7)	3 (5)	1 (1·7)	32	0	0	0	28	4 (14·3)	3 (10·7)	1 (3·6)
10–14	115	5 (4·3)	5 (4·3)	0	68	1 (1·5)	1 (1·5)	0	47	4 (8·5)	4 (8·5)	0
15–19	88	4 (4·5)	4 (4·5)	0	51	0	0	0	37	4 (10·8)	4 (10·8)	0
20–24	40	7 (17·5)	7 (17·5)	0	3	0	0	0	37	7 (18·9)	7 (18·9)	0
25–29	20	3 (15)	3 (15)	0	0	0	0	0	20	3 (15)	3 (15)	0
30–34	19	2 (10·5)	1 (5·3)	1 (5·3)	0	0	0	0	19	2 (10·5)	1 (5·3)	1 (5·3)
35–39	11	0	0	0	0	0	0	0	11	0	0	0
40–44	2	0	0	0	0	0	0	0	2	0	0	0
45–49	1	0	0	0	0	0	0	0	1	0	0	0
Total	386	25 (6·5)	23 (6)	2 (0·5)	168	1 (0·6)	1 (0·6)	0 (0)	218	24 (11)	22 (10·1)	2 (0·9)

PCV_{total}, Proportion of outbreak cases vaccinated (vaccination status known for 386 cases).
PCV_A, Proportion of outbreak cases vaccinated in the anthroposophic community (case group A).
PCV_B, Proportion of outbreak cases vaccinated in the general population (case group B; vaccination status known for 218 cases).

Table 3. *Vaccine effectiveness of measles-containing vaccine (MCV) in pupils at the Salzburg city anthroposophic school*

Vaccination status	Pupils n (% of column total)	Measles cases n (% of row total)	RR (95%CI)	V_E (95%CI)
Unvaccinated	193	149 (77·2%)	—	—
Vaccinated (at least 1 dose)	101 (34·4%)	1 (1%)	0·013 (0·003–0·09)	98·7% (90·97–99·82)
1 MCV dose	47 (16%)	1 (2·1%)	0·0276 (0·0040–0·1919)	97·3% (80·81–99·6)
2 MCV doses	54 (18·4%)	0	Undefined	100% (undefined)
Total	294	150 (51%)		

RR, relative risk (AR_V/AR_U); CI, confidence interval; V_E, vaccine effectiveness.
% of row total = attack rate in unvaccinated (AR_U) and in vaccinated (AR_V).
% of column total = vaccination coverage in pupils at the Salzburg anthroposophic school.

In the past decade measles has been drastically reduced in the general population of Austria through reaching levels of >80% vaccination coverage [2, 5]. Nevertheless, control strategies must include improved surveillance to identify high-risk populations. Data on vaccination coverage have been collected since the birth cohort of 1996 and electronic vaccination registers are kept in four of the nine provinces (Vorarlberg, Tyrol, Upper Austria, Carynthia). However, no reliable data are available on the proportion of measles-susceptible individuals by age groups. As recommended in the ECDC mission report on risk assessment of the measles outbreak in Austria, seroprevalence surveys are needed for identification of immunity gaps in selected population groups to prevent future outbreaks in the identified high-risk population groups [5].

Of Austrian outbreak cases not belonging to the anthroposophic community, vaccination coverage with at least one MCV dose was 11% (10·1% vaccinated with single dose). Similarly, a single-dose vaccination coverage of 10% was observed in the 3582 measles cases reported from 32 European countries to EUVAC.NET in 2007 [17]. Of the cases in the anthroposophic community, vaccination coverage with a single MCV dose was a mere 0·6% (no case had received two doses). Therefore, low vaccine coverage is likely to be the cause of the rapid spread of measles in the anthroposophic school community. The result of the vaccine effectiveness study clearly shows that low V_E played no role in this school outbreak. The higher vaccine coverage in the Austrian general population compared to the anthroposophic community explains the higher proportion of vaccinated cases in the general population compared to the anthroposophic community cases (11% *vs.* 0·6%) [7]. The anthroposophic community is known to favour allowing the body to experience certain infections and to oppose vaccination in childhood [18]. In the pupil population of the anthroposophic school in Salzburg city the vaccine coverage with at least one MCV dose was only 34·4%. Our finding of low MCV coverage in this community (low in comparison to the general population) is consistent with a series of measles outbreaks in other anthroposophic communities, such as in the UK, The Netherlands and Switzerland [19–21].

In measles low-endemic countries, outbreaks of measles have been repeatedly described in communities with low vaccination coverage due to philosophical or religious beliefs [22–25]. The ongoing importation and spread of measles virus within minority groups with low vaccination coverage hamper the efforts to eliminate measles in Europe by 2010 [17, 18, 23].

Measles outbreaks can be prevented only through reducing the number of susceptibles in all population groups below the critical number required to sustain epidemic spread of the virus [26, 27]. It is therefore essential to understand the reasons for low vaccine uptake in certain sub-populations [19, 23]. In the Austrian anthroposophic community 94% of parents willing to give reasons for a child's unvaccinated status stated that having a measles infection is important for a child's development and has a 'beneficial strengthening effect upon the child'. Vaccine safety and effectiveness were also a concern for the parents. These parental attitudes towards measles immunization are similar to those observed in an outbreak of measles in children of an anthroposophic community in Gloucestershire, UK, in 1997–1998 [21].

The differences in the age distribution between the anthroposophic community cases and the general population cases (Fig. 3) might be explained by different age-specific proportions of susceptibles and age-specific social clustering. The measles outbreak in the general population resulted in a higher incidence in the 10–24 years group (8·3/100 000 inhabitants) than in the <10 years group (5·4/100 000 inhabitants). This is probably due to an insufficient vaccination coverage and low proportion of persons with natural immunity in the $\geqslant 10$ years age group [28]. With increasing vaccination coverage of birth cohorts within the past decade, the endemic circulation of measles virus has decreased in the general population in Austria and thus the probability of unvaccinated children having contact with wild-type measles virus has declined, leading to an accumulation of measles-susceptible persons aged $\geqslant 10$ years. Measles cannot be regarded solely as a childhood disease [17]. A shift of the age distribution of measles cases to population groups aged $\geqslant 10$ years has also been observed in other countries, e.g. the outbreaks in Switzerland 2006–2008 and Germany in 2006 [12, 13, 29]. In Salzburg province, the age-group-targeted vaccination activities addressing the $\geqslant 10$ years age group have probably led to sufficiently fast closure of immunization gaps during the measles outbreak. This might explain the surprisingly low spread of measles in the 24 other high schools affected by the outbreak in Salzburg province. An outbreak of mumps in adolescents and young adults in Austria in 2006 had already shown that additional MMR vaccination campaigns targeting the $\geqslant 10$ years age group are warranted in order to prevent outbreaks of mumps, measles and rubella in the future [4]. A rubella outbreak affecting females in the $\geqslant 10$ years age group would be associated with more severe outcomes compared to mumps or measles outbreaks due to the risk of congenital rubella syndrome [30].

Our findings underline the epidemiological significance of minority groups including anthroposophical communities in facilitating the circulation of measles virus and show that suboptimal vaccination coverage in older groups of the general population is hampering the control of measles in Austria. Each outbreak should be seen as an opportunity to gain new knowledge on the epidemiology of vaccine-preventable infections. Sound scientific knowledge is a prerequisite for implementation of targeted public health measures [26, 31]. Vaccination coverage in certain Austrian population groups must be increased in order to prevent future outbreaks and to achieve elimination of measles in Austria. Further research in options to achieve this aim is warranted. The suboptimal vaccination coverage also observed in populations of other European countries such as Switzerland, Germany and Italy raises doubts that the goal of measles elimination by 2010 can be achieved [17, 32].

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DECLARATION OF INTEREST

None.

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