EXPERT REVIEWS

Assessing vaccination coverage in the European Union: is it still a challenge?

Expert Rev. Vaccines 10(8), 1195–1205 (2011)

Manon Haverkate[1,2], Fortunato D'Ancona[3], Kari Johansen[1], Koos van der Velden[2], Johan Giesecke[1] and Pier Luigi Lopalco[†1]

[1]*Scientific Advice Unit, European Centre for Disease Prevention and Control, Stockholm, Sweden*
[2]*Department of Primary and Community Care, Radboud University Nijmegen Medical Centre, The Netherlands*
[3]*Infectious Disease Unit, National Centre for Epidemiology, Surveillance and Health Promotion, Istituto Superiore di Sanitá, Rome, Italy*
[†]*Author for correspondence:*
Tel.: +46 858 601 212
Fax: +46 858 601 296
pierluigi.lopalco@ecdc.europa.eu

Assessing vaccination coverage is of paramount importance for improving quality and effectiveness of vaccination programs. In this article, some of the different systems that are used for assessing vaccination coverage within and outside the EU are reviewed in order to explore the need for improving vaccination coverage data quality. All countries in the EU have implemented vaccination programs for children, which include vaccinations to protect against between nine and 14 infectious diseases. Collecting and assessing vaccination coverage regularly is part of such programs, but the methods used vary widely. Some quality issues are evident when data reported through administrative methods are compared with seroprevalence studies or other surveys. More thorough assessment of vaccination coverage and more effective information sharing are needed in the EU. A homogeneous system for assessing vaccination coverage would facilitate comparability across countries and might increase the level of the quality of both the national and local systems. Cooperative and coordinated responses to vaccine-preventable disease threats might be improved by better information sharing.

Keywords: European Union • vaccination coverage • vaccination programs • vaccine registries

Background

Vaccination is without any comparison the most important medical measure to improve public health. Since the first introduction of vaccination two centuries ago, millions of lives have been saved and many more hospitalizations and subsequent sequelae due to vaccine-preventable diseases (VPDs) have been prevented [1–4].

All countries in the EU have implemented vaccination programs for children [101]. However, the national immunization programs exhibit a wide variability concerning both vaccines included and immunization schedules since immunization programs are the exclusive competence of national authorities. The number of vaccines offered in different EU countries ranges between nine and 14 [102]. Harmonization of vaccination programs at the EU level is not easy under the current legislative framework, but the impact of those programs is expected beyond political borders [5].

Vaccination coverage is one of the key parameters for assessing and monitoring successes and difficulties in the implementation of vaccination programs. Frequently, the main strategic goal of specific vaccination strategies is set as a specific vaccination coverage level to be reached in the target population (i.e., 75% coverage for influenza vaccination in elderly, more than 95% coverage for measles vaccination in children). Vaccination coverage is the number of persons belonging to a specific population (e.g., one birth cohort) receiving a vaccine or series of vaccines divided by the total target population and can be estimated in several ways [6]. Monitoring of coverage data and correlating it with the incidence of infectious diseases is of critical importance in order to evaluate progress towards controlling and eliminating VPDs [7].

For each vaccine, a high overall coverage in a given country is important, but it is also necessary to have adequate coverage on local level [8]. If geographical areas or subpopulations with low vaccination coverage exist – exemplified today by the individuals living in the Bible belt in The Netherlands [9] or the Roma population residing in several EU countries [10,11] – they will continue to be susceptible to VPD outbreaks. In addition to the risk of outbreaks in their own communities, they also pose a risk for the whole community since many of the VPDs are highly communicable. In this article, we will focus on

10.1586/ERV.11.87

ISSN 1476-0584

vaccination coverage data obtained in childhood vaccination programs only. It is important here to distinguish between vaccines offered to all children and vaccines offered to specified risk groups in most countries (i.e., vaccines against seasonal influenza) [12]. Furthermore, all EU member states have adopted immunization schedules for childhood vaccination, whereas recommendations for adult booster and catch-up vaccination often are missing. Assessment of vaccination coverage therefore differs significantly for these groups and deserves separate and thorough discussions.

All EU countries collect and assess vaccination coverage regularly, but the methods used vary widely [7,13]. Sometimes there are even differences in vaccination schedules and vaccination coverage assessment within countries, such as in Belgium or Italy [13,14]. This is not a surprise, as clear objectives and a well-defined target population should be set prior to starting a system for assessing vaccination coverage. As a consequence, different systems have been set up according to country-specific objectives, possibilities and needs. Unfortunately, information on vaccination coverage is usually not comparable between countries. A harmonized system for assessing vaccination coverage would facilitate comparability across countries and might augment quality of the nationally, regionally and locally collected data.

Objective

The objective of this article is to review examples of the different systems that are used for assessing vaccination coverage within and outside the EU and to address the need for improving vaccination coverage data quality in the EU. The objectives and the added value of data collection at international level will also be discussed.

Methods

A literature search was performed in October 2010 using PubMed as a primary source. Combinations of the following keywords were used: 'vaccination OR immunization'; 'coverage'; 'measuring OR measurement OR assessing OR assessment', as well as the different countries for which information was sought. Articles in English, Dutch, French, German and Italian were included. Relevant articles were then screened and chosen based on the quality of the information in the title, the abstract and the year of publication (preferably from 2005 or later, but older articles were included if no more recent article existed). When more information or clarifications were needed, references in the retrieved articles from the literature search were checked for other useful articles.

Information on the vaccination systems and vaccination coverage assessment in specific countries was searched on the website of the WHO and on websites of the corresponding national public health agencies. Further additional information and clarification was retrieved from the internet.

Additional analysis was carried out in order to discuss some issues concerning quality and comparability of vaccination coverage data. We compared the vaccination coverage figures of measles officially reported to the WHO with those resulting from the European Sero-Epidemiology Network 2 (ESEN2) study in 16 EU countries. Measles has been chosen since reliable seroprevalence data with defined limits for protective immunity is available for this disease. The seroprevalence data assessed in the age group of 2–4 years have been compared with the vaccine coverage data reported to WHO [103,104] in the corresponding birth cohorts.

Definitions

There are several methods by which vaccination coverage may be assessed:

- Administrative methods are based on routine estimates of vaccine coverage done by dividing the number of administered vaccine doses by the total estimated number of people in the target population. The coverage estimates calculated using the administrative method can be biased owing to inaccurate numerators or denominators;
- Surveys can be used to estimate the levels of immunization coverage at either the national or subnational level, or even in selected population groups. The primary objective of a vaccination coverage survey is usually to provide coverage estimates that can verify routine administrative coverage data and can provide additional information that usually is not available with administrative systems;
- Seroprevalence surveys. The actual level of protection against a specific infectious disease can be often assessed by performing serological surveys in sample populations. Serological surveys cannot distinguish between protection due to vaccination or naturally acquired immunity, but they can be particularly useful when serology represents a clear correlate of protection from the disease. When seroprevalence surveys are performed, the population-based approach gives a better guarantee that the data are representative compared with simply collecting residual sera from laboratories [15];
- Immunization registries (computerised immunization registries – known also as immunization information systems [IIS]) are population-based, computerized registries that attempt to include individual records about all the residents within a certain area (national or subnational level). The main purpose of IIS is not to assess vaccine coverage but they are very useful tools to increase and sustain high vaccination coverage (i.e., by generating reminder and recall vaccination notices for each client).

Assessment of vaccination coverage in EU countries: the international perspective

The VENICE project

The Vaccine European New Integrated Collaboration Effort (VENICE) project started in 2006, sponsored by the Directorate General for Health and Consumer Affairs (DG SANCO). Since national immunization programs and strategies vary notably among European countries, VENICE aims to collect, share and disseminate knowledge and best practice in the field of vaccination through a network of European experts. All 27 EU member states are participating, as well as Iceland and Norway. After

2 successful years, VENICE II started in December 2008 and is currently run under a grant agreement with the European CDC [105].

In December 2007, VENICE published a report on vaccination coverage assessment in Europe [13]. It was the result of a survey in 27 countries and it focused on different aspects of the methods of vaccination coverage assessment in these countries. The report shows that all participating countries collect and analyze vaccination coverage data regularly, but the methods used and the frequency of assessment are highly variable. Therefore, comparison of coverage data between countries is difficult.

The childhood vaccination coverage assessed differs per country: measles, mumps, rubella, diphtheria, tetanus and pertussis represent the common set of diseases for which all countries assess coverage. The time intervals used for assessment range from monthly to once in every 5 years. Also, differences can be seen in the age groups or cohorts used for assessment. The majority of the EU countries (67%) assess vaccination coverage of children at or by their second birthday. Other commonly used cohorts are children at or by their first birthday (56%) and at age of school entry (56%). There is variability across countries in the administrative level of assessment (national, regional and/or local). The report also demonstrates that in only just over half of the countries, vaccination coverage data is validated, and various methods are used for validation.

Coverage rate in EU countries is estimated using diverse methods. Administrative methods are commonly used and include the number of subjects vaccinated, aggregation of the number of vaccines administered, aggregation of the number of vaccines distributed and collection of data from school or well-baby clinic records. Increasingly, computerized systems are used, but administration on paper is also still common. Other frequently used tools are surveys. For example, these can be face-to-face interviews, focus groups, telephone or mail surveys and household or school surveys [13].

Ten countries (37%) in the VENICE report used more than one method to assess vaccination coverage in their country [13]. More details on these systems as they are used in some EU countries are provided in a later section.

In order to overcome the problems related to the differences in vaccination coverage assessment, VENICE is stressing the need for a harmonized collection of vaccination coverage data in the EU [13].

WHO/UNICEF

The WHO and UNICEF jointly publish annual estimates of national immunization coverage. All countries, including the EU member states, are asked yearly to fill in the WHO/UNICEF Joint Reporting Form on Immunization. It contains, among others questions on incidence of VPD, the immunization schedule of the country, vaccination coverage and official estimates of the country itself of the vaccination coverage. This latter opportunity is given to the member states to be able to take into account other aspects that may affect vaccination coverage figures. This may also be the case when the private or nongovernmental organization sector contributes to immunization programs [16,103].

Starting from the data reported by the countries or retrieved from published and gray literature, the WHO and UNICEF report a WHO estimate. The data from administrative methods or surveys are used to confirm data reported by the countries. If multiple points are available for a given country, data is not averaged, but an effort is made to create a consistent pattern over time from the data source that has the least potential for bias. Local experts are consulted to put the data in the context of national or local events, such as vaccine shortages, changes in policies or civil unrest. Furthermore, survey coverage levels are adjusted for recall bias for multidose antigens and published coverage estimates will not be higher than 99%. Interpolation is used to assign values for years for which data are not available. If there is no data available for the most recent estimation period, the estimate will stay the same as in the previous year [16]. Notes are added to the published data to better explain how the data was reported but in some cases they are not enough to understand all the figures. A careful reading of the methodology used to collect the data and to generate the estimate is needed to interpret the data available on the website.

In the WHO European Region, the Centralized Information System for Infectious Diseases (CISID) is the system used to collect, analyze and present data on infectious diseases [103]. Information on vaccination coverage in this system is also compiled from the Joint Reporting Forms on Immunization. Owing to the aforementioned methodological issues, occasionally the figures on vaccination coverage for the European countries presented by CISID are not the same as the figures presented on the WHO general website [104], which poses another difficulty in interpreting these data.

Currently, the publications of the WHO are the only reliable sources for comparing vaccination coverage in the EU. However, the methods used to assess vaccination coverage in different countries vary broadly. This means that the WHO and UNICEF have developed a systematic way to collect and present data on vaccination coverage, but the data collected are not comparable across countries.

Assessment of vaccination coverage in some EU countries

Two different vaccination systems can be roughly distinguished in the EU: centralized (public) systems and decentralized (private) systems (Table 1). Examples of centralized systems are those in the UK, Italy, The Netherlands, the Scandinavian countries and many central-Eastern EU member states. They are government funded and vaccination is free of charge for most of the vaccines. Usually, centralized systems achieve high vaccination coverage, since they have clear plans for implementation of vaccination schedules, with deadlines for uptake and frequently a reminder system. Decentralized systems, such as in Germany, Austria or France, typically get a lower level of control from the government. Vaccinations are usually provided by family physicians or (private) pediatricians. The use of financial incentives given to parents [17] as well as to pediatricians and family practitioners [18] to improve vaccination coverage is occasional in Europe. The

experience of these two groups of countries is not representative of all the European variability, but they can help in describing some factors that contribute to the diversity among the member states.

France

Vaccination coverage assessment is performed using health certificates – which include a lot of information in addition to the vaccination status – filled in during the mandatory examinations/vaccinations before the age of 24 months. Also, coverage is assessed in children between 3 and 4 years of age from health records during the mandatory health assessment for nursery schools [13,19–20]. Furthermore, since 2000, a triennial cycle of surveys for three generations of children (aged 6, 10 and 15 years) has been set up, in order to assess the coverage for the antigens that should have been received in accordance with the recommended immunization schedule [21].

The vaccination coverage for the mandatory vaccinations is high in France, similar to the coverage in the Nordic countries. However, coverage for the voluntary vaccinations seems to be lower. In particular, the coverage for *Haemophilus influenzae* type b, measles and hepatitis B lags behind [21]. Consequences can be seen from the ongoing measles outbreak in France that started in 2008 [22].

There is some discussion on the use of health certificates to assess vaccination coverage. The quality of the information in the forms, their transmission by the healthcare provider to the health department, their analysis by the department and their dispatching at national level could cause incompleteness. Each year, only half of the expected certificates could be analyzed at national level. Figures from surveys (e.g., local cluster sample surveys) are therefore used to validate the data from the health certificates that often provide slightly higher coverage estimates [13,21].

Germany

Vaccination coverage in Germany is assessed at the age of school entry (~6 years of age). Therefore, vaccination coverage data lags 5–7 years behind and it is hard to confirm if vaccinations are given on time [13,23]. Germany reports relatively lower vaccination coverage compared with other countries in the EU [103]. Also, the administration of recommended vaccines is delayed and there exists a high geographical variation between the 16 federal states [24].

Saxony-Anhalt is the only federal state of Germany with a law that requires the reporting of vaccinations. There are no rules to how the data should be registered and analyzed, but a committee was set up to develop the theoretical principles and a software model for creating a computerized immunization registry. The aim is to link this program to other childcare software in use. With this registry, vaccination coverage data can be obtained more easily and reminders can be sent to parents when their child needs to receive its next vaccination [25].

Another initiative on assessing vaccination coverage data focuses on the use of health insurance data. Physician's billing data seems to provide a promising tool to estimate immunization coverage, especially in countries like Germany where most of the vaccinations are administered by the private sector, but more research is needed on this topic [24].

Additional information on vaccination coverage among children and adolescents is provided by nationwide surveys like the German Health Interview and Examination Survey for Children and Adolescents [26].

Italy

Since 2001 the administration of the healthcare system in Italy is of the exclusive competence of the 21 regions, but the national government still defines health targets, strategic plan and indicates in detail which minimal healthcare levels have to be provided to all Italian citizens through the National Immunization Plan, which defines the vaccination strategies. Vaccination programs have been partially affected by such federal reform: vaccination schedules and strategic targets are defined at national level, in agreement with the regions, but the implementation of the program is fully delegated to the regions [106].

All vaccinations that are included into the national schedule are part of the 'minimal healthcare levels' and for this reason all regions should be obliged to provide them for free within the regional healthcare system. The national health authorities are in charge of assessing and monitoring the vaccination programs [107].

Vaccination coverage is routinely assessed using an administrative method, which is not yet computerized in all the Local Health Units. Both childhood and adult vaccinations are systematically reported yearly from the regional authorities to the central level using paper form with aggregated data. Vaccination coverage is calculated as the number of administered vaccine doses using the target population as denominator. This is only possible for childhood vaccination (coverage is assessed among the 24-month-old population), adolescent vaccination (human papillomavirus vaccine) and for influenza vaccination among the elderly (>64 years). No denominator is available for those vaccines administered to specific risk groups [13].

Since 1998, every fifth year, the National Institute for Health (Istituto Superiore di Sanitá) runs a national survey (ICONA survey) [27–29] based on the EPI cluster sampling method [108]. The scope of the survey is to validate the vaccination coverage data provided by the administrative method and to collect additional information on the reasons for missed or delayed immunizations. To date, three ICONA surveys have been conducted in 1998, 2003 and 2008.

Electronic immunization registries are in place in some regions or provinces but they are not interconnected. A national system collecting computerized data from the various regions is planned [30].

The Netherlands

Vaccination coverage has been very high for years in The Netherlands. National coverage rates for all vaccinations are well over 90%, although the rates in some municipalities are below this figure. These are usually municipalities where relatively more people live who refuse vaccination on religious grounds.

Since 2005, The Netherlands has a computerized information system ('Præventis') to register the individual vaccinations, to assess timeliness of the vaccinations and to assess vaccinations

coverage on different administrative levels. Formerly, completion of the recommended vaccination series was assessed on a fixed date similar for each child, which implicates that the children are not assessed at exactly the same age. Since the introduction of the computerized system, completion is assessed at an individual level. This gives a better opportunity to assess timeliness of vaccination. Information on the place of residence of the children is sent electronically from the municipal administration to the regional offices (five in total), who send the invitations for vaccination and, when necessary, generate reminders [31].

Table 1. Summary of the vaccination systems and vaccination coverage assessment in four EU countries.

Country	System	Mandatory/voluntary vaccinations	Method of vaccine coverage assessment
Italy	Public	Both	Administrative + survey
France	Public/private	Both	Administrative + survey
Germany	Private	Voluntary	Administrative + survey
The Netherlands	Public	Voluntary	Administrative (computerized) + survey

In addition to the computerized information system, seroprevalence surveys are carried out at intervals to gain insight into how well the population is protected against vaccine preventable diseases. Besides immunity from vaccination, these data give insight into naturally acquired immunity. These 'PIENTER' studies – carried out in 1995–1996 and in 2006–2007 – involved a sample of the Dutch population from 0 to 79 years of age [32].

Differences within Europe

As can be seen from the description of four different EU countries and also from the 2007 VENICE report, there are substantial differences in the systems regarding collection of vaccination coverage. National governments can make their own decision on the outline of the vaccination program, which vaccinations to include and if vaccinations will be mandatory or voluntary. Economical, political, historical and epidemiological circumstances vary among countries, which may affect the different systems [33]. Despite all the differences, creating a harmonized system for vaccination coverage assessment would provide the opportunity to compare data from different countries and to better assess the situation in the EU.

Initiatives on vaccination coverage assessment in some non-EU countries

Outside the EU, many countries have managed to implement a system to monitor vaccination coverage. Here we will give an overview of the vaccination coverage assessment systems in some non-EU countries, namely Australia, Canada and the USA.

Australia

Australia is well known for its excellent immunization register. The Australian Childhood Immunization Register (ACIR) is a national computerized database that contains information on vaccinations provided to children aged <7 years who live in Australia. It started operating in 1996 and uses an Australian universal health insurance scheme, Medicare, as its platform. Children registered in Medicare are automatically enrolled in the ACIR. Children who are not registered in Medicare can be added to the ACIR when an immunization provider sends the details of a vaccination to the ACIR. Immunization providers should send details of the vaccination to ACIR via the internet, via a software application or via paper forms. After a child turns 7 years of age, no new records will be added to the register [34,109].

Parents can get financial incentives when their child is age-appropriately immunized or when they have sent a completed form stating that they do not want their child to be vaccinated on medical, religious or philosophical grounds. Also, immunization providers get financial incentives for several parameters regarding vaccination of children. These are a payment for reporting the completion of age-appropriate vaccinations for children aged <7 years, a payment to practices that achieve 90% immunization coverage and funding for organizations providing support to GP's at the local and national level [34].

Advantages of the Australian system are that data are independent of parental recall, data can be available relatively quickly [34], the system can generate immunity history statements automatically (e.g., for school entry) [109] and the system can be linked to other databases (e.g., for adverse events) [35]. However, completeness of the system depends on provider notification, which could cause an underestimation of the vaccination coverage if there is incomplete provider reporting. Also, it is hard to verify if a change in vaccination coverage estimates is attributable to a real change in the number of children vaccinated or to a change in reporting behavior [34].

Canada

In Canada, the information on vaccination coverage is often collected and reported at local, provincial/territorial and national levels. Factors like method and frequency of assessment, age cohorts and populations that are assessed differ per jurisdiction, which makes comparison of coverage rates within Canada difficult. Therefore, an effort was made by the Canadian Immunization Registry Network to define national standards for immunization coverage reporting and to create a national immunization registry [110].

Canada Health Infoway is currently funding the development of a public health surveillance system: Panorama. It is planned to be available for all Canadian jurisdictions. With the use of Panorama, public health officials are able to work within and across multidisciplinary teams, regions, provinces and territories. The system covers a wide range of health information on communicable diseases, including immunization management [111]. Within the immunization section, appointments can be made and recall/reminder notifications can be generated. Also, through

interaction with other health information systems, adverse events can be registered and the immunization provider can check for contraindications for immunization [110,111]. The system is intended to include all children in Canada. As a start-up, all children from birth to 7 years of age should be included, which will be expanded later [112,113].

Each jurisdiction can adjust the system to meet its specific needs, suitable for its situation. It is responsible for its own planning, implementation and operation of its copy of Panorama [111]. However, one jurisdiction (Alberta) has chosen not to implement Panorama. In the rest of the jurisdictions the implementation is anticipated to be completed in 2012 [114].

USA

In the USA, vaccination coverage is currently assessed by the National Immunization Survey (NIS). It is a list-assisted random-digit-dialling household telephone survey followed by a mailed survey to the children's immunization providers (after consent of the household) to assure the accuracy and precision of the estimates. The estimates of the vaccination coverage combine the information provided by the households and the immunization providers. This survey targets children 19–35 months of age who live in the USA at the time of the interview. Estimates of vaccination coverage are produced for the nation and for the 50 states, the District of Columbia and selected large urban areas.

In addition, the NIS-Teen (annually estimating vaccination coverage in adolescents aged 13–17 years, conducted in the same way as the NIS), NIS-Adult (estimating vaccination coverage and reasons for nonvaccination in adults aged 18 years and older, using only a random-digit-dialing telephone survey) and other health surveys are conducted [36,37,115,116].

A telephone survey presents some advantages. Since 96% of the American households can be reached by landline, the sample consists of the general population. With a telephone survey there is rapid contact with respondents and a possibility to ask for clarification. However, nonresponse and noncoverage bias may occur among people without a landline phone, and exclusive use of provider-verified vaccination histories could cause an underestimation, because coverage is regularly underestimated in provider records [38–40]. Furthermore, coverage for small geographical areas cannot be estimated due to sampling methods and sample size constraints of the NIS [37,115].

In 1993, the CDC started awarding planning grants to develop immunization registries in every state. Subsequently, in 1998, the National Vaccine Advisory Committee launched the Initiative of Immunization Registries to develop community- and state-based immunization registries (IIS). These population-based registries should include the majority of children in a geographic area, regardless of healthcare source. They should prevent duplicative vaccinations, provide reminders and recalls and facilitate introduction of new vaccinations or changes in the vaccination schedule. Also, it should be linked to and integrated with other health databases, for example to monitor adverse events [41].

According to National Vaccine Advisory Committee, community- and state-based immunization registries are a critical tool for increasing and sustaining vaccination coverage. A goal set for 2010 is participation of 95% of children <6 years of age in fully operational, population-based immunization registries [42]. In 2008, 75% of all US children <6 years of age participated in an IIS, an increase from 65% in 2006 [43]. For this reason, IIS only partially contribute to the national estimate of vaccination coverage and they still represent a tool that is complementary to the NIS.

Immunization information systems

Immunization information systems are confidential, computerized information systems that collect and consolidate vaccination data from multiple healthcare providers, which allow the assessment of vaccination coverage within a defined geographic area [42]. As described, Australia, Canada and the USA are using a variety of IIS to register vaccinations and to assess vaccination coverage. Experiences from national IIS are also reported in South Korea and New Zealand [43]. A total of 15 EU countries reported in the VENICE survey in 2007 that they used an IIS, either nationally and/or locally. Additionally, six countries pointed out that they were planning to develop a national IIS [13].

Immunization information systems can provide many advantages. If individual-level vaccination data are collected, they can provide fast, accurate and precise vaccination information at both individual and population level. Also, it facilitates appropriate scheduling of vaccine doses and reminders or recall notifications can be sent. Linking the system to other healthcare databases can provide insight in vaccination coverage in certain risk groups and it can be useful in the tracing and notification in the event of safety concerns. Linkage to databases on health outcomes can be helpful in determining the possible connection of adverse events with vaccination [44].

Increasingly, countries are using computerized immunization registries to record vaccinations delivered and to measure vaccination coverage. The expectation is that this will further expand in the near future. Agreements on standards for these registries would contribute to a more meaningful interpretation of these data [13].

Comparability of reported vaccination coverage & data quality issues

As stated previously, comparability of vaccination coverage data is still an issue in the EU. Andrews *et al.* also showed this in their study on measles susceptibility [45]. Large national serum banks were collected from 18 countries through the ESEN2 and tested for measles IgG. The percentage of seropositive children in a country – in absence of significant wild virus circulation – should reflect the vaccination coverage. However, compared with the figures that are officially reported to CISID, some discrepancies stand out (Table 2).

For most of the countries, the officially reported data to CISID corresponds reasonably well with the seropositivity data obtained

Table 2. Comparison of vaccination coverage data from 16 EU countries in CISID and seroprevalence data for measles resulting from the ESEN2 study.

Country	Year†	Birth cohort(s)‡	Seropositive ESEN2¶ (%)	Coverage CISID# (%)	Difference (%)
Belgium	2002–2003	1998–2001	87.6	82.2	-5.4
Bulgaria	2001–2004	1997–2002	69.6	92.9	23.3
Cyprus	2003	1999–2001	78.2	85.3	7.1
Czech Republic	2001	1997–1999	99.0	97.3	-1.7
England and Wales	2000	1996–1998	81.1	91.3††	10.2
Hungary	2003	1999–2001	97.1	99.9	2.8
Ireland	2003	1999–2001	85.8	74.7	-11.1
Latvia	2003	1999–2001	81.0	98.3	17.3
Lithuania	2003	1999–2001	95.3	97.7	2.4
Luxembourg	2000–2001	1996–1997§	94.6	91.0	-3.6
Malta	2003	1999–2001	90.4	73.3	-17.1
Romania	2002	1998–2000	75.7	98.0	22.3
Slovakia	2002	1998–2000	96.2	98.4	2.2
Slovenia	1999–2000	1995–1998	96.0	94.5	-1.5
Spain	1996	1992–1994	95.0	90.0	-5.0
Sweden	1996–1997	1992–1995	99.0	96.5	-2.5

†Year of serum collection (ESEN2 project).
‡Birth cohort(s) considered, taking into account that the antibody titer was determined for the 2–4 years of age group.
§Luxembourg only collected data for children from the age of 4 years.
¶Percentage of the children aged 2–4 years who were seropositive for measles IgG in the ESEN2 project.
#Coverage reported to CISID (WHO Europe) on measles-containing vaccine, dose 1 (MCV1) for infants (until 24 months of age). The mean coverage is taken for the corresponding birth cohorts.
††This figure is for the UK and Northern Ireland and may not be representative for England and Wales.
CISID: Centralized Information System for Infectious Diseases; ESEN2: European Sero-Epidemiology Network 2.
Data from [45].

in the ESEN2 project, with differences ranging from -17.1% 'under-reporting' to 10.2% over-reporting. Unfortunately, seroprevalence screening cannot make a distinction between naturally acquired immunity and vaccination. The under-reporting could therefore also be partly explained by naturally acquired immunity. On the other hand, a comment has also to be made on the correlation between antibody levels and protection from the vaccine. 100% vaccination coverage does not necessarily relate to 100% seroconversion. In particular, after one dose of MMR vaccine, seroconversion rates are usually between 95 and 98% [46].

Nevertheless, three countries (Bulgaria, Latvia and Romania) stand out for their big differences between seroprevalence and reported coverage data; around 20% lower seroprevalence than what one would expect from reported coverage data. That cannot be explained by a lower response to the vaccine alone. Several explanations for this are provided by Andrews *et al.*, from problems with the vaccine or the serum samples to overestimation of the vaccination coverage [45]. Serum sample representativeness might also explain some discrepancies. On the other hand, the recent measles outbreak in Bulgaria is probably a piece of evidence that large pockets of underimmunized population were not covered by the routine administrative system [47]. This strengthens the issue that reported data may not reflect the real vaccination coverage in a country. In addition, such uncertainty about the figures also makes comparisons between European countries difficult.

Murray *et al.* additionally showed that officially reported data to the WHO could be misleading [48]. The officially reported three doses of diphtheria, tetanus and pertussis vaccine (DTP3) coverage was structurally higher than the coverage found from household surveys in 45 countries. Therefore, standardization of data sources and methods of data collection should be implemented in order to increase comparability across countries and over time. Standardized data sets are excellent tools to harmonize reporting from countries.

The use of different systems for data collection (administrative methods, surveys or CIR), the different age at assessment and the different timings of data collection in all the countries also makes comparability low, if not impossible. For example, if one country assesses the coverage of a vaccine at the age of 12 months, this is not comparable to the coverage figures from a country that assesses at the age of 24 months, since the latter children have 12 months extra to complete the vaccination. The same is true if another country assesses vaccination coverage at the age of school entry.

A harmonized system for assessing vaccination coverage would facilitate and provide a tool to overcome these problems. In particular the system in Australia, but also those in Canada and the USA, show that this is possible, although there will be some obstacles to overcome. As mentioned, there are differences in the vaccination schedules and in the vaccination systems in the EU countries. This will make it a challenge to implement a system for assessing vaccination coverage that fits all countries.

In addition, harmonization of vaccination schedules in Europe may seem promising for the future, but several factors complicate this issue. Each country has different values and goals, a different epidemiological situation, a different healthcare delivery system, different logistics of vaccine delivery, different population attitudes to the vaccination and a different economic situation. Creating a uniform immunization schedule may therefore encounter objections [33]. Meanwhile, developing a uniform system to assess vaccination coverage for the EU seems to be easier to achieve and it will help us further in the fight against VPDs.

Expert commentary

Vaccination coverage assessment is a pillar of any immunization program. At the same time it is not a simple task. Even the term 'vaccination coverage' needs to be clearly defined in order to collect information that could be compared across time and space. The use of terms like 'vaccination coverage', 'immunization coverage', 'vaccine uptake' and 'vaccine exposure' may lead to confusion.

Monitoring of vaccination coverage has a lot in common with disease surveillance. In fact, clear objectives and a well-defined target population should be set prior to starting a system for assessing vaccination coverage. Also, as is the case for surveillance, it should always be kept clear in mind that collecting vaccination coverage data is information for action. Any system would be better shaped knowing in advance what the data should be used for. Decision on which birth cohort should be included, at which intervals data should be collected and at which geographical level data should be shared has to be taken accordingly to the overall objectives of the vaccination program.

In this perspective, the way some administrative methods are designed can be useful for limited specific purposes (like assessing trends or fulfilling organizational needs), but are less effective for improving vaccination coverage in the short-to-medium term. As an example, assessing MMR vaccination coverage at school entry would only provide information that cannot be used for control purposes, allowing only a very late catch-up. At least, it should be considered too late in the elimination phase of measles.

The use of computerized systems may improve the quality of vaccine coverage monitoring. As an example, the Cover of Vaccination Evaluated Rapidly (COVER) program started in 1987 to evaluate childhood immunizations in the UK. The COVER program is computerized and monitors vaccination coverage data for all children in the UK at their first, second and fifth birthday during each evaluation quarter. A big advantage of the COVER program is that the information can be send to the local level very quickly, to signalize changes in vaccination coverage fast so coverage can be improved [49,117].

Setting up clear objectives and standardizing data collection is of paramount importance for assuring data comparability at international level.

Whereas the reason to assess vaccination coverage at local or national level is somehow self-evident, it is not clear what the added value of collecting such data at European or international level is.

In our opinion, an international benchmarking system can be of great support to the national immunization programs [50], especially if such benchmarking is performed among countries that are grouped according to geographic or socioeconomic characteristics, as should be the case of EU member states. International goals are often defined in terms of vaccination coverage (i.e., 75% influenza coverage in target groups, 95% coverage for childhood vaccination, and so on). Providing a comparison at EU level of such performance indicator could be leverage for improving the overall quality of the EU programs. But comparable data are necessary for such a scope.

In addition, sharing data on vaccination coverage at the international level should be an important responsibility for national health authorities, especially for diseases like polio, measles and rubella that are targeted by eradication or elimination plans and can easily spread beyond the country borders.

At present, the only official source of information at European level is represented by the CISID and by the WHO/UNICEF systems. The CISID is an authoritative and very effective communication tool that is designed for sharing information on infectious disease epidemiology in the WHO European Region in a standardized way. As discussed, for several different reasons the reported coverage figures are sometimes higher than the actual vaccination coverage and no information is available on subnational areas or specific population groups.

This is highly important for many EU countries, where an extraordinary effort has to be put in place to meet the goal of measles and rubella elimination. More thorough assessment of vaccination coverage and more effective information sharing are needed in the EU. Standardization is required for data comparison and benchmarking purposes. Accurate information shared at the EU level could allow timely cooperative and coordinated responses to VPD threats.

Five-year view

In Europe new technologies, such as computer-based systems, have not contributed significantly to development of more accurate vaccine coverage assessment during the last decade. Even though web-based reporting is progressively available to more vaccine providers, in many European countries, this task is still performed through paper-based administrative systems. In the coming 5 years a strong effort is required in order to set up electronic systems, which is viewed to be the optimal way to obtain better quality data at local and national levels. Using a barcode reader for recording of administered vaccines could be a simple and seamless process and the use of the internet can allow recording of vaccine receipt only once and transmitting it to a central register. Consequently, aggregated or anonymous data could be

easily shared at international level, resolving any potential issue linked to data protection and privacy legislation. Comparability within the EU member states could be improved by developing a standard set of data to be used for European data collection and by having EU-wide consensus on basic standardized guidelines for assessing vaccination coverage at national level. The priority for the coming 5 years should be to provide member states with both scientific and financial support – where needed – and to share good practice at the EU level.

Financial & competing interests disclosure

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

No writing assistance was utilized in the production of this manuscript.

Key issues

- Assessing and monitoring vaccination coverage is of paramount importance for improving immunization programs. Data comparability at international level should be assured.
- All EU countries collect and assess vaccination coverage regularly, but the methods used vary widely. Therefore, information on vaccination coverage is usually not comparable between European countries.
- Data quality issues can lead to overestimation of the vaccination coverage when administrative systems are used.
- Computerised immunization information systems are not widely used in the EU.
- Setting up clear objectives and standardizing data collection could assure data comparability at international level and improving the overall quality of vaccination coverage assessment.

References

1 European Centre for Disease Prevention and Control (ECDC). *Annual epidemiological report on communicable diseases in Europe.* ECDC, Stockholm, Sweden (2009).

2 Centers for Disease Control and Prevention (CDC). Global Measles Mortality, 2000–2008. *Morb. Mortal. Wkly Rep.* 58(47), 1321–1326 (2009).

3 United Nations Children's Fund (UNICEF)/World Health Organization (WHO). Immunization summary: the 2007 edition. UNICEF/WHO, New York, NY, USA (2007).

4 Centers for Disease Control and Prevention (CDC). Global Routine Vaccination Coverage, 2009. *Morb. Mortal. Wkly Rep.* 59(42), 1367–1371 (2010).

5 Lopalco PL, de Carvalho HG, Kreidl P, Leitmeyer K, Gieseke J. Childhood vaccination schedules in Europe vary widely. Is this a problem? *Bundesgesundheitsbl.* 52(11), 1095–1098 (2009).

6 Guerin N. Assessing immunization coverage: how and why? *Vaccine* 16(Suppl.), S81–S83 (1998).

7 Glismann S, Ronne T, Schmidt JE. The EUVAC-NET survey: national measles surveillance systems in the EU, Switzerland, Norway, and Iceland. *Euro Surveill.* 6, 105–110 (2001).

8 Guerin N, Roure C. Immunization coverage in the European Union. *Euro Surveill.* 2(1), 185 (2007).

9 Hahne S, Macey J, van Binnendijk R *et al.* Rubella outbreak in The Netherlands, 2004–2005: high burden of congenital infection and spread to Canada. *Pediatr. Infect. Dis. J.* 28(9), 795–800 (2009).

10 Zeman CL, Depken DE, Senchina DS. Roma health issues: a review of the literature and discussion. *Ethn. Health* 8(3), 223–249 (2003).

11 Orlikova H, Rogalska J, Kazanowska-Zielinska E *et al.* Spotlight on measles 2010: a measles outbreak in a Roma population in Pulawy, eastern Poland, June to August 2009. *Euro Surveill.* 15(17), pii: 19550 (2010).

12 World Health Organization (WHO). WHO position paper on influenza vaccines. *Weekly Epidemiol. Rec.* 33, 279–287 (2005).

13 VENICE Project. *VENICE Work Package 3. Report on Vaccination Coverage Assessment in Europe. VENICE.* VENICE Project, Venice, Italy (2007).

14 D'Ancona F, Alfonsi V, Caporali MR, Ranghiasci A, Ciofi Degli Atti ML. Pneumococcal conjugate, meningococcal C and varicella vaccination in Italy. *Euro Surveill.* 12(2), 25–28 (2007).

15 De Melker HE, Conyn-van Spaendonck MA. Immunosurveillance and the evaluation of national immunization programmes: a population-based approach. *Epidemiol. Infect.* 121(3), 637–643 (1998).

16 Burton A, Monasch R, Lautenbach B *et al.* WHO and UNICEF estimates of national infant immunization coverage: methods and processes. *Bull. World Health Organ.* 87(7), 535–541 (2009).

17 Schmitt HJ, Booy R, Weil-Olivier C, Van Damme P, Cohen R, Peltola H. Child vaccination policies in Europe: a report from the Summits of Independent European Vaccination Experts. *Lancet Infect. Dis.* 3, 103–108 (2003).

18 Lynch ML. The uptake of childhood immunization and financial incentives to general practitioners. *Health Econ.* 3(2), 117–125 (1994).

19 Bois C, Guillemot G. Health checkups for children of 3–4 years of age in the Hauts-de-Seine department (France): results and prospects. *Arch. Pediatr.* 17(3), 233–242 (2010).

20 Guagliardo V, Bouhnik AD, Verger P. Evaluation of vaccine coverage in children from 2 to 4 years old in South-Eastern France. *Arch. Pediatr.* 14(4), 338–344 (2007).

21 Antona D, Bussière E, Guignon N, Badeyan G, Lévy-Bruhl D. Vaccine coverage of pre-school age children in France in 2000. *Euro Surveill.* 8(6), 139–144 (2003).

22 Parent du Châtelet I, Antona D, Freymuth F *et al.* Spotlight on measles 2010: Update on the ongoing measles outbreak in France, 2008–2010. *Euro Surveill.* 15(36), pii: 19656 (2010).

23 Poggensee G, Reuss A, Reiter S, Siedler A. Overview and assessment of available data sources to determine incidence of vaccine preventable diseases, vaccination coverage, and immune status in Germany. *Bundesgesundheitsbl.* 52, 1019–1028 (2009).

24 Kalies H, Redel R, Varga R, Tauscher M, von Kries R. Vaccination coverage data can be estimated from health insurance data. *BMC Public Health* 8, 82–87 (2008).

25 Oppermann H, Wahl G, Borrmann M, Fleischer J. Obligatory vaccination reporting in Saxony-Anhalt – Possibilities and limitations of establishing a computerized vaccination registry. *Bundesgesundheitsbl.* 52, 1029–1036 (2009).

26 Thyen U. The German Health Interview and Examination Survey for Children and Adolescents (KiGGS) 2003–2006 – a milestone in paediatrics. *Bundesgesundheitsbl.* 50, 529–530 (2007).

27 Ciofi Degli Atti ML, Rota MC, Bella A, Salmaso S; ICONA Study Group. Do changes in policy affect vaccine coverage levels? Results of a national study to evaluate childhood vaccination coverage and reasons for missed vaccination in Italy. *Vaccine* 22(31–32), 4351–4357 (2004).

28 Gruppo di lavoro ICONA. *ICONA 2008: national vaccination coverage survey among children and adolescents*. Istituto Superiore di Sanità, Rome, Italy (2009).

29 Salmaso S, Rota MC, Ciofi Degli Atti ML, Tozzi AE, Kreidl P. Infant immunization coverage in Italy: estimates by simultaneous EPI cluster surveys of regions. ICONA Study Group. *Bull. World Health Organ*. 77(10), 843–851 (1999).

30 VENICE Project. VENICE Work Package 3. Survey on Functional Standards for Computerised Immunisation Registries in Europe. VENICE. VENICE Project, Venice, Italy (2008).

31 Rijksinstituut voor Volksgezondheid en Milieu (RIVM). Vaccinatiegraad Rijksvaccinatieprogramma Nederland – Verslagjaar 2009. *Immunization coverage National Immunization Programme in The Netherlands – Year of Report 2009*. RIVM, Bilthoven, The Netherlands (2009).

32 Mollema L, de Melker HE, Hahné SJM, van Weert JWM, Berbers GAM, van der Klis FRM. *PIENTER 2-Project: Second Research Project on the Protection against Infectious Diseases Offered by the National Immunization Programme in The Netherlands*. RIVM, Bilthoven, The Netherlands (2009).

33 Wiese-Posselt M, Reiter S, Gilsdorf A, Krause G. Needs and obstacles of uniform immunisation schedules in the European Union. *Bundesgesundheitsbl.* 52, 1099–1104 (2009).

34 Hull BP, Deeks SL, McIntyre PB. The Australian Childhood Immunisation Register – a model for universal immunisation registers? *Vaccine* 27(37), 5054–5060 (2009).

35 Gold M, Dugdale S, Woodman RJ, McCaul KA. Use of the Australian Childhood Immunisation Register for vaccine safety data linkage. *Vaccine* 28(26), 4308–4311 (2010).

36 Fairbrother G, Freed GL, Thompson JW. Measuring immunization coverage. *Am. J. Prev. Med.* 19(3 Suppl.), 78–88 (2000).

37 Shefer A, Santoli J, Singleton JA. Measuring vaccination coverage – where are we now and where are we going? *J. Public Health Manag. Pract.* 13(6), 541–543 (2007).

38 Centers for Disease Control and Prevention (CDC). National, state, and local area vaccination coverage among children aged 19–35 months – United States, 2009. *Morb. Mortal. Wkly Rep.* 59(36), 1171–1177 (2010).

39 Centers for Disease Control and Prevention (CDC). National, state, and local area vaccination coverage among adolescents aged 13–17 years – United States, 2009. *Morb. Mortal. Wkly Rep.* 59(32), 1018–1023 (2010).

40 Stokley S, Rodewald LE, Maes EF. The impact of record scattering on the measurement of immunization coverage. *Pediatrics* 107(1), 91–96 (2001).

41 Centers for Disease Control and Prevention (CDC). Development of community- and state-based immunization registries. *Morb. Mortal. Wkly Rep.* 50(RR17), 1–17 (2001).

42 Centers for Disease Control and Prevention (CDC). Progress in Immunization Information System – United States, 2008. *Morb. Mortal. Wkly Rep.* 59(5), 133–136 (2010).

43 Jacobson VJ, Szilagyi P. Patient reminder and patient recall systems to improve immunization rates. *Cochrane Database Syst. Rev.* (3), CD003941 (2005).

44 Kwong JC, Foisy J, Quan S *et al.*; Writing team for the Public Health Agency of Canada/Canadian Institutes of Health Research Influenza Research Network Vaccine Coverage Theme Group. Why collect individual-level vaccination data? *CMAJ* 182(3), 273–275 (2010).

45 Andrews N, Tischer A, Siedler A *et al.* Towards elimination: measles susceptibility in Australia and 17 European countries. *Bull. World Health Organ*. 86(3), 197–204 (2008).

46 CDC. MMWR Recommendations and Reports. Measles, mumps, and rubella – vaccine use and strategies for elimination of measles, rubella, and congenital rubella syndrome and control of mumps: recommendations of the Advisory Committee on Immunization Practices (ACIP). 47(RR-8), 1–57 (1998).

47 Marinova L, Kojouharova M, Mihneva Z. An ongoing measles outbreak in Bulgaria, 2009. *Euro Surveill. 2009* 14(26), 19259 (2009). Erratum in: *Euro Surveill*. 14(27), 19262 (2009).

48 Murray CJ, Shengelia B, Gupta N, Moussavi S, Tandon A, Thieren M. Validity of reported vaccination coverage in 45 countries. *Lancet* 362(9389), 1022–1027 (2003).

49 Vyse AJ, Gay NJ, White JM *et al.* Evolution of surveillance of measles, mumps, and rubella in england and wales: providing the platform for evidence-based vaccination policy. *Epidemiol. Rev.* 24, 125–136 (2002).

50 Freed GL. Lessons from across the pond: what the US can learn from European immunization programs. *Vaccine* 25(33), 6148–6157 (2007).

Websites

101 European Centre for Disease Prevention and Control (ECDC). Immunization: Vaccines – Powerful tools http://ecdc.europa.eu/en/healthtopics/spotlight/Spotlight_immunisation/Pages/Vaccines_powerful_tools.aspx

102 EUVAC.net. National Childhood Vaccination Schedules www.euvac.net/graphics/euvac/vaccination/vaccination.html

103 World Health Organization (WHO). Centralized information system for infectious diseases. (CISID) http://data.euro.who.int/cisid/?TabID=260504

104 World Health Organization (WHO). WHO-UNICEF coverage estimates http://apps.who.int/immunization_monitoring/en/globalsummary/timeseries/tscoveragebcg.htm

105 VENICE. Vaccine European New Integrated Collaboration Effort http://venice.cineca.org/

106 Ministero della Salute, Piano Nazionale Vaccini [Italian Ministry of Health, National Vaccination Programme] www.salute.gov.it/malattieInfettive/paginaInternaMalattieInfettive.jsp?menu=pianovaccini&id=651

107 VENICE. Vaccine European New Integrated Collaboration Effort. Participating countries: Italy. Description of the Natioanl Immunisation programme http://venice.cineca.org/documents/italy_ip.pdf

108 WHO. Immunisation coverage cluster survey, reference manual www.who.int/vaccines-documents/DocsPDF05/www767.pdf

109 Australian Government. The Australian Childhood Immunisation Register www.health.gov.au/internet/immunise/publishing.nsf/Content/Handbook-acir

110 Public Health Agency of Canada. National Standards for Immunization Coverage Assessment: Recommendations from the Canadian Immunization Registry Network www.phac-aspc.gc.ca/publicat/ccdr-rmtc/05vol31/dr3109a-eng.php

111 Province of British Columbia. Panorama Application www-03.ibm.com/industries/ca/en/healthcare/files/panorama_application_overview_final.pdf

112 Public Health Agency of Canada. Canadian Immunization Registry Network www.phac-aspc.gc.ca/im/cirn-rcri/index-eng.php

113 Public Health Agency of Canada. Canadian Consensus Conference on a National Immunization Records System www.phac-aspc.gc.ca/im/cirn-rcri/abrep98-eng.php

114 KPMG. Final report: 2009 performance evaluation of the Canada Health Infoway Public Health Surveillance Program. KPMG, Ottawa www2.infoway-inforoute.ca/documents/Infoway-PHS%20Evaluation-Final-March%202009%20-%20EN.pdf

115 Centers for Disease Control and Prevention (CDC). About the National Immunization Survey www.cdc.gov/nis/about_nis.htm

116 Centers for Disease Control and Prevention (CDC). Immunization Coverage in the US www.cdc.gov/vaccines/stats-surv/imz-coverage.htm

117 Health Protection Agency. Vaccination coverage and COVER www.hpa.org.uk/Topics/InfectiousDiseases/InfectionsAZ/VaccineCoverageAndCOVER