Estimation of the incidence of invasive meningococcal disease using a capture-recapture model based on two independent surveillance systems

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Abstract

Background: Invasive meningococcal disease (IMD) is an urgent notifiable disease and its early notification is essential to prevent cases. The objective of the study was to assess the sensitivity of two independent surveillance systems, the statutory disease reporting system (SDR) and the microbiological reporting system (MRS), and to estimate the incidence of IMD.

Methods: The study was performed in Catalonia, Spain, between 2011 and 2015. The variables collected were age, sex, year of report, size of municipality (< 10,000 and ≥ 10,000), clinical form, death, serogroup, country of birth and type of reporting centre (private and public). The capture-recapture analysis and 95% confidence intervals were calculated using the Chapman formula. Multinomial logistic regression was performed for adjusted estimation.

Results: The sensitivity of the two combined surveillance systems was 88.5% (85.0-92.0). SDR had greater sensitivity than the MRS (67.9%; 62.7-73.1 vs. 64.7%; 59.4-70.0). In 2014-2015, the sensitivity of both systems was higher (80.6%; 73.2–87.9 vs. 73.4%; 65.2–81.6) than in 2011-2013 (59.3%; 52.6–66.0 vs. 58.3%; 51.6–65.1). In private centres, the sensitivity was higher for SDR than for MRS (100%; 100–100 vs. 4.8%; -4.4–13.9). The adjusted estimate of cases was lower than that obtained using the Chapman formula (279; 266–296 vs. 313; 295–330). The estimated adjusted incidence of IMD was 0.7/100,000 persons-year.

Conclusions: The sensitivity of enhanced surveillance through the combination of two complementary sources was higher than for the sources individually. Factors associated with under-reporting in different systems should be analysed to improve IMD surveillance.

Background

Invasive meningococcal disease (IMD) continues to be an important cause of morbidity and mortality, mainly in children aged < 4 years and adolescents. [1] In the European regions, the incidence rate of confirmed IMD cases is around 0.6/100,000 persons, [2] similar to Spain (0.58/100,000 persons). [3] The highest incidence is for meningococcal serogroup B, accounting for 51.5% of confirmed IMD cases. The case fatality rate is around 10–15% [3, 4] and long-term sequelae occur in 10–20% of cases. [5]

IMD is an urgent notifiable disease and its early notification is essential to provide an adequate public health response in patients and their close contacts to prevent further cases. Epidemiological surveillance allows monitoring of the impact of public health interventions, including vaccination programmes. Therefore, a robust epidemiological and microbiological system with timely and accurate surveillance providing information on the frequency of cases and the distribution of circulating serogroups is crucial.

Evaluations of surveillance systems should be conducted regularly to increase their utility. [6–8] There are two reporting systems for the epidemiological surveillance of communicable disease in Catalonia: the statutory disease reporting system (SDR) and the microbiological reporting system (MRS). [9]

The capture-recapture method is a statistical method for estimating the real incidence of diseases in a population with two or more information sources. [10, 11] The method is valid if four conditions are met: 1) the population under study has to be closed, i.e., there should be no changes during the study period; 2) there must be a method of determining whether an individual identified by one source is the same as an individual identified by the other; 3) each individual must have the same probability of being captured by either system; 4) the systems must be independent.

The aim of this study was to assess the sensitivity of the two surveillance systems in Catalonia (SDR and MRS) using the capture-recapture method and to estimate the incidence of IMD.

Methods

Information sources

Catalonia is a region in the northeast of Spain with a population of 7,508,106 in 2015. [12]

The SDR is a passive surveillance system through which health professionals declare all infectious diseases subject to surveillance. The reporting of cases to the Public Health Agency of Catalonia (PHAC) is mandatory and includes confirmed cases of IMD and is regulated by a Decree. [9, 13]

The MRS is a surveillance system that consists of microbiologists notifying laboratory confirmed microorganisms that cause infectious diseases. The main objectives of the MRS are to confirm suspected cases of infectious diseases through the identification of the microorganisms and serogroups involved and to determine trends and changes in epidemiological patterns and microbiological resistance. [14]

The MRS was non-compulsory until 2015 and involved 50 health care centres representing over 83% of acute hospital beds. [15] Confirmed IMD cases were reported by microbiologists including sex, age, clinical presentation, serogroup and diagnostic method.

Both systems belong to the PHAC epidemiological surveillance network and, since 2014, transfer information automatically, but the independence of the sources is maintained.

Cases definition, inclusion, and exclusion criteria
A confirmed case of IMD was defined as laboratory confirmed if at least one of the following criteria was fulfilled: isolation in cultures or detection of *Neisseria meningitidis* DNA by PCR in a normally sterile site, detection of gram-negative diplococci or *N. meningitidis* antigen in cerebrospinal fluid.

### Data collection

We made a retrospective study of confirmed IMD cases in Catalonia from January 2011 to December 2015. We extracted all IMD records from the MRS and SDR and linked the databases using the personal identification code (PIC). When the PIC was not available, data on notification, age and sex were used to identify duplicates between the two sources. In cases with inconclusive matching, the hospital was used as a fifth matching criterion.

Estimates were made for the entire 5-year period and by age, sex, year of report, size of municipality (<10,000 and ≥10,000), country of birth, number of hospital beds, clinical form (meningitis, with or without sepsis, sepsis, and others), serogroup, death and reporting centre (private or public).

The study was not submitted for research ethics approval as the activities described were conducted as part of the legislated mandate of the Health Department of Catalonia, the competent authority for surveillance of communicable diseases according to Decree 203/2015 of the 15 September which created the epidemiological surveillance network of Catalonia. [9] All the study activities formed part of public health surveillance and did not require informed consent. Personal data were used only for the matching process and measures to protect the confidentiality of personal data were applied (access to the data restricted to the personnel involved in data analysis, and removal of personal data from the datasets after matching).

### Statistical methods

The total number of IMD cases was estimated using the two-source capture-recapture method, which uses Chapman’s formula, [16] developed to reduce bias due to small samples:

\[
N = \frac{(L_1 + 1)(L_2 + 1)}{a + 1} - 1
\]

95% CI = \[N ± \frac{1.96}{\sqrt{\frac{(L_1 + 1)(L_2 + 1)(L_1 - a)(L_2 - a)}{(a + 1)^2(a + 2)}}}\]

where \(L_1\) is the number of cases in the SDR dataset, \(L_2\) is the number of cases reported to MRS, and \(a\) is the number of cases captured by both systems. The sensitivity (Se) of case ascertainment by the two sources was also calculated as the proportion of true cases detected by each source, i.e. \(Se (1) = L_1/N\) for source 1 and \(Se (2) = L_2/N\) for source 2. The sensitivity of both sources combined was calculated as the proportion of cases detected by one of the two sources or both, i.e., \(Se (1, 2) = (L_1 + L_2 - a)/N\).

The independence of the sources was considered when applying the capture-recapture method. [17, 18] In the two-by-two table, where \(a\) represents cases reported by two sources or combinations of sources, \(b\) and \(c\) cases reported exclusively by either of the two sources and \(x\) the estimated non-reported cases by either of the sources, the odds ratio (OR = \(ax/bc\)) should not differ from one.

A multinomial logit model was used to evaluate patient characteristics and the probability of capture by different sources, which allows more precise estimates of the number of cases. [19, 20] We used a backwards stepwise procedure (using likelihood ratio tests, with a P-value > 0.2 as the criterion for removing variables from the model), [21, 22] starting with a full model including all potential covariates, and we used the parameter estimates from the model to estimate the sizes of population subgroups and their 95% confidence intervals (CI). All analyses were made using R software version 3.0.1.

### Results

#### Patient characteristics

Patient characteristics by source are shown in Table 1. From 2011 to 2015, 212 IMD cases were reported to the SDR and 202 cases to the MRS, representing an incidence of 0.56 and 0.54/100,000 persons-year, respectively. IMD due to serogroup B was the most frequently reported serogroup (77.4% and 75.7% in the SDR and MRS, respectively). Around 63% of patients were aged <15 years; the mean age was 21.4 for the SDR and 20.5 years for the MRS. Male sex was more frequent in the SDR (52.4%) than in the MRS (49%). The SDR presented the most cases in 2015 (48 cases; 22.6%) and the MRS (61 cases; 30.2%) in 2011. The SDR reported that 84% of patients lived in a municipality of ≥10,000 people compared with 73% in the MRS. In both sources, the number of cases declared in a hospital of ≥200 beds were around 70%. The main clinical form in both sources was meningitis (54.7% and 64.8%, respectively) and sepsis (38.7% and 32.7%, respectively). Reports from private centres represented 10% of cases in the SDR and 0.5% in the MRS. Twenty-two cases (10.4%) cases reported by the SDR died compared with 11 cases (5.4%) reported by the MRS.
Table 1
Sociodemographic, clinical and microbiological characteristics of invasive meningococcal disease cases reported to the SDR and MRS, Catalonia 2011–2015

|                                | SDR (n = 212) | MRS (n = 202) |
|--------------------------------|---------------|---------------|
| **Age groups**                 |               |               |
| Mean (SD)                      | 21.4 (27.9)   | 20.5 (26.7)   |
| Median (IQR)                   | 6 (36)        | 6 (32.3)      |
| <2 years, n (%)                | 62 (29.8%)    | 61 (30.7%)    |
| 2–4 years, n (%)               | 35 (16.8%)    | 30 (15.1%)    |
| 5–14 years, n (%)              | 34 (16.3%)    | 35 (17.6%)    |
| 15–24 years, n (%)             | 12 (5.8%)     | 12 (6.0%)     |
| 25–34 years, n (%)             | 12 (5.8%)     | 9 (4.5%)      |
| 35–44 years, n (%)             | 10 (4.8%)     | 12 (6.0%)     |
| 45–54 years, n (%)             | 9 (4.3%)      | 7 (3.5%)      |
| >55 years, n (%)               | 34 (16.3%)    | 33 (16.6%)    |
| NAs                            | 1 (0.5%)      | 2 (1.0%)      |
| **Sex, n (%)**                 |               |               |
| Male                           | 111 (52.4%)   | 99 (49.0%)    |
| Female                         | 101 (47.6%)   | 103 (51.0%)   |
| **Year of report, n (%)**      |               |               |
| 2011                           | 43 (20.3%)    | 61 (30.2%)    |
| 2012                           | 41 (19.3%)    | 29 (14.4%)    |
| 2013                           | 38 (17.9%)    | 30 (14.9%)    |
| 2014                           | 42 (19.8%)    | 34 (16.8%)    |
| 2015                           | 48 (22.6%)    | 48 (23.8%)    |
| **Size of municipality, n (%)**|               |               |
| <10,000 people                 | 27 (12.7%)    | 28 (13.9%)    |
| ≥10,000 people                 | 177 (83.5%)   | 148 (73.3%)   |
| NAs                            | 8 (3.8%)      | 26 (12.9%)    |
| **Country of birth, n (%)**    |               |               |
| Spain                          | 194 (91.5%)   | 188 (93.1%)   |
| Other countries                | 18 (8.5%)     | 14 (6.9%)     |
| **Number of hospital beds, n (%)**|           |               |
| <200                           | 60 (28.3%)    | 65 (32.2%)    |
| ≥200                           | 149 (70.3%)   | 137 (67.8%)   |
| NAs                            | 3 (1.4%)      | 0 (0.0%)      |
| **Clinical form, n (%)**       |               |               |
| Meningitis                     | 116 (54.7%)   | 131 (64.8%)   |
| Sepsis                         | 82 (38.7%)    | 66 (32.7%)    |
| Other forms                    | 14 (6.6%)     | 4 (2.0%)      |
| NAs                            | 0 (0.0%)      | 1 (0.5%)      |
| **Serogroup, n (%)**           |               |               |
| A                              | 0 (0.0%)      | 2 (1.0%)      |

NAs: Not available; SDR: Statutory disease reporting; MDR: Microbiological reporting system
|                | SDR (n = 212) | MRS (n = 202) |
|----------------|---------------|---------------|
| B              | 164 (77.4%)   | 153 (75.7%)   |
| C              | 26 (12.3%)    | 21 (10.4%)    |
| W135           | 4 (1.9%)      | 6 (3.0%)      |
| Y              | 5 (2.4%)      | 2 (1.0%)      |
| Y/ W135        | 1 (0.5%)      | 1 (0.5%)      |
| Non-groupable  | 6 (2.8%)      | 4 (2.0%)      |
| NAs            | 6 (2.8%)      | 13 (6.4%)     |

**Type of reporting centre**

|                | SDR (n = 212) | MRS (n = 202) |
|----------------|---------------|---------------|
| Private        | 21 (10.0%)    | 1 (0.5%)      |
| Public         | 190 (90.0%)   | 201 (99.5%)   |

NAs: Not available; SDR: Statutory disease reporting; MRS: Microbiological reporting system

**Capture-recapture analysis**

The odds ratio (OR) was 1.01 (95%CI 0.62–1.66), reinforcing the independence of the two sources.

During the period studied, 212 and 202 IMD cases were reported by the SDR and MRS, respectively. One hundred thirty-seven cases (43.8%) coincided in both sources and 36 cases (11.5%) were not reported to either source. The estimated number of cases was 313 (95% CI 295–330) (Table 2) and the estimated incidence rate was 0.83/100,000 persons-year.

|                | Identified | Not identified | Total |
|----------------|------------|----------------|-------|
| **MRS**        | 137        | 65             | 202   |
| **Not identified** | 75        | 36             | 111   |
| **Total**      | 212        | 101            | 313   |

SDR: Statutory disease reporting
MRS: Microbiological reporting system

The sensitivity of the SDR was 67.9% (95%CI 62.7–73.1) and that of the MRS was 64.7% (95% CI 59.4–70.0) (P<0.001) (Table 3). The sensitivity increased to 88.5% (95% CI 85.0–92.0) when the datasets were combined.
Table 3
Capture–recapture analysis of all invasive meningococcal disease cases reported to the SDR and MRS stratified by characteristics, Catalonia 2011–2015

| Characteristics             | No. records in SDR | No. records in MRS | Matched records | Calculated unreported cases | Estimated total no. of cases (95% CI) | Sensitivity SDR (%) (95% CI) | Sensitivity MRS (%) (95% CI) | Difference in sensitivities (%) | P-value |
|-----------------------------|--------------------|--------------------|-----------------|-----------------------------|--------------------------------------|-----------------------------|-----------------------------|--------------------------------|---------|
| All cases                   | 212                | 202                | 137             | 36                          | 313 (295, 330)                      | 67.9 (62.7, 73.1)           | 64.7 (59.4, 70.0)           | 3.2                            | <0.001  |
| Age group                   |                    |                    |                 |                             |                                      |                             |                             |                                |         |
| <15 years                   | 131                | 126                | 87              | 20                          | 190 (177, 203)                      | 69.1 (62.6, 75.7)           | 66.5 (59.8, 73.2)           | 2.6                            | 0.468   |
| ≥15 years                   | 80                 | 74                 | 49              | 16                          | 121 (109, 133)                      | 66.4 (58.0, 74.8)           | 61.4 (52.7, 70.1)           | 5.0                            |         |
| Sex                         |                    |                    |                 |                             |                                      |                             |                             |                                |         |
| Male                        | 111                | 99                 | 71              | 16                          | 155 (144, 166)                      | 71.8 (64.7, 78.9)           | 64.0 (56.5, 71.6)           | 7.8                            | 0.588   |
| Female                      | 101                | 103                | 66              | 20                          | 158 (145, 171)                      | 64.2 (56.7, 71.7)           | 65.5 (58.1, 72.9)           | -1.3                           |         |
| Year of report              |                    |                    |                 |                             |                                      |                             |                             |                                |         |
| 2011–2013                   | 122                | 120                | 71              | 35                          | 206 (187, 226)                      | 59.3 (52.6, 66.0)           | 58.3 (51.6, 65.1)           | 1.0                            | <0.001  |
| 2014–2015                   | 90                 | 82                 | 66              | 6                           | 112 (106, 118)                      | 80.6 (73.2, 87.9)           | 73.4 (65.2, 81.6)           | 7.2                            |         |
| Size of municipality        |                    |                    |                 |                             |                                      |                             |                             |                                |         |
| <10,000 people              | 27                 | 28                 | 22              | 2                           | 35 (32, 37)                         | 78.7 (65.0, 92.4)           | 81.6 (68.7, 94.6)           | -2.9                           | 0.100   |
| ≥10,000 people              | 177                | 148                | 110             | 23                          | 238 (225, 252)                      | 74.6 (68.9, 80.0)           | 62.2 (56.1, 68.4)           | 12.2                           |         |
| Country of birth            |                    |                    |                 |                             |                                      |                             |                             |                                |         |
| Spain                       | 194                | 188                | 127             | 32                          | 287 (271, 304)                      | 67.6 (62.2, 73.0)           | 65.5 (60.0, 71.0)           | 2.1                            | 0.696   |
| Other countries             | 18                 | 14                 | 10              | 3                           | 25 (20, 30)                         | 72.3 (54.7, 89.9)           | 56.2 (36.7, 75.7)           | 16.1                           |         |
| Number of hospital beds     |                    |                    |                 |                             |                                      |                             |                             |                                |         |
| <200                        | 60                 | 65                 | 40              | 13                          | 97 (87, 108)                        | 61.7 (52.1, 71.4)           | 66.9 (57.5, 76.2)           | -5.1                           | 0.514   |
| ≥200                        | 149                | 137                | 97              | 22                          | 210 (197, 224)                      | 70.9 (64.7, 77.0)           | 65.2 (58.7, 71.6)           | 5.7                            |         |
| Clinical form               |                    |                    |                 |                             |                                      |                             |                             |                                |         |
| Meningitis                  | 116                | 131                | 84              | 18                          | 181 (169, 193)                      | 64.2 (57.2, 71.2)           | 72.5 (66.0, 79.0)           | -8.3                           | 0.936   |
| Sepsis                      | 82                 | 66                 | 50              | 10                          | 108 (99, 117)                       | 75.9 (67.9, 84.0)           | 61.1 (51.9, 70.3)           | 14.8                           |         |
| Type of reporting centre    |                    |                    |                 |                             |                                      |                             |                             |                                |         |
| Private                     | 21                 | 1                  | 1               | 0                           | 21 (21, 21)                         | 100 (100, 100)             | 4.8 (4.4, 13.9)            | 95.2                           | 0.002   |
| Public                      | 190                | 201                | 136             | 26                          | 281 (267, 295)                      | 67.7 (62.2, 73.2)           | 71.6 (66.4, 76.9)           | -3.9                           |         |

SDR: Statutory disease reporting; MDR: Microbiological reporting system

There were no differences in sensitivity between in <15 years and ≥15 years age groups (P-value = 0.468) in either source although it was higher in the <15 years (69.1%);
95% CI 62.6–75.7 in the SDR and 66.5%; 95% CI 59.8–73.2 in the MRS. The age groups with the highest sensitivity were 2–4 years in the SDR, with 80.3% (95% CI 68.5–92.1), and 35–44 years in the MRS, with 80.5% (95% CI 60.4–100.0) (Fig. 1).

In 2011–2013, sensitivity for the SDR and the MRS were 59.3% (95% CI 52.6–66) and 58.3% (95% CI 51.6–65.1), respectively, lower than that in 2014–2015 (80.6%; 95% CI 73.2–87.9, for the SDR and 73.4%; 95% CI 65.2–81.6, for the MRS (P < 0.001)) (Table 3). 2014 showed the highest sensitivity for both sources: 91.3% (95% CI 83.2–99.4) for the SDR and 73.9% (95% CI 61.2–86.6) for the MRS (Fig. 2). 2011 was the only year in which the MRS had a higher sensitivity than the SDR (56.4%; 95% CI 47.1–65.8 and 39.8%; 95% CI 30.6–49.0, respectively). In private centres the sensitivity of the SDR was 100% (95% CI 100–100) and that of the MRS was 4.8% (95% CI -4.4–13.9). No differences were found in other characteristics analysed.

For I meningitis, 116 and 131 cases were reported by the SDR and the MRS, respectively. The estimated number of meningitis cases was 181, and 18 cases were not reported by either source. The highest sensitivity was detected in the MRS (72.5%; 95% CI 66–79) compared with the SDR (64.2%; 95% CI 57.2–71.2) (P < 0.001) (Table 4). 2014–2015 showed a higher sensitivity in both sources compared with 2011–2013: 82.4% (95% CI 72.7–92) in the MRS and 75.6% (95% CI 64.7–86.5) in the SDR. Public centres had a higher sensitivity in the MRS (77.7%; 95% CI 71.4–84.0) and in the SDR (63.9%; 95% CI 56.6–71.2) (P < 0.037).
Table 4
Capture–recapture analysis of meningococcal meningitis reported to the SDR and MRS stratified by characteristics, Catalonia 2011–2015

| Characteristic         | No. records in SDR | No. records in MRS | Matched records | Calculated unreported cases | Estimated total no. of cases (95% CI) | Sensitivity SDR (%) (95% CI) | Sensitivity MRS (%) (95% CI) | Difference in sensitivities (%) | P-value |
|------------------------|--------------------|--------------------|-----------------|----------------------------|--------------------------------------|-------------------------------|-------------------------------|-------------------------------|---------|
| All cases              | 116                | 131                | 84              | 18                         | 181 (169,193)                       | 64.2 (57.2, 71.2)            | 72.5 (66.0, 79.0)             | -8.3                          | < 0.001 |
| Age group              |                    |                    |                 |                            |                                      |                               |                               |                               |         |
| <15 years              | 72                 | 81                 | 51              | 13                         | 115 (104,125)                       | 63.1 (54.3, 72.0)            | 71.0 (62.7, 79.3)             | -7.9                          | 0.682   |
| ≥15 years              | 43                 | 49                 | 32              | 6                          | 66 (60,73)                          | 65.5 (53.9, 77.0)            | 74.6 (64.1, 85.1)             | -9.1                          |         |
| Sex                    |                    |                    |                 |                            |                                      |                               |                               |                               |         |
| Male                   | 62                 | 69                 | 47              | 7                          | 91 (84,98)                          | 68.2 (58.6, 77.8)            | 75.9 (67.1, 84.7)             | -7.7                          | 0.245   |
| Female                 | 54                 | 62                 | 37              | 12                         | 91 (81,101)                         | 59.9 (49.8, 70.0)            | 68.7 (59.2, 78.3)             | -8.9                          |         |
| Year of report         |                    |                    |                 |                            |                                      |                               |                               |                               |         |
| 2011–2013              | 71                 | 82                 | 47              | 18                         | 124 (111,137)                       | 57.5 (48.8, 66.2)            | 66.4 (58.1, 74.7)             | -8.9                          | 0.013   |
| 2014–2015              | 45                 | 49                 | 37              | 3                          | 60 (56,64)                          | 75.6 (64.7, 86.5)            | 82.4 (72.7, 92.0)             | -6.7                          |         |
| Size of municipality   |                    |                    |                 |                            |                                      |                               |                               |                               |         |
| <10,000 people         | 19                 | 20                 | 16              | 1                          | 24 (22,26)                          | 80.2 (64.1, 96.2)            | 84.4 (69.8, 99.0)             | -4.2                          | 0.765   |
| ≥10,000 people         | 93                 | 93                 | 65              | 12                         | 133 (124,143)                       | 70.0 (62.2, 77.8)            | 70.0 (62.2, 77.8)             | 0.0                           |         |
| Country of birth       |                    |                    |                 |                            |                                      |                               |                               |                               |         |
| Spain                  | 107                | 120                | 77              | 17                         | 167 (155,179)                       | 64.3 (57.0, 71.5)            | 72.1 (65.3, 78.9)             | -7.8                          | 0.862   |
| Other countries        | 9                  | 11                 | 7               | 1                          | 14 (12,17)                          | 64.3 (39.2, 89.4)            | 78.6 (57.1, 100.0)            | -14.3                         |         |
| Number of hospital beds|                    |                    |                 |                            |                                      |                               |                               |                               |         |
| <200                   | 31                 | 40                 | 23              | 6                          | 54 (47,61)                          | 57.7 (44.5, 70.9)            | 74.5 (62.8, 86.2)             | -16.8                         | 0.516   |
| ≥200                   | 84                 | 91                 | 61              | 11                         | 126 (116,135)                       | 67.1 (58.9, 75.4)            | 72.7 (64.9, 80.5)             | -5.6                          |         |
| Type of reporting centre|                   |                    |                 |                            |                                      |                               |                               |                               |         |
| Private                | 9                  | 1                  | 1               | 0                          | 9 (9,9)                             | 100.0 (100.0, 100.0)         | 11.1 (-9.4, 31.6)             | 88.9                          | 0.037   |
| Public                 | 107                | 130                | 83              | 14                         | 168 (158,178)                       | 63.9 (56.6, 71.2)            | 77.7 (71.4, 84.0)             | -13.7                         |         |

SDR: Statutory disease reporting; MDR: Microbiological reporting system

For sepsis, 82 cases and 66 cases were reported by the SDR and the MRS, respectively. The sensitivity was higher for the SDR (75.9%; 95%CI 67.9–84) than the MRS (61.1%; 95%CI 51.9–70.3) (Table 5). There were 108 estimated cases and 10 cases were not reported by either source. The sensitivity was higher in the < 15 years than in the ≥ 15 years in both sources, but higher in the SDR (81.1%; 95%CI 71.1–91.1 versus 71%; 95%CI 59.4–82.5 for the MRS; P = 0.0036), and higher in 2014–2015 than in 2011–2013 (87.6%; 95%CI 78-97.3 for the SDR and 71.9%; 95%CI 58.7–85.1 for the MRS) (P < 0.015).
Table 5
Capture–recapture analysis of meningococcal septicaemia reported to the SDR and MRS stratified by characteristics, Catalonia 2011–2015

|                      | No. records in SDR | No. records in MRS | Matched records | Calculated unreported cases | Estimated total no. of cases (95% CI) | Sensitivity SDR (%) (95% CI) | Sensitivity MRS (%) (95% CI) | Difference in sensitivities (%) | P-value |
|----------------------|--------------------|--------------------|------------------|-----------------------------|-------------------------------------|-----------------------------|-------------------------------|-------------------------------|---------|
| All cases            | 82                 | 66                 | 50               | 10                          | 108 (99, 117)                      | 75.9 (67.9, 84.0)            | 61.1 (51.9, 70.3)              | 14.8                          | < 0.001 |
| Age at notification, years |                |                    |                  |                             |                                     |                             |                               |                               |         |
| <15 years            | 48                 | 42                 | 34               | 4                           | 60 (55, 64)                        | 81.1 (71.1, 91.1)            | 71.0 (59.4, 82.5)              | 10.1                          | 0.036   |
| ≥15 years            | 34                 | 23                 | 16               | 8                           | 49 (40, 58)                        | 70.3 (57.4, 83.1)            | 47.5 (33.4, 61.6)              | 22.7                          |         |
| Sex                  |                    |                    |                  |                             |                                     |                             |                               |                               |         |
| Male                 | 43                 | 27                 | 22               | 5                           | 53 (47, 59)                        | 81.8 (71.3, 92.2)            | 51.3 (37.8, 64.8)              | 30.4                          | 0.315   |
| Female               | 39                 | 39                 | 28               | 5                           | 55 (49, 60)                        | 72.0 (60.0, 83.9)            | 72.0 (60.0, 83.9)              | 0.0                           |         |
| Year of report       |                    |                    |                  |                             |                                     |                             |                               |                               |         |
| 2011–2013            | 43                 | 34                 | 22               | 11                          | 66 (56, 77)                        | 65.2 (53.6, 76.7)            | 51.5 (39.5, 63.6)              | 13.6                          | 0.015   |
| 2014–2015            | 39                 | 32                 | 28               | 2                           | 45 (42, 48)                        | 87.6 (78.0, 97.3)            | 71.9 (58.7, 85.1)              | 15.7                          |         |
| Size of municipality |                    |                    |                  |                             |                                     |                             |                               |                               |         |
| <10,000 people       | 7                  | 7                  | 5                | 1                           | 10 (8, 12)                         | 72.2 (44.0, 100.0)           | 72.2 (44.0, 100.0)             | 0.0                           | 0.918   |
| ≥10,000 people       | 71                 | 52                 | 43               | 6                           | 86 (80, 93)                        | 82.9 (74.9, 90.8)            | 60.7 (50.3, 71.0)              | 22.2                          |         |
| Country of birth     |                    |                    |                  |                             |                                     |                             |                               |                               |         |
| Spain                | 73                 | 63                 | 47               | 9                           | 98 (90, 106)                       | 74.7 (66.1, 83.3)            | 64.5 (55.0, 74.0)              | 10.2                          | 0.275   |
| Other countries      | 9                  | 3                  | 3                | 0                           | 9 (9, 9)                           | 100.0 (100.0, 100.0)         | 33.3 (2.5, 64.1)               | 66.7                          |         |
| Number of hospital beds |                  |                    |                  |                             |                                     |                             |                               |                               |         |
| <200                 | 25                 | 23                 | 16               | 4                           | 36 (31, 42)                        | 70.0 (55.0, 85.1)            | 64.4 (48.7, 80.1)              | 5.6                           | 0.831   |
| ≥200                 | 56                 | 43                 | 34               | 6                           | 71 (65, 78)                        | 79.2 (69.7, 88.7)            | 60.8 (49.4, 72.2)              | 18.4                          |         |
| Type of reporting centre |                  |                    |                  |                             |                                     |                             |                               |                               |         |
| Private              | 9                  | 0                  | 0                | 0                           | 9 (9, 9)                           | 100.0 (100.0, 100.0)         | 0 (0.0, 0.0)                  | 100.0                         | 0.988   |
| Public               | 73                 | 66                 | 50               | 8                           | 97 (89, 104)                       | 75.9 (67.3, 84.4)            | 68.6 (59.3, 77.9)              | 7.3                           |         |

SDR: Statutory disease reporting; MDR: Microbiological reporting system

Serogroup B (Supplementary Table 1) showed the sensitivity of the SDR was higher than that of the MRS (74.6%; 95%CI 68.8–80.3 and 69.6%; 95%CI 63.5–75.6, respectively). There were differences according to the period and the type of centre. In 2014–2015, the sensitivity was 87.1% (95%CI 79.7–94.5) for the SDR and 78.3% (95%CI 69.2–87.4) for the MRS (P < 0.002). In private centres, the sensitivity in SDR was 100% compared with 7.1% (95%CI 6.4–20.6) (P = 0.004) in MRS. The sensitivity was higher for IMD serogroup C cases in SDR than in MRS (76.7%; 95%CI 62.5–90.9 and 62%; 95%CI 45.6–78.3, respectively) (Supplementary Table 2).
All 22 deaths were reported in the SDR ( CFR: 10.4%), and the sensitivity of the SDR was higher than that of the MRS (100%; 95CI% 100–100 vs 50%; 95CI% 29.1–70.9, P = 0.104) (Supplementary Table 3).

The results of the multinomial logit model for all cases are shown in Table 6. The variables considered significant in defining the sensitivity of the two sources were year of report (2011–2013 versus 2014–2015) and size of municipality. With these variables in the model, the adjusted estimate of the total number of cases was 279 cases (95%CI 266–296) and the estimated incidence rate was 0.7/100,000 persons-year.

Table 6

| Variables                  | OR (95%CI)   | p-value |
|----------------------------|-------------|---------|
| Year of report (2014–2015) | 2.29 (1.35, 3.89) | 0.002   |
| Size of municipality (≥ 10,000 people) | 0.51 (0.23, 1.12) | 0.093   |

Discussion

The sensitivity obtained by combining the two surveillance system for IMD cases was 88.5%, greater than for each source s (67.9% and 64.7%, respectively). Globally, the SDR showed higher sensitivity than the MDR, mainly for cases of sepsis, I serogroup B and serogroup C, although for meningitis the sensitivity of the MDR was higher than that of the SDR.

Similar studies found greater sensitivities by combining data systems than we did. Baldovin et al. [23] in Italy, reported an overall sensitivity of 94.7% by combining four data sources (mandatory notification system, laboratory surveillance, invasive bacterial surveillance and hospital discharge). Jansson et al. [24], in Sweden, found a global sensitivity of 98.7%, 91.1% for clinical notification and 85.4% for laboratory reporting. In Austria a good agreement between the National Reference Center for meningococci and the hospital discharge was found, although a clinical review of hospital discharge data was necessary to detect false positive cases recorded. [25]

We found a greater sensitivity for meningitis in the MRS than in the SDR (72.5% vs 64.2%). A possible explanation is that meningitis is considered a more serious disease and, therefore, microbiologists are more sensitive to its reporting. It is difficult to compare our results with those of other studies, since other sources of information were used or the independence of data sources was presumed but not demonstrated, [25] which is essential when using the capture-recapture method.

Notification of confirmed cases of IMD by laboratories is essential in epidemiological surveillance. [27] Molecular information on circulating serogroups that is required to implement public health measures such as vaccination is essential to control the disease [28] and evaluate the impact of available vaccines.

In the absence of automated electronic reporting, monitoring and increasing the speed of laboratory reports may allow the public health department to administer chemoprophylaxis and vaccination to contacts. [28] Although a higher sensitivity has been reported for electronic reporting than for paper-based reports by some authors, [29] during the study period, electronic surveillance was used in the SDR but not in the MDR, which may explain, at least in part, why the MDR had a lower sensitivity than the SDR. [30]

In the multinomial model, the 2014–2015 period and the size of the municipality show a higher sensitivity in the SDR, suggesting that IMD was well recorded in the two surveillance systems, although 36 cases (11.5%) were not captured by either source. This suggests there was underreporting, despite the clinical severity of the disease. It is very important to improve reporting by all physicians and microbiologists to the SDR and MDR to assess the impact of interventions such as immunization.

The estimated IMD incidence rate of 0.7/100,000 persons-year found in the multinomial model is less than that found using capture-recapture (0.83/100,000 persons-year) but higher than that calculated using the SDR (0.56/100,000 persons-year) or MDR data (0.54/100,000 persons-year). Other European studies showed incidence rates of between 0.39 [23] and 1.18/100,000 persons-year. [25]

The sensitivity of the two sources were intermediate (67.9% for the SDR and 64.7% for the MRS). The lower sensitivity of the MRS may be due to the fact that the MRS is a sentinel system with a coverage of 82% of acute hospital beds and without private centres. In our series, 21 cases (10%) included in the SDR were reported by private centres, while only one case (0.5%) was reported to the MSR; this patient was finally transferred to a public hospital. The inclusion of cases that have an equal probability of selection in one source might lead to an overestimation. Other authors have reported this limitation when the hospital discharge data set includes probable cases which are not included in the reference centre. [25]

Death was registered in 22 cases (10.5%), similar to that reported in other European countries (ECDC) but slightly lower than that observed in Italy (14%) using the capture-recapture method. [23] All cases were reported to the SDR but only 50% were reported to the MRS, indicating that clinical data are better in
the SDR than in the MRS. Other authors have used mortality data for capture-recapture analysis and concluded that all deaths were reported in notifiable systems. [26]

The sensitivity of the sources studied for the surveillance of IMD cannot be generalized to other diseases because physicians’ or microbiologists’ perception of the importance of IMD differs from that of other diseases. [29]

The main strength of this study is that the two sources had wide coverage. The SDR is a universal epidemiological surveillance source and, unlike the MDR, is a sentinel source, with a high coverage of 83%. Cases with PIC accounted for 85.5% of all cases reported to detect whether cases were coincident or not. In addition, the independence of the two sources was demonstrated, complying with the premise of the capture-recapture method.

A limitation of the study was that not all cases had the same probability of being selected from a given source. Cases diagnosed in private centres or public centres that did not participate in the MRS could not be reported by this system and this may explain, at least in part, the lower sensitivity than the SDR. This highlights the importance of including public and private centres to increase the robustness of the MRS. Another limitation was that we did not analyse the role of the electronic surveillance system, although a previous study detected greater sensitivity of the SDR when electronic surveillance was introduced. [30]

Conclusions

The sensitivity of enhanced surveillance through the combination of two complementary sources (statutory reporting by physicians and microbiological reporting by microbiologists) was higher than that of the individual sources. These systems are complementary and constitute the basic sources of information necessary for adequate epidemiological surveillance of IMD. Specific studies to estimate the factors associated with under-reporting are needed to reinforce epidemiological surveillance of this disease.

Declarations

Ethics approval and consent to participate

Not applicable

Consent of publication

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Availability of data and materials

The datasets used and analysed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

PC analyzed and interpreted data, studied conception and design of the study and writes the manuscript; MV and NS did statistical analysis; GC revised and collected data; TG, SH, LR collected data; MJ revised the study and AD did critical revision and got funding.

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References
1. World Health Organization. Laboratory methods for the diagnosis of meningitis caused by Neisseria meningitidis, Streptococcus pneumoniae, and Haemophilus influenzae: WHO manual, 2nd ed. Geneve: WHO, 2011.
2. European Centre for Disease Prevention and Control. Invasive meningococcal disease. In: ECDC. Annual epidemiological report for 2017. Stockholm: ECDC, 2019. https://www.ecdc.europa.eu/sites/default/files/documents/AER_for_2017-invasive-meningococcal-disease.pdf (Last accessed 27 January 2021)
3. Diez Izquierdo L, Martínez Sánchez EV, Amillategui dos Santos R, Cano Portero R. Enfermedad meningocócica en España. Análisis de la temporada 2016–2017. Bol Epidemiol Sem 2018;26:59–68. http://revista.isciii.es/index.php/bes/article/view/1063/1314.
4. Centers for Disease Control and Prevention (CDC). Epidemiology and prevention of vaccine-preventable diseases. Washington DC: Public Health Foundation, 2015.

5. Edmond K, Clark A, Korczak VS, Sanderson C, Griffiths UK, Rudan I. Global and regional risk of disabling sequelae from bacterial meningitis: a systematic review and meta-analysis. Lancet Infect Dis 2010;10:317–28.

6. CDC Guidelines Working Group. Updated guidelines for evaluating public health surveillance systems. Morb Mortal Wkly Rep 2001;50:1–35.

7. WHO. Protocol for the evaluation of epidemiological surveillance systems. https://apps.who.int/iris/handle/10665/63639 (Last accessed 6 September 2020).

8. Romaguera RA, German RR, Klaucke DN. Evaluating public health surveillance. In: Teutsch SM, Churchill RE, eds. Principles and practice of public health surveillance. New York: Oxford University Press, 2000: 176–193

9. Generalitat de Catalunya. Decret 2013/2015, de 15 de setembre, pel qual es crea la Xarxa de Vigilància Epidemiològica i es regulen els sistemes de notificació de malalties de declaració obligatòria i els brots epidèmics. DOGC 2015;6958:1–19.

10. Laska EM. The use of capture-recapture methods in public health. Bull World Health Organ 2002;80:845.

11. Freixa Blanxart M, Guàrdia Olmos J, Honrubia Serrano ML, Peró Cebollero. Validation of the capture–recapture method. Psichotema 2000;12(Suppl 2):231–5.

12. Statistical Institute of Catalonia. Statistical Institute of Catalonia. 2015. https://www.idescat.cat (Last accessed 18 January 2019)

13. Generalitat de Catalunya. Manual de notificació per als declarants al sistema de notificació de malalties de declaració obligatòria (MDO). 2016. https://canalsalut.gencat.cat/web/content/Professionals/Vigilancia_epidemiologica/documents/archius/MANUAL_MDO_2016.pdf (Last accessed 27 January 2021).

14. Generalitat de Catalunya. Manual de procediment de notificació microbiològica obligatòria (SNMC). 2016. https://canalsalut.gencat.cat/web/content/Professionals/Vigilancia_epidemiologica/documents/archius/manual_procediment.pdf (last accessed 27 January 2021).

15. Ciruela P, Izquierdo C, Broner S et al. Epidemiology of invasive pneumococcal disease in Catalonia Report 2012–2016. Generalitat de Catalunya 2018. https://canalsalut.gencat.cat/web/content/Professionals/Vigilancia_epidemiologica/documents/archius/invasive_pneumococcal_2012_2016_ang.pdf (Last accessed 27 January 2021).

16. Chapman DG. Some properties of the hypergeometric distribution with applications to zoological sample censuses. Berkeley: University of California Press, 1951.

17. Ballivet S, Salmi LR, Dubourdieu D. Capture-recapture method to determine the best design of surveillance system. Application to a thyroid cancer registry. Eur J Epidemiol 2000;16:147–53.

18. Tilling K, Sterne JAC, Wolfe CDA. Estimation of the incidence of stroke using a capture-recapture model including covariates. Int J Epidemiol 2001;30:1351–9.

19. Alho JM. Logistic regression in capture-recapture models. Biometrics 1999;149:392–400.

20. Tilling K, Sterne JAC. Capture-recapture models including covariate effects. Am J Epidemiol 1999;149:392–400.

21. Maldonado G, Greenland S. Simulation study of confounder-selection strategies. Am J Epidemiol 1993;138:923–36.

22. LaPorte RE, Dearwater SR, Chang Y-F et al. Efficiency and accuracy of disease monitoring systems: Applications of capture-recapture methods to injury monitoring. Am J Epidemiol 1995;142:1069–77.

23. Baldovin T, Lazzari R, Cocchio S et al. Invasive meningococcal disease in the Veneto region of Italy: a capture-recapture analysis for assessing the effectiveness of an integrated surveillance system. BMJ Open 2017;7:e012478.

24. Jansson A, Arneborn M, Ekdahl K. Sensitivity of the Swedish statutory surveillance system for communicable diseases 1998–2002, assessed by the capture-recapture method. Epidemiol Infect 2005;133:401–7.

25. Berghold C, Berghold A, Fülöp G, Heuberger S, Strauss R, Zenz W. Invasive meningococcal disease in Austria 2002: assessment of completeness of notification by comparison of two independent data sources. Wien Klin Wochenschr 2006;118:31–5.

26. Gibson A, Jorm L, McIntyre P. Using linked birth, notification, hospital and mortality data to examine false-positive meningococcal disease reporting and adjust disease incidence estimates for children in New South Wales, Australia. Epidemiol Infect 2015;143:2570–9.

27. Vázquez J A, Taha M K, Findlow J, Gupta S, Borrow R. Global Meningococcal initiative: guidelines for diagnosis and confirmation of invasive meningococcal disease. Epidemiol Infect 2016;144:3052–7.

28. Ratnayake R, Allard R. Challenges to the surveillance of meningococcal disease in an era of declining incidence in Montréal, Quebec. Can J Public Health 2013;104:e335–e339.

29. O’Lorcain P, Bennett DE, Morgan SL et al. A retrospective assessment of the completeness and timeliness of meningococcal disease notifications in the Republic of Ireland over a 16-year period, 1999–2015. Public Health 2018;156:44–51.

30. Carmona G, Vilaró M, Ciruela P et al. Hepatitis A surveillance: sensitivity of two information sources. BMC Infect Dis 2018;18:633.
Figure 2

Sensitivities of the SDR and MRS stratified by year of reporting, Catalonia 2011-2015

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