Prevalence of healthcare-associated infections, estimated incidence and composite antimicrobial resistance index in acute care hospitals and long-term care facilities: results from two European point prevalence surveys, 2016 to 2017

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Point prevalence surveys of healthcare-associated infections (HAI) and antimicrobial use in the European Union and European Economic Area (EU/EEA) from 2016 to 2017 included 310,755 patients from 1,209 acute care hospitals (ACH) in 28 countries and 117,138 residents from 2,221 long-term care facilities (LTCF) in 23 countries. After national validation, we estimated that 6.5% (cumulative 95% confidence interval (cCI): 5.4–7.8%) patients in ACH and 3.9% (95% cCI: 2.4–6.0%) residents in LTCF had at least one HAI (country-weighted prevalence). On any given day, 98,166 patients (95% cCI: 81,022–117,484) in ACH and 129,940 (95% cCI: 79,570–197,625) residents in LTCF had an HAI. HAI episodes per year were estimated at 8.9 million (95% cCI: 4.6–15.6 million), including 4.5 million (95% cCI: 2.6–7.6 million) in ACH and 4.4 million (95% cCI: 2.0–8.0 million) in LTCF; 3.8 million (95% cCI: 3.1–4.5 million) patients acquired an HAI each year in ACH. Antimicrobial resistance (AMR) to selected AMR markers was 31.6% in ACH and 28.0% in LTCF. Our study confirmed a high annual number of HAI in healthcare facilities in the EU/EEA and indicated that AMR in HAI in LTCF may have reached the same level as in ACH.

Introduction

In 2016, the European Centre for Disease Prevention and Control (ECDC) estimated that the burden of six main types of healthcare-associated infection (healthcare-associated pneumonia, urinary tract infection, surgical site infection, \textit{Clostridium difficile} infection, neonatal sepsis and primary bloodstream infection) expressed in disability-adjusted life years (DALYs) in the European Union and European Economic Area (EU/EEA) was higher than the combined burden of 31 other infectious diseases under surveillance by ECDC [1,2]. The estimated number of healthcare-associated infections (HAI) used in the study was based on the data of the first ECDC point prevalence survey (PPS) of HAI and antimicrobial use in acute care hospitals (ACH) from 2011 to 2012 [3] and did not take into account HAI occurring in other healthcare facilities. In particular, ECDC had previously estimated that the number of residents with an HAI on any given day in European long-term care facilities (LTCF) was of the same order
<table>
<thead>
<tr>
<th>Country</th>
<th>Number of hospitals</th>
<th>Type of ACH</th>
<th>Intensive care patients (%)</th>
<th>Number of LTCF</th>
<th>Type of LTCF</th>
<th>Residents in (a) + (b) + (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In PPS sample</td>
<td>Primary</td>
<td>Secondary</td>
<td>In PPS sample</td>
<td>General nursing home (a)</td>
<td>(85 years-old %)</td>
</tr>
<tr>
<td>Austria</td>
<td>162</td>
<td>49</td>
<td>25</td>
<td>11</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Belgium</td>
<td>197</td>
<td>43</td>
<td>27</td>
<td>9</td>
<td>7</td>
<td>0</td>
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<tr>
<td>Bulgaria</td>
<td>241</td>
<td>12</td>
<td>1</td>
<td>4</td>
<td>7</td>
<td>0</td>
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<tr>
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<td>32</td>
<td>34</td>
<td>6</td>
<td>15</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
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<td>2</td>
<td>4</td>
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<tr>
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<td>45</td>
<td>2</td>
<td>30</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Denmark</td>
<td>52</td>
<td>NP</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Estonia</td>
<td>27</td>
<td>23</td>
<td>10</td>
<td>7</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Finland</td>
<td>59</td>
<td>51</td>
<td>18</td>
<td>16</td>
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<td>2</td>
</tr>
<tr>
<td>France</td>
<td>1,237</td>
<td>50</td>
<td>32</td>
<td>10</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Germany</td>
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<td>25</td>
<td>7</td>
<td>4</td>
<td>13</td>
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<tr>
<td>Greece</td>
<td>123</td>
<td>42</td>
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<td>23</td>
<td>16</td>
<td>2</td>
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<tr>
<td>Hungary</td>
<td>94</td>
<td>38</td>
<td>14</td>
<td>10</td>
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<tr>
<td>Iceland</td>
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<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Ireland</td>
<td>60</td>
<td>60</td>
<td>9</td>
<td>17</td>
<td>7</td>
<td>27</td>
</tr>
</tbody>
</table>

**Table 1A**

Key characteristics of healthcare facilities, patients and residents included in the point prevalence survey (PPS) samples, PPS in acute care hospitals (n = 1,275) and long-term care facilities (n = 2,242), 30 EU/EEA countries, Serbia and the former Yugoslav Republic of Macedonia, 2016–2017

ACH: acute care hospital; EU/EEA: European Union/European Economic Area; LTCF: long-term care facility; NA: not applicable; ND: no data collected in national protocol; NP: did not participate; PPS: point prevalence survey; UK: United Kingdom.

Country data representativeness was poor in Bulgaria and the Netherlands for the PPS in ACH and poor in Austria, Croatia, Cyprus, Greece, Luxembourg, Malta and Poland for the PPS in LTCF. The Czech Republic only submitted data on institutional indicators.
<table>
<thead>
<tr>
<th>Country</th>
<th>Number of hospitals</th>
<th>Type of ACH</th>
<th>Intensive care patients (%)</th>
<th>Number of LTCF</th>
<th>Type of LTCF</th>
<th>Residents in (a) + (b) + (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Country total</td>
<td>Primary</td>
<td>Secondary</td>
<td>Tertiary</td>
<td>Specialised</td>
<td>Unknown</td>
</tr>
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<td>Italy</td>
<td>1,134</td>
<td>56</td>
<td>13</td>
<td>14</td>
<td>25</td>
<td>4</td>
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<tr>
<td>Latvia</td>
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<td>14</td>
<td>0</td>
<td>9</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Lithuania</td>
<td>64</td>
<td>62</td>
<td>25</td>
<td>26</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Luxembourg</td>
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<td>12</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Malta</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>The Netherlands</td>
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<td>19</td>
<td>10</td>
<td>8</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Norway</td>
<td>53</td>
<td>43</td>
<td>11</td>
<td>9</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Poland</td>
<td>936</td>
<td>80</td>
<td>22</td>
<td>20</td>
<td>23</td>
<td>15</td>
</tr>
<tr>
<td>Portugal</td>
<td>225</td>
<td>93</td>
<td>24</td>
<td>40</td>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td>Romania</td>
<td>311</td>
<td>40</td>
<td>16</td>
<td>10</td>
<td>3</td>
<td>11</td>
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<tr>
<td>Slovakia</td>
<td>107</td>
<td>50</td>
<td>20</td>
<td>11</td>
<td>7</td>
<td>12</td>
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<tr>
<td>Slovenia</td>
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<td>20</td>
<td>0</td>
<td>11</td>
<td>3</td>
<td>6</td>
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<tr>
<td>Spain</td>
<td>576</td>
<td>96</td>
<td>17</td>
<td>39</td>
<td>32</td>
<td>5</td>
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<td>Sweden</td>
<td>144</td>
<td>NP</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>UK–England</td>
<td>158</td>
<td>32</td>
<td>0</td>
<td>19</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>UK–Northern Ireland</td>
<td>16</td>
<td>16</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>UK–Scotland</td>
<td>46</td>
<td>45</td>
<td>12</td>
<td>14</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>UK–Wales</td>
<td>21</td>
<td>21</td>
<td>6</td>
<td>10</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>EU/EEA</td>
<td>8,307</td>
<td>1,209</td>
<td>357</td>
<td>414</td>
<td>245</td>
<td>165</td>
</tr>
<tr>
<td>EU/EEA (n, %, mean of countries)</td>
<td>252</td>
<td>100%</td>
<td>29.5%</td>
<td>34.2%</td>
<td>20.3%</td>
<td>13.6%</td>
</tr>
<tr>
<td>Former Yugoslav Republic of Macedonia</td>
<td>ND</td>
<td>NP</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Serbia</td>
<td>66</td>
<td>66</td>
<td>1</td>
<td>45</td>
<td>14</td>
<td>6</td>
</tr>
</tbody>
</table>

**ACH**: acute care hospital; **EU/EEA**: European Union/European Economic Area; **LTCF**: long-term care facility; **NA**: not applicable; **ND**: no data collected in national protocol; **NP**: did not participate; **PPS**: point prevalence survey; **UK**: United Kingdom. Country data representativeness was poor in Bulgaria and the Netherlands for the PPS in ACH and poor in Austria, Croatia, Cyprus, Greece, Luxembourg, Malta and Poland for the PPS in LTCF. The Czech Republic only submitted data on institutional indicators.
of magnitude as the number of patients with an HAI on any given day in ACH [4-6].

In the period from 2016 to 2017, ECDC organised two PPS of HAI and antimicrobial use: the second PPS in ACH and the third PPS in LTCF in the EU/EEA. The objective of the current study was to report on the HAI and antimicrobial resistance results of both surveys and to estimate the combined total number of HAI on any given day and the number of HAI per year in 2016 and 2017 in the EU/EEA.

Methods

Participation of countries
All EU/EEA countries and EU candidate and potential candidate countries were invited to organise a national PPS in ACH and LTCF in their country in any of four periods (April to June or September to November of 2016 or 2017). For reasons of feasibility at national level, the PPS in ACH and LTCF could be organised during different periods. Data were collected according to two specific standardised ECDC protocols [7,8]. All countries used the ECDC protocols and included all HAI types except for one country (Norway) for ACH and four countries (France, the Netherlands, Norway and Sweden) for LTCF. Norway used national protocols with the same case definitions as in the ECDC protocols, but provided fewer details and did not require the inclusion of all types of HAI. LTCF data from France and the Netherlands were also collected using national protocols not including all types of HAI. LTCF protocols in France, the Netherlands and Norway all included urinary tract infections, lower respiratory tract infections and skin infections, in addition to other HAI types varying by country. Surveys in separate healthcare administrations in the United Kingdom (UK), i.e. England, Northern Ireland, Scotland and Wales, were organised independently and results were reported separately.

Selection of participating facilities and patients
It was recommended that countries selected the participating ACH and LTCF by systematic random sampling from national lists ranked by type and size to ensure optimal country representativeness. For each country, the required sample size was calculated for an estimated prevalence of 6% for ACH and 4% for LTCF, based on the results of the previous PPS [3,6], with an absolute precision of 1%. Representativeness was categorised as optimal, good, poor or very poor, depending on the sampling method of the facilities, the number of included patients/residents and the number of included facilities [7,8]. For example, 'optimal representativeness' meant that the country performed systematic sampling of at least 25 healthcare facilities or included at least 75% of all facilities or beds at national level, and achieved the recommended sample size.

For ACH, the protocol recommended that data from a single ward should be collected on one single day and that the time frame for data collection for all wards of a single hospital would not exceed 3 weeks. For LTCF, it was recommended to collect data on a single day, except for larger LTCF.

We included all patients/residents present on the hospital ward or LTCF at 8:00 on the day of the PPS and still present at the time of day when the PPS was performed. In addition, LTCF residents needed to be full-time residents (i.e. living 24 hours a day in the LTCF). Patients/residents who were temporarily absent from their room, e.g. for diagnostic procedures, had to be included.

Case definitions
Case definitions for HAI differed for ACH and for LTCF, reflecting differences in access to diagnostic methods between the two settings, as well as the specific signs and symptoms of infection in elderly LTCF residents [7,8]. For both PPS, an HAI was defined as active on the day of the PPS when signs and symptoms were present on the date of the PPS, or when signs and symptoms were no longer present but the patient/resident was still receiving treatment for that infection on the date of the PPS. HAI present on admission were included in both protocols. In the LTCF protocol, HAI associated with a stay in any other healthcare facility – another LTCF or a hospital – were included. In the ACH protocol, however, only HAI imported from other ACH were included, excluding HAI present on admission associated with a previous LTCF stay. LTCF data in France and Sweden did not include HAI imported from other healthcare facilities.

Data analysis
Data were analysed with Stata, version 14.1 (StataCorp, Texas, United States). The prevalence of HAI was expressed as the percentage of patients/residents with at least one HAI on the day of the PPS. To account for clustering within ACH or LTCF, 95% confidence intervals (CI) were calculated using the svy proportion command in Stata. Overall weighted prevalence percentages were calculated by applying the country-specific prevalence on the number of occupied beds in each country and summing up the total number of patients with at least one HAI for EU/EEA countries. National denominator data were obtained by questionnaire from national survey coordinators, from Eurostat data if national denominator data were not submitted [9-11] or from the previous PPS if Eurostat data were missing or incomplete [3,4,6]. To estimate the total number of HAI or patients with at least one HAI for the whole EU/EEA, the average results from participating EU/EEA countries were applied to the national denominator data from non-participating EU/EEA countries. For data collected using national protocols which did not include all types of HAI, imputation of non-included types of HAI was done based on EU/EEA averages to make prevalence percentages comparable. In ACH, imputation resulted in adding 7.3% (36/495) of patients with HAI in Norway. In LTCF, imputation resulted in adding 5.8% (12/206) of residents with HAI in France, 6.9% (11/160)
## Table 2A

Prevalence and estimated incidence of healthcare-associated infections in European acute care hospitals, 28 EU/EEA countries and Serbia, 2016–2017 (n = 325,737 patients)

<table>
<thead>
<tr>
<th>Country</th>
<th>Patients in PPS sample</th>
<th>Patients with at least one HAI in PPS sample (HAI prevalence)a</th>
<th>Validation-corrected HAI prevalenceb</th>
<th>Occupied beds in the country (average per day)</th>
<th>Patients with at least one HAI on a given day, estimated</th>
<th>Hospital discharges annually in the country</th>
<th>HAI incidence, estimated</th>
<th>Patients with at least one HAI, annually, estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>95% CI</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>95% CI</td>
<td>n</td>
</tr>
<tr>
<td>Austria</td>
<td>13,461</td>
<td>541</td>
<td>4.0</td>
<td>3.4–4.7</td>
<td>36,351</td>
<td>1,461</td>
<td>1,243–1,716</td>
<td>2,707,753</td>
</tr>
<tr>
<td>Belgium</td>
<td>11,800</td>
<td>856</td>
<td>7.3</td>
<td>6.4–8.3</td>
<td>NR</td>
<td>37,651</td>
<td>2,731</td>
<td>2,397–3,109</td>
</tr>
<tr>
<td>Bulgariac</td>
<td>2,200</td>
<td>76</td>
<td>3.5</td>
<td>1.7–6.8</td>
<td>NR</td>
<td>25,324</td>
<td>875</td>
<td>434–1,733</td>
</tr>
<tr>
<td>Croatia</td>
<td>10,466</td>
<td>551</td>
<td>5.3</td>
<td>4.5–6.2</td>
<td>NR</td>
<td>11,047</td>
<td>581</td>
<td>495–683</td>
</tr>
<tr>
<td>Cyprus</td>
<td>1,036</td>
<td>85</td>
<td>8.2</td>
<td>5.4–12.4</td>
<td>ND</td>
<td>1,437</td>
<td>118</td>
<td>77–178</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>15,117</td>
<td>1,015</td>
<td>6.7</td>
<td>5.9–7.6</td>
<td>NR</td>
<td>40,691</td>
<td>2,732</td>
<td>2,413–3,090</td>
</tr>
<tr>
<td>Estonia</td>
<td>4,220</td>
<td>178</td>
<td>4.2</td>
<td>2.4–7.3</td>
<td>NR</td>
<td>4,582</td>
<td>193</td>
<td>111–332</td>
</tr>
<tr>
<td>Finland</td>
<td>9,079</td>
<td>803</td>
<td>8.8</td>
<td>7.5–10.4</td>
<td>NR</td>
<td>15,894</td>
<td>1,406</td>
<td>1,187–1,660</td>
</tr>
<tr>
<td>France</td>
<td>16,522</td>
<td>965</td>
<td>5.8</td>
<td>4.9–7.0</td>
<td>NR</td>
<td>159,810</td>
<td>9,334</td>
<td>7,823–11,116</td>
</tr>
<tr>
<td>Germany</td>
<td>11,324</td>
<td>409</td>
<td>3.6</td>
<td>2.8–4.7</td>
<td>NR</td>
<td>400,132</td>
<td>14,452</td>
<td>11,087–18,789</td>
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<tr>
<td>Greece</td>
<td>9,401</td>
<td>938</td>
<td>10.0</td>
<td>8.5–11.6</td>
<td>NR</td>
<td>18,252</td>
<td>1,821</td>
<td>1,599–2,121</td>
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<tr>
<td>Hungary</td>
<td>20,588</td>
<td>818</td>
<td>4.0</td>
<td>3.3–4.8</td>
<td>NR</td>
<td>46,134</td>
<td>1,833</td>
<td>1,516–2,212</td>
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<tr>
<td>Iceland</td>
<td>633</td>
<td>40</td>
<td>6.3</td>
<td>5.8–36.8</td>
<td>5.7</td>
<td>642</td>
<td>41</td>
<td>5–237</td>
</tr>
<tr>
<td>Ireland</td>
<td>10,333</td>
<td>633</td>
<td>6.1</td>
<td>5.0–7.5</td>
<td>NR</td>
<td>10,932</td>
<td>670</td>
<td>546–820</td>
</tr>
<tr>
<td>Italy</td>
<td>14,773</td>
<td>1,186</td>
<td>8.0</td>
<td>6.8–9.5</td>
<td>NR</td>
<td>167,619</td>
<td>13,457</td>
<td>11,362–15,899</td>
</tr>
</tbody>
</table>

CI: confidence interval; EU/EEA: European Union/European Economic Area; HAI: healthcare-associated infection; NA: not applicable; ND: validation study not done NR: validation study not representative of country PPS sample; PPS: point prevalence survey; UK: United Kingdom.

a Country-weighted HAI prevalence for the EU/EEA = estimated number of patients with at least one HAI a single day / occupied beds.

b Validation-corrected prevalence of patients with at least one HAI: only given for countries that reached national representativeness for their national validation study (at least 75% of recommended sample size of 750 validated patients and/or validation of at least 75% of included hospitals).

c Poor country representativeness in Bulgaria and the Netherlands.
Table 2b. Prevalence and estimated incidence of healthcare-associated infections in European acute care hospitals, 28 EU/EEA countries and Serbia, 2016–2017 (n = 325,737 patients)

<table>
<thead>
<tr>
<th>Country</th>
<th>Patients in PPS sample (HAI prevalence)</th>
<th>Patients with at least one HAI in PPS sample</th>
<th>Validation-corrected HAI prevalence</th>
<th>Occupied beds in the country (average per day)</th>
<th>Patients with at least one HAI on a given day, estimated</th>
<th>Hospital discharges annually in the country</th>
<th>HAI incidence, estimated</th>
<th>Patients with at least one HAI, annually, estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>n %</td>
<td>95% CI</td>
<td>n %</td>
<td>n %</td>
<td>n %</td>
<td>95% CI</td>
<td>n %</td>
</tr>
<tr>
<td>Latvia</td>
<td>3,807</td>
<td>140 3.7</td>
<td>2.6–5.2</td>
<td>4.9</td>
<td>5,127</td>
<td>189 132–268</td>
<td>300,575</td>
<td>2.5 1.4–4.1</td>
</tr>
<tr>
<td>Lithuania</td>
<td>12,415</td>
<td>359 2.9</td>
<td>2.1–4.0</td>
<td>3.2</td>
<td>14,613</td>
<td>423 301–590</td>
<td>705,224</td>
<td>2.6 1.3–4.6</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>2,018</td>
<td>103 5.1</td>
<td>4.0–6.5</td>
<td>8.5</td>
<td>1,860</td>
<td>95 75–120</td>
<td>74,782</td>
<td>3.4 2.1–5.3</td>
</tr>
<tr>
<td>Malta</td>
<td>961</td>
<td>60 6.2</td>
<td>5.2–7.4</td>
<td>7.9</td>
<td>972</td>
<td>61 51–72</td>
<td>72,909</td>
<td>2.6 1.9–3.4</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>4,441</td>
<td>170 3.8</td>
<td>3.4–4.3</td>
<td>NR</td>
<td>24,167</td>
<td>925 826–1,036</td>
<td>1,700,000</td>
<td>2.3 1.6–3.2</td>
</tr>
<tr>
<td>Norway</td>
<td>9,628</td>
<td>495 5.1</td>
<td>4.1–6.4</td>
<td>ND</td>
<td>10,505</td>
<td>540 430–677</td>
<td>7,762–203</td>
<td>2.4 1.5–3.6</td>
</tr>
<tr>
<td>Poland</td>
<td>21,712</td>
<td>1,249 5.8</td>
<td>4.8–6.9</td>
<td>4.7</td>
<td>120,492</td>
<td>6,931 5,764–8,317</td>
<td>8,254,611</td>
<td>3.5 2.3–5.0</td>
</tr>
<tr>
<td>Portugal</td>
<td>16,982</td>
<td>1,544 9.1</td>
<td>8.1–10.2</td>
<td>7.8</td>
<td>27,997</td>
<td>2,537 2,236–2,841</td>
<td>1,128,245</td>
<td>5.9 4.4–7.8</td>
</tr>
<tr>
<td>Romania</td>
<td>11,443</td>
<td>417 3.6</td>
<td>2.8–4.7</td>
<td>5.9</td>
<td>57,091</td>
<td>2,080 1,610–2,682</td>
<td>3,674,275</td>
<td>2.6 1.7–4.0</td>
</tr>
<tr>
<td>Slovakia</td>
<td>9,145</td>
<td>370 4.1</td>
<td>3.1–5.3</td>
<td>NR</td>
<td>20,279</td>
<td>820 630–1,066</td>
<td>1,005,003</td>
<td>3.1 2.1–4.6</td>
</tr>
<tr>
<td>Slovenia</td>
<td>5,720</td>
<td>373 6.5</td>
<td>5.8–7.3</td>
<td>ND</td>
<td>5,581</td>
<td>363 322–409</td>
<td>380,077</td>
<td>4.4 3.3–5.6</td>
</tr>
<tr>
<td>Spain</td>
<td>19,546</td>
<td>1,516 7.8</td>
<td>7.1–8.5</td>
<td>NR</td>
<td>84,908</td>
<td>6,586 5,983–7,243</td>
<td>5,247,215</td>
<td>4.9 3.6–6.4</td>
</tr>
<tr>
<td>UK-England</td>
<td>20,148</td>
<td>1,297 6.4</td>
<td>5.4–7.6</td>
<td>NR</td>
<td>96,774</td>
<td>6,230 5,264–7,358</td>
<td>9,450,142</td>
<td>2.2 1.4–3.2</td>
</tr>
<tr>
<td>UK-Northern Ireland</td>
<td>3,813</td>
<td>234 6.1</td>
<td>4.8–7.9</td>
<td>5.8</td>
<td>4,965</td>
<td>305 236–392</td>
<td>302,008</td>
<td>3.5 1.8–5.9</td>
</tr>
<tr>
<td>UK-Scotland</td>
<td>11,623</td>
<td>504 4.3</td>
<td>3.5–5.3</td>
<td>NR</td>
<td>11,448</td>
<td>496 406–606</td>
<td>1,156,473</td>
<td>2.2 1.5–3.2</td>
</tr>
<tr>
<td>UK-Wales</td>
<td>6,400</td>
<td>362 5.7</td>
<td>4.7–6.7</td>
<td>6.0</td>
<td>6,715</td>
<td>380 318–453</td>
<td>827,063</td>
<td>2.2 1.3–3.3</td>
</tr>
<tr>
<td>Participating EU/EEA countries</td>
<td>310,755</td>
<td>18,287 5.5</td>
<td>4.5–6.7</td>
<td>6.5</td>
<td>1,469,903</td>
<td>80,665 66,864–97,824</td>
<td>89,762,505</td>
<td>3.7 2.4–5.3</td>
</tr>
<tr>
<td>Serbia</td>
<td>14,982</td>
<td>650 4.3</td>
<td>3.5–5.4</td>
<td>NR</td>
<td>18,920</td>
<td>821 656–1,024</td>
<td>988,833</td>
<td>3.3 2.3–4.6</td>
</tr>
<tr>
<td>EU/EEA, corrected d,f</td>
<td>NA</td>
<td>NA 5.5</td>
<td>4.5–7.8</td>
<td>6.5</td>
<td>1,503,881</td>
<td>82,713 67,674–99,256</td>
<td>91,885,503</td>
<td>3.7 2.4–5.3</td>
</tr>
<tr>
<td>EU/EEA, corrected after validation</td>
<td>NA</td>
<td>NA 6.5</td>
<td>5.4–7.8</td>
<td>7.8</td>
<td>1,503,881</td>
<td>98,166 81,022–117,484</td>
<td>91,885,503</td>
<td>4.1 3.4–4.9</td>
</tr>
</tbody>
</table>

CI: confidence interval; EU/EEA: European Union/European Economic Area; HAI: healthcare-associated infection; NA: not applicable; ND: validation study not done NR: validation study not representative of country PPS sample; PPS: point prevalence survey; UK: United Kingdom.

*a Country-weighted HAI prevalence for the EU/EEA = estimated number of patients with at least one HAI a single day / occupied beds.

*b Validation-corrected prevalence of patients with at least one HAI: only given for countries that reached national representativeness for their national validation study (at least 75% of recommended sample size of 750 validated patients and/or validation of at least 75% of included hospitals).

c Poor country representativeness in Bulgaria and the Netherlands.

d Norway used a national PPS protocol requiring imputation of non-included types of HAI for 24 hospitals.

*e Cumulative 95% CI for the EU/EEA. Cumulative sums are rounded and may differ from the sum of the individual rounded country estimates.

f Corrected for non-participating EU countries with estimation for Denmark and Sweden combined.
### Table 3
Country-weighted prevalence and estimated incidence of healthcare-associated infections (HAI) by type of HAI in European acute care hospitals (n = 19,626) and long-term care facilities (n = 3,858), 30 EU/EEA countries, 2016–2017

<table>
<thead>
<tr>
<th>Type of HAI</th>
<th>Acute care hospitals</th>
<th></th>
<th></th>
<th>Long-term care facilities</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HAI in PPS sample</td>
<td>Country-weighted HAI prevalence</td>
<td>Estimated HAI on a given day, EU/EEA</td>
<td>Estimated annual HAI, EU/EEA</td>
<td>HAI in PPS sample</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>% total</td>
<td>95% cCI</td>
<td>N</td>
<td>95% cCI</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>4,200</td>
<td>21.4</td>
<td>1.26</td>
<td>0.96–1.68</td>
<td>18,935</td>
</tr>
<tr>
<td>Other lower respiratory tract infection</td>
<td>838</td>
<td>4.3</td>
<td>0.24</td>
<td>0.15–0.41</td>
<td>3,568</td>
</tr>
<tr>
<td>Common cold/ influenza</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Urinary tract infection</td>
<td>3,710</td>
<td>18.9</td>
<td>1.10</td>
<td>0.85–1.43</td>
<td>16,491</td>
</tr>
<tr>
<td>Surgical site infection</td>
<td>3,601</td>
<td>18.3</td>
<td>1.08</td>
<td>0.81–1.44</td>
<td>16,130</td>
</tr>
<tr>
<td>Bloodstream infection</td>
<td>2,116</td>
<td>10.8</td>
<td>0.69</td>
<td>0.48–1.00</td>
<td>10,294</td>
</tr>
<tr>
<td>Clostridium difficile infection</td>
<td>951</td>
<td>4.8</td>
<td>0.32</td>
<td>0.21–0.51</td>
<td>4,786</td>
</tr>
<tr>
<td>Other gastrointestinal infection</td>
<td>792</td>
<td>4.0</td>
<td>0.24</td>
<td>0.14–0.41</td>
<td>4,549</td>
</tr>
<tr>
<td>Skin and soft tissue infection</td>
<td>823</td>
<td>4.2</td>
<td>0.21</td>
<td>0.13–0.36</td>
<td>4,346</td>
</tr>
<tr>
<td>Eye, ear, nose or mouth infection</td>
<td>557</td>
<td>2.8</td>
<td>0.16</td>
<td>0.09–0.35</td>
<td>2,460</td>
</tr>
<tr>
<td>Systemic infection</td>
<td>1,069</td>
<td>5.4</td>
<td>0.29</td>
<td>0.17–0.52</td>
<td>4,882</td>
</tr>
<tr>
<td>Other infection</td>
<td>969</td>
<td>4.9</td>
<td>0.39</td>
<td>0.29–0.50</td>
<td>4,538</td>
</tr>
<tr>
<td>All types of HAI, EU/EEA</td>
<td>19,626</td>
<td>100</td>
<td>NA</td>
<td>NA</td>
<td>88,204</td>
</tr>
<tr>
<td>All types of HAI, EU/EEA, corrected after validation</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>104,177</td>
</tr>
</tbody>
</table>

cCI: cumulative 95% confidence interval (sum of country-specific lower respectively upper country interval limits); EU/EEA: European Union/European Economic Area; HAI: healthcare-associated infection; NA: not applicable; NI: not included in protocol; PPS: point prevalence survey.

a After correction for non-participating countries. Cumulative sums are rounded and may differ from the sum of the individual rounded country estimates.

b Other lower respiratory tract infections included bronchitis, tracheobronchitis, bronchiolitis, tracheitis, lung abscess or empyema, without evidence of pneumonia.
Antimicrobial resistance

Antimicrobial resistance (AMR) in HAI was evaluated using two indicators: a composite index of AMR and the percentage of carbapenem-resistant Enterobacteriaceae. The composite index of AMR was calculated as the percentage of resistant isolates for the ‘first level’ AMR markers in the PPS protocols divided by the sum of the isolates for which results from antimicrobial susceptibility testing (AST) were reported. These first level markers were *Staphylococcus aureus* resistant to meticillin, *Enterococcus faecium* and *Enterococcus faecalis* resistant to vancomycin, Enterobacteriaceae resistant to third-generation cephalosporins, *Pseudomonas aeruginosa* and *Acinetobacter baumannii* resistant to carbapenem; EARS-Net: Enterobacteriaceae other than *Escherichia coli* and *Klebsiella pneumoniae* not included. Other species represented 32.5% of tested Enterobacteriaceae in ACH. France: percentage non-susceptible (resistant + intermediate) isolates instead of percentage resistant isolates. In addition, sensitivity analyses of the conversion were carried out using a method developed by Willrich et al. (personal communication: Niklas Willrich, 24 May 2018), in which the estimates of the length of stay were based on a Grenander estimator for discrete monotonously decreasing distributions [15].

Prevalence to incidence conversion

Estimates of the total number of HAI and patients acquiring at least one HAI per year in ACH were based on prevalence to incidence conversion using the Rhame and Sudderth formula [14]. Details of the method are reported in the ECDC PPS report for 2011 and 2012 [3]. In addition, sensitivity analyses of the conversion were carried out using a method developed by Willrich et al. (personal communication: Niklas Willrich, 24 May 2018), in which the estimates of the length of stay were based on a Grenander estimator for discrete monotonously decreasing distributions [15].
<table>
<thead>
<tr>
<th>Country</th>
<th>Acute care hospitals</th>
<th>Long-term care facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tested isolates</td>
<td>Resistant isolates</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Austria</td>
<td>217</td>
<td>12.4</td>
</tr>
<tr>
<td>Belgium</td>
<td>495</td>
<td>18.6</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>53</td>
<td>56.6</td>
</tr>
<tr>
<td>Croatia</td>
<td>280</td>
<td>41.4</td>
</tr>
<tr>
<td>Cyprus</td>
<td>37</td>
<td>51.4</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>627</td>
<td>30.8</td>
</tr>
<tr>
<td>Denmark</td>
<td>188</td>
<td>7.4</td>
</tr>
<tr>
<td>Estonia</td>
<td>107</td>
<td>13.1</td>
</tr>
<tr>
<td>Finland</td>
<td>107</td>
<td>13.1</td>
</tr>
<tr>
<td>France</td>
<td>738</td>
<td>21.4</td>
</tr>
<tr>
<td>Germany</td>
<td>197</td>
<td>18.8</td>
</tr>
<tr>
<td>Greece</td>
<td>456</td>
<td>61.2</td>
</tr>
<tr>
<td>Hungary</td>
<td>256</td>
<td>37.9</td>
</tr>
<tr>
<td>Iceland</td>
<td>15</td>
<td>0.0</td>
</tr>
<tr>
<td>Ireland</td>
<td>192</td>
<td>25.0</td>
</tr>
<tr>
<td>Italy</td>
<td>555</td>
<td>42.3</td>
</tr>
<tr>
<td>Latvia</td>
<td>47</td>
<td>59.6</td>
</tr>
<tr>
<td>Lithuania</td>
<td>108</td>
<td>32.4</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>67</td>
<td>14.9</td>
</tr>
</tbody>
</table>

AMR: antimicrobial resistance; CI: confidence interval; EU/EEA: European Union/European Economic Area; HAI: healthcare-associated infection; NA: not applicable; ND: no data collected in national PPS; NP: did not participate; PPS: point prevalence survey; UNK: unknown; UK: United Kingdom.

*Antimicrobial resistance data were not reported by Norway and UK–Scotland in the PPS in acute care hospitals and by Denmark, Norway and UK–Scotland in the PPS in long-term care facilities. Cyprus did not submit case-based HAI data for long-term care facilities. For France, the percentage of non-susceptible (resistant + intermediate) isolates is given instead of the percentage resistant isolates.

Country data representativeness was poor in Bulgaria and the Netherlands for the PPS in acute care hospitals and poor in Austria, Croatia, Cyprus, Greece, Luxembourg, Malta and Poland for the PPS in long-term care facilities.

Cumulative 95% confidence intervals for the EU/EEA. Cumulative sums are rounded and may differ from the sum of the individual rounded country estimates.

Composite index of AMR: Staphylococcus aureus resistant to meticillin, Enterococcus faecium and Enterococcus faecalis resistant to vancomycin, Enterobacteriaceae resistant to third generation cephalosporins, Pseudomonas aeruginosa and Acinetobacter baumannii resistant to carbapenems. Enterobacteriaceae selected for the AMR markers: Escherichia coli, Klebsiella spp., Enterobacter spp., Proteus spp., Citrobacter spp., Serratia spp. and Morganella spp. The percentage of resistance was not calculated if less than 10 isolates were reported.
### Table 4b

Composite index of antimicrobial resistance in bacteria from healthcare-associated infections in acute care hospitals (n = 8,413) and long-term care facilities (n = 565), 30 EU/EEA countries, Serbia and the former Yugoslav Republic of Macedonia, 2016–2017

<table>
<thead>
<tr>
<th>Country</th>
<th>Acute care hospitals</th>
<th>Long-term care facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Composite index of AMR</td>
<td>Carbenem-resistant Enterobacteriaceae</td>
</tr>
<tr>
<td></td>
<td>Tested isolates</td>
<td>Resistant isolates</td>
</tr>
<tr>
<td>Maltab</td>
<td>33</td>
<td>24.2</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>110</td>
<td>14.5</td>
</tr>
<tr>
<td>Norway</td>
<td>ND</td>
<td>NA</td>
</tr>
<tr>
<td>Poland</td>
<td>531</td>
<td>39.9</td>
</tr>
<tr>
<td>Portugal</td>
<td>829</td>
<td>38.4</td>
</tr>
<tr>
<td>Romania</td>
<td>164</td>
<td>68.9</td>
</tr>
<tr>
<td>Slovakia</td>
<td>164</td>
<td>34.8</td>
</tr>
<tr>
<td>Slovenia</td>
<td>194</td>
<td>17.0</td>
</tr>
<tr>
<td>Spain</td>
<td>926</td>
<td>26.6</td>
</tr>
<tr>
<td>Sweden</td>
<td>NP</td>
<td>NA</td>
</tr>
<tr>
<td>UK–England</td>
<td>370</td>
<td>20.5</td>
</tr>
<tr>
<td>UK–Northern Ireland</td>
<td>40</td>
<td>25.0</td>
</tr>
<tr>
<td>UK–Scotland</td>
<td>ND</td>
<td>NA</td>
</tr>
<tr>
<td>UK–Wales</td>
<td>35</td>
<td>37.1</td>
</tr>
<tr>
<td>EU/EEA</td>
<td>8,031</td>
<td>31.6</td>
</tr>
<tr>
<td>Former Yugoslav Republic of Macedonia</td>
<td>NP</td>
<td>NA</td>
</tr>
<tr>
<td>Serbia</td>
<td>382</td>
<td>62.0</td>
</tr>
</tbody>
</table>

AMR: antimicrobial resistance; CI: confidence interval; EU/EEA: European Union/European Economic Area; HAI: healthcare-associated infection; NA: not applicable; ND: no data collected in national PPS; NP: did not participate; PPS: point prevalence survey; UNK: unknown; UK: United Kingdom.

Antimicrobial resistance data were not reported by Norway and UK–Scotland in the PPS in acute care hospitals and by Denmark, Norway and UK–Scotland in the PPS in long-term care facilities. Cyprus did not submit case-based HAI data for long-term care facilities. The Czech Republic only collected institutional indicators for the PPS in long-term care facilities. For France, the percentage of non-susceptible (resistant + intermediate) isolates is given instead of the percentage resistant isolates.

Country data representativeness was poor in Bulgaria and the Netherlands for the PPS in acute care hospitals and poor in Austria, Croatia, Cyprus, Greece, Luxembourg, Malta and Poland for the PPS in long-term care facilities.

Cumulative 95% confidence intervals for the EU/EEA. Cumulative sums are rounded and may differ from the sum of the individual rounded country estimates.

Composite index of AMR: *Staphylococcus aureus* resistant to meticillin, *Enterococcus faecium* and *Enterococcus faecalis* resistant to vancomycin, *Enterobacteriaceae* resistant to third-generation cephalosporins, *Pseudomonas aeruginosa* and *Acinetobacter baumannii* resistant to carbapenems. *Enterobacteriaceae* selected for the AMR markers: *Escherichia coli*, *Klebsiella spp.*, *Enterobacter spp.*, *Proteus spp.*, *Citrobacter spp.*, *Serratia spp.* and *Morganella spp.* The percentage of resistance was not calculated if less than 10 isolates were reported.
### Table 5

Prevalence of healthcare-associated infections in long-term care facilities, 23 EU/EEA countries, Serbia and the former Yugoslav Republic of Macedonia, 2016–2017 (n = 103,763 residents)

<table>
<thead>
<tr>
<th>Country</th>
<th>LTCF included in analysis</th>
<th>Residents included in analysis</th>
<th>Residents with at least one HAI in PPS sample (HAI prevalence)</th>
<th>HAI from other facility</th>
<th>HAI prevalence origin own LTCF</th>
<th>LTCF beds in the country</th>
<th>Residents with at least one HAI on a given day, estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>n</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>Austria*</td>
<td>12</td>
<td>2,065</td>
<td>105</td>
<td>5.1</td>
<td>2.8–8.9</td>
<td>6.5</td>
<td>4.6</td>
</tr>
<tr>
<td>Belgium</td>
<td>79</td>
<td>8,206</td>
<td>354</td>
<td>4.3</td>
<td>3.6–5.1</td>
<td>4.9</td>
<td>3.6</td>
</tr>
<tr>
<td>Croatia*</td>
<td>8</td>
<td>1,803</td>
<td>15</td>
<td>0.9</td>
<td>0.4–1.9</td>
<td>13.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Cyprus*</td>
<td>11</td>
<td>222</td>
<td>15</td>
<td>4.8</td>
<td>2.7–7.8</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Denmark</td>
<td>95</td>
<td>3,366</td>
<td>175</td>
<td>5.2</td>
<td>4.3–6.1</td>
<td>5.0</td>
<td>6.8</td>
</tr>
<tr>
<td>Finland</td>
<td>149</td>
<td>5,914</td>
<td>208</td>
<td>3.5</td>
<td>2.0–4.1</td>
<td>5.1</td>
<td>3.2</td>
</tr>
<tr>
<td>France</td>
<td>91</td>
<td>6,957</td>
<td>206</td>
<td>3.0</td>
<td>2.6–4.4</td>
<td>ND</td>
<td>3.0</td>
</tr>
<tr>
<td>Germany</td>
<td>82</td>
<td>6,795</td>
<td>115</td>
<td>1.7</td>
<td>1.2–2.3</td>
<td>13.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Greece*</td>
<td>13</td>
<td>812</td>
<td>51</td>
<td>6.3</td>
<td>3.7–10.5</td>
<td>3.8</td>
<td>5.9</td>
</tr>
<tr>
<td>Hungary</td>
<td>75</td>
<td>7,670</td>
<td>73</td>
<td>1.0</td>
<td>0.7–1.4</td>
<td>4.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Ireland</td>
<td>109</td>
<td>5,653</td>
<td>276</td>
<td>4.9</td>
<td>4.2–5.8</td>
<td>6.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Italy</td>
<td>196</td>
<td>11,477</td>
<td>442</td>
<td>3.9</td>
<td>3.3–4.6</td>
<td>13.4</td>
<td>3.2</td>
</tr>
<tr>
<td>Lithuania</td>
<td>26</td>
<td>3,438</td>
<td>32</td>
<td>0.9</td>
<td>0.4–1.9</td>
<td>15.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Luxembourg*</td>
<td>16</td>
<td>1,666</td>
<td>30</td>
<td>1.9</td>
<td>1.1–3.0</td>
<td>0.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Malta</td>
<td>11</td>
<td>2,685</td>
<td>76</td>
<td>3.1</td>
<td>1.6–5.9</td>
<td>12.3</td>
<td>3.3</td>
</tr>
<tr>
<td>The Netherlands*</td>
<td>57</td>
<td>4,547</td>
<td>160</td>
<td>3.5</td>
<td>3.0–4.1</td>
<td>5.0</td>
<td>3.2</td>
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<tr>
<td>Norway*</td>
<td>62</td>
<td>2,447</td>
<td>119</td>
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<td>4.0–5.8</td>
<td>2.5</td>
<td>4.6</td>
</tr>
<tr>
<td>Poland*</td>
<td>26</td>
<td>2,281</td>
<td>90</td>
<td>3.9</td>
<td>2.1–7.3</td>
<td>7.6</td>
<td>3.5</td>
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<tr>
<td>Portugal</td>
<td>132</td>
<td>3,933</td>
<td>214</td>
<td>5.9</td>
<td>4.5–7.6</td>
<td>15.9</td>
<td>4.3</td>
</tr>
<tr>
<td>Slovakia</td>
<td>59</td>
<td>5,091</td>
<td>108</td>
<td>2.1</td>
<td>1.5–3.0</td>
<td>4.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Spain</td>
<td>46</td>
<td>6,808</td>
<td>579</td>
<td>8.5</td>
<td>7.0–10.3</td>
<td>18.9</td>
<td>6.2</td>
</tr>
<tr>
<td>Sweden</td>
<td>285</td>
<td>3,604</td>
<td>57</td>
<td>1.6</td>
<td>1.2–2.1</td>
<td>ND</td>
<td>1.6</td>
</tr>
<tr>
<td>UK–Northern Ireland</td>
<td>70</td>
<td>2,814</td>
<td>97</td>
<td>3.7</td>
<td>2.9–4.7</td>
<td>7.1</td>
<td>3.4</td>
</tr>
<tr>
<td>UK–Scotland</td>
<td>52</td>
<td>2,147</td>
<td>125</td>
<td>5.8</td>
<td>4.5–7.5</td>
<td>2.4</td>
<td>5.3</td>
</tr>
<tr>
<td>UK–Wales</td>
<td>28</td>
<td>966</td>
<td>58</td>
<td>6.0</td>
<td>4.4–8.2</td>
<td>0.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Participating EU/EEA countries**</td>
<td>1,188</td>
<td>102,301</td>
<td>3,780</td>
<td>3.6</td>
<td>2.9–4.5</td>
<td>8.9</td>
<td>3.1</td>
</tr>
<tr>
<td>Former Yugoslav Republic of Macedonia</td>
<td>6</td>
<td>294</td>
<td>10</td>
<td>3.4</td>
<td>2.3–4.9</td>
<td>0.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Serbia</td>
<td>6</td>
<td>1,168</td>
<td>37</td>
<td>3.2</td>
<td>1.9–5.1</td>
<td>7.3</td>
<td>2.8</td>
</tr>
<tr>
<td>EU/EEA, corrected**</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>3.6</td>
<td>2.9–4.5</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>EU/EEA, corrected after validation</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>3.9</td>
<td>2.4–6.0</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

EU/EEA: European Union/European Economic Area; HAI: healthcare-associated infection; LTCF: long-term care facility; PPS: point prevalence survey; ND: no data collected in national protocol; UK: United Kingdom.

- The Czech Republic only submitted data on institutional indicators from 11 LTCF and was not included in the current analysis.
- Country-weighted HAI prevalence for the EU/EEA = estimated number of residents with at least one HAI on a single day / occupied beds; occupied beds = number of LTCF beds × average occupancy of 0.95.
- Percentage of HAI imported from a hospital or another LTCF not included in France and Sweden, and unknown for Cyprus (aggregated data).
- HAI prevalence for HAI with the own LTCF as origin, i.e. excluding HAI imported from other healthcare facilities and HAI with unknown origin (Supplement).
- Country data representativeness was poor in Austria, Croatia, Cyprus, Greece, Luxembourg, Malta and Poland.
- Former Yugoslavia Republic of Macedonia = Serbia.
- France, the Netherlands and Norway used a national protocol which required imputation of non-included types of HAI.
- Mean and 95% confidence intervals for the EU/EEA.
- Corrected for non-participating EU/EEA countries with estimation for Bulgaria, Czech Republic, Estonia, Iceland, Latvia, Romania, Slovenia and UK-England combined.
In LTCF, only the number of HAI could be estimated. As LTCF usually are permanent residences, HAI do not prolong the length of stay of a resident as they do in ACH. Therefore, the incidence of HAI in LTCF per year was estimated by multiplying the prevalence by 365 days and dividing it by the duration of infection (in days), with a correction for an average occupancy of LTCF beds of 95%, calculated from institutional denominator data. The duration of infection was estimated, by type of HAI, from the date of onset to the date of the PPS, using the median duration of HAI until the day of the PPS multiplied by 2.

Validation studies

It was strongly recommended that all participating EU/EEA countries perform validation studies of their national PPSs. For the PPS in ACH, ECDC also offered financial support to national institutions coordinating PPS so that they could organise validation studies with a minimum requirement to re-examine 250 patient charts in five ACH. For both the PPS in ACH and that in LTCF, the objective was to estimate representative validity parameters at the EU/EEA level rather than at country level ([16]; ACH validation protocol available from the authors on request). Validation studies were performed by national validation teams composed of members of the national coordination teams, using the ECDC HAI case definitions as gold standard. Validation results were calculated for each country, by matching patients included in the validation sample with their corresponding data collected in the primary PPS. The percentage of false positives (FP) and false negatives (FN) was calculated from the matched analysis and applied to the total national database to calculate the sensitivity and specificity for each country, as several countries selected high prevalence wards for validation to improve precision as recommended by the validation study protocol. For correction of the EU/EEA prevalence of HAI, the EU/EEA mean FN and FP were applied to the total number of patients. The validation-corrected HAI prevalence was converted using the Rhame and Sudderth formula to estimate the corrected annual incidence of patients acquiring at least one HAI per year in the period 2016 to 2017, estimated using the Rhame and Sudderth formula to convert the latter percentage, the corrected annual incidence was estimated at 4.1 (95% CI: 3.4–4.9) patients per 100 admissions. Applying the EU/EEA averages to denominator data from non-participating EU/EEA countries, the weighted annual incidence of patients acquiring at least one HAI per year in the period 2016 to 2017, estimated using prevalence to incidence conversion, was 3.7 (95% CI: 2.4–5.3) patients per 100 admissions. National PPS validation studies were carried out by 28 countries and the percentage of patients requiring intensive care by country is shown in Table 1.

Prevalence and estimated incidence of healthcare-associated infections

A total of 19,626 HAI were reported in 18,287 patients with HAI (1.07 HAI per infected patient). The prevalence of patients with at least one HAI in the EU/EEA sample was 5.9% (country range: 2.9–10.0%; Table 2). The prevalence varied between 4.4% (2,177/49,381 patients) in primary care hospitals (n = 333) to 7.1% (7,591/104,562 patients) in tertiary care hospitals (n = 222) and was highest in patients admitted to intensive care units, where 19.2% (2,751/14,258) patients had at least one HAI compared with 5.2% (15,536/296,397) on average for all other specialties combined (Supplement).

When extrapolated to the average daily number of occupied beds per country, the weighted HAI prevalence was 5.5% (95% CI: 4.5–6.6%). The weighted annual incidence of patients acquiring at least one HAI per year in the period 2016 to 2017, estimated using prevalence to incidence conversion, was 3.7 (95% CI: 2.4–5.3) patients per 100 admissions. National PPS validation studies were carried out by 28 countries (UK administrations counted separately) in a total of 236 ACH in the EU/EEA. National validation teams re-examined 12,228 patient charts independently from the primary PPS surveyors. These studies showed that on average, 2.3% (country range: 0.3–5.6%) of patients who were reported as not having a HAI actually had an HAI (false negatives) while one in five (mean: 20.3%, country range: 0–46.2%) patients from non-participating EU/EEA hospitals were reported as not having an HAI but actually did have an HAI (false positives), resulting in a mean sensitivity of HAI detection of 69.4% (country range: 40.1–94.4%) and a mean specificity of 98.8% (country range: 96.1–100%). When correcting for these results, the adjusted prevalence of patients with at least one HAI was estimated at 6.5% (95% CI: 5.4–7.8%). Using the Rhame and Sudderth formula to convert the latter percentage, the corrected annual incidence was estimated at 4.1 (95% CI: 3.4–4.9) patients per 100 admissions. Applying the EU/EEA averages to denominator data from non-participating EU/EEA
countries (Denmark and Sweden), this resulted in an estimated total of 98,166 (95% cCl: 81,022–117,484) patients with at least one HAI on any given day and 3,758,014 (95% cCl: 3,122,024–4,509,617) patients with at least one HAI per year in the period 2016 to 2017 in ACH in the EU/EEA.

Types of HAI and isolated microorganisms
The most frequently reported types of HAI were respiratory tract infections (21.6% pneumonia and 4.3% other lower respiratory tract infections), urinary tract infections (18.9%), surgical site infections (18.4%), bloodstream infections (10.8%) and gastro-intestinal infections (8.9%), with *C. difficile* infections accounting for 44.6% of the latter or 4.9% of all HAI. Twenty-three per cent of HAI were present on admission. One third of HAI on admission were surgical site infections. Country-weighted prevalence percentages and estimated numbers of HAI per year are shown in Table 3. After correction for non-participating countries and validation, a total of 4.5 million (95% cCI: 2.6–7.6 million) HAI were estimated to occur per year in the period 2016 to 2017 in ACH in the EU/EEA.

A total of 13,085 microorganisms were reported in 10,340 (52.7%) HAI. The 10 most frequently isolated microorganisms were *E. coli* (16.1%), *S. aureus* (11.6%), *Klebsiella* spp. (10.4%), *Enterococcus* spp. (9.7%), *P. aeruginosa* (8.0%), *C. difficile* (7.3%), coagulase-negative staphylococci (7.1%), *Candida* spp. (5.2%), *Enterobacter* spp. (4.4%) and Proteus spp. (3.8%).

Antimicrobial resistance in healthcare-associated infections and correlation with EARS-Net data
AST data were available for 8,031 (88.9%) of 9,034 microorganisms included in the composite index of AMR. The index was 31.6% overall (mean of countries: 30.8%) and varied from 0% in Iceland to 68.9% in Romania. The index by country was strongly correlated with the index calculated from 2016 EARS-Net data on invasive isolates (Spearman’s correlation coefficient rho: 0.93; p < 0.001; R²: 0.86. Figure) and was on average 36% higher for HAI in ACH from the PPS than in the EARS-Net data (mean of countries in EARS-Net: 20.3%). Carbapenem resistance in Enterobacteriaceae was 6.2% overall (mean of countries: 5.9%) and ranged from 0% in Estonia, Finland, Iceland, Lithuania and UK–Northern Ireland to 43.7% in Greece (Table 4). This indicator also correlated well with carbapenem resistance in *E. coli* and *K. pneumoniae* in EARS-Net data (Spearman’s rho: 0.76; p < 0.001) and was on average 45% higher in HAI in ACH from the PPS than in EARS-Net data (mean of countries in EARS-Net: 2.6%). The total number of patients acquiring an HAI with at least one resistant microorganism was estimated at 291,067 (95% cCl: 162,417–504,270) patients for the composite index of AMR and 31,696 (95% cCl: 14,611–78,205) patients for carbapenem-resistant Enterobacteriaceae.

**Point prevalence survey in long-term care facilities**

**Participation**
In total, 3,062 LTCF from 24 EU/EEA countries and two EU candidate countries (Serbia and the former Yugoslav Republic of Macedonia) participated in the third PPS of HAI and antimicrobial use in European LTCF in the period 2016 to 2017. Counting UK administrations separately, good or optimal representativeness of the national sample was obtained in 18 of 24 EU/EEA countries. After adjustment for over-representation, 117,138 residents from 2,221 LTCF were included for analysis. The main aggregated results were reported for 80.5% of participating LTCF, i.e. general nursing homes (n = 1,025), residential homes (n = 176) and mixed LTCF (n = 587), corresponding to 102,301 residents and 1,788 LTCF in EU/EEA countries. The characteristics of LTCF and residents by country are shown in Table 1.

**Prevalence of healthcare-associated infections**
A total of 3,858 HAI were reported in 3,780 residents with HAI (1.02 HAI per infected resident). The prevalence of residents with at least one HAI was 3.7% (country range: 0.9–8.5%). When extrapolated to the average number of occupied LTCF beds per country, the weighted HAI prevalence in LTCF was 3.6% (95% cCl: 2.9–4.5%). Validation of the PPS in LTCF was performed for 953 residents in 17 LTCF in 10 countries. National validation teams found 1.1% (95% CI: 0.5–2.0%) false-negative residents and 19.6% (95% CI: 9.4–33.9%) false-positive residents, yielding a sensitivity of 73.7% and a specificity of 99.2% when applied on the total EU/EEA database. The country-weighted, validation-corrected HAI prevalence was 3.9% (95% cCl: 2.4–6.0%). Applying the EU/EEA prevalence to denominator data from non-participating EU/EEA countries, the total number of residents with at least one HAI on any given day in EU/EEA LTCF was estimated at 129,940 (95% cCl: 79,570–197,625) residents (Table 5).

**Types of healthcare-associated infections and isolated microorganisms**
The most frequently reported types of HAI in LTCF were respiratory tract infections (33.2% overall, 3.7% pneumonia, 22.0% other lower respiratory tract infections, 7.2% common cold/pharyngitis, 0.3% influenza), urinary tract infections (32.0%) and skin infections (21.5%). The majority of the reported HAI (84.7%) were associated with the LTCF where the PPS was performed, while 7.5% and 1.4% were associated with a hospital or the LTCF where the PPS was performed, respectively. The origin was unknown for 6.4% of HAI in LTCF. Country-weighted prevalence percentages and estimated number of infections per year are given by type of HAI in Table 3. The total number of HAI in LTCF in the EU/EEA, after applying EU averages for non-participating EU/EEA countries and correcting for validation, was estimated at 4.4 million (95% cCI: 2.0–8.0 million). Microbiological data in LTCF were available for 742 (19.2%) HAI. The 10 most frequently isolated bacteria were *E. coli* (30.7%), *S. aureus* (11.6%), *Klebsiella* spp. (11.6%), *Enterococcus* spp. (9.7%), *P. aeruginosa* (8.0%), *C. difficile* (7.3%), coagulase-negative staphylococci (7.1%), *Candida* spp. (5.2%), *Enterobacter* spp. (4.4%) and Proteus spp. (3.8%).
Antimicrobial resistance in healthcare-associated infections and correlation with data from the hospital point prevalence survey

AST results were available for 553 (77.6%) of 713 microorganisms included in the composite index of AMR. The index could be calculated for 11 countries with at least 10 isolates, and was 28.0% overall, ranging from 6.8% in Finland to 60.0% in Malta (Table 4). The composite index of AMR correlated well between ACH and LTCF, although Malta was an outlier (Figure, Spearman’s rho excluding Malta: 0.86; p<0.001; R² = 0.69). On average, the percentage of resistant microorganisms was similar in both settings (regression coefficient excluding Malta: 1.08). Carbapenem resistance in Enterobacteriaceae in LTCF was 4.2% overall and did not correlate significantly with the percentage in ACH (Table 4).

Discussion

Because both the PPS in ACH and that in LTCF were performed during 2016 and 2017, this provided the first opportunity to estimate the prevalence, incidence and annual number of HAI for ACH and for LTCF in the EU/EEA for the same time period. As expected, the overall prevalence of HAI was higher in ACH than in LTCF, also after correction based on validation study results. However, when estimating the total number of HAI, both settings were shown to have similarly high numbers of HAI annually. In total, 8.9 million distinct HAI episodes were estimated to occur annually in ACH and LTCF in the EU/EEA. In ACH, where the incidence per patient could be calculated, the number of patients with at least one HAI was estimated at 3.8 (95% cCI: 3.1–4.6) million patients per year in the period 2016 to 2017.

The country-weighted HAI prevalence before validation correction in ACH of 5.5% (95% cCI: 4.5–6.7%) was similar to the HAI prevalence of 5.7% (95% cCI: 4.5–7.4%) in the ECDC PPS in ACH in the period 2011 to 2012 [3]. The unweighted HAI prevalence in LTCF of 3.7% before correction was only slightly higher than the prevalence of 3.4% found in the ECDC PPS in LTCF in 2013 [6], although imported HAI were included in the period 2016 to 2017. The final corrected country-weighted HAI prevalence estimates of 6.5% in ACH and 3.9% in LTCF were higher because they were corrected for the results of the validation studies, which made the current estimates more robust than the previous estimates. Similarly, the estimated incidence and number of HAI in ACH presented in this study were higher than the number estimated in the ECDC PPS from 2011 to 2012 [3] because of the correction for the results of the validation study and should therefore not be interpreted as an increase for ACH compared with the period 2011 to 2012.

The strong correlation of the composite index of AMR in the ECDC PPS in ACH with the EARS-Net data supports the validity of AMR data collected in the PPSs. The 36% higher percentage of resistant isolates in HAI in the ECDC PPS was expected given that EARS-Net only includes data from invasive isolates, i.e. from bloodstream infections and meningitides, and that a large proportion of isolates reported to EARS-Net are from community-associated bloodstream infections, especially for MRSA and E. coli resistant to third-generation cephalosporins. However, the fact that the composite index of AMR in LTCF was at the same level as in ACH, at least in countries where both indicators could be calculated, is of concern. Even though the low testing frequency in LTCF is probably biased towards HAI which are non-responsive to empiric treatment, this finding emphasises the urgent need to reinforce measures to improve infection prevention and control, antimicrobial stewardship as well as microbiological laboratory support for LTCF.

Our study has several limitations. Firstly, the small number of countries and LTCF that performed validation studies in the PPS in LTCF resulted in less robust prevalence estimates for LTCF than for ACH, even though the LTCF validation results could be used at the EU/EEA level. Secondly, the conversion from prevalence to incidence using the Rhamé and Sudderth formula has been shown to have several limitations in itself, especially for smaller samples [17,18]. The estimates depend on the estimators used, as not all data can be acquired from a cross-sectional prevalence study. Nevertheless, sensitivity analyses that we performed with more recent estimator methodology (personal communication: Niklas Willrich, 24 May 2018) [15] yielded EU/EEA estimates which were close to those reported here, with few exceptions at individual country level. Especially considering the wide CI, this gave more weight to our estimates (Supplement). Thirdly, the estimates also strongly depended on the quality of the national denominator data of the number of beds, and, for ACH, discharges and patient days. Providing reliable national denominator data has been shown to be difficult for many countries that sometimes provided estimates rather than precise numbers, especially for LTCF. In addition, as national denominator data for specialised LTCF were only available in two countries, a specific incidence for these types of LTCF could not be estimated. In several countries, however, the number of beds for these LTCF are included in the total number of LTCF beds for the country. We only reported results for the main types of LTCF, as these types were consistently included in all countries. Fourthly, the number of residents with at least one HAI each year could not be estimated for LTCF in the EU/EEA. Longitudinal HAI incidence data would be required to produce such estimates. Fifthly, three countries preferred using their national PPS protocols for LTCF and one country for

*aureus* (12.3%), *Klebsiella* spp. (11.4%), *Proteus* spp. (10.6%), *P. aeruginosa* (7.1%), *Enterococcus* spp. (4.8%), *C. difficile* (4.4%), *Streptococcus* spp. (2.8%) *Enterobacter* spp. (2.1%) and coagulase-negative staphylococci (1.9%).
ACH, resulting in less robust estimates. Sixthly, the total number of HAI with resistant pathogens could only be estimated for ACH because of the poor availability of microbiological results in LTCF. Moreover, the annual incidence estimates of HAI with resistant pathogens in ACH are underestimated because: (i) in almost half of the HAI in ACH, a microorganism was not reported, (ii) for 11% of the reported microorganisms, AST results were not yet available on the day of the PPS and (iii) correction for countries without data and correction for validation was not performed. Despite these limitations, the estimated number of HAI with carbapenem-resistant Enterobacteriaceae using Rhame and Sudderth conversion in our study (31,696 infections, of which 27,393 were HAI with carbapenem-resistant *E. coli* or *K. pneumoniae*) was close to the number of 33,172 infections with carbapenem-resistant *E. coli* or *K. pneumoniae* recently estimated by Cassini et al. using a different methodology [19].

The main strengths of this study are its large sample size and the use of standardised protocols for data collection and validation across participating ACH and LTCF. Despite some countries providing less representative samples, these PPSs as a whole offer a representative picture of HAI in the EU/EEA, with benchmarks to help direct future action in ACH and LTCF in participating countries.

**Conclusion**

This study reports, to our knowledge, the most accurate and robust estimates of the total number of HAI in healthcare facilities in the EU/EEA to date, and confirms that HAI, and AMR in bacteria responsible for HAI, represent a significant healthcare issue and public health challenge for the EU/EEA. Considering that previous studies have shown that HAI in ACH alone are responsible for more deaths in the EU/EEA than all other infectious diseases under surveillance at European level [1,2], and that our study showed that there are as many HAI in LTCF as there are in ACH, more focus needs to be dedicated to the prevention of HAI and AMR, through the application of available recommendations and guidelines [20-25], in both ACH and LTCF.

*Erratum*

The list of members of the Healthcare-Associated Infections Prevalence Study Group was left out in the original publication and was added on 16 November 2018.

**Members of the Healthcare-Associated Infections Prevalence Study Group**

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**Conflict of interest**

None declared.

**Authors’ contributions**

Carl Suetens performed the analysis and wrote the original draft; Katrien Latour, Tommi Kärki, Enrico Ricchizi and Pete Kinross performed analyses, contributed to the development of the study design and the coordination of the execution of the study; Katrien Latour, Enrico Ricchizi, Béatrice Jans and Maria Luisa Moro were the contractor team that supported ECDC for the coordination of the third PPS in long-term care facilities (ECDC-funded HALT-3 project). Sonja Hansen, Susan Hopkins, Outi Lyytikäinen, Jacqui Reilly, Alexander Deptula and Walter Zingg were members of the HALT-3 PPS expert group that developed the methodology of the survey in acute care hospitals; Pete Kinross contributed to the coordination of the execution of the study; Diamantis Plachouras and Dominique L Monnet contributed to the analysis plan and the methodology of the survey; the members of the Healthcare-Associated Infections study group members contributed to the development of the study design, approved the design of the survey, contributed to the coordination of the execution of the study in their respective countries, and provided national interpretations on the analysis. All authors critically reviewed and edited the manuscript.

**References**


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