# Health-care-associated infections in neonates, children, and adolescents: an analysis of paediatric data from the European Centre for Disease Prevention and Control point-prevalence survey

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**Summary**

**Background.** In 2011–12, the European Centre for Disease Prevention and Control (ECDC) held the first Europe-wide point-prevalence survey of health-care-associated infections in acute care hospitals. We analysed paediatric data from this survey, aiming to calculate the prevalence and type of health-care-associated infections in children and adolescents in Europe and to determine risk factors for infection in this population.

**Methods.** Point-prevalence surveys took place from May, 2011, to November, 2012, in 1149 hospitals in EU Member States, Iceland, Norway, and Croatia. Patients present on the ward at 0800 h on the day of the survey and who were not discharged at the time of the survey were included. Data were collected by locally trained health-care workers according to patient-based or unit-based protocols. We extracted data from the ECDC database for all paediatric patients (age 0–18 years). We report adjusted prevalence for health-care-associated infections by clustering at the hospital and country level. We also calculated risk factors for development of health-care-associated infections with use of a generalised linear mixed-effects model.

**Findings.** We analysed data for 17 273 children and adolescents from 29 countries. 770 health-care-associated infections were reported in 726 children and adolescents, corresponding to a prevalence of 4.2% (95% CI 3.7–4.8). Bloodstream infections were the most common type of infection (343 [45%] infections), followed by lower respiratory tract infections (171 [22%]), gastrointestinal infections (64 [8%]), eye, ear, nose, and throat infections (55 [7%]), urinary tract infections (37 [5%]), and surgical-site infections (34 [4%]). The prevalence of infections was highest in paediatric intensive care units (15.5%, 95% CI 11.6–20.3) and neonatal intensive care units (10.7%, 9.0–12.7). Independent risk factors for infection were age younger than 12 months, fatal disease (via ultimately and rapidly fatal McCabe scores), prolonged length of stay, and the use of invasive medical devices. 392 microorganisms were reported for 342 health-care-associated infections, with Enterobacteriaceae being the most frequently found (113 [15%]).

**Interpretation.** Infection prevention and control strategies in children should focus on prevention of bloodstream infections, particularly among neonates and infants.

## Research in context

### Evidence before this study

We searched PubMed with the search terms "cross infection" [MeSH], "healthcare-associated infection$", "nosocomial infection$", and "hospital-acquired infection$") in combination with "prevalence", with age restriction (0–18 years) but without language or time restriction (up to June 30, 2016). Of 928 titles and abstracts, 15 reports were multicentre national or multinational prevalence surveys in high-income countries. One report was the pilot testing of the European Centre for Disease Prevention and Control (ECDC) point-prevalence survey in 2010. Two national surveys (Scotland and Poland) were part of the ECDC point-prevalence survey 2011–12 reported in this study. Most surveys were done in acute care adult or mixed adult and paediatric health-care settings. Only one multinational point-prevalence survey reported paediatric data. Between 1983 and 1987, WHO conducted a multinational prevalence survey in 47 hospitals of 14 high-income and upper-middle-income countries. Nine surveys were conducted in a general population in which children were included, two addressed neonatal intensive care only, and one was done in general paediatric wards. Finally, one study in the UK and Ireland focused exclusively on respiratory tract infections in children.

### Added value of this study

This analysis of paediatric data from the ECDC point-prevalence survey 2011–12 represents the largest multinational study on prevalence of health-care-associated infections in children. The adjusted prevalence of health-care-associated infections was 4.2% (95% CI 3.7–4.8). The survey confirms that the burden of infections is highest in infants younger than 12 months and in neonatal and paediatric intensive care units. Bloodstream infection was the most common type of health-care-associated infection, not only in neonates and infants in their first 11 months of life but throughout most of childhood. With older age, infections such as lower respiratory tract infections or surgical-site infections were more common. The variation of prevalence among countries could not be explained by the distribution of paediatric settings, nor did it follow a geographical or socioeconomic pattern.

### Implications of all the available evidence

Infection prevention and control should focus on the prevention of bloodstream infections in the youngest age groups, particularly in neonatal and paediatric intensive care units.

## Introduction

For many years, point-prevalence surveys have been used for surveillance of health-care-associated infections.[1] The pioneering project Study on the Efficacy of Nosocomial Infection Control (SENIC), initiated in the 1970s by the US Centers for Disease Control and Prevention (CDC), used repeated point-prevalence surveys to study the benefit of establishing infection prevention and control teams in US hospitals.[2] In the following years, the US National Nosocomial Infection Surveillance (NNIS) system established prospective surveillance for health-care-associated infections in intensive care units, which was adopted for use by national surveillance networks in other countries. Incidence surveillance has become the gold standard for surveillance of health-care-associated infections in high-risk specialties such as intensive care, oncology, or neonatal care, and for selected infections such as ventilator-associated pneumonia and catheter-associated urinary tract and bloodstream infections. However, incidence surveillance is almost never done for all infection types because it is cumbersome and resource-demanding. Point-prevalence surveys offer an alternative method to incidence surveillance to estimate the hospital-wide burden of health-care-associated infections within a reasonable budget.[1] Thus, they can be used a wider range of settings including institutes with limited resources and allow broader comparison of rates across a wider range of sociocultural contexts.

In July, 2008, the coordination of the European Union (EU)-funded network Improving Patient Safety in Europe (IPSE) and its surveillance component (previously Hospitals in Europe Link for Infection Control through Surveillance [HELICS]) were transferred to the European Centre for Disease Prevention and Control (ECDC) to form a new surveillance network (HAI-Net), which, in 2009, started planning the first EU-wide point-prevalence survey of health-care-associated infections and antimicrobial use in acute care hospitals.[3]

In 2011–12, the EU Member States, Iceland, Norway, and Croatia participated in this ECDC point-prevalence survey. Data for 273,753 patients from 1149 hospitals were submitted to ECDC and, to obtain similar precision in health-care-associated infections prevalence estimates for all participating countries, a representative subsample of hospitals was drawn from the data for countries that were over-represented such as Belgium, Portugal, and Spain. 231,459 patients from 947 hospitals remained in the final ECDC database.[3] The prevalence of patients with one or more health-care-associated infections was 6.0% (country range 2.3–10.8%).3 When extrapolated to the average daily number of occupied beds per country, the adjusted overall prevalence of health-care-associated infections was estimated to be 5.7% (95% CI 4.5–7.4). The most frequent types of infections were lower respiratory tract infections (pneumonia and other lower respiratory tract infections), followed by surgical-site infections, urinary tract infections, bloodstream infections, and gastrointestinal infections.[3] In this Article, we present results of an analysis of data from paediatric patients who were enrolled in the ECDC point-prevalence survey. We aimed to calculate the prevalence of health-care-associated infections among hospitalised children and adolescents in Europe; to describe the distribution of types of health-care-associated infections in different paediatric settings and age groups; and to determine risk factors for health-care-associated infections among hospitalised children and adolescents in Europe.

## Methods

### The ECDC point-prevalence survey

National contact-points in EU Member States, Iceland, Norway, and Croatia agreed to organise a point-prevalence survey of health-care-associated infections and antimicrobial use in acute care hospitals in their country based on a standardised study protocol developed by ECDC.[4] These surveys took place on one day during one of the following periods: May to June, 2011, September to October, 2011, May to June, 2012, and September to November, 2012. These periods were chosen to fall outside winter (when there is a higher antimicrobial use) and outside summer (when there is a lower staffing rate). Countries had to organise their national surveys in one of the specified periods. The choice of the period was free depending on national priorities and work plans. Each country defined their own start date which they communicated to their hospitals. The only recommendations in the ECDC protocol were to avoid Mondays in wards that admit more patients on Mondays, to collect data for one ward on a single day, and to collect data for all hospital wards within 3 weeks. The national point-prevalence survey could be performed according to two methods for data collection: a patient-based protocol (referred to as the standard protocol) and a unit-based protocol (light protocol). In the standard protocol, demographic and risk factor data were collected for every single patient. In the light protocol, denominator data were aggregated at the ward level and for each specialty (e.g., total of paediatric surgical patients in the ward), and demographic and risk factor data were collected individually for each patient with at least one health-care-associated infection. Data were collected by locally trained health-care workers and submitted to the national point-prevalence survey coordinators, who themselves submitted the data to ECDC. Additional information about the ECDC point-prevalence survey methodology is available in the ECDC report.[3]

### Procedures

All children and adolescents (aged 0–18 years) were eligible for the ECDC point-prevalence survey if hospitalised in general paediatric wards, paediatric surgery wards, paediatric intensive care units (PICU), neonatal care units, or neonatal intensive care units (NICU), and admitted before 0800 h on the day of the survey. Those in day-care or long-term-care wards and healthy newborn babies in maternity wards were excluded. Data for patients and health-care-associated infections were retrieved from patient charts and other sources (e.g., hospital information system, laboratory database) using standardised data collection forms.

We extracted data from the ECDC database for the type of infection according to the case definitions;[4] the date of onset of the infection; the presence of invasive devices in the 48 h before onset of infection (for lower respiratory tract infections, urinary tract infections, and bloodstream infections); the microorganisms isolated; and selected antimicrobial resistance data. All data were collected by hospital point-prevalence survey staff on the day of the survey as part of the protocol.[4]

Definitions for health-care-associated infections were based on those from the German Krankenhaus Infektions Surveillance System (KISS) for neonatal infections[5] and from the European Society for Clinical Microbiology and Infectious Diseases Study Group for *Clostridium difficile* (ESGCD).[6] The definitions of health-care-associated infections used for paediatric patients are shown online (appendix).

### Statistical analysis

Our main outcomes were the prevalence of health-care-associated infections (defined as the proportion with one or more infections among all paediatric patients) and distribution of infection types in children and adolescents among countries and clinical settings. To calculate these outcomes, we combined data obtained with the standard and the light protocol. To calculate prevalence and 95% CIs we used two nested levels of clustering at the hospital level and country level to take into account the correlation of data within the levels.

Other outcomes were patient characteristics, exposure, and clinical settings, stratified by cases (children with a health-care-associated infection) and controls (children without a health-care-associated infection). To calculate data for these outcomes we did a descriptive analysis on data obtained with the standard protocol. We compared categorical variables using the $\chi 2$ test. We summarised continuous variables as means or medians and compared using the Student's *t* test or the Wilcoxon's rank-sum test where appropriate. 95% CI for proportions of patients are binomial exact CIs.

For our analysis of risk factors for health-care-associated infections we used data obtained with the standard protocol. We used a generalised linear mixed effects model with a logit link function to adjust for risk factors. In the multivariable model, we adjusted for the following confounders: sex; age stratified into five groups (<1 month, 1–11 months, 1–4 years, 5–10 years, ≥11 years); McCabe score (non-fatal disease, ultimately fatal disease [i.e., fatal outcome within the next 5 years], and rapidly fatal disease [i.e., fatal outcome within the next 6 months]);[7] use of any invasive medical device (central catheter, peripheral line, urinary catheter, and ventilation)

alone or combined; and length of hospital stay, defined as the days before and including the day of the point-prevalence survey for controls and as before and including the first day of infection for children with health-care-associated infections and stratified into four categories (<4 days, 4–7 days, 8–14 days, and >14 days). Patients with missing data were not included in this analysis. No consistent information was available about the size of the paediatric settings or whether hospitals were for children only. As a proxy we stratified the analysis into four groups by number of children from that centre enrolled in the survey (≤25, 26–40, 41–70, and >70 children).

Data reporting was done according to STROBE.[8] Ethical approval was at the discretion of each national public health and government body in charge of each national point-prevalence survey (approval is not needed in all countries because point-prevalence surveys are part of national public health/health-care-associated infection surveillance plans). Anonymised patient and hospital level data were shared with the ECDC. Under EU legislation, patient consent for this surveillance study was not needed.

**Role of the funding source**
There was no specific funder for this analysis. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

## Results

Of the 231 459 patients included in the final ECDC point-prevalence survey database, 17,273 were children in 29 countries. Children were hospitalised in 1356 wards in 618 hospitals, of which 148 (24%) were primary hospitals, 260 (42%) secondary hospitals, 146 (24%) tertiary hospitals, 39 (6%) specialised hospitals, and 25 (4%) of unknown status. Most children were hospitalised in general paediatric wards (n=8298; 48%), followed by neonatal units (n=4467; 26%), NICUs (2283; 13%), paediatric surgery wards (1437; 8%), and PICUs (788, 5%; figure 1). 16 237 (94%) children were registered on the study with use of the standard protocol, and 1036 (6%) with use of the light protocol. In the standard protocol population, most children were younger than 12 months of age (5587 [34%] younger than 1 month; 4024 [25%] aged 1–11 months). 2970 (18%) children were aged 1–4 years, 1753 (11%) aged 5–10 years, and 1864 (12%) aged 11 years or older. Data for age were missing for 39 (<1%) children.

In the unadjusted descriptive analysis (table 1), children with health-care-associated infections were of lower age, more likely to have a rapidly fatal McCabe score, had previous surgery, had any invasive device in place 48 h before infection or on the day of survey, had prolonged length of stay up to the survey, and were more likely to be hospitalised in PICUs or NICUs (table 1).

770 health-care-associated infections were recorded in 726 children, corresponding to a prevalence of 4.2% (95% CI 3.7–4.8). The range of prevalence in Europe was 1.2–10.4% (figure 1; appendix). Poland, Finland, and Cyprus had a prevalence above the upper limit of the 95% CI for the total population (figure 1) and the Czech Republic and Italy had a prevalence below the lower limit of the 95% CI (figure 1).

PICUs (15.5%, 95% CI 11.6–20.3) and NICUs (10.7%, 9.0–12.7) had the highest prevalence of health-care-associated infections, followed by neonatology wards (3.5%, 2.8–4.5), paediatric surgery wards (3.4%, 2.3–4.9), and general paediatric wards (1.8%, 1.4–2.4). These prevalence data were similar after we accounted for the number of children in these settings (appendix). Centres contributing more than 70 children to the database had a higher prevalence of health-care-associated infections (6.5%, 95% CI 6.1–6.8) compared with centres contributing 41–70 children (4.9%, 4.6–5.2), 26–40 children (3.2%, 3.0–3.5), and 25 children or fewer (2.4%, 2.2–2.5) to the database. Patients from centres contributing more children also had less favourable McCabe scores, more patients hospitalised in NICUs or PICUs, higher use of invasive medical devices, and enrolled children who were hospitalised longer (appendix). Most health-care-associated infections (592 [77%] of 770 infections) were identified in infants younger than 12 months. The prevalence of health-care-associated infections per age group was as follows: 5.1% (95% CI 4.5–5.7) in children younger than 1 month; 6.5% (5.7–7.2) in those aged 1–11 months; 2.2% (1.6–2.7) in those aged 1–4 years; 2.1% (1.4–2.8) in those aged 5–10 years; and 2.8% (2.0–3.5) in those aged 11 years or older.

Bloodstream infection was the most common type of health-care-associated infection (44.6%, 95% CI 41.0–48.1), followed by lower respiratory tract infections (22.2%, 19.3–25.2), gastrointestinal infections (8.3%, 6.4–10.3), eye, ear, nose, and throat infections (7.1%, 5.3–9.0), urinary tract infections (4.8%, 3.3–6.3), and surgical-site infections (4.4%, 3.0–5.9). The distribution of the types of infections differed by country and this could not be explained by the distribution of the different paediatric settings (appendix). Bloodstream infection was the most common type of these infections in all age groups apart from for children aged 5–10 years, in whom lower respiratory tract infections were most common (figure 2). Urinary tract infections were uncommon in neonates, but

contributed to up to a tenth of health-care-associated infections in older age groups. Surgical-site infections became more frequent in older age groups (figure 2).

Compared with neonates, children in older age groups, particularly after 11 months of age, were less likely to develop a health-care-associated infection (table 2). Both ultimately and rapidly fatal McCabe scores were significantly associated with having at least one infection. Length of stay up to the day of the survey was a time dependent risk for health-care-associated infections (table 2). Having one or more invasive medical devices in place was highly associated with having a health-care-associated infection (table 2).

392 microorganisms were reported in 342 (44%) of the 770 health-care-associated infections; 343 (88%) were bacteria, 28 (7%) fungi, and 21 (5%) viruses. Enterobacteriaceae were the most commonly isolated microorganisms (113 [15%]), followed by coagulase negative staphylococci and *Staphylococcus aureus* (table 3). Coagulase-negative staphylococci were the most common microorganism in neonates and infants younger than 12 months (table 3). 19% of *S aureus* isolates were resistant to meticillin. 44% of Enterobacteriaceae isolates were resistant to third-generation cephalosporins and 9% were resistant to carbapenems (appendix). Of the few reported viruses, rotaviruses were the most frequently identified (13 of 21 isolates); other viruses identified were cytomegalovirus (three), HIV (one), herpes simplex virus (one), norovirus (one), respiratory syncytial virus (one), and without further specification (one).

## Discussion

Our results show that the burden of health-care-associated infections in childhood is highest in the first year of life and demonstrate the importance of bloodstream infections as the most common type of infections in children. Lower respiratory tract infections and surgical-site infections were more frequent in older age groups and the distribution of infections in children aged 5 years or older was close to the distribution of health-care-associated infections in adults.[1,3,9,10] These findings suggest that age-adapted strategies are needed for infection prevention and control in paediatric settings, with focus on the prevention of bloodstream infections.

We observed variations in the prevalences and distribution of health-care-associated infections among European countries. These variations could not be explained by the distribution of paediatric settings in the database, nor did they follow a geographical pattern. Although the range of prevalence by country was wide, only a few countries were significant high or low outliers (figure 1). No specific conclusion on the effectiveness of national infection prevention and control practices could be drawn from our results. Age as well as ultimately and rapidly fatal McCabe scores, length of stay, and invasive medical device use were independent risk factors for health-care-associated infections (table 2). As a proxy for the effects of the size of the participating settings and whether they were children's hospitals, our analysis found that hospitals that had enrolled more children had a higher prevalence of health-care-associated infections.

The low prevalence in the age group younger than 1 month was unexpected. A closer look revealed that this was due to the fact that, in the sample of paediatric settings that participated in the ECDC point-prevalence survey, (non-intensive) neonatal units contributed 66% of the neonatal population. Indeed, most neonates were hospitalised in regular non-intensive-care neonatology units. This observation is of interest because, in the published work, studies of preterm neonates in NICUs are more common than those of infants in other neonatal units and thus, might contribute to a perceived high risk for health-care-associated infections in the neonatal population as a whole. However, some neonates with prolonged hospital stay were classified in the age group of 1–11 months, and thus, contributed to the high prevalence in this age group.

Very few paediatric data have been reported from cross-national point-prevalence surveys. Between 1983 and 1987, WHO held a multinational point-prevalence survey in 47 hospitals from 14 countries (Australia, China, Czechoslovakia, Denmark, Egypt, Greece, Kuwait, Malaysia, Nepal, Netherlands, Singapore, Spain, Thailand, and UK).[11] 28,861 patients were included, of whom 3147 (11%) were children. Prevalences of health-care-associated infections in the four age groups of children (<1 month, 1–11 months, 1–4 years, and 5–14 years) were 8.8%, 13.5%, 9.3%, and 6.7%, respectively. Since few data are provided from multinational studies, more information can be obtained from national point-prevalence surveys (table 4).[9,12–25] One point-prevalence survey was the ECDC pilot survey in 2010.[25] Eight national point-prevalence surveys were done in a general patient population in which children were included,[9,12,14,16,18–22] two specifically addressed children in NICUs,[17,23] and one was done in general paediatric wards.[24] One study in the UK and Ireland focused exclusively on lower respiratory tract infections in children.[15] The largest paediatric dataset was from a national point-prevalence survey conducted in France in 2001.[19] In this survey, the prevalence of health-care-associated infections among children was 2.4% (95% CI 2.2–2.6%; table 4). The group of neonates also included newborn babies in maternity units, which might be the reason for the low prevalence of health-care-associated infections in this group (1.2%, 95% CI 1.0–1.5). Additionally, the

proportion of laboratory-confirmed health-care-associated infections (456 [81%] of 562) was unusually high, which raises concerns about the possible underestimation of infection prevalence, in particular lower respiratory tract infections and clinical sepsis.

As in our study, bloodstream infection was the most common type of health-care-associated infection in these reports (range 22.1–52.6% of infections).[14,17,18,26] However, although the vast majority of bloodstream infections in our study were reported in infants younger than 12 months, the proportion of bloodstream infections remained high in other age groups. Lower respiratory tract infections and surgical-site infections were more frequent in children aged 5 years or older. Urinary tract infections were not common and overall were less important than other types, particularly in older age groups (figure 2).

Our results suggest that neonates and infants requiring intensive care are at high risk of health-care-associated infections. Other reports identified risk factors for health-care- associated infections similar to those identified in our study—i.e., young age and surgery,[14] presence of an invasive device and prolonged length of stay,[26] central venous catheter or mechanical ventilation,[20] and young age and an ultimately or rapidly fatal McCabe score.[18] In our study, all tested risk variables were independently and significantly associated with health-care-associated infections, but the highest effects were found for the use of invasive medical devices and for length of stay of longer than 14 days up to the day of the survey or the first day of infection (table 2)

The two most common groups of microorganisms among children in our study were Enterobacteriaceae and coagulase-negative staphylococci (table 3), which was similar to findings in France (Enterobacteriaceae 21.9%; coagulase-negative staphylococci 21.9%),[19] Switzerland (50.0% and 29.2%, respectively),[18] and the USA (25.6% and 31.6%, respectively).[17] In a Mexican study, the most common pathogen in health-care-associated infections among children was *Klebsiella pneumoniae* (31.0%).[27] The proportion of meticillin-resistant *S aureus* (MRSA) in health-care-associated infections in children in the French point-prevalence survey was 26.7%.[19] No MRSA was reported in paediatric patients in the Swiss study.[18] The relatively low number of microbiologically documented health-care-associated infections was due to the high proportion of infection types that did not require microbiology testing, such as clinical sepsis or pneumonia.

Our study has some limitations. First, data for the ECDC survey were collected by many individuals in different countries. Training was provided in all participating countries but data validation based on samples of sufficient size was not possible due to resource limitations. Second, the results of this study might not be representative of the paediatric patient populations in acute care in all European countries. Future point-prevalence surveys should take into account representativeness of subgroups of paediatric patients. Third, conducting the survey at four different time periods might have introduced bias in the case-mix of patients, particularly because they took place in different seasons and over 2 years. However, these time periods were not in winter and summer seasons where paediatric settings are particularly prone to either low or high ward occupancy. Fourth, the data collection forms had limited fields for paediatric data. For example, more information about birth-weight and prematurity would have been needed to adjust for relevant risk factors for health-care-associated infections in neonates, and specific information was missing about the paediatric settings (e.g., free standing children's hospital, level of care, casemix). Fifth, only microbiology data available on the day of the point-prevalence survey were included and thus, both the distribution of microorganisms and antibiotic resistance data might not be representative for the sample. Although having incomplete microbiology data does not interfere directly with identification of health-care-associated infections, it might have consequences in subcategorising the type of infection. Sixth, healthy newborn infants might have been coded as belonging to a non-intensive neonatal unit, instead of being in gynaecology and obstetrics departments. We assume that the proportion of miscoded infants was low, but it could have affected data for the overall prevalence of health-care-associated infections in neonatal wards. Seventh, calculating weighted EU and European Economic Area estimates as reported in the ECDC point-prevalence survey report for the overall survey[3] was not possible because no specific information was available on the number of paediatric beds and patient-days in the countries.

Our analysis of paediatric data from the ECDC point-prevalence survey 2011–12 represents the largest multinational study on the prevalence of health-care-associated infections in children so far. Despite its limitations, our findings provide detailed information on the prevalence and distribution of health-care-associated infections among hospitalised children in Europe. Our results show that the prevalence of health-care-associated infections in NICUs and PICUs in Europe remains unacceptably high. Bloodstream infections in neonates and children are associated with a high mortality and longterm adverse neurological outcomes.[28] Prevention of health-care-associated infections in children in Europe requires a multinational quality improvement programme, with a focus on NICUs and PICUs and on health-care-associated bloodstream infections.

**Contributors**

WZ, AG-A, MS, and CS planned the paediatric data analysis and WZ and AGA did the analysis. WZ wrote the first draft of the manuscript. All authors and study group members reviewed and contributed to subsequent drafts and approved the final version for publication.

**Declaration of interests**
We declare no competing interests.

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**Table 1. Patient characteristics, exposures, and clinical areas (standard protocol)**

| | All (N = 16,237) | Without HAI (N = 15,538) | With HAI (N = 699) | *P*-value |
|---|---|---|---|---|
| **Patient characteristics** | | | | |
| Female gender, % [95%CI] | 46.0 [45.3-46.8] | 46.2 [45.4-47.0] | 42.5 [38.8-46.2] | 0.055 |
| Age (months), median [IQR] | 3 [0-48] | 3 [0-48] | 1 [0-7] | <0.001 |
| Neonates, % [95%CI] | 33.2 [32.5-33.9] | 32.9 [32.2-33.6] | 39.8 [36.1-43.4] | <0.001 |
| Rapidly fatal McCabe score, % [±SD] | 0.7 [0.6-0.8] | 0.6 [0.4-0.7] | 3.9 [2.4-5.3] | <0.001 |
| **Exposures** | | | | |
| Surgery*, % [95%CI] | 9.1 [8.7-9.6] | 8.5 [8.0-8.9] | 23.9 [27.1] | <0.001 |
| Central catheter*, % [95%CI] | 7.1 [6.7-7.5] | 5.8 [5.4-6.1] | 36.9 [33.3-40.5] | <0.001 |
| Peripheral line*, % [95%CI] | 38.7 [37.9-39.4] | 37.4 [36.6-38.2] | 67.2 [63.8-70.7] | <0.001 |
| Urinary catheter*, % [95%CI] | 2.2 [2.0-2.4] | 1.8 [1.6-2.0] | 11.6 [9.2-14.0] | <0.001 |
| Ventilation*, % [95%CI] | 3.0 [2.8-3.3] | 2.2 [1.9-2.5] | 22.0 [19.0-25.1] | <0.001 |
| Length of stay (days)**, median [IQR] | 4 [2-8] | 4 [2-8] | 12 [6-26] | <0.001 |
| **Clinical areas** | | | | |
| Paediatric intensive care, % [95%CI] | 4.7 [4.4-5.0] | 4.1 [3.8-4.5] | 17.3 [14.5-20.1] | <0.001 |
| Neonatal intensive care, % [95%CI] | 13.2 [12.6-13.7] | 12.3 [11.7-12.8] | 33.3 [29.8-36.8] | <0.001 |
| Neonatology, % [95%CI] | 25.8 [25.1-26.4] | 25.9 [25.2-26.6] | 22.5 [19.4-25.6] | 0.042 |
| Paediatric surgery, % [95%CI] | 8.0 [7.6-8.4] | 8.1 [7.6-8.5] | 6.7 [4.9-8.6] | 0.210 |
| General paediatrics, % [95%CI] | 48.4 [48.4-49.2] | 49.7 [48.9-50.4] | 20.2 [17.2-23.2] | <0.001 |

*Before or on the day of the point-prevalence survey
**Before and including the day of the point-prevalence survey
95%CI: 95% confidence interval; HAI: health-care-associated infection; IQR: interquartile range

**Table 2. Independent risk factors for health-care-associated infection from the multivariable model**

| | OR | 95%CI | *P*-value |
|---|---|---|---|
| **Gender** | | | |
| Girl | 1.0 | - | - |
| Boy | 1.1 | 1.0-1.4 | 0.150 |
| **Age group** | | | |
| <1 month | 1.0 | - | - |
| 1-11 months | 0.6 | 0.5-0.7 | <0.001 |
| 1 – 4 years | 0.2 | 0.2-0.3 | <0.001 |
| 5 – 10 years | 0.2 | 0.1-0.3 | <0.001 |
| ≥11 years | 0.2 | 0.2-0.3 | <0.001 |
| **McCabe classification** | | | |
| Nonfatal | 1.0 | - | - |
| Ultimately fatal | 2.3 | 1.3-4.1 | 0.003 |
| Rapidly fatal | 2.5 | 1.7-3.6 | <0.001 |
| **Length of stay (days)*** | | | |
| <4 | 1.0 | - | - |
| 4-7 | 3.3 | 2.4-4.5 | <0.001 |
| 8-14 | 6.7 | 4.9-9.1 | <0.001 |
| >14 | 14.9 | 11.0-20.1 | <0.001 |
| **Presence of at least one invasive medical device** | | | |
| No | 1.0 | - | - |
| Yes | 15.3 | 11.9-19.7 | <0.001 |

*For cases: before and including the first day of health-care-associated infection. For controls: before and including the day of the point-prevalence survey.
95%CI: 95% confidence interval; OR: odds ratio

**Table 3. Identified microorganisms for all children and adolescents with health-care-associated infections and by age group**

| Microorganism | Age group | | | | | |
|---|---|---|---|---|---|---|
| | All | <1 month | 1-11 months | 1-4 years | 5-10 years | ≥11 years |
| Coagulase-negative staphylococci | 82 (21.0%) | 33 (31.4%) | 38 (21.3%) | 3 (7.0%) | 1 (3.1%) | 7 (21.9%) |
| *Staphylococcus aureus* | 41 (10.5%) | 15 (14.3%) | 14 (7.9%) | 4 (9.3%) | 4 (12.5%) | 4 (12.5%) |
| *Escherichia coli* | 37 (9.5%) | 7 (6.7%) | 17 (9.6%) | 4 (9.3%) | 4 (12.5%) | 5 (15.6%) |
| *Klebsiella* spp. | 37 (9.5%) | 6 (5.7%) | 21 (11.8%) | 7 (16.3%) | 2 (6.3%) | 1 (3.1%) |
| *Enterobacter* spp. | 27 (6.9%) | 14 (13.3%) | 10 (5.6%) | 2 (4.7%) | 0 (0.0%) | 1 (3.1%) |
| *Pseudomonas aeruginosa* | 26 (6.7%) | 3 (2.9%) | 10 (5.6%) | 7 (16.3%) | 4 (12.5%) | 2 (6.3%) |
| *Candida* spp.* | 23 (5.9%) | 3 (2.9%) | 12 (6.7%) | 3 (7.0%) | 1 (3.1%) | 4 (12.5%) |
| Viruses | 21 (5.4%) | 3 (2.9%) | 13 (7.3%) | 4 (9.3%) | 1 (3.1%) | 0 (0.0%) |
| *Enterococcus* spp. | 20 (5.1%) | 5 (4.8%) | 12 (6.7%) | 2 (4.7%) | 1 (3.1%) | 0 (0.0%) |
| *Streptococcus* spp. | 18 (4.6%) | 6 (5.7%) | 5 (2.8%) | 1 (2.3%) | 4 (12.5%) | 2 (6.3%) |
| *Stenotrophomonas malthophilia** | 12 (3.1%) | 0 (0.0%) | 8 (4.5%) | 1 (2.3%) | 3 (9.4%) | 0 (0.0%) |
| *Serratia marcescens* | 8 (2.1%) | 4 (3.8%) | 3 (1.7%) | 1 (2.3%) | 0 (0.0%) | 0 (0.0%) |
| *Acinetobacter baumannii* | 7 (1.8%) | 3 (2.9%) | 4 (2.2%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| *Clostridium difficile* | 4 (1.0%) | 0 (0.0%) | 1 (0.6%) | 1 (2.3%) | 2 (6.3%) | 0 (0.0%) |
| *Haemophilus influenzae* | 4 (1.0%) | 0 (0.0%) | 1 (0.6%) | 1 (2.3%) | 1 (3.1%) | 1 (3.1%) |
| *Moraxella catarrhalis* | 4 (1.0%) | 0 (0.0%) | 2 (1.1%) | 1 (2.3%) | 1 (3.1%) | 0 (0.0%) |
| *Proteus mirabilis* | 4 (1.0%) | 0 (0.0%) | 1 (0.6%) | 1 (2.3%) | 1 (3.1%) | 1 (3.1%) |
| *Aspergillus fumigatus* | 3 (0.8%) | 0 (0.0%) | 2 (1.1%) | 0 (0.0%) | 0 (0.0%) | 1 (3.1%) |
| Other | 12 (3.1%) | 3 (2.9%) | 4 (2.2%) | 0 (0.0%) | 2 (6.3%) | 3 (9.4%) |

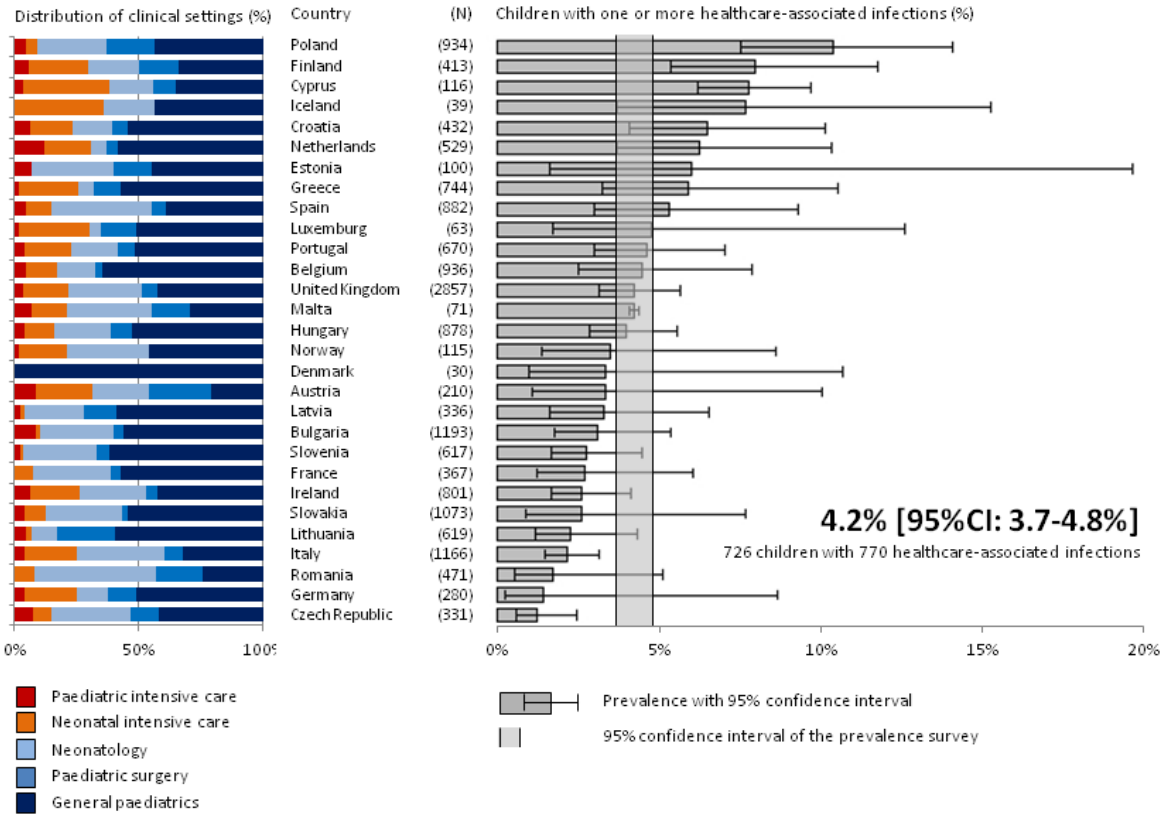
*Data for age were missing for one isolate and thus not included in the table

**Table 4. Paediatric data of national and multi-national prevalence surveys in high-income countries**

| Survey | Setting | Patients (N) | Children (N) | Prevalence, by age group[§] | | | |
|---|---|---|---|---|---|---|---|
| | | | | **All** (% [95%CI])* | **Neonates** (% [95%CI])* | **Infants** (% [95%CI])* | **Children** (% [95%CI])* |
| Moro, Italy, 1983 [12] | Adult/children | 34,577 | 3099 | 7.7 [6.8-8.7] | - | 11.5 [9.6-13.5] | 5.8 [4.8-6.9] |
| Campins, Spain, 1990[†] [13,14] | Adult/children | 38,489 | 4081 | 8.5 [8.2-8.7] | - | - | 8.5 [7.6-9.3] |
| Kelsey, UK/Ireland, 1993/1994 [15] | LRTI/children | 6183 | 6183 | 1.3 [1.1-1.7] | - | 1.7 [1.3-2.2] | 0.7 [0.4-1.2] |
| Gikas, Greece, 1999 [16] | Adult/children | 3925 | 332 | 9.9 [6.9-13.7 ] | - | 19.7 [13.2-27.7] | 3.9 [1.7-7.5] |
| Sohn, USA, 1999 [17] | NICU | 827 | 827 | 11.4 [9.3-13.8] | 11.4 [9.3-13.8] | - | - |
| Mühlemann, Switzerland, 2000 [18] | Adult/children | 520 | 520 | 6.7 [4.7-9.2] | 6.9 [3.0-13.1] | 10.1 [6.2-15.1] | 4.7 [2.6-7.6] |
| Branger, France, 2001 [19] | Adult/children | 305,656 | 21,596 | 2.4 [2.2-2.6 ] | 1.2 [1.0-1.5 ] | - | 3.3 [3.0-3.6 ] |
| Gravel, Canada, 2002[†] [20,21] | Adult/children | 6747 | 997 | 10.0 [9.4-10.8] | 18.5 [13.9-23.9] | 2.2 [1.0-4.4] | 8.0 [6.4-9.9] |
| Valinteliene, Lithuania, 2003/2005/2007 [22] | Adult/children | 10,102 | 3733 | 3.3 [2.7-3.9] | - | - | - |
| Sarvikivi, Finland, 2008/2009 [23] | NICU | 2562 | 2562 | 6.4 [5.4-7.4] | 6.4 [5.4-7.4] | - | - |
| Rutledge, Canada, 2009 [24] | Children | 1353 | 1353 | 9.2 [7.7-10.9] | 4.8 [2.9-7.4] | 14.0 [10.7-17.8] | 10.9 [7.4-15.4] |
| Zarb, Europe, 2010 [25] | Adult/children | 19,888 | 1024 | 7.1 [6.7-7.4] | - | 7.8 [6.0-9.9] | 3.7 [2.6-5.1] |
| Magill, USA, 2011 [9] | Adult/children | 11,282 | 1611 | 3.4 [2.6-4.4] | - | 3.1 [2.2-4.3] | 4.1 [2.5-6.4] |
| ECDC PPS 2011/2012 (this analysis)[‡] | Adult/children | 231,459 | 16,237 | 4.2 [3.7-4.8] | 5.1% [4.5-5.7] | 6.5 [5.7-7.2] | 2.3 [2.0-2.7] |

*95% confidence intervals were calculated from published data
[†]Added numbers from separate publications of adult and children data of the same national prevalence survey
[‡]Data from the standard protocol
[§]Age groups: neonates: 1 month of life; infants: <1 year of life; children: 1 year and older
95%CI: 95% confidence interval; LRTI: lower respiratory tract infection; NICU: neonatal intensive care unit

**Figure 1. Clinical setting, distribution, and prevalence of children with one or more health-care-associated infection, by country**




N: Number of children included in the point prevalence survey; 95%CI: 95% confidence interval

**Figure 2. Distribution of health-care-associated infections in children, by age group**