Surveillance and outbreak report

Antimicrobial use in European long-term care facilities: results from the third point prevalence survey of healthcare-associated infections and antimicrobial use, 2016 to 2017

Enrico Ricchizzi[1], Katrien Latour[2], Tommi Kärki[3], Rossella Buttazzi[1], Béatrice Jans[2], Maria Luisa Moro[1], Olivia Aya Nakitanda[3], Diamantis Plachouras[3], Dominique L Monnet[3], Carl Suetens[3], Pete Kinross[3], the HALT Study Group[4]

1. Agenzia sanitaria e sociale regionale – Regione Emilia Romagna, Bologna, Italy
2. Sciensano, Brussels, Belgium
3. European Centre for Disease Prevention and Control, Solna, Sweden
4. Members of the HALT Study Group have been listed at the end of this article

Correspondence: Tommi Karki (Tommi.karki@ecdc.europa.eu)

Citation style for this article:
Ricchizzi Enrico, Latour Katrien, Kärki Tommi, Buttazzi Rossella, Jans Béatrice, Moro Maria Luisa, Nakitanda Olivia Aya, Plachouras Diamantis, Monnet Dominique L., Suetens Carl, Kinross Pete, the HALT Study Group. Antimicrobial use in European long-term care facilities: results from the third point prevalence survey of healthcare-associated infections and antimicrobial use, 2016 to 2017. Euro Surveill. 2018;23(46):published ahead of print.

Article submitted on 17 Jul 2018 / accepted on 14 Oct 2018 / published on 15 Nov 2018

Antimicrobials are commonly prescribed and contribute to the development of antimicrobial resistance in long-term care facilities (LTCFs). In 2010, the European Centre for Disease Prevention and Control initiated point prevalence surveys (PPS) of healthcare-associated infections and antimicrobial use in European LTCFs, performed by external contractors as the Healthcare-Associated infections in Long-Term care facilities (HALT) projects. Here, we investigated prevalence and characteristics of antimicrobial use and antimicrobial stewardship indicators in European LTCFs in 2016–17. Twenty-four European Union/European Economic Area (EU/EEA) countries, the former Yugoslav Republic of Macedonia and Serbia participated in the third PPS in European LTCFs. Overall, 4.9% (95% confidence interval: 4.8–5.1) of LTCF residents in the EU/EEA participating countries received at least one antimicrobial. The most commonly reported Anatomical Therapeutic Chemical (ATC) groups were beta-lactam antibacterials/penicillins (J01C), other antibacterials (J01X) (e.g. glycopeptide antibacterials, polymyxins), quinolones (J01M), sulfonamides and trimethoprim (J01E), and other beta-lactams (J01D). Urinary tract infections and respiratory tract infections were the main indications for antimicrobial prescription. This PPS provides updated and detailed information on antimicrobial use in LTCFs across the EU/EEA that can be used to identify targets for future interventions, follow-up of these interventions and promote prudent use of antimicrobials in European LTCFs.

Introduction

Life expectancy is increasing steadily in the European Union/European Economic Area (EU/EEA). Population projections estimate that by 2050 the old-age dependency ratio, calculated as the number of individuals aged over 65 years per 100 people of working age, will reach 50% [1]. The ageing population is one reason for the transitions in healthcare delivery systems taking place in several EU/EEA countries. This includes reductions in hospital beds and in several countries more patient care being provided in long-term care settings [2]. Long-term care facilities (LTCFs) deliver a blend of health and social services to people who are limited in their ability to live independently, especially due to old age, and are in need of less intensive medical care than that usually provided in hospitals [3].

Despite the fact that less intensive medical care is provided in LTCFs than in hospitals, healthcare-associated infections (HAIs) are common in the vulnerable LTCF populations [4-9]. For this reason, antimicrobials are commonly prescribed in LTCFs, contributing to the development of antimicrobial resistance (AMR) and possibly leading to adverse events such as *Clostridium difficile* infection, and infections that are more difficult to treat [10,11]. As there is increasing evidence that LTCFs can serve as a reservoir for the transmission of resistant organisms to other healthcare settings, close monitoring of the situation is needed [12,13]. Furthermore, the lack of diagnostic capabilities may lead to suboptimal antimicrobial prescription in LTCFs [14,15].

Table 1

Prevalence of antimicrobial use, by country, 23 European Union/European Economic Area countries[a], the former Yugoslav Republic of Macedonia and Serbia, 2016–2017

Country	LTCFs	Eligible residents	Antimicrobial use			
			Residents with at least one antimicrobial	Observed prevalence	Mean prevalence of LTCFs	Median prevalence of LTCFs
	n	n	n	% (95% CI)	%	IQR (%)
Austria	12	2,065	67	3.2 (2.5 to 4.1)	2.9	2.4 (1.0 to 4.7)
Belgium	79	8,206	482	5.9 (5.4 to 6.4)	5.8	5.1 (2.9 to 8.1)
Croatia	8	1,607	32	2.0 (1.4 to 2.8)	3.2	3.6 (0.8 to 4.9)
Cyprus	11	312	29	9.3 (6.3 to 13.1)	10.1	7.7 (4.8 to 17.0)
Denmark	95	3,346	350	10.5 (9.4 to 11.5)	10.7	9.0 (6.3 to 15.0)
Finland	149	5,914	394	6.7 (6.0 to 7.3)	7.0	5.9 (2.3 to 10.5)
France	91	6,957	187	2.7 (2.3 to 3.1)	2.7	2.3 (0 to 4.3)
Germany	82	6,705	85	1.3 (1.0 to 1.6)	1.3	0.9 (0 to 1.9)
Greece	13	812	49	6.0 (4.5 to 7.9)	7.5	4.2 (3.0 to 11.6)
Hungary	75	7,670	71	0.9 (0.7 to 1.2)	0.9	0 (0 to 1.4)
Ireland	109	5,613	543	9.7 (8.9 to 10.5)	11.7	8.6 (5.4 to 14.7)
Italy	196	11,417	495	4.3 (4.0 to 4.7)	5.5	3.1 (0.8 to 6.6)
Lithuania	26	3,438	25	0.7 (0.5 to 1.1)	0.9	0 (0 to 1.0)
Luxembourg	16	1,616	42	2.6 (1.9 to 3.5)	2.5	1.5 (0.9 to 4.2)
Malta	11	2,485	66	2.7 (2.1 to 3.4)	1.6	1.4 (0.5 to 2.4)
The Netherlands	57	4,547	202	4.4 (3.9 to 5.1)	5.1	4.3 (1.6 to 6.7)
Norway	62	2,447	169	6.9 (5.9 to 8.0)	7.0	4.6 (2.1 to 10.3)
Poland	24	2,281	73	3.2 (2.5 to 4.0)	4.4	2.9 (0.9 to 6.5)
Portugal	132	3,633	220	6.1 (5.3 to 6.9)	6.8	4.3 (0 to 10.0)
Slovakia	59	5,091	113	2.2 (1.8 to 2.7)	2.9	1.2 (0 to 3.4)
Spain	46	6,808	717	10.5 (9.8 to 11.3)	11.7	10.8 (3.5 to 17.3)
Sweden	285	3,604	118	3.3 (2.7 to 3.9)	3.2	0 (0 to 5.6)
UK – Northern Ireland	70	2,614	270	10.3 (9.2 to 11.6)	10.4	9.8 (5.0 to 14.3)
UK – Scotland	52	2,147	138	6.4 (5.4 to 7.5)	6.2	5.1 (0 to 10.9)
UK – Wales	28	966	98	10.1 (8.3 to 12.2)	10.1	8.2 (5.5 to 11.4)
EU/EEA	**1,788**	**102,301**	**5,035**	**4.9 (4.8 to 5.1)**	**5.8**	**3.6 (0 to 8.5)**
former Yugoslav Republic of Macedonia	4	294	26	8.8 (5.9 to 12.7)	5.2	5.1 (2.5 to 7.9)
Serbia	6	1,168	57	4.9 (3.7 to 6.3)	6.0	4.0 (3.7 to 5.5)

CI: confidence interval; EU/EEA: European Union/European Economic Area; IQR: interquartile range; LTCFs: long-term care facilities; UK: United Kingdom.

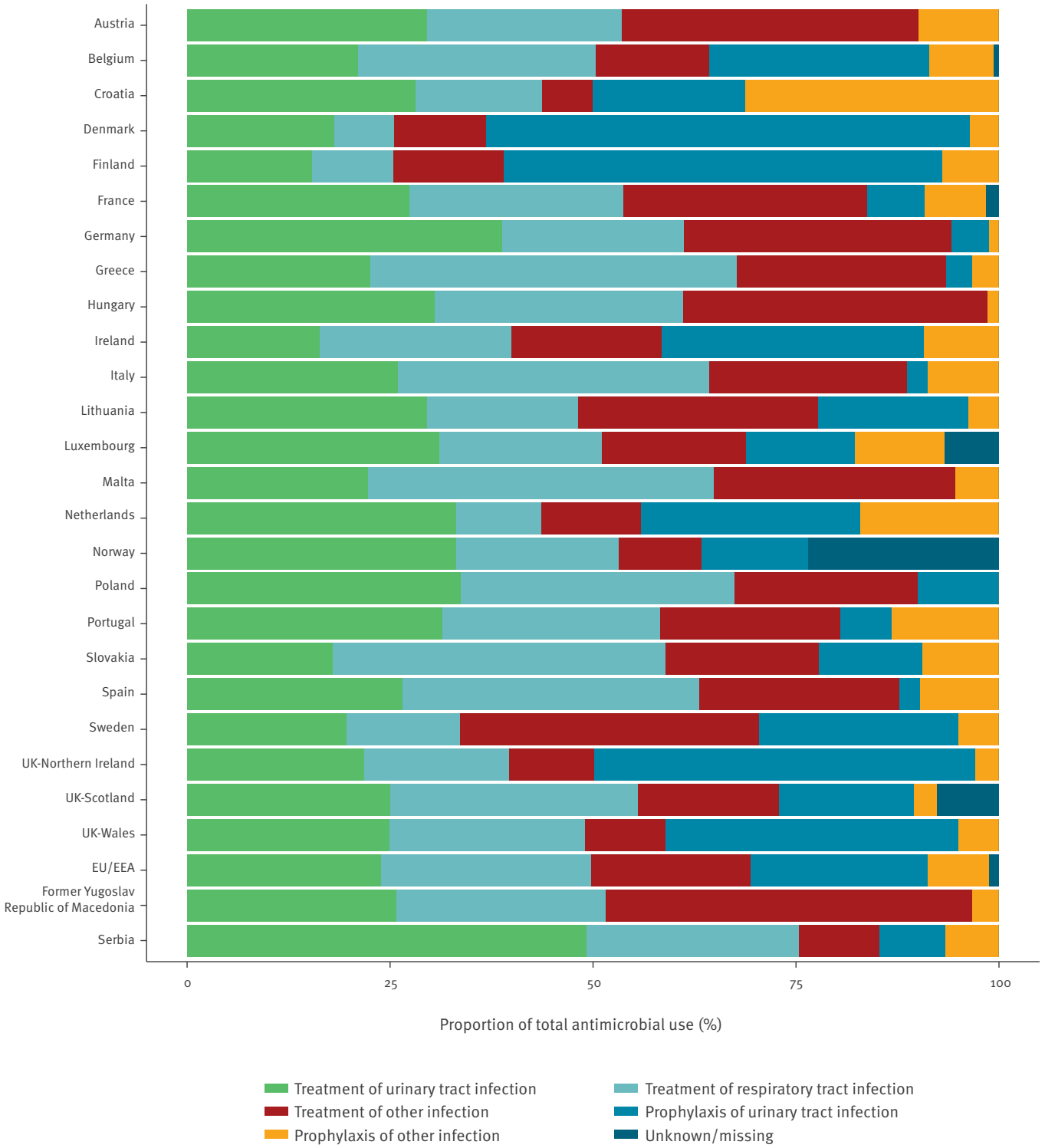
[a]For the United Kingdom, data for Northern Ireland, Scotland and Wales are presented separately. England did not participate in the survey. The Czech Republic did not provide resident-level data.

Data on antimicrobial use in LTCFs are necessary to understand the reasons, magnitude and determinants of antimicrobial prescribing and to inform public health policies on prudent use of antimicrobials. In June 2017, the European Commission published guidelines for the prudent use of antimicrobials in human medicine, recommending to establish antimicrobial stewardship programmes in all healthcare facilities, including LTCFs [16]. Although several European countries already measure antimicrobial consumption, methodologies have not been consistent precluding meaningful comparisons, furthermore they have often concentrated in the acute care settings, with little attention given to LTCFs.

For this reason, the European Centre for Disease Prevention and Control (ECDC) initiated surveillance of HAIs and antimicrobial use in European LTCFs with point prevalence surveys (PPSs) under the Healthcare-Associated infections in Long-Term Care facilities (HALT) projects in 2010, 2013 and, most recently, in 2016–17. In the present study, we investigated the prevalence and characteristics of antimicrobial use and antimicrobial stewardship indicators in European LTCFs reported in the third European PPS of HAIs and antimicrobial use in LTCFs (HALT-3) in 2016–17.

Figure 1

Indications (treatment or prophylaxis, for the most commonly sites of infection) for antimicrobial use in long-term care facilities, by country, 22 European Union/European Economic Area countries[a], the former Yugoslav Republic of Macedonia and Serbia, 2016–2017

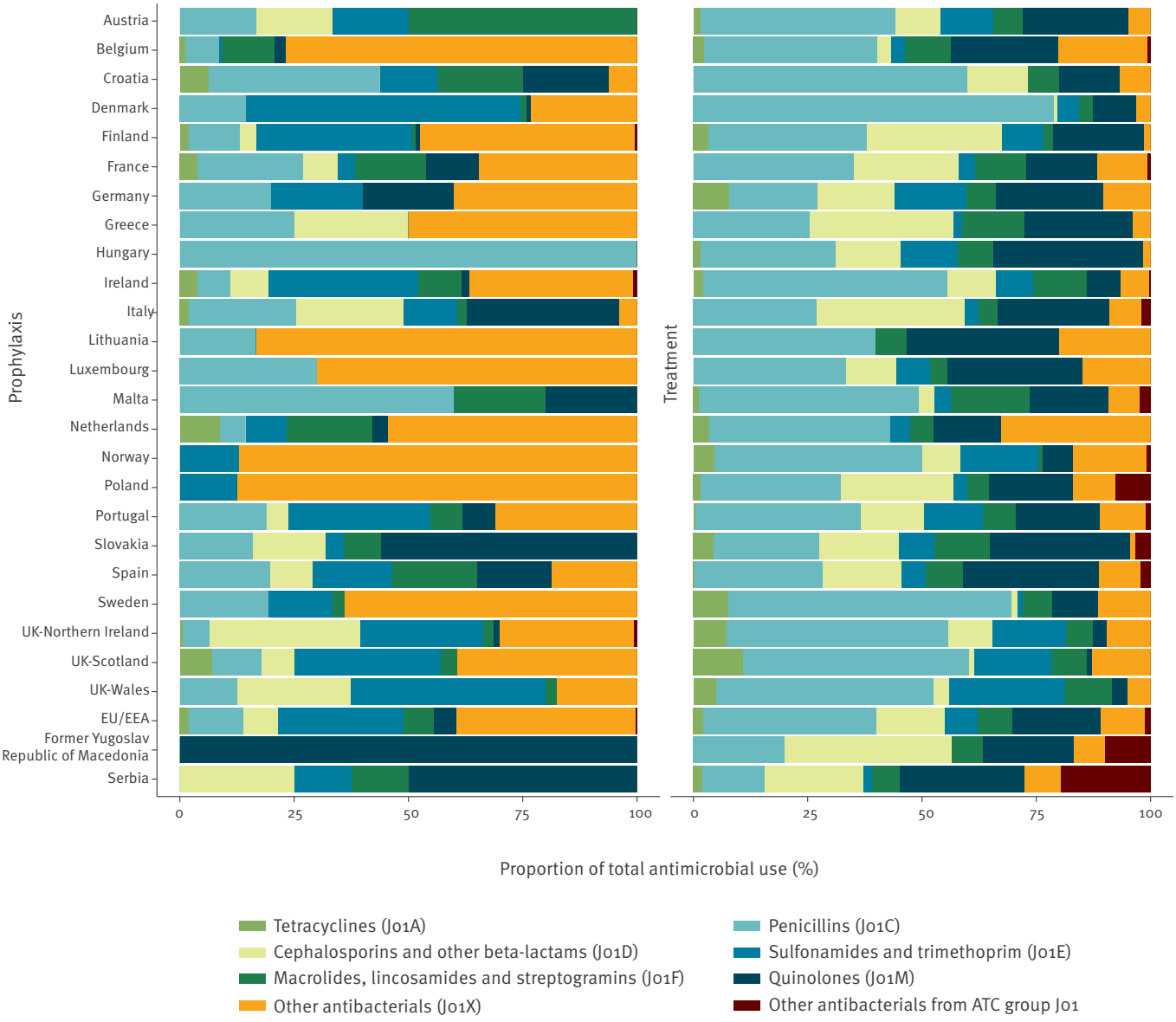


EU/EEA: European Union/European Economic Area.

[a]For the United Kingdom, data for Northern Ireland, Scotland and Wales are presented separately. England did not participate in the survey. The Czech Republic did not provide resident-level data. Cyprus did not provide detailed information on antimicrobial prescribing.

Figure 2

Distribution of antibacterials for systemic use (ATC group J01) into groups, by main indication (prophylaxis or treatment) and by country, 22 European Union/European Economic Area countries[a], the former Yugoslav Republic of Macedonia and Serbia, 2016–2017



EU/EEA: European Union/European Economic Area.

[a]For the United Kingdom, data for Northern Ireland, Scotland and Wales were reported separately. England did not participate in the survey. The Czech Republic did not provide resident-level data. Cyprus did not provide detailed information on antimicrobial prescribing.

Methods

Survey design

The survey was performed in 24 EU/EEA countries and two EU candidate countries, the former Yugoslav Republic of Macedonia and Serbia. The countries were asked to recruit LTCFs in their country for participation in the survey. According to the protocol [17], the selected LTCFs had to provide a broad range of services and assistance to people with limited abilities to function independently on a daily basis (i.e. to autonomously perform the basic activities of daily living over an extended period of time). In addition, these LTCFs could also provide basic medical services (wound dressing, pain management, medication, health monitoring, prevention, rehabilitation or palliative care), but the LTCF residents had to be medically stable, without the need for constant specialised medical care or invasive medical procedures. Resident stay in the selected

Table 2

Multivariable linear regression analysis of long-term care facility and resident characteristics in relation to the prevalence of antimicrobial use, 19 European Union/European Economic Area countries[a], the former Yugoslav Republic of Macedonia and Serbia, 2016–2017

Characteristics	Coefficient (95% CI)	p-value
Type of LTCF		
Residential home	Ref	
General nursing home	0.38 (-0.54 to 1.31)	0.418
Mixed	1.41 (0.40 to 2.42)	0.006
Size of LTCF		
≥ 105 beds	Ref	
65–104 beds	0.62 (-0.47 to 1.71)	0.266
37–64 beds	2.25 (1.22 to 3.29)	< 0.001
< 37 beds	3.27 (2.25 to 4.29)	< 0.001
Characteristics of LTCF residents (%)		
Aged over 85 years	0.05 (0.03 to 0.08)	< 0.001
Male	0.08 (0.05 to 0.11)	< 0.001
Using a wheelchair or bedridden	-0.04 (-0.06 to -0.02)	< 0.001
Disoriented in time and/or space	0.00 (-0.01 to 0.02)	0.648
Urinary and/or faecal incontinence	0.02 (-0.00 to 0.04)	0.052
Pressure sore	-0.03 (-0.09 to 0.02)	0.229
Other wound	0.10 (0.06 to 0.14)	< 0.001
Surgery in the previous 30 days	0.20 (0.10 to 0.30)	< 0.001
Urinary catheter	0.04 (0.00 to 0.08)	0.043
Vascular catheter	0.26 (0.18 to 0.33)	< 0.001

CI: confidence interval; EU/EEA: European Union/European Economic Area; LTCF: long-term care facility.

[a]For the United Kingdom, data for Northern Ireland, Scotland and Wales were reported separately. England did not participate in the survey. The Czech Republic did not provide resident-level data. France, Portugal, Norway and Sweden were excluded from the multivariable analysis (see Methods).

Significant p-values are shown in bold.

LTCFs could vary from temporary to permanent (until end of life).

To improve country representativeness, a recommended minimum number of LTCFs per country was calculated and provided to the national coordinators. For each country, the recommended sample size was calculated anticipating a national crude HAI prevalence of 4%, with a 95% confidence interval (CI) of 3–5% (1% precision). Although representative sampling was strongly recommended, purposive sampling, including convenience sampling or voluntary participation after the invitation of all LTCFs, was also accepted. Different types of LTCF could be recruited. While also specialised LTCF types (such as psychiatric facilities, rehabilitation centres and palliative care centres) were invited to participate, only data from general nursing homes (providing principally care to seniors with severe illnesses or injuries), residential homes (facilities usually providing personal care, housekeeping and three meals a day) and mixed LTCFs (providing mixed services for elderly or other resident populations) were considered for analysis. For countries contributing to the survey with more residents than in the calculated recommended sample size, a randomised sub-sample was used in the final analysis [17].

Data collection

Participating countries were asked to organise the survey during one of four proposed periods: April–June or September–November in 2016 or 2017. Ideally, data had to be collected on a single day for each LTCF. In large LTCFs, data collection could take place over 2 or more consecutive days, but all residents within one ward or unit had to be surveyed on the same day.

Data collection was conducted either by an external data collector (i.e. the national coordinator or a person trained by the national coordinator) or by a local data collector (i.e. an LTCF staff member, e.g. designated physician, infection control practitioner or nurse). To ensure standardisation of data collection, a 'train-the-trainers' workshop for the national coordinators was held in December 2015. It was recommended that national coordinators organise at least one 1-day information and training session for the LTCFs before the national survey [17].

A resident questionnaire was used to collect data for each resident receiving a systemic antimicrobial on the day of the survey. Data included resident characteristics (age, gender, length of stay in the LTCF (less or greater than 1 year)), risk factors (urinary catheter, vascular catheter, pressure sores, other wounds), care load indicators (faecal and/or urinary incontinence, disorientation in time and/or space, impaired mobility) and antimicrobial use (name of antimicrobial agent(s), indication and reasons for antimicrobial use, place of prescription, administration route, end or review date of documented prophylaxis or treatment) [17].

The 2018 version of the Anatomical Therapeutic Chemical/Defined Daily Dose (ATC/DDD) Index of the World Health Organization Collaborating Centre for Drug Statistics Methodology was used to classify the antimicrobials into different groups [18]. Antimicrobial agents for systemic use within ATC groups A07AA (intestinal antiinfectives), D01BA (dermatological antifungals for systemic use), J01 (antibacterials for systemic use), J02 (antimycotics for systemic use), J04 (antimycobacterials), when used for treatment of mycobacteria (including tuberculosis) or as reserve for multidrug-resistant bacteria and P01AB (nitroimidazole-derived antiprotozoals), were included. Antiviral agents were not included.

Two main indications for antimicrobial use were recorded, i.e. prophylaxis and treatment. The indication

Table 3

Structure and process indicators of antimicrobial stewardship reported in participating LTCFs, by country, 23 European Union/European Economic Area countries[a], the former Yugoslav Republic of Macedonia and Serbia, 2016–2017

Country[a]	Responding LTCFs	Written guidelines for appropriate antimicrobial use in the LTCF		Annual regular training on appropriate antimicrobial prescribing		Responding LTCFs	A 'restrictive list' of antimicrobials to be prescribed		Antimicrobial groups reported as being restricted ('restrictive list')(ATC code)							
									J01DD	J01MA	J01DH	J01XA	J01XA01	IAA	BSA	D06AX09, R01AX06
	n	n	%	n	%	n	n	%	n	n	n	n	n	n	n	n
Austria	12	9	75.0	2	16.7	12	2	16.7	0	0	2	1	0	0	0	0
Belgium	78	27	34.6	5	6.4	79	11	13.9	1	1	2	2	2	3	2	5
Croatia	8	1	12.5	0	0	8	1	12.5	1	0	0	0	0	0	1	0
Cyprus	11	2	18.2	1	9.1	11	1	9.1	1	1	0	0	1	0	0	0
Czech Republic	9	1	11.1	1	11.1	9	1	11.1	0	0	1	1	1	0	0	0
Denmark	95	2	2.1	0	0	95	1	1.1	0	0	0	0	0	0	0	0
Finland	147	20	13.6	7	4.8	149	4	2.7	0	0	0	0	0	4	0	0
Germany	82	1	1.2	2	2.4	82	0	0.0	0	0	0	0	0	0	0	0
Greece	13	0	0	0	0	13	5	38.5	4	4	4	4	4	4	4	4
Hungary	72	6	8.3	2	2.8	75	10	13.3	0	0	2	2	5	10	1	0
Ireland	106	41	38.7	8	7.5	109	15	13.8	6	1	7	2	5	6	1	3
Italy	193	41	21.2	19	9.8	195	110	56.4	36	19	91	60	77	45	29	16
Lithuania	26	0	0	0	0	26	1	3.8	0	0	1	1	1	0	0	1
Luxembourg	16	1	6.3	0	0	16	0	0.0	0	0	0	0	0	0	0	0
Malta	11	5	45.5	1	9.1	11	0	0.0	0	0	0	0	0	0	0	0
The Netherlands[b]	21	21	100	NA[c]	NA	22	21	95.5	0	0	0	0	0	0	0	0
Norway	51	39	76.5	9	17.6	NA[c]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Poland	24	7	29.2	2	8.3	24	8	33.3	4	2	6	4	5	2	3	0
Portugal	130	49	37.7	28	21.5	132	102	77.3	51	35	67	53	68	57	48	48
Slovakia	59	19	32.2	0	0	59	59	100.0	59	59	59	59	59	59	59	0
Spain	42	31	73.8	14	33.3	46	25	54.3	6	0	21	13	11	5	7	3
Sweden	285	285	100	236	82.8	285	0	0.0	0	0	0	0	0	0	0	0
UK – Northern Ireland	70	20	28.6	2	2.9	70	2	2.9	0	0	0	0	0	2	0	0
UK –Scotland	52	15	28.8	1	1.9	51	5	9.8	1	1	0	0	0	4	1	0
UK – Wales	26	3	11.5	0	0	28	2	7.1	0	0	0	0	0	1	1	0
EU/EEA	**1 639**	**646**	**39.4**	**340**	**20.7**	**1 607**	**386**	**24.0**	**170**	**123**	**263**	**202**	**239**	**202**	**157**	**80**
Former Yugoslav Republic of Macedonia	4	1	25.0	1	25.0	4	0	0.0	0	0	0	0	0	0	0	0
Serbia	6	2	33.3	1	16.7	6	1	16.7	1	1	0	0	0	1	1	0

BSA: Broad-spectrum antibiotics; D06AX09, R01AXA6: Mupirocin; EU/EAA: European Union/European Economic Area; IAA: Intravenously-administered antibiotics; J01DD: Third-generation cephalosporins; J01DH: Carbapenems; J01MA: Fluoroquinolones; J01XA: Glycopeptides; J01XA01: Vancomycin (parenteral); LTCF: long-term care facility; NA: not available.

[a]For the United Kingdom, data for Northern Ireland, Scotland and Wales are presented separately. England did not participate in the survey.

[b]Only a limited number of participating LTCFs in the Netherlands collected antimicrobial stewardship data.

[c]Data were not collected.

France did not provide data for the items presented in the table.

was further divided according to the anatomical site or diagnosis of prophylaxis or treatment: urinary tract, genital tract, skin or wound, respiratory tract, gastrointestinal tract, eye, ear-nose-mouth, surgical site, tuberculosis, systemic infection, unexplained fever or other site or diagnosis not previously specified.

An LTCF institutional questionnaire was used to collect data on structures and processes in place in each participating LTCF, including current infection control practices and antimicrobial policies, e.g. written guidelines for appropriate antimicrobial use in the facility, annual regular training on appropriate antimicrobial prescribing or a 'restrictive list' of antimicrobials to be prescribed. In addition, anonymised and aggregated denominator data were also collected for the entire eligible LTCF population and included information on gender distribution, as well as the proportion of residents aged over 85 years who were receiving at least one antimicrobial agent, were disoriented in time and/or space, had urinary and/or faecal incontinence, had impaired mobility, had pressure sores, had a urinary catheter, had a vascular catheter, had other wounds and/or had surgery in the previous 30 days.

Statistical analysis

All data were checked for errors, omissions and inconsistent answers on the national level and centrally before analysis.

Analyses were performed in SAS 9.3 (SAS Institute, Cary, NC, United States) and R 3.5.0 (R Foundation for Statistical Computing, Vienna, Austria). We calculated the crude, pooled prevalence of antimicrobial use as the number of residents receiving at least one antimicrobial agent divided by the total number of eligible residents on the day of the survey. We also calculated the mean, median and interquartile range (IQR) for the prevalence of antimicrobial use for the included LTCFs overall and within each country.

Multivariable linear regression was used to assess the association between antimicrobial use on the day of the survey and the type and size of LTCFs, as well as characteristics of the LTCF resident population, including care load indicators. Countries reporting data by LTCF ward without indication of the corresponding LTCF (Portugal and Sweden), or data from LTCFs with missing population data on the LTCF questionnaire (France and Norway), as well as LTCFs which reported a prevalence of antimicrobial use of more than 60%, were excluded from this analysis. The latter were considered outliers and represented less than 0.2% of all participating LTCFs.

Ethical considerations and confidentiality

Each participating country had different requirements for ethical approval for the survey, with some requiring approval from an ethics committee as well as written informed consent of the residents (or their proxies). Confidentiality of the data was ensured by the use of a unique, coded survey identification number for each LTCF and for each resident.

Results

Participation

In total, 3,052 LTCFs with 181,462 eligible residents from 24 EU/EEA countries participated in the survey. After adjustment for over-representation of countries contributing to the survey with more than the recommended number of residents, 102,301 eligible residents from 1,788 LTCFs remained in the dataset used for this analysis (Table 1). Data from the United Kingdom (UK) were reported separately for three administrations: UK-Northern Ireland, UK-Scotland and UK-Wales. UK-England did not participate in the survey. The Czech Republic only provided institutional-level data for nine LTCFs and was therefore excluded in the antimicrobial use and resident data analysis.

Antimicrobial use and resident data

On the day of the survey, 5,035 residents received at least one antimicrobial agent, resulting in a crude, pooled prevalence of antimicrobial use of 4.9% (95% CI: 4.8 to 5.1). The mean antimicrobial use prevalence of LTCFs was 5.8% and the median was 3.6% (interquartile range (IQR): 0.0–8.5) (Table 1).

Detailed information on antimicrobial prescribing was provided for 5,006 residents (i.e. all participating countries except Cyprus and the Czech Republic). The median age of residents was 85 years; 65.7% were female and 93.8% received one antimicrobial agent, while 5.8% received two and 0.4% received more than two. In total, 5,344 antimicrobial agents were reported to have been given on the day of the survey, an average of 1.07 antimicrobial agents per resident. Antimicrobials were mainly administered orally (88.1%) The parenteral route (intramuscular or intravenous) was used for 10.9% of prescribed antimicrobials and nasal or rectal administration route was reported for only 0.7% of prescribed antimicrobials.

Antimicrobials were most frequently prescribed within the same LTCF (77.9%), followed by an acute care hospital (12.9%) or another location (5.1%), with no data provided for the remaining 4.2%. The indication was reported as treatment for 69.5% and prophylaxis for 29.4% of prescribed antimicrobials, and indication was missing for the remaining 1.1%. An end or review date for the prescription was documented for 64.6% of prescribed antimicrobials and was higher for treatment (81.6%) than for prophylaxis (26.2%). Figure 1 shows the distribution of antimicrobial use by indication and common site of infection for the EU/EEA overall and for each country.

Overall, the urinary tract was the most common body site for which antimicrobials were prescribed (46.1%), followed by respiratory tract (29.4%) and skin or wound (12.6%). Combined, these sites accounted for 88.0% of

all antimicrobial prescriptions. When stratified by indication, the most common sites for antimicrobial treatment were the respiratory tract (37.2%), urinary tract (34.4%), skin or wound (15.8%) and gastrointestinal tract (2.8%). For prophylaxis, the urinary tract was the most common body site (74.0%), followed by respiratory tract (11.3%), skin or wound (4.8%), another non-specified body site (3.4%) and gastrointestinal tract (2.4%).

Antibacterials for systemic use (ATC J01) accounted for 95.4% of all antimicrobial prescriptions. Other antimicrobial groups accounted for the remaining 4.6%, i.e. nitroimidazole derivatives (P01AB, 1.5%), intestinal anti-infectives–antibiotics (A07AA, 1.3%), antimycotics for systemic use (J02, 1.2%), antimycobacterials for treatment of tuberculosis (J04A, 0.5%) and antifungals for systemic use (D01B, 0.2%).

In total, 5,098 prescriptions of antibacterials for systemic use (ATC J01) were reported. Within this group, the most frequently reported subgroups were: beta-lactam antibacterials, penicillins (J01C: 30.2%), other antibacterials (J01X: 18.6%), quinolones (J01M: 14.9%), sulfonamides and trimethoprim (J01E: 13.3%) and other beta-lactams (J01D: 12.6%). Other groups accounted for the remaining 10.4% of antibacterials for systemic use. Figure 2 shows the distribution of antibacterials for systemic use by indication (prophylaxis or treatment) and by country.

For prophylaxis of urinary tract infection (UTI), the most frequently used antimicrobial agents were trimethoprim (J01EA01: 29.7%), nitrofurantoin (J01XE01: 27.0%), methenamine (J01XX05: 11.6%), cefalexin (J01DB01: 6.1%) and fosfomycin (J01XX01: 5.9%); these accounted for 81.8% of all antimicrobials used for prophylaxis of UTI.

The LTCF and LTCF population characteristics associated with prevalence of antimicrobial use, as identified in the multivariable linear regression analysis, are presented in Table 2. The regression model indicated that LTCF and LTCF population characteristics only explained 19% of the variance in the prevalence of antimicrobial use (R^2 = 0.1889). Prevalence of antimicrobial use was significantly higher in mixed LTCFs, as well as in LTCFs with less than 65 beds. For the demographic characteristics, for one percent increase in the proportion of male residents the prevalence of antimicrobial use increased by 7%. For one percent increase in the proportion of residents over 85 years of age, the prevalence of antimicrobial use increased by 5%. For the care load indicators and risk factors, the most significant increases in antimicrobial use prevalence were associated with the proportion of residents with a vascular catheter and with surgery in the previous 30 days; for one percent increase in the proportion of these risk factors, the prevalence increased by 26% and 20%, respectively.

Antimicrobial stewardship indicators

Of the antimicrobial stewardship indicators reported at LTCF level, the most common was 'written guidelines for appropriate antimicrobial use in the LTCF' (39.4%). Annual regular training on appropriate antimicrobial prescribing was reported by 20.7% of LTCFs included in the sample. Having a 'restrictive list' of antimicrobials was reported by 24.0% of LTCFs; the antimicrobials most commonly restricted were carbapenems (J01DH, 70.1%), parenteral vancomycin (J01XA01, 63.7%), all intravenously administered antibiotics (53.9%), glycopeptides (J01XA, 53.9%), third-generation cephalosporins (J01DD, 45.3%), 'broad-spectrum antibiotics' (41.9%), fluoroquinolones (J01MA, 32.8%) and mupirocin (D06AX09 and R01AX06, 21.3%) (Table 3).

Discussion

This study examined antimicrobial prescribing in LTCFs in 24 EU/EEA countries. The crude prevalence of residents receiving at least one antimicrobial agent was 4.9%; the majority of antimicrobials being administered orally. Antimicrobials were more frequently prescribed for the treatment of an infection, while almost one third were given as prophylaxis. The crude prevalence of antimicrobial use in this survey in 2016–17 was similar to that reported in previous similar HALT surveys from 2010 (4.3%) and 2013 (4.4%) [19,20]. UTIs and respiratory tract infections were the main indications for antimicrobial use, both for treatment or as prophylaxis. This and previous similar surveys in the EU/EEA consistently show large variations of antimicrobial prescribing practices in LTCFs, across and within participating countries [19-21]. The prevalence of residents receiving antimicrobials for prophylaxis also varied largely across countries. In Denmark and Finland, prophylaxis was reported more frequently than treatment, confirming the high proportion of prophylaxis reported in previous surveys from these countries [19,20].

The most commonly prescribed antimicrobials were: penicillins, other antibacterials, quinolones, sulfonamides and trimethoprim, and other beta-lactams. Penicillins, other antibacterials and quinolones were also the most frequently prescribed antimicrobials in both the 2010 and 2013 HALT surveys. For UTI prophylaxis, other antibacterials, sulfonamides and trimethoprim, and penicillins were the most commonly prescribed antimicrobials, as in both the 2010 and 2013 surveys [19,20].

There is variation within the EU/EEA in what is considered long-term care with regard to sheltered housing, length of stay and range of beneficiaries, as well as an absence of a clear division between medical and social services [22]. To enhance comparability, we only included nursing homes, residential homes and mixed LTCFs in this analysis. Despite this, we noted differences in the case-mix of resident populations. For example, Spain reported that post-acute care residents were commonly included to the surveyed population. In

the Netherlands, the level of care provided in the LTCFs covers residents that previously would have often been admitted to a hospital. Therefore, such differences in the definition of long-term care might partially explain a high prevalence of antimicrobial use in some EU/EEA countries. The large variation between LTCFs in the prevalence of residents with a vascular catheter or with previous surgery is an indication that some of the participating LTCFs could, in fact, be step-down facilities with a very different resident case-mix than an average nursing home.

Large differences were observed in the prevalence of care load indicators and risk factors between countries, as well as within each country (unpublished data). Our multivariable analysis showed that several of these indicators and risk factors were independently and positively associated with prevalence of antimicrobial use. However, our model that took into account LTCF characteristics and resident characteristics, including care load and risk factors, only explained 19% of the variation in the prevalence of antimicrobial use in LTCFs in EU/EEA countries. This suggests that other factors, such as national or regional regulations on antimicrobial use, as well as local habits and prescriber preferences and practices, have a larger impact than characteristics of the residents' population [23]. In this survey, prophylaxis of UTI was a frequent indication for antimicrobial use in LTCFs, remaining the most common indication in several countries and showing no significant decline since the HALT surveys performed in 2010 or 2013 [19,20]. Although evidence suggests that long-term antimicrobials for prophylaxis may reduce the risk of recurrence of UTIs in women [24], this benefit diminishes immediately on cessation of antimicrobial use and, more importantly, is associated with a large increase in the proportion of antibiotic-resistant bacteria isolated from urine and faeces. Therefore, the practice of prescribing antimicrobials for prophylaxis of UTI should be carefully evaluated, and more studies about the effectiveness of prophylaxis of UTIs in the LTCF populations may be needed, depending also on the chosen antimicrobial. For example, the characteristics of methenamine (ATC J01XX05) are very different from that of other antimicrobials commonly prescribed for prophylaxis of UTI [25,26].

Information on antimicrobial stewardship indicators was collected to describe the resources available in LTCFs to support rational use of antimicrobials. Documentation of the end or review date for the prescription in the residents' notes is an indicator of the quality of antimicrobial prescription, and this end or review date was documented for almost two out of three prescriptions overall; however, end or review dates were only reported in one out of four prescriptions for prophylaxis. Other antimicrobial stewardship indicators, such as guidelines for appropriate use, were reported by a small proportion of LTCFs in the EU/EEA. Some countries, such as France, Germany, the Netherlands and Norway, reported the dissemination of national guidelines and Norway and the Netherlands reported that the guidelines were specific for the elderly patient population. The antimicrobial stewardship indicator data in this survey were comparable with that from previous similar surveys, which indicate that improvements in antimicrobial stewardship are urgently needed in LTCFs in the EU/EEA [16,27].

The strengths of this survey include the use of a standardised protocol across all participating LTCFs, the collection of detailed data on the LTCF characteristics and antimicrobial stewardship practices and the inclusion of a wide variety of LTCF residents and data on their antimicrobial use. The survey is characterised by broad participation and a very large sample size, providing a good overall picture of antimicrobial use in LTCFs in the EU/EEA, with meaningful benchmarks for participating countries and LTCFs. Considering the participation and representativeness of the current survey, it is important to note that the overall number of participating countries increased from the previous HALT survey in 2013; in addition, the number of participating LTCFs increased progressively between the first survey in 2010 and this iteration in 2016–17. Increasing participation remains important, as repeating the survey at European level with regular time intervals can encourage countries to develop their own national surveillance network for LTCFs, as has been the case in the Netherlands, Norway and Sweden, for example [28-30].

One limitation of this survey was its cross-sectional design, as a survey conducted on one single day can be prone to variation. Nevertheless, this methodology was chosen because of its feasibility when applied in settings with limited resources for surveillance and for infection prevention and control, such as LTCFs. Another limitation was that country representativeness was not optimal in all countries and convenience sampling was often used; both of these factors add to the limitations for inter-country comparisons. An additional limitation of our analysis was the large number of LTCFs that did not report any resident with at least one antimicrobial agent on the day of the survey, which may be another consequence of the differences between participating LTCFs and might warrant more sophisticated statistical methods to take this into account in future analyses.

In conclusion, this third PPS provided overall representative data on antimicrobial use in LTCFs across the EU/EEA countries, and demonstrated that continued surveillance for antibiotic use and stewardship practices in LTCFs remains critical. The survey data allow for identifying targets for future antimicrobial stewardship interventions, specifically in LTCFs; for example focusing on prophylaxis for UTIs, following up on the impact of interventions and, ultimately, contributing to the promotion of prudent use of antimicrobials in LTCFs.

Members of the HALT Study Group

Luigi Segagni Lusignani (Medical University Vienna, Vienna, Austria; luigi.segagnilusignani@meduniwien.ac.at)

Reinhild Strauss (Federal Ministry for Labour, Social Security, Health and Consumer Protection (BMAGSK) Vienna, Austria; Reinhild.strauss@sozialministerium.at)

Katrien Latour (Sciensano, Brussels, Belgium; Katrien.Latour@sciensano.be)

Béatrice Jans (Sciensano, Brussels, Belgium; beatrice.jans@telenet.be)

Dana Hedlová (National Institute of Public Health, Prague, Czech Republic; dana.hedlova@uvn.cz)

Vlastimil Jindrák (National Institute of Public Health, Prague, Czech Republic; vlastimil.jindrak@gmail.com)

Zrinka Bošnjak (University of Zagreb School of Medicine, University Hospital Centre Zagreb, Zagreb, Croatia; zbosnjak@kbc-zagreb.hr)

Ana Budimir (University of Zagreb School of Medicine, University Hospital Centre Zagreb, Zagreb, Croatia; abudimir@kbc-zagreb.hr)

Elena Gabriel (Ministry of Health, Nicosia, Cyprus; EGabriel@ns.moh.gov.cy)

Christian Stab Jensen (Statens Serum Institut (SSI), Copenhagen, Denmark; csj@ssi.dk)

Outi Lyytikäinen (National Institute for Health and Welfare, Helsinki, Finland; outi.lyytikainen@thl.fi)

Emmi Sarvikivi (National Institute for Health and Welfare, Helsinki, Finland; emmi.sarvikivi@thl.fi)

Anne Savey (CPias Auvergne-Rhône-Alpes, University Hospital (HCL), Lyon, France; anne.savey@chu-lyon.fr)

Côme Daniau (National Public Health Agency (Santé publique France), Saint Maurice, France; come.daniau@santepubliquefrance.fr)

Nicole Schmidt (Healthcare-associated Infections, Surveillance of Antibiotic Resistance and Consumption, Infectious Disease Epidemiology, Robert Koch-Institute (RKI), Berlin, Germany; schmidtn@rki.de)

Claudia Ruscher (Applied Infection Control and Hospital Hygiene; Department of Infectious Diseases, Robert Koch-Institute (RKI); Berlin, Germany; ruscherc@rki.de)

Maria-Evangelia Adami (Heraklion University Hospital (PAGNH), Heraklion, Greece; emaria.adami@gmail.com)

Symeon H. Panagiotakis (Heraklion University Hospital (PAGNH), Heraklion, Greece; simeongpan@hotmail.com)

István Veress (Department of Hospital Hygiene and Epidemiological Surveillance, Budapest, Hungary; istvan.veress@emmi.gov.hu)

Karen Burns (Health Protection Surveillance Centre, Beaumont Hospital & Royal College of Surgeons in Ireland, Dublin, Ireland; karen.burns1@hse.ie)

Helen Murphy (Health Protection Surveillance Centre, Dublin, Ireland; helen.murphy@hpsc.ie)

Carla M. Zotti (Dept. Public Health Sciences and Paediatrics, Turin, Italy; carla.zotti@unito.it)

Maria Francesca Furmenti (Dept. Public Health Sciences and Paediatrics, Turin, Italy; mariafrancesca.furmenti@unito.it)

Justina Avelytė (Institute of Hygiene (HI), Vilnius, Lithuania; justina.avelyte@hi.lt)

Murielle Weydert (Ministère de la Famille, de l'Intégration et à la Grande Région, Luxembourg, Luxembourg; murielle.weydert@fm.etat.lu)

Branka Petrovska Basovska (Institute of Public Health of Republic of Macedonia – Skopje, Skopje, the former Yugoslav Republic of Macedonia; branka.petrovska@yahoo.com)

Dragan Kochinski (Institute of Public Health of Republic of Macedonia – Skopje, Skopje, the former Yugoslav Republic of Macedonia; dragan.kocinski@gmail.com)

Michael A. Borg (Mater Dei Hospital & University of Malta, Msida, Malta; michael.a.borg@gov.mt)

Mark Bonanno (St. Vincent de Paul Residence, Luqa, Malta; mark.bonanno@gov.mt)

Linda Verhoef (National Institute for Public Health and Environment (RIVM), Bilthoven, The Netherlands; 'l.p.b.verhoef@nvwa.nl')

Kati Halonen (National Institute for Public Health and Environment (RIVM), Bilthoven, The Netherlands; kati.halonen@rivm.nl)

Hanne-M. Eriksen (Norwegian Institute of Public Health, Oslo, Norway; hmer@fhi.no)

Horst Bentele (Norwegian Institute of Public Health, Oslo, Norway; hobe@fhi.no)

Jadwiga Wojkowska-Mach (Chair of Microbiology, Faculty of Medicine Jagiellonian University Medical School, Krakow, Poland; mbmach@cyf-kr.edu.pl)

Beata Mazińska (National Medicines Institute (NMI), Warsaw, Poland; b.mazinska@nil.gov.pl)

Pedro Pacheco (Direção-Geral da Saúde (DGS), Lisbon, Portugal; pedrojorgepacheco@gmail.com)

Margarida Valente (Direção-Geral da Saúde (DGS), Lisbon, Portugal; margaridavalente@dgs.min-saude.pt)

Ljiljana Markovic-Denic (University of Belgrade, Faculty of Medicine, Belgrade, Serbia; markovic.denic@gmail.com)

Gordana Krtinic (General Hospital, Subotica, Serbia; gordana.krtinic@bolnicasubotica.com)

Mária Kopilec Garabášová (Regional Public Health Authority in Trenčín, Slovakia; garabasova.majka@yahoo.com)

Mária Štefkovičová (Alexander Dubcek University in Trenčín and Regional Public Health Authority in Trenčín, Slovakia; tn.stefkovicova@uvzsr.sk)

Enric Limon Caceres (VINCat program, Spain & University of Barcelona, Barcelona, Spain; elimon@iconcologia.net)

Maria José Torijano Castillo (Epidemiology Area of the Autonomous Community of Madrid, General Directorate of Public Health, Madrid, Spain; mariajose.torijano@salud.madrid.org)

Tomas Söderblom (The Public Health Agency of Sweden, Solna Sweden; tomas.soderblom@folkhalsomyndigheten.se)

Jenny Hellman (The Public Health Agency of Sweden, Solna, Sweden; jenny.hellman@folkhalsomyndigheten.se)

Muhammad Sartaj (HSC Public Health Agency, Belfast, Northern Ireland, UK; muhammad.sartaj@hscni.net)

Tony Crockford (HSC Public Health Agency, Belfast, Northern Ireland UK; tony.crockford@hscni.net)

Shona Cairns (National Services Scotland, Health Protection Scotland, Glasgow, Scotland, UK; shona.cairns@nhs.net)

Cheryl Gibbons (National Services Scotland, Health Protection Scotland, Glasgow, Scotland, UK; cheryl.gibbons@nhs.net)

Wendy Harrison (Public Health Wales, Cardiff, Wales, UK; wendy.harrison2@wales.nhs.uk)

Christine Jeffrey (Public Health Wales, Cardiff, Wales, UK; Christine.jeffrey@wales.nhs.uk)

Acknowledgements

The authors would like to thank all the participating LTCFs and, in particular, all LTCF staff who collected, validated and entered the data during the survey and the national teams that coordinated the survey in each participating country.

The authors would also like to acknowledge the contribution of the following persons in particular: Vivika Adamson (Tartu University Hospital, Tartu, Estonia); Mait Altmets (North Estonia Medical Centre, Tallinn, Estonia); Mailis Hansen (West-Tallinn Central Hospital, Tallinn, Estonia); Saija Toura (National Institute for Health and Welfare, Helsinki, Finland); Dinah Arifulla, (National Institute for Health and Welfare, Helsinki, Finland); Anaïs Machut (CPias Auvergne-Rhône-Alpes, University hospital (HCL), Lyon, France); Gaëtan Gavazzi (University Hospital, Grenoble, France); Konstantinos Papanikolaou (Heraklion University Hospital (PAGNH), Heraklion, Greece) Andreas Panoskaltsis (Heraklion University Hospital (PAGNH), Heraklion, Greece); Ria Benkő and Mária Matuz (Operational Contact Points for Epidemiology – Antimicrobial Consumption (AMC), University of Szeged, Hungary); Henny Lugten (Accoladezorg, Bosch en Duin, the Netherlands); Barbara Gryglewska (Department of Internal Medicine and Gerontology, Faculty of Medicine, Jagiellonian University Medical College, Kraków, Poland); Małgorzata Bulanda (Chair of Microbiology, Faculty of Medicine Jagiellonian University Medical School, Krakow, Poland); Waleria Hryniewicz (National Medicines Institute (NMI), Warsaw, Poland); the National Programme for Protection of Antibiotics (NPOA) funded by the Ministry of Health; Maria Goreti Silva (Direção-Geral da Saúde (DGS), Lisbon, Portugal); Elena Noriega (Direção-Geral da Saúde (DGS), Lisbon, Portugal); Ana Paula Cruz (Direção-Geral da Saúde (DGS), Lisbon, Portugal).

Conflict of interest

None declared.

Authors' contributions

Enrico Ricchizzi (ER) wrote the original draft; Katrien Latour, Pete Kinross and ER managed and coordinated planning and execution of the survey, and performed the data analysis; Tommi Kärki contributed to the design of the survey and co-ordination of its execution, contributed to the data analysis and wrote the advanced draft; Rossella Buttazzi contributed to the data analysis; Béatrice Jans, Maria Luisa Moro, Dominique L. Monnet and Carl Suetens contributed to the design of the survey; Olivia Aya Nakitanda and Diamantis Plachouras contributed to coordination of the execution of the survey; the HALT Study Group members contributed to design of the survey, coordinated its execution in their respective countries and provided national interpretations on the results of the analysis. All authors critically reviewed and edited the manuscript.

References

1. European Union (EU) Eurostat. Eurostat – Population projections 2015 based. Projected old-age dependency ratio. [Accessed: 04 Apr 2018]. Europe: EU Eurostat. Available from: http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&pcode=tps00200&language=en
2. European Union (EU) Eurostat. Healthcare resource statistics - beds. Europe: EU Eurostat; 2017. Available from: http://ec.europa.eu/eurostat/statistics-explained/index.php/Healthcare_resource_statistics_-_beds
3. World Health Organisation (WHO). Eurostat, OECD. A System of Health Accounts. OECD Publishing. Geneva: WHO; 2011. Available from: http://www.who.int/health-accounts/methodology/sha2011.pdf
4. Cotter M, Donlon S, Roche F, Byrne H, Fitzpatrick F. Healthcare-associated infection in Irish long-term care facilities: results from the First National Prevalence Study. J Hosp Infect. 2012;80(3):212-6. https://doi.org/10.1016/j.jhin.2011.12.010 PMID: 22305100
5. Rummukainen ML, Mäkelä M, Noro A, Finne-Soveri H, Lyytikäinen O. Assessing prevalence of antimicrobial use and infections using the minimal data set in Finnish long-term care facilities. Am J Infect Control. 2013;41(4):e35-7. https://doi.org/10.1016/j.ajic.2012.09.007 PMID: 23332375
6. Eilers R, Veldman-Ariesen MJ, Haenen A, van Benthem BH. Prevalence and determinants associated with healthcare-associated infections in long-term care facilities (HALT) in the Netherlands, May to June 2010. Euro Surveill. 2012;17(34):20252. PMID: 22939212
7. Heudorf U, Boehlcke K, Schade M. Healthcare-associated infections in long-term care facilities (HALT) in Frankfurt am Main, Germany, January to March 2011. Euro Surveill. 2012;17(35):20256. PMID: 22958607
8. Moro ML, Ricchizzi E, Morsillo F, Marchi M, Puro V, Zotti CM, et al. Infections and antimicrobial resistance in long term care facilities: a national prevalence study. Ann Ig. 2013;25(2):109-18. PMID: 23471448
9. Wójkowska-Mach J, Gryglewska B, Czekaj J, Adamski P, Grodzicki T, Heczko PB. Infection control: point prevalence study versus incidence study in Polish long-term care facilities in 2009-2010 in the Małopolska Region. Infection. 2013;41(1):1-8. https://doi.org/10.1007/s15010-012-0351-5 PMID: 23086684
10. Nicolle LE. Infection prevention issues in long-term care. Curr Opin Infect Dis. 2014;27(4):363-9. https://doi.org/10.1097/QCO.0000000000000071 PMID: 24921424
11. van Buul LW, van der Steen JT, Veenhuizen RB, Achterberg WP, Schellevis FG, Essink RTGM, et al. Antibiotic use and resistance in long term care facilities. J Am Med Dir Assoc. 2012;13(6):568.e1-13. https://doi.org/10.1016/j.jamda.2012.04.004 PMID: 22575772
12. van den Dool C, Haenen A, Leenstra T, Wallinga J. The role of nursing homes in the spread of antimicrobial resistance over the healthcare network. Infect Control Hosp Epidemiol. 2016;37(7):761-7. https://doi.org/10.1017/ice.2016.59 PMID: 27052880
13. Verhoef L, Roukens M, de Greeff S, Meessen N, Natsch S, Stobberingh E. Carriage of antimicrobial-resistant commensal bacteria in Dutch long-term-care facilities. J Antimicrob Chemother. 2016;71(9):2586-92. https://doi.org/10.1093/jac/dkw183 PMID: 27246237
14. Cassone M, Mody L. Colonization with multidrug-resistant organisms in nursing homes: scope, importance, and

management. Curr Geriatr Rep. 2015;4(1):87-95. https://doi.org/10.1007/s13670-015-0120-2 PMID: 25664233

15. van Buul LW, Veenhuizen RB, Achterberg WP, Schellevis FG, Essink RTGM, de Greeff SC, et al. Antibiotic prescribing in Dutch nursing homes: how appropriate is it? J Am Med Dir Assoc. 2015;16(3):229-37. https://doi.org/10.1016/j.jamda.2014.10.003 PMID: 25458444
16. European Centre for Disease prevention and Control (ECDC) and European Commission. (EC). EU Guidelines for the prudent use of antimicrobials in human health. Stockholm: ECDC; Jun 2017. Available from: https://ec.europa.eu/health/amr/sites/amr/files/amr_guidelines_prudent_use_en.pdf
17. European Centre for Disease Prevention and Control (ECDC). Protocol for point prevalence surveys of healthcare-associated infections and antimicrobial use in European long-term care facilities – version 2.1. Stockholm: ECDC; 2016. Available from: https://ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/HALT-3-LTCF-PPS-Protocol-v2.1.pdf
18. World Health Organization (WHO) Collaborating Centre for Drug Statistics Methodology. Guidelines for ATC classification and DDD assignment 2018. Oslo: WHO; 2017. Available from: https://www.whocc.no/filearchive/publications/guidelines.pdf
19. European Centre for Disease Prevention and Control (ECDC). Point prevalence survey of healthcare associated infections and antimicrobial use in European long-term care facilities. May–September 2010. Stockholm: ECDC; 2014. Available from: https://ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/healthcare-associated-infections-antimicrobial-consumption-point-prevalence-survey-long-term-care-facilities-2010.pdf
20. European Centre for Disease Prevention and Control (ECDC). Point prevalence survey of healthcare-associated infections and antimicrobial use in European long-term care facilities. April-May 2013. Stockholm: ECDC; 2014. Available from: https://ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/healthcare-associated-infections-point-prevalence-survey-long-term-care-facilities-2013.pdf
21. McClean P, Hughes C, Tunney M, Goossens H, Jans B, Jans BEuropean Surveillance of Antimicrobial Consumption (ESAC) Nursing Home Project Group. Antimicrobial prescribing in European nursing homes. J Antimicrob Chemother. 2011;66(7):1609-16. https://doi.org/10.1093/jac/dkr183 PMID: 21596722
22. Moro ML, Jans B, Cookson B, Fabry J. The burden of healthcare□associated infections in European long□term care facilities. Infect Control Hosp Epidemiol. 2010;31(S1) Suppl 1;S59-62. https://doi.org/10.1086/655989 PMID: 20929373
23. Daneman N, Gruneir A, Bronskill SE, Newman A, Fischer HD, Rochon PA, et al. Prolonged antibiotic treatment in long-term care: role of the prescriber. JAMA Intern Med. 2013;173(8):673-82. https://doi.org/10.1001/jamainternmed.2013.3029 PMID: 23552741
24. Ahmed H, Davies F, Francis N, Farewell D, Butler C, Paranjothy S. Long-term antibiotics for prevention of recurrent urinary tract infection in older adults: systematic review and meta-analysis of randomised trials. BMJ Open. 2017;7(5):e015233. https://doi.org/10.1136/bmjopen-2016-015233 PMID: 28554926
25. Lo TS, Hammer KD, Zegarra M, Cho WC. Methenamine: a forgotten drug for preventing recurrent urinary tract infection in a multidrug resistance era. Expert Rev Anti Infect Ther. 2014;12(5):549-54. https://doi.org/10.1586/14787210.2014.904202 PMID: 24689705
26. Lee BS, Bhuta T, Simpson JM, Craig JC. Methenamine hippurate for preventing urinary tract infections. Cochrane Database Syst Rev. 2012;10(11):CD003265. PMID: 23076896
27. Falcone M, Paul M, Yahav D, Orlando G, Tiseo G, Prendki V, et al. Antimicrobial consumption and impact of antimicrobial stewardship programmes in long-term care facilities. Clin Microbiol Infect. 2018;S1198-743X(18)30559-7. PMID: 30076978
28. Zomer TP, VAN DER Maaden T, VAN Gageldonk-Lafeber AB, DE Greeff SC, VAN DER Steen JT, Verhoef L. Incidence of pneumonia in nursing home residents with dementia in the Netherlands: an estimation based on three differently designed studies. Epidemiol Infect. 2017;145(11):2400-8. https://doi.org/10.1017/S0950268817001339 PMID: 28669365
29. Alberg T, Holen Ø, Salvesen Blix H, Lindbæk M, Bentele H, Eriksen HM. Antibiotic use and infections in nursing homes. Tidsskr Nor Legeforen 2017;137: 357-61. Available from: https://tidsskriftet.no/en/2017/03/original-article/antibiotic-use-and-infections-nursing-homes
30. Public health Agency Sweden (PHAS). Punktprevalensmätning av vårdrelaterade infektioner och antibiotikaanvändning inom särskilt boende i Sverige: Svenska-HALT [Point Prevalence Measurement of Health-Related Infections and Antibiotic Use in Special Accommodation in Sweden: Swedish-HALT]. Stockholm: PHAS; 2017. Swedish. Available from: https://www.folkhalsomyndigheten.se/contentassets/e215ba49156d437381688f4c260cd359/protokoll_svenskahalt.pdf

License and copyright

Surveillance and outbreak report

Antimicrobial use in European acute care hospitals: results from the second point prevalence survey (PPS) of healthcare-associated infections and antimicrobial use, 2016 to 2017

Diamantis Plachouras[1], Tommi Kärki[1], Sonja Hansen[2], Susan Hopkins[3], Outi Lyytikäinen[4], Maria Luisa Moro[5], Jacqui Reilly[6,7], Peter Zarb[8], Walter Zingg[9], Pete Kinross[1], Klaus Weist[1], Dominique L Monnet[1], Carl Suetens[1], the Point Prevalence Survey Study Group[10]

1. European Centre for Disease Prevention and Control, Stockholm, Sweden
2. Institute of Hygiene and Environmental Medicine, Charité – University Medicine Berlin, Berlin, Germany
3. Public Health England, London, United Kingdom
4. National Institute for Health and Welfare (THL), Department of Health Security, Helsinki, Finland
5. Agenzia sanitaria e sociale regionale – Regione Emilia Romagna, Bologna, Italy
6. National Services Scotland, Health Protection Scotland, Glasgow, United Kingdom
7. Glasgow Caledonian University, Glasgow, United Kingdom
8. Mater Dei Hospital, Msida, Malta
9. Imperial College, London, United Kingdom
10. Members of the Point Prevalence Survey Study Group are listed at the end of this article

Correspondence: Diamantis Plachouras (Diamantis.Plachouras@ecdc.europa.eu)

Citation style for this article:
Plachouras Diamantis, Kärki Tommi, Hansen Sonja, Hopkins Susan, Lyytikäinen Outi, Moro Maria Luisa, Reilly Jacqui, Zarb Peter, Zingg Walter, Kinross Pete, Weist Klaus, Monnet Dominique L., Suetens Carl, the Point Prevalence Survey Study Group. Antimicrobial use in European acute care hospitals: results from the second point prevalence survey (PPS) of healthcare-associated infections and antimicrobial use, 2016 to 2017. Euro Surveill. 2018;23(46):published ahead of print.

Article submitted on 18 Jul 2018 / accepted on 16 Oct 2018 / published on 15 Nov 2018

Antimicrobial agents used to treat infections are life-saving. Overuse may result in more frequent adverse effects and emergence of multidrug-resistant microorganisms. In 2016–17, we performed the second point-prevalence survey (PPS) of healthcare-associated infections (HAIs) and antimicrobial use in European acute care hospitals. We included 1,209 hospitals and 310,755 patients in 28 of 31 European Union/European Economic Area (EU/EEA) countries. The weighted prevalence of antimicrobial use in the EU/EEA was 30.5% (95% CI: 29.2–31.9%). The most common indication for prescribing antimicrobials was treatment of a community-acquired infection, followed by treatment of HAI and surgical prophylaxis. Over half (54.2%) of antimicrobials for surgical prophylaxis were prescribed for more than 1 day. The most common infections treated by antimicrobials were respiratory tract infections and the most commonly prescribed antimicrobial agents were penicillins with beta-lactamase inhibitors. There was wide variation of patients on antimicrobials, in the selection of antimicrobial agents and in antimicrobial stewardship resources and activities across the participating countries. The results of the PPS provide detailed information on antimicrobial use in European acute care hospitals, enable comparisons between countries and hospitals, and highlight key areas for national and European action that will support efforts towards prudent use of antimicrobials.

Background

Antimicrobials are commonly used in acute care hospitals for the treatment of both community-acquired and healthcare-associated infections (HAIs), and for surgical prophylaxis [1]. Studies have indicated that some antimicrobial use may be unnecessary and in instances when use is required, the selection, dose, route of administration and duration of treatment may be inappropriate [2,3]. Through selection pressure, antimicrobials contribute to the emergence and spread of antimicrobial resistance (AMR) [4]. Moreover, antimicrobial use has adverse consequences, including HAIs caused by *Clostridium difficile* [5,6], multidrug-resistant organisms [7] and fungi [8].

Data on antimicrobial consumption in acute care hospitals are necessary to assess the magnitude, the reasons and determinants of antimicrobial use and to inform public health policies that are promoting prudent use of antimicrobials. In June 2017, the European Commission published the European guidelines for the prudent use of antimicrobials in human medicine [9]. These guidelines recommend establishing antimicrobial stewardship programmes in all healthcare facilities. Although antimicrobial consumption in hospitals is measured at a national level by some EU/EEA countries, methodologies are not always consistent between countries and therefore preclude valid comparisons. The European Surveillance of Antimicrobial

Table 1a

Prevalence of antimicrobial use, structure and process indicators of antimicrobial stewardship, by country, 28 European Union/European Economic Area countries[a] and Serbia, 2016–2017

Country	Number of hospitals	Number of eligible patients	Antimicrobial use				Antimicrobial stewardship consultant in the hospital			Formal procedure for post-prescription review in the hospital[b]		Participation in a national or regional hospital antimicrobial consumption surveillance network	
			Number of patients with at least one antimicrobial	Observed prevalence % (95% CI)	Predicted prevalence %	DDD per 100 patients	Total number replied	Mean FTE per 250 beds	Median FTE per 250 beds	Total number replied	Number with procedure	Total number replied	Number with participation
Austria	49	13,461	3,663	27.2 (24.3–30.2)	31.9	40.3	49	0.14	0	49	31	9	9
Belgium	43	11,800	3,320	28.1 (26.6–29.7)	30.2	45.5	35	0.33	0.23	41	18	25	18
Bulgaria	12	2,200	995	45.2 (39.8–50.3)	38.7	54.3	12	0.63	0.50	11	9	3	2
Croatia	34	10,466	3,263	31.2 (26.6–35.8)	33.8	42.0	31	0.60	0	34	12	25	20
Cyprus	8	1,036	475	45.8 (42.9–48.8)	42.3	70.6	8	0	0	8	1	5	0
Czech Republic	45	15,117	4,386	29.0 (27.2–30.8)	36.9	48.1	45	0.49	0.28	5	2	45	0
Estonia	23	4,220	1,059	25.1 (21.2–29.0)	29.6	38.0	14	0.13	0.13	20	11	15	2
Finland	51	9,079	3,485	38.4 (35.0–41.7)	34.8	49.8	35	0.28	0.08	46	23	9	9
France	50	16,522	3,259	19.7 (17.9–21.5)	26.6	26.5	50	0.67	0.25	50	46	50	44
Germany	49	11,324	2,437	21.5 (17.2–25.8)	28.2	31.8	46	0.14	0	49	12	49	16
Greece	42	9,401	5,227	55.6 (53.1–58.1)	42.1	N	27	0.14	0.09	27	18	36	18
Hungary	38	20,588	3,282	15.9 (13.2–18.6)	23.9	19.8	38	0.16	0	35	5	8	8
Iceland	2	633	190	30.0 (28.5–31.5)	28.3	35.4	2	0	0	2	0	1	0
Ireland	60	10,333	4,104	39.7 (37.4–42.0)	35.2	68.2	56	0.54	0.60	58	43	60	46
Italy	56	14,773	6,579	44.5 (42.6–46.5)	40.0	64.6	55	0.42	0	55	21	53	20
Latvia	14	3,807	1,459	38.3 (35.1–41.6)	34.7	51.0	11	0.11	0	14	2	14	1
Lithuania	62	12,415	3,370	27.1 (23.9–30.4)	26.6	37.9	60	0.35	0	61	34	62	60
Luxembourg	12	2,018	516	25.6 (19.4–31.7)	27.7	39.8	12	0.71	0	12	3	9	7
Malta	4	961	385	40.1 (37.8–42.4)	35.1	64.8	4	0.16	0	4	1	4	1
The Netherlands	19	4,441	1,471	33.1 (31.5–34.7)	37.8	49.7	7	0.03	0	4	3	12	10

CI: confidence interval; DDD: defined daily dose; EU/EEA: European Union/European Economic Area; FTE: full-time equivalent; N: not available; NA: not applicable; UK: United Kingdom.

[a]For the UK, data for England, Northern Ireland, Scotland and Wales are presented separately.

[b]Review of the appropriateness of prescribed antimicrobials within 72 hours (three calendar days) from the initial order, in at least one of the hospital wards.

The three EU/EEA countries that did not participate were Denmark, Lichtenstein and Sweden.

Table 1b

Prevalence of antimicrobial use, structure and process indicators of antimicrobial stewardship, by country, 28 European Union/European Economic Area countries[a] and Serbia, 2016–2017

Country	Number of hospitals	Number of eligible patients	Antimicrobial use				Antimicrobial stewardship consultant in the hospital			Formal procedure for post-prescription review in the hospital[b]		Participation in a national or regional hospital antimicrobial consumption surveillance network	
			Number of patients with at least one antimicrobial	Observed prevalence % (95% CI)	Predicted prevalence %	DDD per 100 patients	Total number replied	Mean FTE per 250 beds	Median FTE per 250 beds	Total number replied	Number with procedure	Total number replied	Number with participation
Norway	43	9,628	2,868	29.8 (28.0–31.4)	34.7	55.0	24	0.22	0.08	24	18	24	24
Poland	80	21,712	6,073	28.0 (25.7–30.2)	33.4	36.7	80	0.16	0.07	79	32	43	4
Portugal	93	16,982	6,722	39.6 (36.9–42.3)	37.2	51.7	81	0.22	0	93	37	60	38
Romania	40	11,443	4,829	42.2 (38.7–45.7)	35.4	53.7	36	0.54	0.24	40	27	36	34
Slovakia	50	9,145	2,641	28.9 (26.2–31.6)	30.2	42.6	46	0.50	0	50	32	29	4
Slovenia	20	5,720	1,787	31.2 (28.8–33.7)	37.4	45.3	20	0.07	0	20	3	20	12
Spain	96	19,546	9,054	46.3 (44.8–47.9)	39.3	66.4	80	0.46	0.12	72	29	78	30
UK – England	32	20,148	7,533	37.4 (35.3–39.5)	35.2	64.2	32	0.58	0.45	32	32	32	32
UK – Northern Ireland	16	3,813	1,385	36.3 (32.3–40.3)	36.6	68.8	16	0.53	0.55	16	14	16	16
UK – Scotland	45	11,623	4,093	35.2 (33.3–37.1)	35.1	69.2	42	0.58	0.29	45	28	45	39
UK – Wales	21	6,400	2,186	34.2 (32.0–36.4)	34.5	56.9	21	0.75	0.32	19	17	21	17
EU/EEA	**1 209**	**310,755**	**102,093**	**30.5 (29.2–31.9)[c]**	**NA**	**46.0**	**1,075**	**0.37**	**0.08**	**1,075**	**564**	**898**	**541**
Serbia	66	14,982	6,185	41.3 (38.9–43.7)	36.9	53.1	61	0.32	0	66	24	8	7

CI: confidence interval; DDD: defined daily dose; EU/EEA: European Union/European Economic Area; FTE: full-time equivalent; N: not available; NA: not applicable; UK: United Kingdom.

[a]For the UK, data for England, Northern Ireland, Scotland and Wales are presented separately.

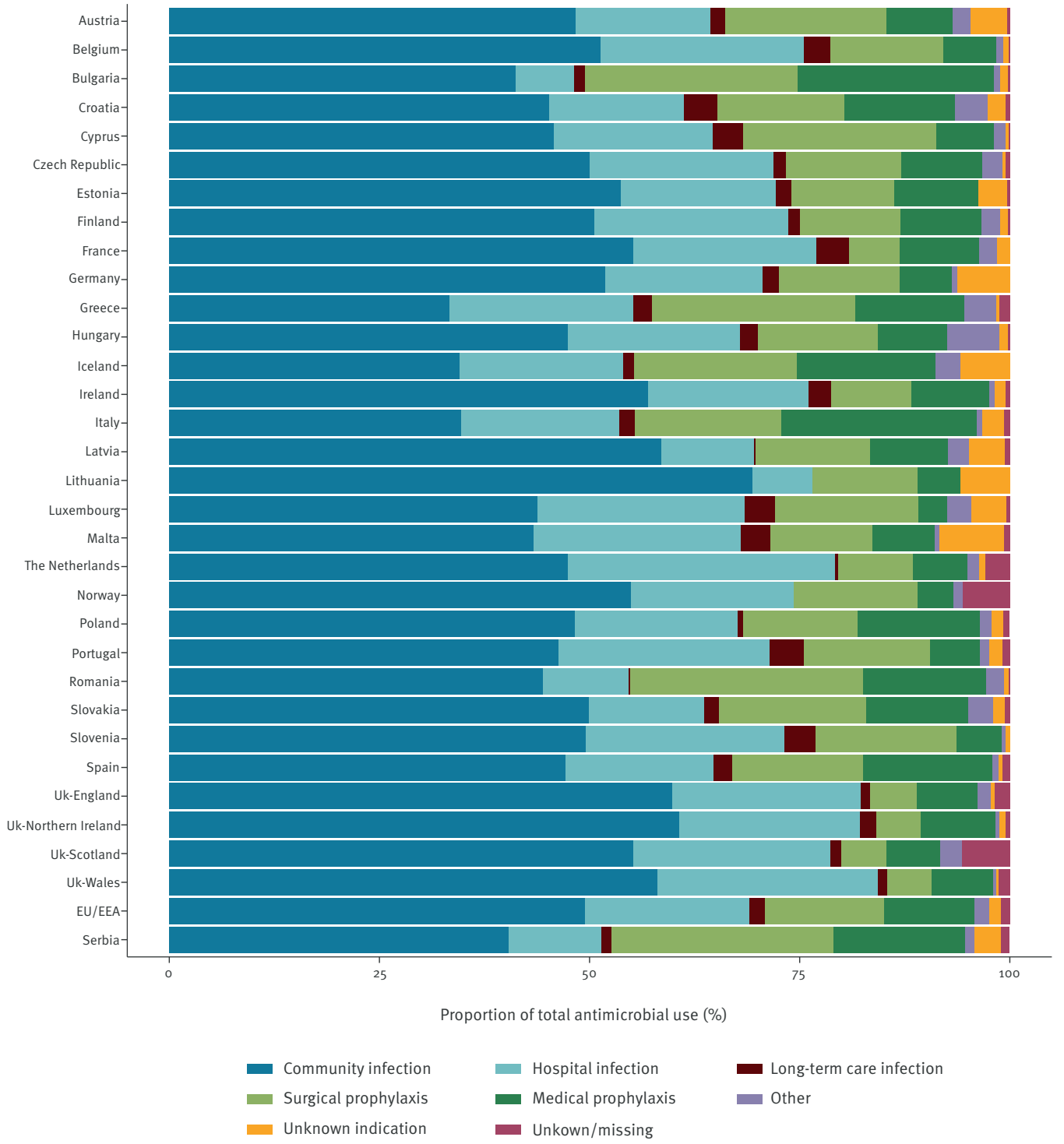
[b]Review of the appropriateness of prescribed antimicrobials within 72 hours (three calendar days) from the initial order, in at least one of the hospital wards.

[c]Observed prevalence is weighted.

The three EU/EEA countries that did not participate were Denmark, Lichtenstein and Sweden.

Figure 1

Indications for antimicrobial use in acute care hospitals, 28 European Union/European Economic Area countries[a] and Serbia, 2016–2017



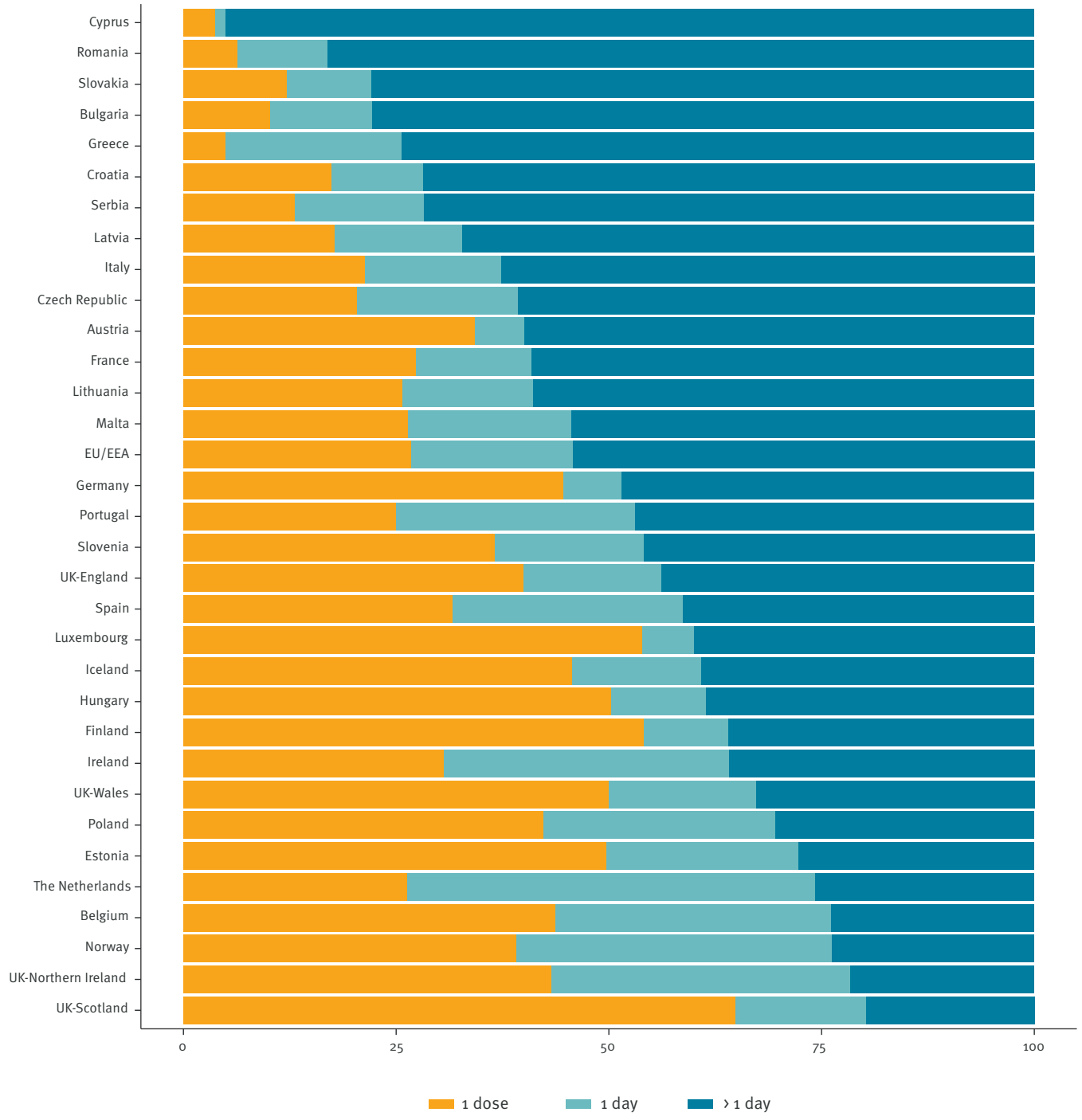
UK: United Kingdom.

[a]For the UK, data for England, Northern Ireland, Scotland and Wales are presented separately.

The three EU/EEA countries that did not participate were Denmark, Lichtenstein and Sweden.

Figure 2

Surgical prophylaxis in acute care hospitals, by dose and duration, 28 European Union/European Economic Area countries[a] and Serbia, 2016–2017



UK: United Kingdom.

[a]For the UK, data for England, Northern Ireland, Scotland and Wales are presented separately.

The three EU/EEA counties that did not participate were Denmark, Lichtenstein and Sweden.

Consumption Network (ESAC-Net) monitors the use of antimicrobials in the EU/EEA, but does not provide uniform information on antimicrobial use in hospitals and does not include clinical data to assess the appropriateness of antimicrobial prescriptions [10].

Point prevalence surveys (PPSs) are a feasible method to assess antimicrobial use in hospitals, and their value in identifying targets for interventions has been demonstrated [2,11]. The European Centre for Disease Prevention and Control (ECDC) PPS of HAIs and antimicrobial use in European acute care hospitals applies a standardised methodology for the estimation of the prevalence of both HAIs and antimicrobial use across the EU/EEA. The first ECDC PPS in 2011–12 indicated that 32.7% of patients in acute care hospitals received one or more antimicrobial agents on the day of the survey, which translated to more than 450,000 patients receiving at least one antimicrobial agent on any given day in European acute care hospitals [1].

In this study, based on data from the second PPS in 2016–17, we aimed at estimating the prevalence of antimicrobial use and describing the indications and the prescribed antimicrobial agents. Further, we aimed to raise awareness, identify targets for improvement and provide a standardised tool for evaluating the effect of local, regional and national policies on strengthening prudent use of antimicrobials in European acute care hospitals.

Methods

Survey design

The PPS was performed in 28 EU/EEA countries and one EU candidate country, Serbia. The countries were recommended to select the participating acute care hospitals by systematic random sampling. Data were collected by trained staff on 1 day per ward during four possible periods in 2016–17. The periods were selected to be out of the winter period (December–February) when antimicrobial use is the highest and out of the summer holiday season (July–August) when staffing at hospitals is usually low.

All participating countries applied a standardised protocol updated from a version used in an earlier PPS conducted in 2011–12 [12]; the main update was the addition of a larger number of structure and process indicators for the prevention of HAIs and for antimicrobial stewardship. All patients admitted to the ward before or at 0800 on the day of the PPS and were still present at the time of the PPS were included. It was also possible to provide aggregated denominator data at ward level ('light' protocol).

Data collection

Data collected included; hospital type and size, ward specialty, patient demographic data and risk factors and whether the patient was receiving one or more antimicrobial agent at the time of the PPS.

For patients receiving one or more antimicrobials additional data were collected for each antimicrobial prescribed including; the agent, the route of administration, the dosage and indication based on prescriber judgement (treatment of community, hospital or long-term care acquired infection, surgical or medical prophylaxis), diagnosis by anatomical site in case of treatment (e.g. pneumonia, urinary tract infection etc.), documentation of the reason for antimicrobial prescription in the medical records, and whether the current antimicrobial regimen was the same as the one that had been initiated. In case of change, the reason for change had to be indicated (escalation, de-escalation, switch from intravenous to oral, adverse effects, other or unknown).

Prevalence of antimicrobial use and the number of Defined Daily Doses

The 2018 version of the Anatomical Therapeutic Chemical/Defined Daily Dose (ATC/DDD) index of the World Health Organization (WHO) Collaborating Centre for Drug Statistics Methodology was used for calculating the prevalence of antimicrobial use and the number of DDDs per 100 patients on the day of PPS [13]. Antimicrobial agents for systemic use within ATC groups A07AA (intestinal antiinfectives), D01BA (dermatological antifungals for systemic use), J01 (antibacterials for systemic use), J02 (antimycotics for systemic use), J04 (antimycobacterials) as second-line treatment of e.g. meticillin-resistant *Staphylococcus aureus* (MRSA) infections (rifampicin) or for treatment of mycobacteria other than tuberculosis (MOTT) and P01AB (nitroimidazole-derived antiprotozoals) were included. Antiviral agents and antimicrobials for the treatment of mycobacteria were not included. For the calculation of the number of DDD per 100 patients, children and adolescents (< 18 years of age) and neonates were excluded, as DDDs are defined for adults only.

Structure and process indicators

Data on the structure and process indicators in relation to antimicrobial stewardship were collected at hospital level including; number of full-time equivalent antimicrobial stewardship consultants, existence of a formal hospital procedure for post-prescription review of the appropriateness of an antimicrobial within 72 hours (3 calendar days) from the initial order and participation in a national or regional hospital antimicrobial consumption surveillance network.

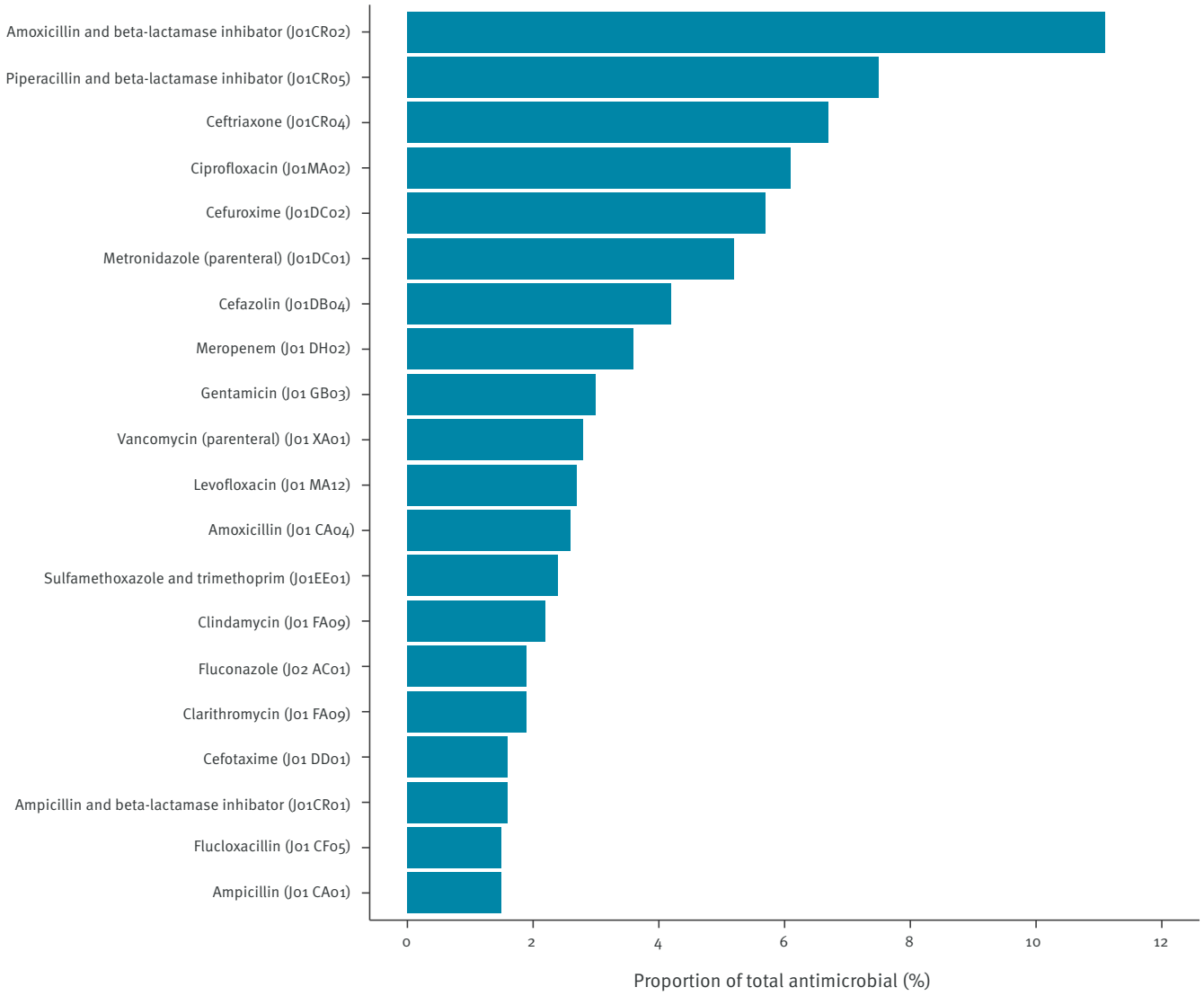
Data from the United Kingdom (UK) were reported separately for the four administrations: UK-England, UK-Northern Ireland, UK-Scotland and UK-Wales.

Descriptive analysis

All analyses were performed with R, version 3.4.0 (R Foundation for Statistical Computing, Vienna, Austria). Country representativeness of the sample was considered 'optimal' if the recommended systematic random sampling of hospitals was used, 'good' if a sufficient number of representative hospitals was selected

Figure 3

Antimicrobial agents (ATC code) accounting for 75% of antimicrobial use (Drug Utilisation 75%) in acute care hospitals, European Union/European Economic Area countries, 2016–2017



ATC: Anatomical Therapeutic Chemical.

The three EU/EEA counties that did not participate were Denmark, Lichtenstein and Sweden.

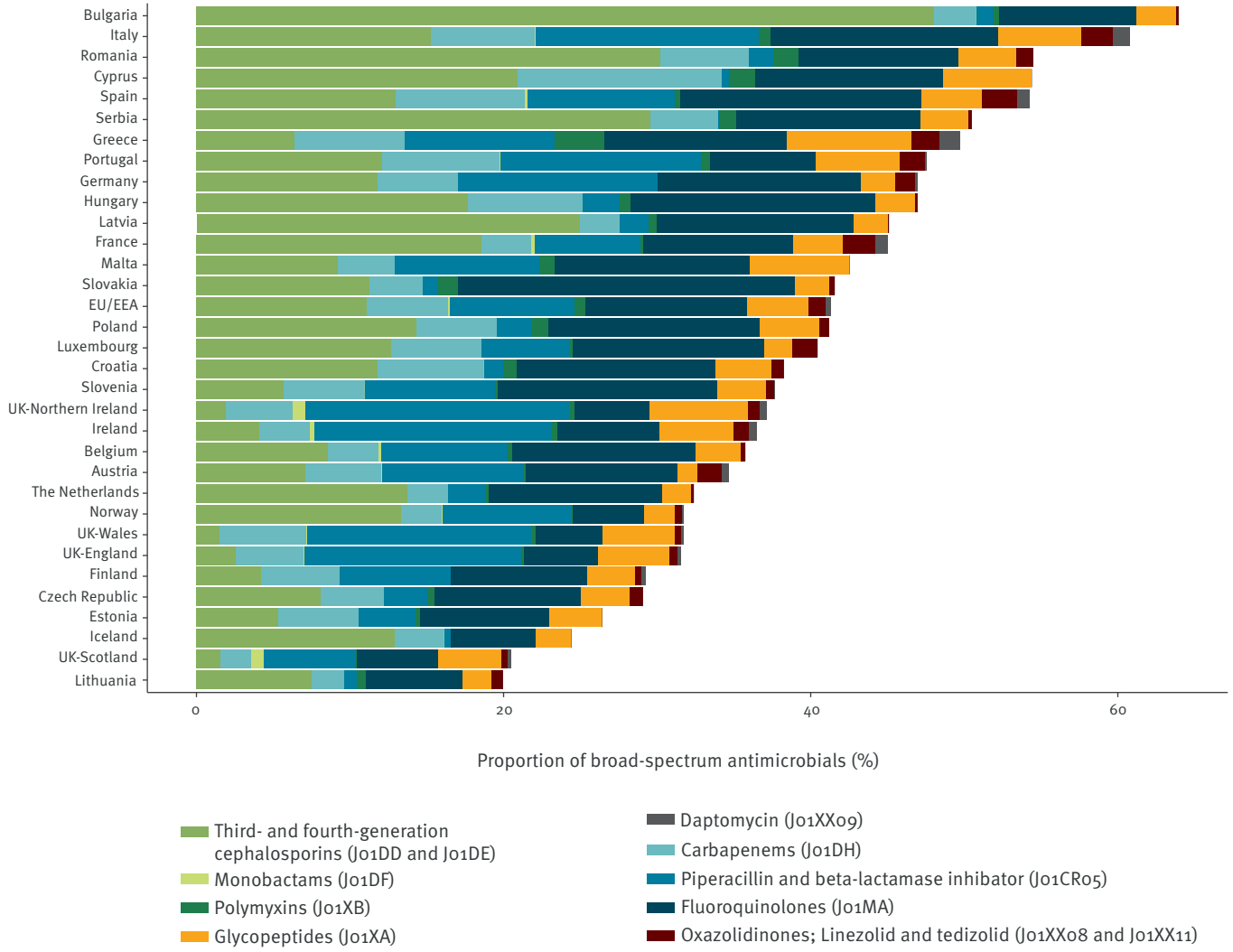
applying a different methodology or 'poor' if there was no systematic selection of a representative sample hospitals. For countries contributing to the survey with more than 20,000 patients, a randomised sub-sample was used in the final analysis to avoid over-representation of these countries when making analyses for the EU/EEA overall.

The prevalence of antimicrobial use was reported as the percentage of patients receiving at least one antimicrobial agent on the day of the survey. Antimicrobial groups and agents were classified according to the ATC/DDD index at the level of the chemical group (4^{th} ATC level) and the chemical substance (5^{th} ATC level). The relative frequencies of antimicrobial groups (4^{th} ATC level) were calculated. In addition, the relative frequencies of individual antimicrobial agents (5^{th} ATC level) that represented the Drug Utilisation 75% (DU75%), i.e. describing the agents that made 75% of total antimicrobial use in the participating hospitals, were also reported [14].

The proportion of the broad-spectrum antibacterials, among all antibacterials for systemic use (ATC J01), was also calculated – as proposed in the ECDC, European Food Safety Authority (EFSA) and European Medicines

Figure 4

Proportion of broad-spectrum antibacterials[a] among all antibacterials for systemic use (J01), 28 European Union/European Economic Area countries[b] and Serbia, 2016–2017



UK: United Kingdom.

[a]As defined in the European Centre for Disease Prevention and Control, European Food Safety Authority and European Medicines Agency Joint Scientific Opinion: piperacillin and beta-lactamase inhibitor (ATC J01CR05), third- and fourth-generation cephalosporins (J01DD and J01DE), monobactams (J01DF), carbapenems (J01DH), fluoroquinolones (J01MA), glycopeptides (J01XA), polymyxins (J01XB), daptomycin (J01XX09) and oxazolidinones: linezolid (J01XX08) and tedizolid (J01XX11) [15].

[b]For the UK, data for England, Northern Ireland, Scotland and Wales are presented separately.

The three EU/EEA counties that did not participate were Denmark, Lichtenstein and Sweden.

Agency (EMA) Joint Scientific Opinion on a list of outcome indicators for surveillance of AMR and antimicrobial consumption in humans and food producing animals [15]. The following antimicrobial groups and agents were included under broad-spectrum antimicrobials: piperacillin and beta-lactamase inhibitor (ATC J01CR05), third- and fourth-generation cephalosporins (J01DD and J01DE), monobactams (J01DF), carbapenems (J01DH), fluoroquinolones (J01MA), glycopeptides (J01XA), polymyxins (J01XB), daptomycin (J01XX09) and oxazolidinones: linezolid (J01XX08) and tedizolid (J01XX11) [15].

Statistical analysis

Adjustment for design effect due to clustering of antimicrobial use in the participating hospitals for estimation of the confidence intervals was performed with the 'survey' package (v. 3.33–2) for analysis of complex survey samples in R.

For the calculation of the EU/EEA prevalence of antimicrobial use, the participating countries' prevalence was weighted using the number of occupied beds per day as estimated by the latest available Eurostat data [16].

For countries applying the standard protocol, a multiple logistic regression model was built to predict the country prevalence of patients receiving one or more antimicrobial agents on the day of survey based on case-mix. The variables included in the model were age, sex, length of hospital stay (i.e. number of days up to the day of survey), McCabe score, intubation, presence of urinary catheter, surgery since admission, patient/consultant specialty, hospital type and hospital size [1].
For countries applying the 'light' protocol, and thus only submitting aggregated denominator data, the model included only patient/consultant specialty, hospital type and hospital size.

Ethics statement

Ethical approval was at the discretion of each national public health and government body. All data shared with ECDC on patient and institutional level were anonymous.

Results

In total, 1,753 hospitals from 29 countries participated in the PPS, of which two countries, Germany and Norway, provided aggregated denominator data on a ward level. The representativeness of the sample was optimal in 17 countries, good in 10 countries and poor in two countries (Bulgaria and the Netherlands). After adjustment for over-representation of countries contributing to the PPS with more than 20,000 patients, 325,737 patients from 1,275 hospitals remained in the dataset used for this analysis.

Pooled results were only reported for the EU/EEA corresponding to 310,755 patients from 1,209 hospitals. Of these, 357 (29.5%) were primary care hospitals, 414 (34.2%) were secondary care hospitals, 245 (20.3%) were tertiary care hospitals and 165 (13.6%) were specialised hospitals. The hospital type was unknown for 28 (2.3%) hospitals.

Prevalence of antimicrobial use

Among all patients, 102,093 (32.9%) received at least one antimicrobial agent. Among these, 72,094 (70.6%) received one antimicrobial agent, 24,091 (23.6%) received two, 4,631 (4.5%) received three, and 1,277 (1.3%) received four or more antimicrobial agents (maximum eight). In total, 139,609 prescribed antimicrobial agents were recorded. The overall weighted prevalence of antimicrobial use in EU/EEA countries was 30.5% (range 15.9–55.6%) (Table 1). Antimicrobials for systemic use (J01) accounted for 128,881 (92.3%) prescriptions, antimycotics for systemic use (J02) for 4,425 (3.2%), antimycobacterials (J04) as second-line treatment of e.g. MRSA infections (rifampicin) or for treatment of mycobacteria other than tuberculosis (MOTT) for 2,315 (1.7%), nitroimidazole-derived antiprotozoals (P01AB) for 2,113 (1.5%), intestinal antiinfectives (A07AA) for 1,857 (1.3%) and dermatological antifungals for systemic use (D01BA) for 18 (1.3%). Most antimicrobial agents (101,638 prescriptions, 72.8%) were administered parenterally, 37,530 (26.9%) orally, 266 (0.2%) by inhalation, and 175 (0.1%) by other routes. The reason for prescribing the antimicrobial was documented in the patient's medical records for 112,033 (80.2%) prescriptions.

Indications for antimicrobial use

Of 139,609 antimicrobial agents prescribed, 98,986 (70.9%) were for treatment of infection and of these 69.8% were prescribed for the treatment of a community-acquired infection (Figure 1). The most common site of infection was the respiratory tract (31.8%), followed by systemic infections (14.7%), the urinary tract (13.9%) and the gastrointestinal tract (13.6%). Other body sites accounted for 26.0% of the site of infection for antimicrobial treatment.

The proportion of antimicrobial agents prescribed for prophylaxis was 24.9%. More than half (10,741/19,798, 54.2%) of surgical prophylaxis courses were prescribed for more than 1 day (country range 19.8–95.0%) (Figure 2).

Most commonly used antimicrobial agents

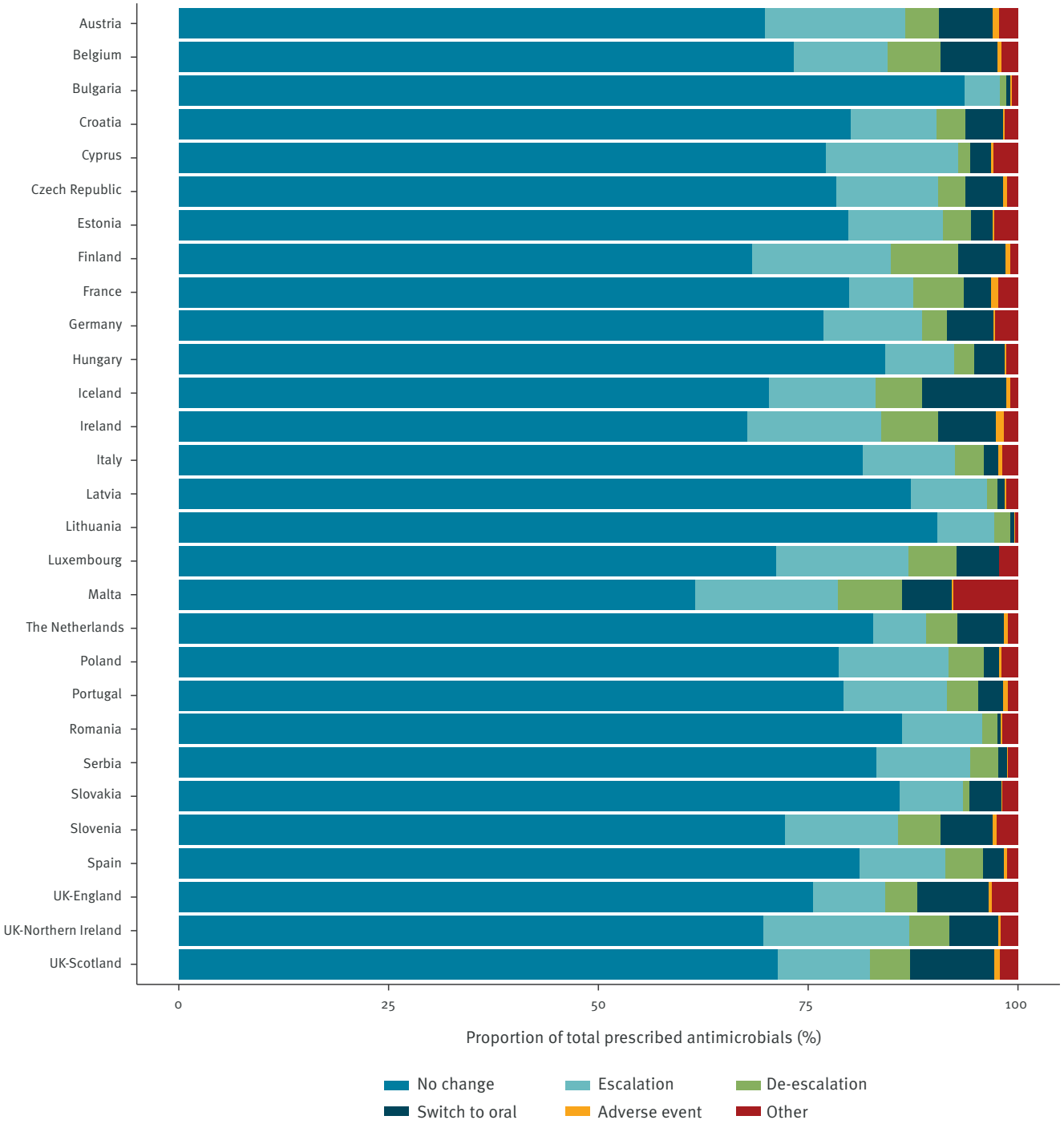
The antimicrobial agents that accounted for 75% of total antimicrobial use (DU75%) are presented in Figure 3. Antimicrobial prescription varied by indication. Of 27,324 antimicrobial prescriptions used for the treatment of HAIs, combination of penicillins with beta-lactamase inhibitors (J01CR) were the antimicrobial agents most commonly used (19.8%) followed by carbapenems (J01DH) and fluoroquinolones (J01MA) with 9.9% and 9.4%, respectively.

Of 69,067 antimicrobial prescriptions for the treatment of community-acquired infections, the three antimicrobial agents most commonly prescribed were combinations of penicillins and beta-lactamase inhibitors (J01CR: mainly amoxicillin and beta-lactamase inhibitor, J01CR02, and piperacillin and beta-lactamase inhibitor, J01CR05) followed by third-generation cephalosporins (J01DD) and fluoroquinolones (J01MA) with 23.2%, 11.7% and 11.1%, respectively.

Of 19,798 antimicrobial prescriptions for surgical prophylaxis, the three most common antimicrobial agents were first-generation cephalosporins (J01DB), second-generation cephalosporins (J01DC) and combinations of penicillins with beta-lactamase inhibitors (J01CR), with 26.6%, 17.9% and 15.1%, respectively. The proportion of broad-spectrum antibacterials among all antibacterials for systemic use (J01) is shown in Figure 4.

Figure 5

Change of antimicrobial during the infection episode and reported reason for change, 26 European Union/European Economic Area countries[a] and Serbia, 2016–2017



UK: United Kingdom.

[a]For the UK, data for England, Northern Ireland and Scotland are presented separately.

Greece, Norway and UK-Wales did not collect information on change of antimicrobials.

The three EU/EEA counties that did not participate were Denmark, Lichtenstein and Sweden.

Change of antimicrobial agent

In total, information about change of the antimicrobial during the infection episode was reported for 76.8% of antimicrobial prescriptions. For antimicrobial prescriptions where the information was reported, most (79.0%, country range: 61.5–93.6%) had not been changed since the initiation of the treatment (Figure 5). Escalation, de-escalation and switch from intravenous to oral use were reported for 10.9%, 3.9%, and 4.0% antimicrobial prescriptions, respectively. The change was due to adverse effects for 0.4% and to other reasons for 1.8% prescriptions.

Antimicrobial stewardship structure and process indicators

The median full-time equivalents for antimicrobial stewardship consultants per 250 beds was 0.08 (country range: 0–0.60), with 76.3% of the participating hospitals reporting antimicrobial use guidelines and 54.3% reporting some dedicated time for antimicrobial stewardship. Among the hospitals that submitted information on structure and process indicators for antimicrobial stewardship, the proportion of hospitals in the EU/EEA participating countries that had implemented a formal policy for post-prescription review in at least one ward was 52.5% while the proportion of hospitals participating in a national or regional hospital antimicrobial consumption surveillance network was 60.2% (Table 1).

Discussion

One in three patients hospitalised in acute care hospitals in the EU/EEA received one or more antimicrobials on the day of the PPS. The majority of the antimicrobials were prescribed for the treatment of a community-acquired infection. However, almost one in five antimicrobial prescriptions was for the treatment of a HAI. Prevention and control of HAIs reduces the need for antimicrobials and is an essential component of strategies to reduce unnecessary antimicrobial use. Antimicrobial use was similar to or lower than what was observed in other studies, such as the international PPS (range: 27.4–50.0%) [17] or the United States (US) 2011 PPS (49.9%) [18].

About one in seven antimicrobial prescriptions was for surgical prophylaxis, which represented the third most common indication. Surgical prophylaxis is recommended for the prevention of surgical site infections [19,20]. For the majority of surgical procedures, one preoperative dose is sufficient. In this PPS, however, more than half of the antimicrobial courses for surgical prophylaxis lasted more than 1 day. Although this proportion slightly decreased since the first survey in 2011–12 (54% vs 59%), it remains very high and outside the recommended duration in common with other studies where it ranged from 40.6% to 86.3% [17]. This is an important source of unnecessary use of antimicrobials and should be a priority target for future efforts on antimicrobial stewardship in many European acute care hospitals.

Overall, more than one in 10 antimicrobial prescriptions were for medical prophylaxis. This proportion is higher than the proportion of medical prophylaxis in the international PPS (7.4%) [17] and the proportion of medical prophylaxis in the US 2011 PPS (6.9%) [18]. Given the limited number of indications for medical prophylaxis and that it should only be used when indicated in relevant guidelines [9], a proportion of these prescriptions may represent antimicrobial use without clear indication and are therefore, unnecessary.

Pneumonia was by far the most common indication for antimicrobial treatment, accounting for one in four antimicrobials prescribed for therapeutic indications. Lower urinary tract infection was the second most frequent indication, accounting for almost one in 10 prescribed antimicrobials for therapeutic indications. These results are comparable with those of the 2011–12 survey (where 23.1% of prescriptions for therapeutic indications were for pneumonia and 11.1% for lower urinary tract infection) and in line with the US 2011 PPS on antimicrobial use [18], although the proportion of antimicrobials for treatment of a urinary tract infection was slightly lower in the international PPS than in our survey [17].

There was considerable variability in the prevalence of antimicrobial use among participating countries. Although part of this variability may be explained by differences in patient case-mix and the incidence of HAIs, it also reflects differences in antimicrobial prescription practices in acute care hospitals e.g. variation in the ratio between penicillins vs other beta-lactam antibiotics (including cephalosporins and carbapenems) and fluoroquinolones between participating countries (data not shown).

The most commonly prescribed antimicrobial agents were amoxicillin and beta-lactamase inhibitor, piperacillin and beta-lactamase inhibitor and ceftriaxone. Despite extensive global shortage in 2017 [21], piperacillin and beta-lactamase inhibitor was the second most commonly used antimicrobial whereas it ranked fifth in the 2011–12 survey. By contrast, ciprofloxacin, which was the second most commonly prescribed antimicrobial agent in the 2011–12 survey, ranked fourth in 2016–17. This decrease may reflect the antimicrobial stewardship efforts or focused attempts to reduce *Clostridium difficile* infections. Fluoroquinolone and glycopeptide use was lower in the EU/EEA in 2016–17 than reported in the US 2011 PPS where these antimicrobials were the first and second most commonly prescribed ones (accounting for 14.4% and 10.8% of prescriptions, respectively) [18].

Among the reasons for change of antimicrobial during the infection episode, the proportion of de-escalation and switch from intravenous to oral administration varied among participating countries. In several countries, de-escalation or switch to oral treatment was uncommon. It was not possible to assess the appropriateness

of low proportions of change, as no information was collected about the reasons for continuing or changing antimicrobial. However, both de-escalation and switch to oral treatment likely reflect the result of review of antimicrobial treatment when microbiological information is available, or when the condition of the patient improves, and are recommended measures to support prudent use of antimicrobials [9,22].

There was large variability among participating countries in the human resources available for antimicrobial stewardship as well as in the implemented antimicrobial stewardship strategies. For almost all participating countries, some hospitals had a consultant in charge of antimicrobial stewardship and while this is encouraging, considering that the majority of hospitals still have no or limited dedicated staff for antimicrobial stewardship (or access to such a consultant), promoting this must be a priority in the coming years.

In this PPS, the proportion of broad-spectrum antibacterials among all antibacterials for systemic use, as proposed by the ECDC, EFSA and EMA Joint Scientific Opinion, reflects their level of consumption in hospitals and the corresponding selection pressure [15]. These antibacterials can be found in the 'Watch' and 'Reserve' groups of antimicrobials, as defined in the WHO Model Lists of Essential Medicines [23]. In this PPS, the proportion of broad-spectrum antibacterials ranged from less than 20% to more than 50% depending on the country. This could in part be explained by the high prevalence of resistance among a number of reported microorganisms, e.g. MRSA, vancomycin-resistant enterococci or third-generation cephalosporin-resistant Enterobacteriaceae [24]. However, many of these antibacterials are also associated with both emergence and spread of healthcare-associated *Clostridium difficile* and multidrug-resistant microorganisms and in particular for third-generation cephalosporins, fluoroquinolones and carbapenems, with the emergence of multidrug-resistant Gram-negative bacteria [7], which are currently among the most important public health threats related to AMR. The wide variation and sometimes extensive use of broad-spectrum antibacterials indicates the need to review their indications in many countries and hospitals. Antimicrobial stewardship programmes must be designed to take into account both the risk of emergence of AMR and patient safety. Ensuring that broad-spectrum antibacterials are used appropriately is a key element of any strategy against AMR.

An important indicator of the quality of antimicrobial prescription is the documentation of the reason for the prescription in the patient notes. In our survey, almost one in five antimicrobial prescriptions did not include documentation of the reason for antimicrobial prescription. While this was lower than in the 2011–12 survey, it still indicates that ensuring that antimicrobial prescriptions can be reviewed effectively in all cases to assess their appropriateness remains an ongoing challenge. In the US 2011 PPS, the rationale for the antimicrobial prescription was missing only in 6.9% of prescriptions [18].

The strengths of this survey are its large size and the use of a standardised protocol across all participating hospitals in 28 EU/EEA countries and Serbia. With only two EU/EEA countries (Bulgaria and the Netherlands) having provided data on a non-representative sample of acute care hospitals and two additional EU/EEA countries (Denmark and Sweden) having declined participation, we believe that this PPS offers a representative picture of antimicrobial consumption in acute care hospitals in the EU/EEA, with meaningful benchmarks for participating countries and hospitals. The results were largely comparable to those of the 2011–12 PPS, which is both reassuring in terms of methodology but disappointing in terms of little change of antimicrobial prescription practice in European acute care hospitals in the past 5 years.

One limitation of this survey is its cross-sectional design, which evaluated antimicrobial use on 1 day only. However, this design has been shown to provide reliable results that can be used for identifying targets for intervention [2]. Moreover, the size and representativeness of the sample counterbalance this limitation. Another limitation is that we were not able to assess whether antimicrobial prescription was in line with existing international or national guidelines. However, observations such as prolonged duration of surgical prophylaxis as well as the high use of fluoroquinolones, third-generation cephalosporins and carbapenems, likely indicate inappropriate antimicrobial use that can be addressed by specific actions.

In conclusion, this second ECDC PPS of HAIs and antimicrobial use provided representative data on antimicrobial use in acute care hospitals across EU/EEA countries. These data allow for identifying targets for future antimicrobial stewardship interventions. Ultimately, these results will be helpful to promote prudent use of antimicrobials at national and European level and contribute to the efforts to ensure that European patients are receiving appropriate treatment while at the same time minimising the risk of adverse effects, and the emergence and spread of AMR.

Members of the Point Prevalence Survey Study Group

Reinhild Strauss, (Federal Ministry for Labour, Social Security, Health and Consumer Protection (BMAGSK) Vienna, Austria); Elisabeth Presterl (Medical University of Vienna, Vienna, Austria); Katrien Latour (Sciensano, Brussels, Belgium); Eline Vandael (Sciensano, Brussels, Belgium); Elina Dobreva (National Center of Infectious and Parasitic Diseases (NCIPD), Sofia, Bulgaria); Ivan N. Ivanov (National Center of Infectious and Parasitic Diseases (NCIPD), Sofia, Bulgaria); Ana Budimir (University of Zagreb School of Medicine, University Hospital Centre Zagreb, Zagreb, Croatia); Zrinka Bošnjak (University of Zagreb School of Medicine, University Hospital Centre Zagreb, Zagreb, Croatia); Linos Hadjihannas (Ministry of Health, Nicosia, Cyprus); Vlastimil Jindrák

(National Institute of Public Health, Prague, Czech Republic); Pille Märtin (West Tallinn Central Hospital, Health Board, Tallinn, Estonia); Piret Mitt (Tartu University Hospital, Tartu, Estonia); Outi Lyytikäinen (National Institute for Health and Welfare, Helsinki, Finland); Emmi Sarvikivi (National Institute for Health and Welfare, Helsinki, Finland); Côme Daniau (National Public Health Agency (Santé publique France), Saint Maurice, France); Anne Berger-Carbonne (National Public Health Agency (Santé publique France), Saint Maurice, France); Seven Aghdassi (Institute of Hygiene and Environmental Medicine, Charité – University Medicine Berlin, Berlin, Germany); Petra Gastmeier (Institute of Hygiene and Environmental Medicine, Charité – University Medicine Berlin, Berlin, Germany); Flora Kontopidou (Hellenic Center for Disease Control and Prevention, Athens, Greece); Kostoula Arvaniti (Antibiotic Committee and Infection Control Unit, Papageorgiou University-affiliated Hospital, Thessaloniki, Greece); Agnes Hajdu (Department of Hospital Hygiene and Epidemiological Surveillance, Ministry of Human Capacities, Budapest, Hungary); Ólafur Guðlaugsson (Landspitali University Hospital, Reykjavik, Iceland); Carla M. Zotti (Dept. Public Health Sciences and Paediatrics; Turin, Italy); Francesca Quattrocolo (Dept. Public Health Sciences and Paediatrics; Turin, Italy); Karen Burns (Health Protection Surveillance Centre, Dublin, Ireland); Elīna Dimiņa (Centre for Disease Prevention and Control, Riga Latvia); Aija Vilde (Pauls Stradins Clinical University Hospital, Riga, Latvia); Justė Staniulytė (Institute of Hygiene (HI), Vilnius, Lithuania); Martine Debacker (Ministère de la santé - Direction de la santé, Luxembourg, Luxembourg); Vic Arendt (Centre Hospitalier de Luxembourg (CHL), Luxembourg, Luxembourg); Michael A. Borg (Mater Dei Hospital, Msida, Malta); Titia Hopmans (Centre for Infectious Disease Control Netherlands, Bilthoven, the Netherlands); Emma Smid (Centre for Infectious Disease Control Netherlands, Bilthoven, the Netherlands); Thale C. Berg (Norwegian Institute of Public Health, Oslo, Norway); Torunn Alberg (Norwegian Institute of Public Health, Oslo, Norway); Aleksander Deptuła (Nicolaus Copernicus University, Toruń; Ludwik Rydygier Collegium Medicum; Bydgoszcz, Poland); Isabel Neves (Direção-Geral da Saúde (DGS), Lisbon, Portugal); Pedro Pacheco (Direção-Geral da Saúde (DGS), Lisbon, Portugal); Roxana Ioana Serban (National Institute of Public Health (NIPH), Bucharest, Romania); Andreea Sorina Niculcea (National Institute of Public Health (NIPH), Bucharest, Romania); Ljiljana Markovic-Denic (University of Belgrade, Faculty of Medicine, Belgrade, Serbia); Gorana Dragovac (Institute of Public Health of Vojvodina; University of Novi Sad, Faculty of Medicine, Novi Sad, Serbia); Slavka Litvová (Regional Public Health Authority, Trenčín, Slovakia); Mária Štefkovičová (Alexander Dubcek University, Trenčín, and Regional Public Health Authority, Trenčín, Slovakia); Tatjana Lejko Zupanc (University Medical Center Ljubljana, Ljubljana, Slovenia); Aleš Korošec (National Institute of Public Health, Ljubljana, Slovenia); Angel Asensio (Hospital Universitario Puerta de Hierro-Majadahonda, Madrid, Spain); Mireia Cantero (Hospital Universitario Puerta de Hierro-Majadahonda, Madrid, Spain); Alan Johnson (Public Health England, London, UK); Muhammad Sartaj (Public Health Agency, Belfast, Northern Ireland, UK); Mark McConaghy (Public Health Agency, Belfast, Northern Ireland, UK); Shona Cairns (National Services Scotland, Health Protection Scotland, Glasgow, Scotland, UK); Cheryl Gibbons (National Services Scotland, Health Protection Scotland, Glasgow, Scotland, UK); Wendy Harrison (Public Health Wales, Cardiff, Wales, UK); David Florentin (Public Health Wales, Cardiff, Wales, UK).

Acknowledgements

The authors would like to thank all the participating hospitals and in particular, the hospital staff that collected, validated and entered the data during the survey and the national teams that coordinated the survey in each participating country; the Belgian Antibiotic Policy Coordination Committee (BAPCOC); Martyn Nedyalkov (National Center of Infectious and Parasitic Diseases (NCIPD), Sofia, Bulgaria); Rumyana Hristova (National Center of Infectious and Parasitic Diseases (NCIPD), Sofia, Bulgaria); Violeta Voynova–Georgieva (Military Medical Academy (MMA), Sofia, Bulgaria); Alexander Hristov (National Center of Infectious and Parasitic Diseases (NCIPD), Sofia, Bulgaria); Nadezhda Vladimirova (National Center of Infectious and Parasitic Diseases (NCIPD), Sofia, Bulgaria); Vivika Adamson (Tartu University Hospital, Tartu, Estonia); Mait Altmets (North Estonia Medical Centre, Tallinn, Estonia); Mailis Hansen (West-Tallinn Central Hospital, Tallinn, Estonia); Prof Uga Dumpis (Pauls Stradins Clinical University Hospital, Riga, Latvia); Jaap ten Oever (Department of Internal Medicine and Radboud Center for Infectious Diseases, Radboud University Medical Center); Maria Goreti Silva (Direção-Geral da Saúde (DGS), Lisbon, Portugal); Carlos André Palos (Hospital Beatriz Ângelo (BHA), Loures, Portugal); Jana Námešná (Regional Public Health Authority in Banská Bystrica, Slovakia).

Conflict of interest

None declared.

Authors' contributions

Diamantis Plachouras performed the analysis and wrote the original draft; Carl Suetens managed and coordinated the survey planning and execution and performed analysis; Tommi Kärki contributed to the development of the study design and the coordination of the execution of the study; Sonja Hansen, Susan Hopkins, Outi Lyytikäinen, Maria Luisa Moro, Jacqui Reilly, Peter Zarb and Walter Zingg were members of the HAI-Net expert group that developed the methodology of the survey; Pete Kinross contributed to the coordination of the execution of the study; Dominique L. Monnet and Klaus Weist contributed to the analysis plan and the methodology of the survey; the PPS 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

1. European Centre for Disease Prevention and Control (ECDC). Point prevalence survey of healthcare-associated infections and antimicrobial use in European acute care hospitals. Stockholm: ECDC; 2013. Available from: http://ecdc.europa.eu/en/publications/Publications/healthcare-associated-infections-antimicrobial-use-PPS.pdf
2. Zarb P, Amadeo B, Muller A, Drapier N, Vankerckhoven V, Davey P, et al. ESAC-3 Hospital Care Subproject Group. Identification of targets for quality improvement in antimicrobial prescribing: the web-based ESAC Point Prevalence Survey 2009. J Antimicrob Chemother. 2011;66(2):443-9. https://doi.org/10.1093/jac/dkq430 PMID: 21084362
3. Hecker MT, Aron DC, Patel NP, Lehmann MK, Donskey CJ. Unnecessary use of antimicrobials in hospitalized patients: current patterns of misuse with an emphasis on the antianaerobic spectrum of activity. Arch Intern Med. 2003;163(8):972-8. https://doi.org/10.1001/archinte.163.8.972 PMID: 12719208
4. Willemsen I, Bogaers-Hofman D, Winters M, Kluytmans J. Correlation between antibiotic use and resistance in a hospital: temporary and ward-specific observations. Infection. 2009;37(5):432-7. https://doi.org/10.1007/s15010-009-8325-y PMID: 19499184
5. Carignan A, Allard C, Pépin J, Cossette B, Nault V, Valiquette L. Risk of Clostridium difficile infection after perioperative antibacterial prophylaxis before and during an outbreak of infection due to a hypervirulent strain. Clin Infect Dis.

2008;46(12):1838-43. https://doi.org/10.1086/588291 PMID: 18462108

6. Bartlett JG. Clinical practice. Antibiotic-associated diarrhea. N Engl J Med. 2002;346(5):334-9. https://doi.org/10.1056/NEJMcp011603 PMID: 11821511
7. Paterson DL. "Collateral damage" from cephalosporin or quinolone antibiotic therapy. Clin Infect Dis. 2004;38(Suppl 4):S341-5. https://doi.org/10.1086/382690 PMID: 15127367
8. Ben-Ami R, Olshtain-Pops K, Krieger M, Oren I, Bishara J, Dan M, et al. Israeli Candidemia Study Group. Antibiotic exposure as a risk factor for fluconazole-resistant Candida bloodstream infection. Antimicrob Agents Chemother. 2012;56(5):2518-23. https://doi.org/10.1128/AAC.05947-11 PMID: 22314534
9. European Commission. EU Guidelines for the prudent use of antimicrobials in human health. Luxembourg: European Commission; 2017. Available from: https://ec.europa.eu/health/amr/sites/amr/files/amr_guidelines_prudent_use_en.pdf
10. European Centre for Disease Prevention and Control (ECDC). Summary of the latest data on antibiotic consumption in the European Union: ESAC-Net surveillance data. Stockholm: ECDC; 2017. Available from: https://ecdc.europa.eu/sites/portal/files/documents/Final_2017_EAAD_ESAC-Net_Summary-edited%20-%20FINALwith%20erratum.pdf
11. Willemsen I, Groenhuijzen A, Bogaers D, Stuurman A, van Keulen P, Kluytmans J. Appropriateness of antimicrobial therapy measured by repeated prevalence surveys. Antimicrob Agents Chemother. 2007;51(3):864-7. https://doi.org/10.1128/AAC.00994-06 PMID: 17210766
12. European Centre for Disease Prevention and Control (ECDC). Point prevalence survey of healthcare-associated infections and antimicrobial use in European acute care hospitals: protocol version 5.3, ECDC PPS 2016-2017. Stockholm: ECDC; 2016. Available from: https://publications.europa.eu/en/publication-detail/-/publication/39a84b73-dee0-11e6-ad7c-01aa75ed71a1/language-en
13. WHO Collaborating Centre for Drug Statistics and Methodology. Guidelines for ATC classification and DDD assignment 2018. Oslo: WHO Collaborating Centre for Drug Statistics and Methodology; 2017. Available from: https://www.whocc.no/filearchive/publications/guidelines.pdf
14. Zarb P, Ansari F, Muller A, Vankerckhoven V, Davey PG, Goossens H. Drug utilization 75% (DU75%) in 17 European hospitals (2000-2005): results from the ESAC-2 Hospital Care Sub Project. Curr Clin Pharmacol. 2011;6(1):62-70. https://doi.org/10.2174/157488411794941322 PMID: 21235461
15. European Centre for Disease Prevention and Control (ECDC), European Food Safety Agency (EFSA), European Medicines Agency (EMA). ECDC, EFSA and EMA Joint Scientific Opinion on a list of outcome indicators as regards surveillance of antimicrobial resistance and antimicrobial consumption in humans and food-producing animals. EFSA journal. 2017;15(10):5017.
16. Eurostat. Hospital beds by type of care 2017. [Accessed 18 May 2018]. Available from: http://ec.europa.eu/eurostat/web/health/health-care/data/database
17. Versporten A, Zarb P, Caniaux I, Gros MF, Drapier N, Miller M, et al. Global-PPS network. Antimicrobial consumption and resistance in adult hospital inpatients in 53 countries: results of an internet-based global point prevalence survey. Lancet Glob Health. 2018;6(6):e619-29. https://doi.org/10.1016/S2214-109X(18)30186-4 PMID: 29681513
18. Magill SS, Edwards JR, Beldavs ZG, Dumyati G, Janelle SJ, Kainer MA, et al. Emerging Infections Program Healthcare-Associated Infections and Antimicrobial Use Prevalence Survey Team. Prevalence of antimicrobial use in US acute care hospitals, May-September 2011. JAMA. 2014;312(14):1438-46. https://doi.org/10.1001/jama.2014.12923 PMID: 25291579
19. European Centre for Disease Prevention and Control (ECDC). Systematic review and evidence-based guidance on perioperative antibiotic prophylaxis. Stockholm: ECDC; 2013. Available from: https://www.ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/Perioperative%20antibiotic%20prophylaxis%20-%20June%202013.pdf
20. World Health Organization (WHO). Global Guidelines for the Prevention of Surgical Site Infection. Geneva: WHO; 2016. Available from: http://apps.who.int/iris/bitstream/handle/10665/250680/9789241549882-eng.pdf;jsessionid=D9392589CE8819145EC804EA139481F3?sequence=1
21. Kessel J, Dolff B, Wichelhaus T, Keiner N, Hogardt M, Reinheimer C, et al. für das Antibiotic-Stewardship-Team (UKF). [Piperacillin/Tazobactam Shortage: Central Restriction and Alternative Recommendations as Effective Antibiotic-Stewardship Intervention at a Maximal Care Hospital]. Dtsch Med Wochenschr. 2018;143(8):e59-67. PMID: 29237206
22. Barlam TF, Cosgrove SE, Abbo LM, MacDougall C, Schuetz AN, Septimus EJ, et al. Implementing an Antibiotic Stewardship Program: Guidelines by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America. Clin Infect Dis. 2016;62(10):e51-77. https://doi.org/10.1093/cid/ciw118 PMID: 27080992
23. World Health Organization (WHO). Model list of essential medicines. Geneva: WHO; 2017. Available from: http://www.who.int/medicines/publications/essentialmedicines/20th_EML2017.pdf
24. European Centre for Disease Prevention and Control (ECDC). Surveillance of antimicrobial resistance in Europe: annual report of the European Antimicrobial Resistance Surveillance Network (EARS-Net): 2016. Stockholm: ECDC; 2017. Available from: https://ecdc.europa.eu/sites/portal/files/documents/AMR-surveillance-Europe-2016.pdf

License and copyright

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

Carl Suetens[1], Katrien Latour[2], Tommi Kärki[1], Enrico Ricchizzi[3], Pete Kinross[1], Maria Luisa Moro[3], Béatrice Jans[2], Susan Hopkins[4], Sonja Hansen[5], Outi Lyytikäinen[6], Jacqui Reilly[7,8], Aleksander Deptula[9], Walter Zingg[10], Diamantis Plachouras[1], Dominique L Monnet[1], the Healthcare-Associated Infections Prevalence Study Group[11]

1. European Centre for Disease Prevention and Control, Solna, Sweden
2. Sciensano, Brussels, Belgium
3. Agenzia sanitaria e sociale regionale – Regione Emilia Romagna, Bologna, Italy
4. Public Health England, London, United Kingdom
5. Institute of Hygiene and Environmental Medicine, Charité – University Medicine Berlin, Berlin, Germany
6. National Institute for Health and Welfare, Department of Health Security, Helsinki, Finland
7. National Services Scotland, Health Protection Scotland, Glasgow, United Kingdom
8. Glasgow Caledonian University, Glasgow, United Kingdom
9. Department of Propaedeutics of Medicine, Nicolaus Copernicus University, Toruń; Ludwik Rydygier Collegium Medicum; Bydgoszcz, Poland
10. Imperial College London, London, United Kingdom
11. Members of the Healthcare-Associated Infections Prevalence Study Group are listed at the end of this article

Correspondence: Carl Suetens (carl.suetens@ecdc.europa.eu)

Citation style for this article:
Suetens Carl, Latour Katrien, Kärki Tommi, Ricchizzi Enrico, Kinross Pete, Moro Maria Luisa, Jans Béatrice, Hopkins Susan, Hansen Sonja, Lyytikäinen Outi, Reilly Jacqui, Deptula Aleksander, Zingg Walter, Plachouras Diamantis, Monnet Dominique L, the Healthcare-Associated Infections Prevalence Study Group, Members of the Healthcare-Associated Infections Prevalence Study Group. 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. Euro Surveill. 2018;23(46):published ahead of print.

Article submitted on 20 Sep 2018 / accepted on 07 Nov 2018 / published on 15 Nov 2018

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, *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 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

Country	ACH								LTCF								
	Number of hospitals		Type of ACH					Intensive care patients	Number of LCTF		Type of LTCF				Residents in (a) + (b) + (c)		
	Country total	In PPS sample	Primary	Secondary	Tertiary	Specialised	Unknown	(%)	Country total	In PPS sample	General nursing home (a)	Residential home (b)	Mixed LTCF (c)	Other LTCF types	>85 years-old (%)	Urinary catheter (%)	Recent surgery (%) (past 30 days)
Austria	162	49	25	11	2	11	0	4.0	817	14	0	7	5	2	35.8	10.8	1.0
Belgium	197	43	27	9	7	0	0	4.9	1,559	86	79	0	0	7	56.5	3.1	0.9
Bulgaria	241	12	1	4	7	0	0	6.9	33	NP	NA	NA	NA	NA	NA	NA	NA
Croatia	32	34	6	15	9	4	0	6.0	325	8	0	0	8	0	40.9	3.1	1.1
Cyprus	83	8	2	4	2	0	0	9.6	90	13	7	0	4	2	54.8	8.0	4.8
Czech Republic	144	45	2	30	11	2	0	8.1	73	11	0	4	5	2	NA	NA	NA
Denmark	52	NP	NA	NA	NA	NA	NA	NA	827	95	0	0	95	0	51.8	9.0	1.7
Estonia	27	23	10	7	1	4	1	3.3	59	NP	NA	NA	NA	NA	NA	NA	NA
Finland	59	51	18	16	14	2	1	3.8	1,928	157	148	0	1	8	51.4	4.2	0.6
France	1,237	50	32	10	6	2	0	3.8	9,744	91	91	0	0	0	61.6	1.6	0.8
Germany	1,857	49	25	7	4	13	0	5.0	10,389	84	55	15	12	2	49.6	8.6	1.3
Greece	123	42	1	23	16	2	0	7.6	263	13	0	0	13	0	48.8	12.1	0.7
Hungary	94	38	14	10	6	7	1	2.8	1,177	111	65	9	1	36	25.3	1.9	0.7
Iceland	8	2	0	1	1	0	0	5.2	43	NP	NA	NA	NA	NA	NA	NA	NA
Ireland	60	60	9	17	7	27	0	3.0	578	185	75	0	34	76	47.7	7.0	1.5

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 1b

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

Country	ACH								LTCF								
	Number of hospitals		Type of ACH					Intensive care patients	Number of LCTF		Type of LTCF				Residents in (a)+(b)+(c)		
	Country total	In PPS sample	Primary	Secondary	Tertiary	Specialised	Unknown	(%)	Country total	In PPS sample	General nursing home (a)	Residential home (b)	Mixed LTCF (c)	Other LTCF types	>85 years-old (%)	Urinary catheter (%)	Recent surgery (%) (past 30 days)
Italy	1,134	56	13	14	25	4	0	6.0	3219	215	61	85	50	19	54.0	12.1	1.3
Latvia	24	14	0	9	3	2	0	3.5	82	NP	NA	NA	NA	NA	NA	NA	NA
Lithuania	64	62	25	26	8	3	0	2.8	154	26	0	0	26	0	12.4	0.8	0.3
Luxembourg	12	12	2	5	1	3	1	5.9	62	16	15	1	0	0	58.4	5.3	1.5
Malta	4	4	1	1	1	1	0	4.8	41	11	0	8	3	0	51.1	5.0	0.6
The Netherlands	79	19	10	8	1	0	0	6.0	700	57	0	0	57	0	43.0	6.6	3.5
Norway	53	43	11	9	4	0	19	6.3	907	62	62	0	0	0	NA	10.0	3.4
Poland	936	80	22	20	23	15	0	3.8	373	25	12	12	0	1	30.5	19.4	0.9
Portugal	225	93	24	40	18	9	2	4.2	360	268	0	0	132	136	29.6	15.1	0.9
Romania	311	40	16	10	3	11	0	6.4	628	NP	NA	NA	NA	NA	NA	NA	NA
Slovakia	107	50	20	11	7	12	0	5.2	677	69	27	0	32	10	28.3	3.1	1.1
Slovenia	21	20	0	11	3	6	0	5.8	90	NP	NA	NA	NA	NA	NA	NA	NA
Spain	576	96	17	39	32	5	3	5.0	5,387	46	0	0	46	0	48.1	5.1	5.1
Sweden	144	NP	NA	NA	NA	NA	NA	NA	2,300	417	285	0	0	132	57.9	9.9	2.1
UK–England	158	32	0	19	10	3	0	3.4	17,473	NP	NA	NA	NA	NA	NA	NA	NA
UK–Northern Ireland	16	16	6	4	2	4	0	3.2	445	70	0	15	55	0	44.8	5.0	0.6
UK–Scotland	46	45	12	14	7	12	0	2.8	873	52	34	17	1	0	43.9	8.5	0.3
UK–Wales	21	21	6	10	4	1	0	3.7	795	30	9	7	12	2	49.7	7.8	1.7
EU/EEA	8,307	1,209	357	414	245	165	28	4.6%	62,471	2,232	1025	180	592	435	45.6%	6.7%	1.5%
EU/EEA (n, %, mean of countries)	252	100%	29.5%	34.2%	20.3%	13.6%	2.3%	4.9%	1,893	100%	45.9%	12.3%	22.3%	19.5%	44.8%	7.3%	1.5%
Former Yugoslav Republic of Macedonia	ND	NP	NA	NA	NA	NA	NA	NA	21	4	3	0	1	0	15.3	8.8	0.7
Serbia	66	66	1	45	14	6	0	6.5	90	6	0	0	6	0	28.1	6.1	0.6

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 from 2016 to 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 LCTF 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 LCTF 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 LCTF. 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 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 LCTF 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 LCTF, 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 LCTF, it was recommended to collect data on a single day, except for larger LCTF.

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 LCTF, 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 LCTF, 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 LCTF, 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)

Country	Patients in PPS sample	Patients with at least one HAI in PPS sample (HAI prevalence)[a]			Validation-corrected HAI prevalence[b]	Occupied beds in the country (average per day)	Patients with at least one HAI on a given day, estimated		Hospital discharges annually in the country	HAI incidence, estimated		Patients with at least one HAI, annually, estimated	
	n	n	%	95% CI	%	n	n	95% CI	n	%	95% CI	n	95% CI
Austria	13,461	541	4.0	3.4–4.7	NR	36,351	1,461	1,243–1,716	2,707,753	2.3	1.5–3.3	62,306	40,978–89,762
Belgium	11,800	856	7.3	6.4–8.3	NR	37,651	2,731	2,397–3,109	1,858,726	5.4	3.7–7.6	101,110	68,186–141,713
Bulgaria[c]	2,200	76	3.5	1.7–6.8	NR	25,324	875	434–1,733	1,632,089	1.8	0.9–3.8	29,572	13,909–61,597
Croatia	10,466	551	5.3	4.5–6.2	NR	11,047	581	495–683	667,849	4.1	2.8–5.6	27,129	18,937–37,561
Cyprus	1,036	85	8.2	5.4–12.4	ND	1,437	118	77–178	166,295	4.8	2.5–8.7	8,010	4,158–14,541
Czech Republic	15,117	1,015	6.7	5.9–7.6	NR	40,691	2,732	2,413–3,090	2,260,239	5.4	3.9–7.3	122,313	87,039–165,208
Estonia	4,220	178	4.2	2.4–7.3	NR	4,582	193	111–332	222,363	3.3	1.6–6.6	7,393	3,558–14,761
Finland	9,079	803	8.8	7.5–10.4	NR	15,894	1,406	1,187–1,660	915,892	5.1	3.3–7.5	46,735	30,053–68,350
France	16,522	965	5.8	4.9–7.0	NR	159,810	9,334	7,823–11,116	11,330, 996	4.1	2.7–5.9	467,961	311,830–671,498
Germany	11,324	409	3.6	2.8–4.7	NR	400,132	14,452	11,087–18,789	19,480,504	3.1	1.9–4.8	604,495	373,766–938,383
Greece	9,401	938	10.0	8.5–11.6	NR	18,252	1,821	1,559–2,121	1,562,761	4.3	3.1–5.7	66,487	48,386–89,068
Hungary	20,588	818	4.0	3.3–4.8	NR	46,134	1,833	1,516–2,212	2,226,485	3.5	2.1–5.4	78,095	46,906–120,082
Iceland	633	40	6.3	0.8–36.8	5.7	642	41	5–237	39,198	6.7	0.6–48.6	2,609	239–19,038
Ireland	10,333	633	6.1	5.0–7.5	NR	10,932	670	546–820	705,000	4.2	2.7–6.3	29,671	18,846–44,323
Italy	14,773	1,186	8.0	6.8–9.5	NR	167,619	13,457	11,362–15,899	8,930,979	6.0	4.2–8.3	534,709	373,705–740,544

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)

Country	Patients in PPS sample	Patients with at least one HAI in PPS sample (HAI prevalence)[a]			Validation-corrected HAI prevalence[b]	Occupied beds in the country (average per day)	Patients with at least one HAI on a given day, estimated		Hospital discharges annually in the country	HAI incidence, estimated		Patients with at least one HAI, annually, estimated	
	n	n	%	95% CI	%	n	n	95% CI	n	%	95% CI	n	95% CI
Latvia	3,807	140	3.7	2.6–5.2	4.9	5,127	189	132–268	300,575	2.5	1.4–4.1	7,447	4,322–12,399
Lithuania	12,415	359	2.9	2.1–4.0	3.2	14,613	423	301–590	705,224	2.6	1.3–4.6	18,046	9,322–32,167
Luxembourg	2,018	103	5.1	4.0–6.5	8.5	1,860	95	75–120	74,782	3.4	2.1–5.3	2,569	1,560–3,995
Malta	961	60	6.2	5.2–7.4	7.9	972	61	51–72	72,909	2.6	1.9–3.4	1,877	1,380–2,507
The Netherlands[c]	4,441	170	3.8	3.4–4.3	NR	24,167	925	826–1,036	1,700,000	2.3	1.6–3.2	39,585	27,525–54,115
Norway[d]	9,628	495	5.1	4.1–6.4	ND	10,505	540	430–677	776,203	2.4	1.5–3.6	18,767	11,873–28,340
Poland	21,712	1,249	5.8	4.8–6.9	4.7	120,492	6,931	5,764–8,317	8,254,611	3.5	2.3–5.0	289,602	193,881–415,274
Portugal	16,982	1,544	9.1	8.1–10.2	7.8	27,907	2,537	2,236–2,841	1,128,245	5.9	4.4–7.8	66,860	49,568–87,500
Romania	11,443	417	3.6	2.8–4.7	5.9	57,091	2,080	1,610–2,682	3,674,275	2.6	1.7–4.0	97,257	62,340–146,893
Slovakia	9,145	370	4.1	3.1–5.3	NR	20,279	820	630–1,066	1,005,003	3.1	2.1–4.6	31,519	20,848–46,607
Slovenia	5,720	373	6.5	5.8–7.3	ND	5,581	363	322–409	380,077	4.4	3.3–5.6	16,635	12,630–21,441
Spain	19,546	1,516	7.8	7.1–8.5	NR	84,908	6,586	5,983–7,243	5,247,215	4.9	3.6–6.4	255,169	186,398–335,644
UK–England	20,148	1,297	6.4	5.4–7.6	NR	96,774	6,230	5,264–7,358	9,450,142	2.2	1.4–3.2	205,722	130,191–303,990
UK–Northern Ireland	3,813	234	6.1	4.8–7.9	5.8	4,965	305	236–392	302,008	3.5	1.8–5.9	10,527	5,559–17,841
UK–Scotland	11,623	504	4.3	3.5–5.3	NR	11,448	496	406–606	1,156,473	2.2	1.5–3.2	25,539	16,992–36,977
UK–Wales	6,400	362	5.7	4.7–6.7	6.0	6,715	380	318–453	827,634	2.2	1.3–3.3	17,880	10,595–27,545
Participating EU/EEA countries[a,e]	**310,755**	**18,287**	**5.5**	**4.5–6.7**	**6.5**	**1,469,903**	**80,665**	**66,864–97,824**	**89,762,505**	**3.7**	**2.4–5.3**	**3,293,595**	**2,185,484–4,789,661**
Serbia	14,982	650	4.3	3.5–5.4	NR	18,920	821	656–1,024	988,383	3.3	2.3–4.6	32,337	22,714–45
EU/EEA, corrected[e,f]	NA	NA	5.5	4.5–6.7	6.5	1,503,881	82,713	67,674–99,256	91,885,503	3.7	2.4–5.3	3,372,146	2,220,554–4,854,535
EU/EEA, corrected after validation	**NA**	**NA**	**6.5**	**5.4–7.8**	**NA**	**1,503,881**	**98,166**	**81,022–117,484**	**91,885,503**	**4.1**	**3.4–4.9**	**3,758,014**	**3,122,024–4,509,617**

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

Type of HAI	Acute care hospitals								Long-term care facilities							
	HAI in PPS sample		Country-weighted HAI prevalence		Estimated HAI on a given day, EU/EEA[a]		Estimated annual HAI, EU/EEA[a]		HAI in PPS sample		Country-weighted HAI prevalence		Estimated HAI on a given day, EU/EEA[a]		Estimated annual HAI, EU/EEA[a]	
	N	% total	n	95% cCI	N	95% cCI	n	95% cCI	n	% total	%	95% cCI	n	95% cCI	n	95% cCI
Respiratory tract infection																
Pneumonia	4,200	21.4	1.26	0.96–1.68	18,935	14,398–25,265	862,084	567,728–1 283,203	143	3.7	0.15	0.06–0.32	4,948	1,946–10 658	112,868	44,390–243,134
Other lower respiratory tract infection[b]	838	4.3	0.24	0.15–0.41	3,568	2,208–6,192	183,232	91,731–376,990	847	22.0	0.88	0.59–1.14	29,010	19,412–37,826	1,058,853	708,542–1 380,653
Common cold/ influenza	NI	NA	NA	NA	NA	NA	NA	NA	290	7.5	0.29	0.13–0.51	9,678	4,368–16,782	441,543	199,312–765,693
Urinary tract infection	3,710	18.9	1.10	0.85–1.43	16,491	12,822–21,455	869,941	572,105–1,278,951	1,233	32.0	1.29	0.87–1.66	42,687	28,898–54,825	1,298,388	878,983–1,667,596
Surgical site infection	3,601	18.3	1.08	0.81–1.44	16,130	12,185–21,715	518,182	293,036–858,222	66	1.7	0.09	0.03–0.20	2,829	944–6,500	57,366	19,133–131,803
Bloodstream infection	2,116	10.8	0.69	0.48–1.00	10,294	7,241–15,097	375,050	227,552–613,624	19	0.5	0.04	0.01–0.07	1,168	193–2,389	23,692	3,908–48,442
Gastrointestinal infection																
Clostridium difficile infection	951	4.8	0.32	0.21–0.51	4,786	3,105–7,721	189,526	105,154–340,978	37	1.0	0.05	0.01–0.14	1,787	424–4,755	18,118	4,296–48,206
Other gastrointestinal infection	792	4.0	0.24	0.14–0.41)	3,549	2,108–6,166	144,926	64,880–312,212	75	1.9	0.1	0.03–0.20	3,187	1,012–6,473	145,409	46,184–295,333
Skin and soft tissue infection	823	4.2	0.21	0.13–0.36	3,146	1,900–5,451	108,269	45,149–242,816	828	21.5	0.83	0.51–1.19	27,459	17,021–39,307	626,415	388,293–896,687
Eye, ear, nose or mouth infection	557	2.8	0.16	0.09–0.35	2,400	1,278–5 194	123,091	54,155–303,206	183	4.7	0.17	0.08–0.31	5,712	2,707–10,369	173,733	82,323–315,390
Systemic infection	1,069	5.4	0.29	0.17–0.52	4,388	2,586–7,799	251,237	110,732–549,877	35	0.9	0.04	0.01–0.08	1,223	286–2,534	37,201	8,691–77,061
Other infection	969	4.9	0.30	0.19–0.50	4,518	2,867–7,574	154,138	65,647–332,357	102	2.6	0.12	0.04–0.24	3,878	1,366–8,077	117,958	41,556–245,683
All types of HAI, EU/EEA[a]	19,626	100	NA	NA	88,204	62,697–129,630	3,779,677	2,197,869–6,492,437	3,858	100	NA	NA	133,565	78,576–200,494	4,111,544	2,425,610–6,115,682
All types of HAI, EU/EEA, corrected after validation	**NA**	**NA**	**NA**	**NA**	**104,177**	**74,743–152,575**	**4,464,159**	**2,620,139–7,641,606**	**NA**	**NA**	**NA**	**NA**	**143,565**	**64,736–260,655**	**4,422,629**	**1,998,384–7,950,784**

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.

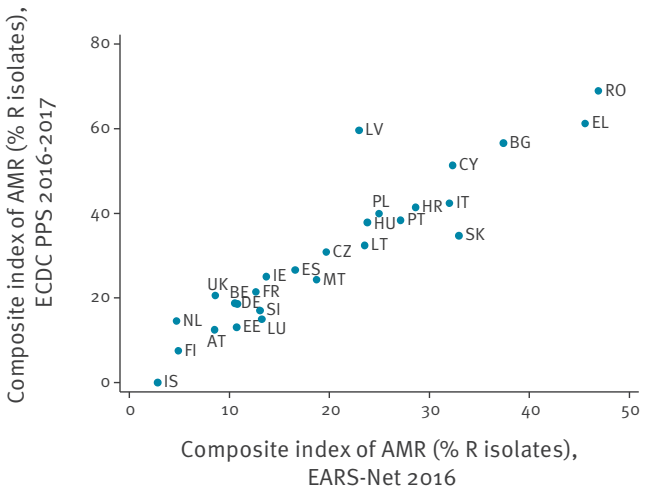
[a] After correction for non-participating countries. Cumulative sums are rounded and may differ from the sum of the individual rounded country estimates.

[b] Other lower respiratory tract infections included bronchitis, tracheobronchitis, bronchiolitis, tracheitis, lung abcess or empyema, without evidence of pneumonia.

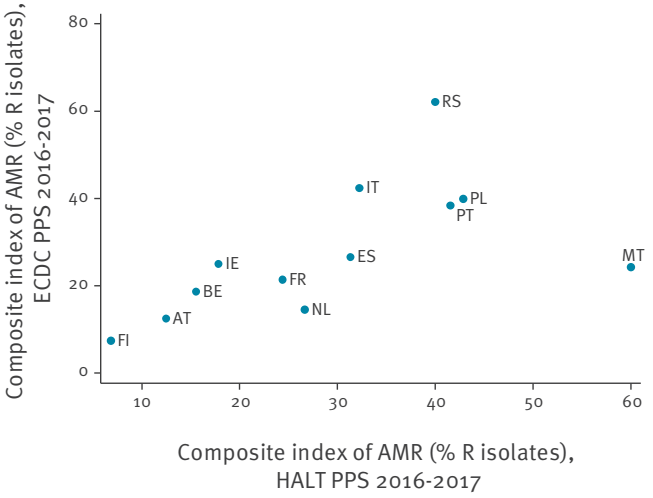
Figure

Correlations of composite index of antimicrobial resistance, EU/EEA countries and Serbia, 2016–2017

A. Correlation between the composite indices of AMR from the PPS in acute care hospitals, 2016-2017 and EARS-Net, 2016 (n = 27 countries)



B. Correlation between the composite indices of AMR from the PPS in acute care hospitals, 2016-2017 and the PPS in long-term care facilities, 2016-2017 (n = 12 countries)



ACH: acute care hospital; AMR: antimicrobial resistance; AT: Austria; BE: Belgium; BG: Bulgaria; CY: Cyprus; CZ: Czech Republic; DE: Germany; EARS-Net: European Antimicrobial Resistance Surveillance Network; ECDC: European Centre for Disease Prevention and Control; EE: Estonia; EL: Greece; ES: Spain; FI: Finland; FR: France; HALT: Healthcare-associated infections in LTCF project; HR: Croatia; HU: Hungary; IE: Ireland; IS: Iceland; IT: Italy; LT: Lithuania; LTCF: long-term care facility; LU: Luxembourg; LV: Latvia; MT: Malta; NL: the Netherlands; NO: Norway; PL: Poland; PPS: point prevalence survey; PT: Portugal; RO: Romania; RS: Serbia; SI: Slovenia; SK: Slovakia; UK: United Kingdom.

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; 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 to poor representativeness of participating LCTF in Malta, specimens in these LCTF were known to be taken predominantly in cases of treatment failure (panel B).

in the Netherlands and 7.6% (9/119) in Norway, or 0.8% (32/3,780) overall. As these imputations were done for the aggregated national results, correction of CI for clustering within LCTF could not be applied for these countries and binomial exact CI were used instead.

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 (MRSA), *Enterococcus faecium* and *Enterococcus faecalis* resistant to vancomycin, Enterobacteriaceae resistant to third-generation cephalosporins, and *Pseudomonas aeruginosa* and *Acinetobacter baumannii* resistant to carbapenems. The percentage of resistant isolates was not calculated when less than 10 isolates with known AST results were reported. The composite index of AMR at country level was validated by examining the correlation with the composite AMR index calculated from EARS-Net data from 2016, including all components of the index except AST results for Enterobacteriaceae other than *Escherichia coli* and *Klebsiella pneumoniae* because they are not included in EARS-Net [12,13]. Correlations were analysed using the Spearman correlation coefficient rho and the R-squared (R^2) and regression coefficient from linear regression.

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 4a

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[a], 2016–2017

Country	Acute care hospitals[a]								Long-term care facilities[a]			
	Composite index of AMR				Carbapenem-resistant Enterobacteriaceae				Composite index of AMR		Carbapenem-resistant Enterobacteriaceae	
	Tested isolates	Resistant isolates	Estimated annual HAI		Tested isolates	Resistant isolates	Estimated annual HAI		Tested isolates	Resistant isolates	Tested isolates	Resistant isolates
	n	%	n	95% CI	n	%	n	95% CI	n	%	n	%
Austria[b]	217	12.4	1,759	713–3,984	124	0.8	55	8–387	16	12.5	12	0.0
Belgium	495	18.6	8,458	4,422–14,621	318	1.3	261	104–654	45	15.6	34	0.0
Bulgaria[b]	53	56.6	8,687	3,189–23,328	30	10.0	2,014	479–8,291	NP	NA	NA	NA
Croatia[b]	280	41.4	3,823	2,491–5,808	114	5.3	300	80–1,053	6	NA	4	NA
Cyprus[a,b]	37	51.4	1,070	431–2,380	15	6.7	19	3–119	0	NA	NA	NA
Czech Republic[a]	627	30.8	16,348	9,726–25,665	393	0.8	87	30–261	NP[a]	NA	NA	NA
Denmark[a]	NP	NA	UNK	NA	NA	NA	UNK	NA	0	NA	0	NA
Estonia	107	13.1	462	138–1,398	58	0.0	0	NA	NP	NA	NA	NA
Finland	188	7.4	298	139–619	92	0.0	0	NA	44	6.8	36	0.0
France[a]	738	21.4	44,953	21,316–86,180	413	0.5	785	129–4,943	41	24.4	35	14.3
Germany	197	18.8	27,228	13,378–52,651	95	2.1	1,769	420–7,444	2	NA	1	NA
Greece[b]	456	61.2	10,605	7,809–14,193	197	43.7	4,157	2,467–6,831	2	NA	1	NA
Hungary	256	37.9	5,383	2,578–9,837	126	0.8	41	6–289	7	NA	6	NA
Iceland	15	0.0	0	NA	10	0.0	0	NA	NP	NA	NA	NA
Ireland	192	25.0	1,206	454–2,704	107	0.9	45	6–306	28	17.9	12	8.3
Italy	555	42.3	63,930	39,969–98,909	306	16.7	11,660	6,489–20,554	93	32.3	67	5.6
Latvia	47	59.6	804	309–2,043	19	5.3	38	4–356	NP	NA	NA	NA
Lithuania	108	32.4	1,509	680–3,224	35	0.0	0	NA	2	.	3	NA
Luxembourg[b]	67	14.9	79	26–228	38	2.6	4	0–46	3	.	2	NA

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.

[a]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.

[b]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.

[c]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 Macedoniaa, 2016–2017

Country	Acute care hospitals[a]								Long-term care facilities[a]			
	Composite index of AMR				Carbapenem-resistant Enterobacteriaceae				Composite index of AMR		Carbapenem-resistant Enterobacteriaceae	
	Tested isolates	Resistant isolates	Estimated annual HAI		Tested isolates	Resistant isolates	Estimated annual HAI		Tested isolates	Resistant isolates	Tested isolates	Resistant isolates
	n	%	n	95% CI	n	%	n	95% CI	n	%	n	%
Malta[b]	33	24.2	195	69–544	25	4.0	23	0–2,216	15	60.0	7	NA
The Netherlands[b]	110	14.5	2,755	1,201–6,052	73	2.7	167	40–688	15	26.7	13	0.0
Norway[a]	ND	NA	UNK	NA	ND	NA	UNK	NA	ND	NA	ND	NA
Poland[b]	531	39.9	30,356	18,445–47,719	262	6.9	2,535	976–6,569	21	42.9	13	0.0
Portugal	829	38.4	9,177	5,431–14,287	462	6.9	1,062	347–2,643	65	41.5	47	10.6
Romania	164	68.9	13,913	7,377–25,458	80	33.8	3,475	1,726–6,923	NP	NA	NA	NA
Slovakia	164	34.8	3,061	1,543–5,848	101	2.0	247	60–1,022	8	NA	4	NA
Slovenia	194	17.0	969	397–2,087	117	1.0	3	1–17	NP	NA	NA	NA
Spain	926	26.6	25,722	15,842–38,973	512	4.1	2,632	1,136–5,609	134	31.3	82	0.0
Sweden	NP	NA	UNK	NA	NA	NA	UNK	NA	3	NA	1	NA
UK–England	370	20.5	7,634	3,950–13,560	205	1.5	316	101–986	NP	NA	NA	NA
UK–Northern Ireland	40	25.0	333	145–758	17	0.0	0	NA	2	NA	0	NA
UK–Scotland[a]	ND	NA	UNK	NA	ND	NA	UNK	NA	ND	NA	ND	NA
UK–Wales	35	37.1	351	67–1,213	8	NA	0	NA	1	NA	0	NA
EU/EEA[c]	8,031	31.6	291,067	162,417–504,270	4,352	6.2	31,696	14,611–78,205	553	28.0	380	4.2
Former Yugoslav Republic of Macedonia	NP	NA	UNK	NA	ND	NA	UNK	NA	2	NA	1	NA
Serbia	382	62.0	7,555	4,516–12,230	201	25.4	1,435	801–2,481	10	40.0	8	NA

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.

[a]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.

[b]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.

[c]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 countriesa, Serbia and the former Yugoslav Republic of Macedonia, 2016–2017 (n = 103,763 residents)

Country	LCTF included in analysis	Residents included in analysis	Residents with at least one HAI in PPS sample (HAI prevalence)[b]			HAI from other facility[c]	HAI prevalence origin own LTCF[d]	LTCF beds in the country	Residents with at least one HAI on a given day, estimated	
	n	n	n	%	95%CI	%	n	n	n	(95% CI)
Austria[e]	12	2,065	105	5.1	2.8–8.9	6.5	4.6	72,602	3,504	1,966–6,145
Belgium	79	8,206	354	4.3	3.6–5.1	4.9	3.6	146,462	5,997	5,037–7,152
Croatia[e]	8	1,607	15	0.9	0.4–1.9	13.3	0.7	37,249	329	159–679
Cyprus[e]	11	312	15	4.8	2.7–7.8	ND	ND	3,436	157	89–255
Denmark	95	3,346	175	5.2	4.5–6.1	5.0	4.8	42,668	2,120	1,808–2,481
Finland	149	5,914	208	3.5	3.0–4.1	5.1	3.2	50,373	1,685	1,436–1,967
France[f]	91	6,957	206	3.0	2.6–3.4	ND	3.0	687,936	19,352	16,831–22,134
Germany	82	6,705	115	1.7	1.3–2.3	13.0	1.3	852,849	13,936	10,209–18,878
Greece[e]	13	812	51	6.3	3.7–10.5	3.8	5.9	10,849	647	381–1,079
Hungary	75	7,670	73	1.0	0.7–1.4	4.1	0.9	57,929	523	369–743
Ireland	109	5,613	276	4.9	4.2–5.8	6.0	4.5	30,531	1,427	1,207–1,682
Italy	196	11,417	442	3.9	3.3–4.6	13.6	3.1	186,872	6,870	5,787–8,149
Lithuania	26	3,438	32	0.9	0.4–1.9	15.6	0.6	11,722	104	50–212
Luxembourg[e]	16	1,616	30	1.9	1.1–3.0	0.0	1.8	6,966	123	75–199
Malta[e]	11	2,485	76	3.1	1.6–5.9	12.3	2.3	5,035	146	75–281
The Netherlands[f]	57	4,547	160	3.5	3.0–4.1	5.0	3.2	92,000	3,075	2,624–3,580
Norway[f]	62	2,447	119	4.9	4.0–5.8	2.5	4.6	39,583	1,829	1,521–2,178
Poland[e]	24	2,281	90	3.9	2.1–7.3	7.6	3.5	17,291	649	345–1,198
Portugal	132	3,633	214	5.9	4.5–7.6	15.9	4.3	8,400	470	362–608
Slovakia	59	5,091	108	2.1	1.5–3.0	4.5	2.0	27,497	554	392–778
Spain	46	6,808	579	8.5	7.0–10.3	18.9	6.2	372,306	30,064	24,688–36,501
Sweden	285	3,604	57	1.6	1.2–2.1	ND	1.6	93,000	1,396	1,051–1,864
UK–Northern Ireland	70	2,614	97	3.7	2.9–4.7	7.1	3.4	15,924	561	443–710
UK–Scotland	52	2,147	125	5.8	4.5–7.5	2.4	5.3	37,746	2,087	1,610–2,697
UK–Wales	28	966	58	6.0	4.4–8.2	0.0	6.0	24,646	1,405	1,026–1,915
Participating EU/EEA countries[b,g]	**1,788**	**102,301**	**3,780**	**3.6**	**2.9–4.5**	**8.9**	**3.1**	**2,931,872**	**99,008**	**79,539–124,064**
Former Yugoslav Republic of Macedonia	4	294	10	3.4	2.3–4.9	0.0	2.7	1,166	38	26–55
Serbia	6	1,168	37	3.2	1.9–5.1	7.3	2.8	19,654	592	362–960
EU/EEA, corrected[g,h]	NA	NA	NA	3.6	2.9–4.5	NA	NA	3,486,999	117,754	94,599–147,553
EU/EEA, corrected after validation	**NA**	**NA**	**NA**	**3.9**	**2.4–6.0**	**NA**	**NA**	**3,486,999**	**129,940**	**79,570–197,625**

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.

[a] The Czech Republic only submitted data on institutional indicators from 11 LCTF and was not included in the current analysis.

[b] 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.

[c] Percentage of HAI imported from a hospital or another LTCF; not included in France and Sweden, and unknown for Cyprus (aggregated data).

[d] 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).

[e] Country data representativeness was poor in Austria, Croatia, Cyprus, Greece, Luxembourg, Malta and Poland.

[f] France, the Netherlands and Norway used a national protocol which required imputation of non-included types of HAI.

[g] Cumulative 95% confidence intervals for the EU/EEA.

[h] Corrected for non-participating EU/EAA countries with estimation for Bulgaria, Czech Republic, Estonia, Iceland, Latvia, Romania, Slovenia and UK–England combined.

In LCTF, 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 LCTF 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 LCTF, 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 HAI incidence and total number of patients in ACH with at least one HAI per year in the period 2016 to 2017.

To calculate CI around EU/EEA estimates, the number of patients with at least one HAI obtained from the lower and upper limits of the country-specific 95% CIs were summed up and divided by the total number of occupied beds (for prevalence) or the total number of discharges (for estimated incidence) in the EU/EEA. These 'cumulative 95% CI' (95% cCI) therefore reflect a larger, more conservative uncertainty than would be obtained by calculating 95% CI on the EU/EEA totals, which is in accordance with the limitations of the prevalence measurement and the uncertainty inherent to the conversion of prevalence to incidence.

Results

Point prevalence survey in acute care hospitals

Participation

In total, 1,735 hospitals from 28 EU/EEA countries and one EU candidate country (Serbia) participated in the second PPS of HAI and antimicrobial use in European ACH in the period 2016 to 2017. Counting UK administrations separately, the country representativeness of the sample was optimal in 20 countries, good in 10, and poor in two countries. After adjustment for over-representation of countries contributing more than 20,000 patients to the PPS, 325,737 patients from 1,275 ACH remained in the final sample. Aggregated results were only reported for the EU/EEA, corresponding to 310,755 patients from 1,209 ACH. The distribution of the type of ACH 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% cCI: 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% cCI: 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 reported as having an HAI did not 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% cCI: 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% cCI: 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% cCI: 81,022–117,484) patients with at least one HAI on any given day and 3,758,014 (95% cCI: 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 (21.4% 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; $p < 0.001$; R^2: 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% cCI: 162,417–504,270) patients for the composite index of AMR and 31,696 (95% cCI: 14,611–78,205) patients for carbapenem-resistant Enterobacteriaceae.

ACH: acute care hospital; AMR: antimicrobial resistance; AT: Austria; BE: Belgium; BG: Bulgaria; CY: Cyprus; CZ: Czech Republic; DE: Germany; EARS-Net: European Antimicrobial Resistance Surveillance Network; ECDC: European Centre for Disease Prevention and Control; EE: Estonia; EL: Greece; ES: Spain; FI: Finland; FR: France; HALT: Healthcare-associated infections in LTCF project; HR: Croatia; HU: Hungary; IE: Ireland; IS: Iceland; IT: Italy; LT: Lithuania; LCTF: long-term care facility; LU: Luxembourg; LV: Latvia; MT: Malta; NL: the Netherlands; NO: Norway; PL: Poland; PPS: point prevalence survey; PT: Portugal; RO: Romania; RS: Serbia; SI: Slovenia; SK: Slovakia; UK: United Kingdom.

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; 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 to poor representativeness of participating LCTF in Malta, specimens in these LCTF were known to be taken predominantly in cases of treatment failure (panel B).

Point prevalence survey in long-term care facilities

Participation

In total, 3,062 LCTF 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 LCTF 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 LCTF were included for analysis. The main aggregated results were reported for 80.5% of participating LCTF, i.e. general nursing homes (n = 1,025), residential homes (n = 176) and mixed LCTF (n = 587), corresponding to 102,301 residents and 1,788 LCTF in EU/EEA countries. The characteristics of LCTF 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 LCTF was 3.6% (95% cCI: 2.9–4.5%). Validation of the PPS in LCTF was performed for 953 residents in 17 LCTF 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% cCI: 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 LCTF was estimated at 129,940 (95% cCI: 79,570–197,625) residents (Table 5).

Types of healthcare-associated infections and isolated microorganisms

The most frequently reported types of HAI in LCTF 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 another LTCF, respectively. The origin was unknown for 6.4% of HAI in LCTF. 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 LCTF 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 LCTF were available for 742 (19.2%) HAI. The 10 most frequently isolated bacteria were *E. coli* (30.7%), *S. 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%).

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 LCTF, although Malta was an outlier (Figure, Spearman's *rho* excluding Malta: 0.86; $p<0.001$; $R^2 = 0.69$). On average, the percentage of resistant microorganisms was similar in both settings (regression coefficient excluding Malta: 1.08). Carbapenem resistance in Enterobacteriaceae in LCTF 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 LCTF 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 LCTF in the EU/EEA for the same time period. As expected, the overall prevalence of HAI was higher in ACH than in LCTF, 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 LCTF 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 LCTF of 3.7% before correction was only slightly higher than the prevalence of 3.4% found in the ECDC PPS in LCTF 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 LCTF 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 indices 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 LCTF 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 LCTF 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 LCTF.

Our study has several limitations. Firstly, the small number of countries and LCTF that performed validation studies in the PPS in LCTF resulted in less robust prevalence estimates for LCTF 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 Rhame 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 LCTF. In addition, as national denominator data for specialised LCTF 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 LCTF 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 LCTF 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 LCTF and one country for 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 LCTF. 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 totally 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 LCTF. 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 LCTF 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.

Acknowledgements

The authors would like to thank all the participating hospitals and long-term care facilities in particular, the staff that collected, validated and entered the data during the survey and the national teams that coordinated the surveys in each participating country and that performed the validation studies.

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 HAI-Net 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

1. Cassini A, Plachouras D, Eckmanns T, Abu Sin M, Blank HP, Ducomble T, et al. Burden of six healthcare-associated infections on European population health: estimating incidence-based disability-adjusted life years through a population prevalence-based modelling study. PLoS Med. 2016;13(10):e1002150. https://doi.org/10.1371/journal.pmed.1002150 PMID: 27755545
2. Cassini A, Colzani E, Pini A, Mangen MJ, Plass D, McDonald SA, et al. Impact of infectious diseases on population health using incidence-based disability-adjusted life years (DALYs): results from the Burden of Communicable Diseases in Europe study, European Union and European Economic Area countries, 2009 to 2013. Euro Surveill. 2018;23(16):17-00454. https://doi.org/10.2807/1560-7917.ES.2018.23.16.17-00454 PMID: 29692315
3. European Centre for Disease Prevention and Control (ECDC). Point prevalence survey of healthcare-associated infections and antimicrobial use in European acute care hospitals,

2011-2012. Stockholm: ECDC; 2013. Available from: http://www.ecdc.europa.eu/en/publications/Publications/healthcare-associated-infections-antimicrobial-use-PPS.pdf

4. European Centre for Disease Prevention and Control (ECDC). Point prevalence survey of healthcare-associated infections and antimicrobial use in European long-term care facilities. May–September 2010. Stockholm: ECDC; 2014. Available from: https://ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/healthcare-associated-infections-antimicrobial-consumption-point-prevalence-survey-long-term-care-facilities-2010.pdf
5. Suetens C. Healthcare-associated infections in European long-term care facilities: how big is the challenge? Euro Surveill. 2012;17(35):20259. PMID: 22958606
6. European Centre for Disease Prevention and Control (ECDC). Point prevalence survey of healthcare-associated infections and antimicrobial use in European long-term care facilities. April–May 2013. Stockholm: ECDC; 2014. Available from: http://ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/healthcare-associated-infections-point-prevalence-survey-long-term-care-facilities-2013.pdf
7. European Centre for Disease Prevention and Control (ECDC). Point prevalence survey of healthcare-associated infections and antimicrobial use in European acute care hospitals. Protocol version 5.3. Stockholm: ECDC; 2016. Available from: https://ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/PPS-HAI-antimicrobial-use-EU-acute-care-hospitals-V5-3.pdf
8. European Centre for Disease Prevention and Control (ECDC). Protocol for point prevalence surveys of healthcare-associated infections and antimicrobial use in European long-term care facilities. Version 2.1. Stockholm: ECDC; 2016. Available from: https://ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/HALT-3-LTCF-PPS-Protocol-v2.1.pdf
9. Eurostat database. Health care facilities. Hospital beds by type of care. [Accessed: 12 October 2018]. Available from: https://ec.europa.eu/eurostat/web/products-datasets/-/hlth_rs_bds
10. Eurostat database. Health care activities. Hospital discharges and length of stay for inpatient and curative care. [Accessed 12 October 2018]. Available from: https://ec.europa.eu/eurostat/web/products-datasets/-/hlth_co_dischls
11. Eurostat database. Health care facilities. Long-term care beds in nursing and residential care facilities by NUTS 2 regions. [Accessed 17 Jul 2018]. Available from: https://ec.europa.eu/eurostat/web/products-datasets/-/hlth_rs_bdsns
12. European Centre for Disease Prevention and Control (ECDC). Surveillance of antimicrobial resistance in Europe 2016. Annual Report of the European Antimicrobial Resistance Surveillance Network (EARS-Net). Stockholm: ECDC; 2017. Available from https://ecdc.europa.eu/sites/portal/files/documents/AMR-surveillance-Europe-2016.pdf
13. European Centre for Disease Prevention and Control (ECDC). Data from the ECDC Surveillance Atlas - Antimicrobial resistance. Stockholm: ECDC. [Accessed: 24 August 2018]. Available from https://ecdc.europa.eu/en/antimicrobial-resistance/surveillance-and-disease-data/data-ecdc
14. Rhame FS, Sudderth WD. Incidence and prevalence as used in the analysis of the occurrence of nosocomial infections. Am J Epidemiol. 1981;113(1):1-11. https://doi.org/10.1093/oxfordjournals.aje.a113058 PMID: 7457475
15. Jankowski HK, Wellner JA. Estimation of a discrete monotone distribution. Electron J Stat. 2009;3(0):1567-605. https://doi.org/10.1214/09-EJS526 PMID: 20419057
16. European Centre for Disease Prevention and Control (ECDC). Protocol for validation of point prevalence surveys of healthcare-associated infections and antimicrobial use in European long-term care facilities. 2016-2017 version 1.1. Stockholm: ECDC; 2016. Available from https://ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/HALT-3-Validation-Protocol-v1.1.pdf
17. Gastmeier P, Bräuer H, Sohr D, Geffers C, Forster DH, Daschner F, et al. Converting incidence and prevalence data of nosocomial infections: results from eight hospitals. Infect Control Hosp Epidemiol. 2001;22(1):31-4. https://doi.org/10.1086/501821 PMID: 11198019
18. Meijs AP, Ferreira JA, DE Greeff SC, Vos MC, Koek MB. Incidence of surgical site infections cannot be derived reliably from point prevalence survey data in Dutch hospitals. Epidemiol Infect. 2017;145(5):970-80. https://doi.org/10.1017/S0950268816003162 PMID: 28065193
19. Cassini A, Högberg LD, Plachouras D, Quattrocchi A, Hoxha A, Simonsen GS, et al. Attributable deaths and disability-adjusted life-years caused by infections with antibiotic-resistant bacteria in the EU and the European Economic Area in 2015: a population-level modelling analysis. Lancet Infect Dis. 2018. Published ahead of print.
20. Council of the European Union. Council Recommendation of 9 June 2009 on patient safety, including the prevention and control of healthcare associated infections. Official Journal of the European Union. 2009. C 151/1. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2009:151:0001:0006:EN:PDF
21. Zingg W, Holmes A, Dettenkofer M, Goetting T, Secci F, Clack L, et al. systematic review and evidence-based guidance on organization of hospital infection control programmes (SIGHT) study group. Hospital organisation, management, and structure for prevention of health-care-associated infection: a systematic review and expert consensus. Lancet Infect Dis. 2015;15(2):212-24. https://doi.org/10.1016/S1473-3099(14)70854-0 PMID: 25467650
22. World Health Organization (WHO). Guidelines on core components of infection prevention and control programmes at the national and acute health care facility level. Geneva: WHO; 2016. Available from: http://www.who.int/gpsc/ipc-components-guidelines/en/
23. World Health Organization (WHO). Global guidelines for the prevention of surgical site infection. Geneva: WHO; 2016. Available from: http://apps.who.int/iris/bitstream/handle/10665/250680/9789241549882-eng.pdf;jsessionid=D9392589CE8819145EC804EA139481F3?sequence=1.
24. Tschudin-Sutter S, Kuijper EJ, Durovic A, Vehreschild MJGT, Barbut F, Eckert C, et al. Committee. Guidance document for prevention of Clostridium difficile infection in acute healthcare settings. Clin Microbiol Infect. 2018;24(10):1051-4. https://doi.org/10.1016/j.cmi.2018.02.020 PMID: 29505879
25. European Centre for Disease Prevention and Control (ECDC). Systematic review and evidence-based guidance on perioperative antibiotic prophylaxis. Stockholm: ECDC; 2013. Available from: https://www.ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/Perioperative%20antibiotic%20prophylaxis%20-%20June%202013.pdf

License and copyright