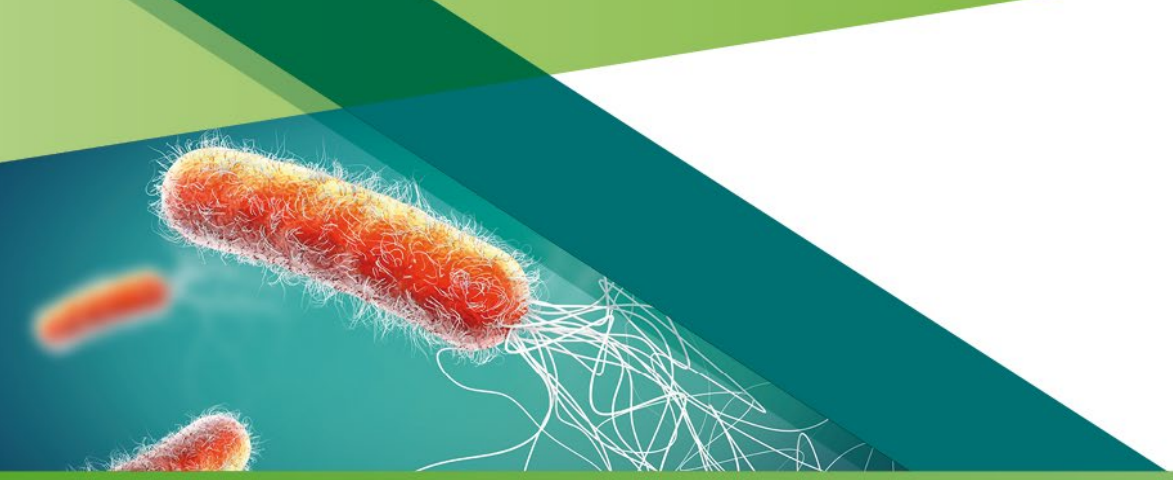

SURVEILLANCE REPORT

Antimicrobial resistance in the EU/EEA (EARS-Net)

Annual Epidemiological Report for 2023

Key facts

- In 2024, all European Union/European Economic Area (EU/EEA) countries reported data for 2023 to the European Antimicrobial Resistance Surveillance Network (EARS-Net).
- Antimicrobial resistance (AMR) can be expressed as the estimated total incidence of bloodstream infections with antimicrobial-resistant bacteria (infections per 100 000 population).

EU targets on antimicrobial resistance

- In 2023, the estimated total EU incidence of meticillin-resistant *Staphylococcus aureus* (MRSA) bloodstream infections was 4.64 per 100 000 population (country range 0–15.5). This was 17.6% lower than in 2019 (baseline year) and 0.15 per 100 000 population lower than the 2030 target of 4.79 per 100 000 population. For the EU overall, a statistically significant decreasing trend was detected between 2019 (baseline year) and 2023.
- The estimated total EU incidence of third-generation cephalosporin-resistant *Escherichia coli* bloodstream infections was 10.35 per 100 000 population (country range 0–19.56) in 2023. This was 3.6% lower than in 2019 (baseline year) and 0.68 per 100 000 population higher than the 2030 target of 9.67 per 100 000 population. For the EU overall, there was no statistically significant trend detected between 2019 (baseline year) and 2023.
- The estimated total EU incidence of carbapenem-resistant *Klebsiella pneumoniae* bloodstream infections was 3.97 per 100 000 population (country range 0.00–21.44) in 2023. This was 57.5% higher than in 2019 (baseline year) and 1.58 per 100 000 population higher than the 2030 target of 2.39 per 100 000 population. For the EU overall, a statistically significant increasing trend was detected between 2019 (baseline year) and 2023.
- In summary, while the EU target for the incidence of MRSA bloodstream infections had already been reached by 2023, the EU incidence of third-generation cephalosporin-resistant *E. coli* bloodstream infections only showed a small decrease compared to 2019 (baseline year) and the EU incidence of carbapenem-resistant *K. pneumoniae* bloodstream infections showed an increase by over 50% compared to 2019 (baseline year), which counteracts the target of a 5% reduction by 2030.

Overall antimicrobial resistance situation in the EU/EEA

- Data from EARS-Net show that, as in previous years, AMR levels remained high in the EU/EEA in 2023.
- Increases in the estimated EU incidences of bloodstream infections with resistant bacteria were observed not only for two of the above-mentioned AMR-pathogen combinations with an EU target, but also for many other bacteria and antimicrobial groups under surveillance, such as antimicrobial-resistant *K. pneumoniae* (other than carbapenem-resistant), vancomycin-resistant *Enterococcus faecium* and piperacillin-tazobactam-, ceftazidime-, and carbapenem-resistant *Pseudomonas aeruginosa*.

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Stockholm, November 2024

- The AMR situation reported by EU/EEA countries varied widely, depending on the bacterial species, antimicrobial group and geographical region. The highest estimated incidences of antimicrobial-resistant bloodstream infections were generally reported by countries in the south or southeast of Europe.
- For each bacterial species, country-specific information on the estimated incidence of antimicrobial-resistant bloodstream infections (including the recommended EU targets on AMR), the percentage of invasive isolates with AMR, data availability and the percentage of intensive care unit patients is available in country summaries. Results by age group and sex are available in the ECDC Surveillance Atlas of Infectious Diseases (https://atlas.ecdc.europa.eu/).

Public health conclusions

- Estimates based on EARS-Net data from 2020 indicate that each year more than 35 000 people die in the EU/EEA as a direct consequence of antimicrobial-resistant infections.
- The overall poor progress towards the EU targets on AMR and, more particularly, the continued increase in the incidence of carbapenem-resistant *K. pneumoniae* bloodstream infections, highlights the urgent need for intensified public health action against AMR.
- The Council Recommendation on stepping up EU actions to combat antimicrobial resistance in a One Health approach (2023/C 220/01) encourages Member States to develop and implement national action plans against AMR, and highlights the need for Member States to allocate appropriate human and financial resources for the effective implementation of these plans.
- The plans should include key elements, such as enhanced surveillance and strengthened infection prevention and control programmes in hospitals and other healthcare settings, integrated with antimicrobial stewardship programmes and good diagnostic practices.
- In the absence of stronger, swifter public health action, it is unlikely that the EU will reach all its AMR targets by 2030. The consequence will be an increased number of infections with antibiotic-resistant bacteria that will be more difficult to treat, leading to increasing challenges for patients and AMR-related deaths.

Methods

The results presented in this report are based on antimicrobial resistance (AMR) data from invasive isolates (retrieved from blood or cerebrospinal fluid samples) reported to the European Antimicrobial Resistance Surveillance Network (EARS-Net) by all (n=30) European Union (EU) and European Economic Area (EEA) countries in 2024 (data referring to 2023). Until the end of 2019, EARS-Net collected data from the United Kingdom (UK), however this stopped as of 2020 when the UK withdrew from the European Union. Data from the UK are excluded from the results in this report. Results for the UK from before 2020 can be found in previous Annual Epidemiological Reports. In 2024, France reported aggregated data for some of the bacterial species - antimicrobial group combinations. Therefore, data from France are excluded from the results in several instances in this report. The latest country-specific data, based on the isolate level data reported to ECDC, can be retrieved from the ECDC Surveillance Atlas of Infectious Diseases [1].

EARS-Net

EARS-Net is coordinated by ECDC with the aim of collecting, analysing and reporting data on AMR through a network of national surveillance systems across EU/EEA countries and, as defined in the EARS-Net reporting protocol [2], facilitating action to address AMR.

EARS-Net is based on a network of representatives nominated by EU/EEA countries (i.e. national focal points for AMR, and operational contact points for epidemiology, for microbiology and for The European Surveillance System (TESSy)/IT data manager interaction for diseases caused by antimicrobial-resistant microorganisms) who collect routine clinical antimicrobial susceptibility testing (AST) data through national AMR surveillance networks. Participating institutions are listed in Annex 1. Scientific guidance and support are provided by the EARS-Net Disease Network Coordination Committee, which is composed of experts elected from among the nominated national focal points and operational contact points, complemented by observers from organisations involved in AMR surveillance. EARS-Net activities are coordinated in close collaboration with three other ECDC surveillance networks: the European Antimicrobial Resistance Genes Surveillance Network (EURGen-Net), the European Surveillance of Antimicrobial Consumption Network (ESAC-Net) and the Healthcare-Associated Infections Surveillance Network (HAI-Net). EARS-Net also collaborates with the European Society of Clinical Microbiology and Infectious Diseases (ESCMID) and with the European Committee on Antimicrobial Susceptibility Testing (EUCAST), which is supported by ECDC and ESCMID.

Data from EARS-Net are provided to the World Health Organization Regional Office for Europe (WHO/Europe) and made available via the WHO/Europe AMR dashboard together with AMR data from the WHO European Region [3]. A summary for the WHO European Region is published jointly with WHO/Europe [4]. ECDC also provides EARS-Net data via WHO/Europe to the WHO Global Antimicrobial Resistance and Use Surveillance System (GLASS) [5].

In 2023, all EU Member States and three EEA countries participated in EARS-Net. Since the initiation of the network, there has been a large increase in the number of participating laboratories, which suggests that national AMR surveillance systems in the EU/EEA are being strengthened. The laboratories that participate in the annual EARS-Net external quality assessment (EQA) exercise contribute to improved data quality and an increasing ability of EU/EEA countries to report comparable AMR data [6]. However, not all the laboratories providing EARS-Net data for 2023 chose to participate in the 2023 EARS-Net EQA exercise. The results from the EARS-Net EQA exercise for 2023, including details about the participation rate by country, are published in a separate report [6].

Antimicrobial susceptibility data

Each year, countries report routine AST results, collected from one or more clinical microbiology laboratories, to ECDC. When it is not possible to include data from all the relevant laboratories, countries can report data from sentinel laboratories. Either way, the data reflect the laboratory AST data that are collected in the surveillance system of each country. The AMR surveillance focuses on invasive (blood and cerebrospinal fluid) isolates, of eight key bacterial species (*Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Acinetobacter* species, *Streptococcus pneumoniae*, *Staphylococcus aureus, Enterococcus faecalis* and *Enterococcus faecium*). Other notifiable diseases caused by microorganisms with AMR, such as *Campylobacter* spp., *Mycobacterium tuberculosis, Neisseria gonorrhoeae*, and *Salmonella* spp., are also monitored by ECDC [7] but are not included in EARS-Net.

EARS-Net collects AMR data from EU/EEA countries through TESSy in EpiPulse [8], a web-based platform for data submission and storage hosted by ECDC. Previously TESSy was a separate web-based platform, but since 2 July 2023, TESSy has been part of a larger platform called EpiPulse. For detailed information on data collection, refer to the EARS-Net reporting protocol [2].

Only data from invasive (blood and cerebrospinal fluid) isolates are included in EARS-Net. This restriction aims to reduce the impact of different sampling frames between laboratories and countries which, to some extent, hamper data interpretation. Any bacterial isolate of the species under surveillance found in a sample taken from a normally sterile body fluid may be considered a pathogen. Including routine, non-invasive isolates may produce results that cannot be compared for surveillance purposes because healthcare-seeking behaviour may differ and the processing of such samples is heavily influenced by clinical interpretation, and diagnostic and treatment guidelines, which vary between countries. Historically, EARS-Net accepted data on isolates from both blood and cerebrospinal fluid samples for *E. coli*, *K. pneumoniae*, *P. aeruginosa*, *Acinetobacter* spp. and *S. pneumoniae*, but only isolates from blood samples for *S. aureus*, *E. faecalis* and *E. faecium*. Starting with 2019 data, in order to harmonise data collection between the Central Asian and European Surveillance of Antimicrobial Resistance (CAESAR) network and EARS-Net, EARS-Net includes data from both blood and cerebrospinal fluid samples for all bacterial species under surveillance.

Starting with the data collected for 2019, EARS-Net now only accepts data generated using EUCAST clinical breakpoints [9]. Before this, the use of EUCAST breakpoints was encouraged, but results based on other interpretive criteria used by reporting countries were also accepted for analysis.

From 2020 onwards, EUCAST clinical breakpoints for aminoglycosides indicate that in systemic infections caused by *E. coli*, *K. pneumoniae*, *P. aeruginosa* and *Acinetobacter* spp., aminoglycosides should be used in combination with other active therapies.

Starting with the data collected for 2023, EARS-Net allowed (pilot-tested) collection of data on novel antimicrobials (cefiderocol, ceftazidime-avibactam, ceftolozane-tazobactam, imipenem-relebactam, and meropenem-vaborbactam) for *E. coli, K. pneumoniae, P. aeruginosa* and *Acinetobacter* spp. The novel antimicrobials were selected based on inclusion in the 'Reserve' group under WHO's Access Watch Reserve (AWaRe) classification [10] and their potential use to treat infections with carbapenem-resistant gram-negative bacteria.

It is possible for reporting countries to correct and re-upload historical data. The latest published report therefore supersedes previous reports and reflects the most recent available data. This report is based on data reported to EARS-Net for the period 2019–2023 and retrieved from EpiPulse on 19 August 2024.

Coverage and representativeness of population, hospitals and patients included in EARS-Net

Data sources

Since 2018, data on population coverage, number of blood culture sets, and country representativeness have been collected via TESSy/EpiPulse [8]. Data for previous years combined TESSy data with data collected through questionnaires distributed to the national focal points for AMR.

Indicators of coverage and representativeness

Population coverage

Population coverage is expressed as the estimated percentage of the population in an entire country under surveillance by the laboratories reporting data to EARS-Net. This value should be considered as an indication of the crude population coverage, since the exact percentage of the population under surveillance is often difficult to assess, due to overlapping hospital catchment areas and patients seeking care in areas where they do not reside. The population coverage is calculated as the mean of the coverage for the following bacterial species: *E. coli*, *K. pneumoniae*, *P. aeruginosa*, *S. aureus*, *E. faecalis* and *E. faecium*. Due to outliers in some countries, *S. pneumoniae* and *Acinetobacter* spp. are not included in the calculation.

Geographical representativeness

Geographical representativeness is a qualitative indicator referring to geographical coverage. The categories for 2023 are listed and described in Table 1. The definition was adjusted as of the data collection in 2022 [2]. For data reported for 2019–2020, the definition of geographical representativeness can be found in the report 'Antimicrobial resistance surveillance in Europe 2022 – 2020 data' [11].

Hospital representativeness

Hospital representativeness is a qualitative indicator referring to representativeness of hospitals served by the EARS-Net-participating laboratories, compared to the country distribution of the various types of hospitals. The categories are listed and described in Table 1.

Isolate representativeness

Isolate representativeness is a qualitative indicator referring to representativeness of data reported by EARS-Net laboratories in relation to the microorganisms causing invasive infections in the included hospitals. The categories are listed and described in Table 1. The collection of data related to isolate representativeness was adjusted as of the data collection in 2022 [2]. With data reported for 2019–2020, isolate representativeness refers to patient and isolate representativeness, defined in the report 'Antimicrobial resistance surveillance in Europe 2022 – 2020 data' [11].

Blood culture rate

The blood culture rate refers to the number of blood culture sets taken per 1 000 patient-days in hospitals served by EARS-Net laboratories and sent to these laboratories. The definition of a 'blood culture set' and a 'patient-day' may differ between and within countries, and this may influence the estimate. Blood culture rates were calculated as the mean of the number of blood culture sets divided by the mean total number of patient-days for hospitals served by laboratories that provided the number of performed blood culture sets, as reported for the following bacterial species: *E. coli*, *K. pneumoniae*, *P. aeruginosa*, *S. aureus*, *E. faecalis* and *E. faecium* and multiplied by 1 000. Due to outliers in some countries, data reported for *S. pneumoniae* and *Acinetobacter* spp. are not included in the calculation of the mean blood culture rate.

Isolates from intensive care units

The percentage of isolates reported from intensive care units (ICUs) was calculated for each year and each bacterial species. Isolates with missing information on hospital department were excluded from the calculation, and the results were only presented if there were ≥ 20 isolates, with 70% having data on hospital department.

Data analysis

Before being analysed, data are de-duplicated to include only the first isolate per patient, year, and bacterial species.

Estimated EU/EEA incidence of invasive isolates

Invasive isolates refer to isolates from blood or cerebrospinal fluid samples. EARS-Net only includes isolates from these types of samples. For each bacterial species, the total number of invasive isolates was estimated by dividing the number of isolates for the bacterial species reported by a country to EARS-Net by the reported population coverage of the country, and then adding the resulting numbers. This sum was then divided by the EU/EEA population to arrive at the estimated EU/EEA incidence of invasive isolates for the specific pathogen.
If information on the estimated population coverage was missing, the most recently reported population coverage for the respective year was used (i.e. either the one preceding or following it, whichever came first).

Susceptibility test categories

For the analysis, the qualitative susceptibility categories – 'susceptible, standard dosing regimen' (S), 'susceptible, increased exposure' (I) and 'resistant' (R) – are used, as reported by the laboratory, since quantitative susceptibility information is missing for a large part of the data. An isolate is considered resistant to an antimicrobial agent when tested and interpreted as R, in accordance with the clinical breakpoint criteria used by the local laboratory.

For *P. aeruginosa*, *E. coli*, *K. pneumoniae*, and *Acinetobacter* spp. and some antimicrobial agent combinations presented in this report, EUCAST breakpoints are available, as of 2021, for isolates from meningitis versus other isolates ('non-meningitis'). When possible, and starting with 2021 data, it is recommended that EU/EEA countries that generate the susceptibility categorisation of isolates at national level use 'non-meningitis' breakpoints for all interpretations, although EARS-Net does accept data as they are. As clinical patient data are not collected in EARS-Net, information was not available on which breakpoint had been used to categorise susceptibility. However, it is assumed that only a very small number of infections reported to EARS-Net are meningitides cases and the large majority are bloodstream infections. Moreover, as even in the case of cerebrospinal fluid samples, it is recommended that countries report the susceptibility categories according to 'non-meningitis' breakpoints the impact on the overall results is expected to be minor.

The term 'penicillin non-wild-type' is used in this report for *S. pneumoniae*, referring to *S. pneumoniae* isolates reported by local laboratories as I or R to penicillin, assuming minimum inhibitory concentrations (MICs) to benzylpenicillin above those of wild-type isolates (> 0.06 mg/L).

Estimated incidence of bloodstream infections with resistant bacteria

The estimated incidence of invasive isolates is considered to reflect the incidence of bloodstream infections with the respective resistant bacteria since, in the de-duplicated EARS-Net data, the number of isolates from blood samples far outweigh that from cerebrospinal fluid samples. As an example, during the period 2019–2023, each year the dataset consisted of more than 99% isolates from blood samples and less than 1% isolates from cerebrospinal fluid samples.

For each bacterial species–antimicrobial agent/group combination, the national estimated incidence of bloodstream infections with resistant bacteria was calculated by dividing the number of cases reported as R by the national population, as reported to Eurostat [12], multiplied by the estimated population coverage, as reported to EARS-Net. When information on the estimated population coverage was missing, the most recently reported population coverage for the respective year was used (i.e. either the one preceding or following it, whichever came first). The national results are included in the respective country summary. For the EU[1], first the number of cases in each country was divided by the respective national coverage. The results for all countries were then totalled, resulting in the estimated number of cases in the EU, which was then divided by the total EU population to arrive at the estimated EU incidence of bloodstream infections with resistant bacteria.

It should be noted that the reported incidence rates per population are estimates which are based on the estimated national population coverage of the AMR data, as reported by each country. The estimated incidence of bloodstream infections with resistant bacteria may therefore need to be interpreted with caution if the national population coverage is estimated as less than 100%. In addition, when national representativeness is considered by a country to be less than high, further caution may be advisable when interpreting. Where relevant in the country summary tables, the estimated incidence of bloodstream infections with resistant bacteria is marked with a footnote if one or more of the three representativeness indicators (geographical, hospital and/or isolate representativeness) were not reported as 'High', or when the antimicrobial group/agent was tested for <90% of isolates.

For the EU and each individual country, the statistical significance of temporal trends in the estimated incidence for the last five years (2019–2023) was assessed by negative binomial regression, and a p-value of <0.05 was considered significant.

National percentages

AMR (or for *S. pneumoniae* and penicillin, non-wild-type) percentages are presented for a single antimicrobial agent and/or group of antimicrobial agents. The bacterial species–antimicrobial agent combinations presented in this report for 2023 are shown in Table 2. When combining results for antimicrobial agents representing an antimicrobial group, the outcome is based on the most resistant result. For example, if the AST result of a bacterial species for imipenem is I and the AST result for meropenem is R, then the AST result for the group carbapenems, which comprises imipenem and meropenem, is set as R. The definition of combined AMR is determined as R to at least one antimicrobial agent in each of the antimicrobial groups (except for *S. pneumoniae*, for which combined AMR is calculated as combined penicillin non-wild-type and R to macrolides). Isolates with missing data for one or more of the required antimicrobial groups are excluded from the analysis of combined AMR. If fewer than 20 isolates are reported for a specific bacterial species–antimicrobial group combination in a country, percentages are not displayed in this report.

Since the analysis of combined resistance excludes isolates with incomplete AST information for the included antimicrobial groups, the analysis can also highlight bacterial species for which AMR results in EARS-Net may be biased, due to selective testing or reporting. For example, if there is a high proportion of isolates with missing AST information on the antimicrobials included for one of the species under EARS-Net surveillance, then this could indicate selective testing.

[1] Please note that as ECDC collects data from EU/EEA Member States, 2019 data were collected from the UK as the UK was still a Member State of the EU at this time.

Population-weighted EU/EEA mean percentage

A population-weighted EU/EEA mean percentage is calculated for each bacterial species–antimicrobial agent/group combination, based on data reported by EU/EEA countries. Country weightings are used to adjust for imbalances in reporting propensity and population coverage, as in most cases the total number of reported isolates by country does not reflect the population size.

The population-weighted EU/EEA mean percentage is determined by multiplying the AMR percentage for each country with the population weight (i.e. the proportion of the total EU/EEA population represented by each country) and summing the results. Weights are rescaled if AMR percentages are not available for one or more countries. Annual population data are retrieved from the Eurostat online database [12].

The statistical significance of temporal trends in AMR percentages by country and for the population-weighted EU/EEA (excluding the UK) mean is calculated based on data for the last five years (2019–2023). EU/EEA countries that did not report data for all years within the period under consideration, or reported fewer than 20 isolates for the specific bacterial species–antimicrobial agent/group combination in any year within the period are not included in the analysis. The statistical significance of trends is assessed by a chi-square test for trend, and a p-value of <0.05 is considered significant. An additional sensitivity analysis is performed when assessing the significance of the trends by including only laboratories that continuously reported data for the full five-year period. This minimises bias due to changes in reporting laboratories over time (due to expansion of the surveillance network, for instance). In some cases, this restriction results in a considerably lower number of isolates when compared with the analysis that includes all laboratories.

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Table 1. Population and hospitals contributing data: coverage, representativeness and blood culture rate, EU/EEA, 2023

Country	Estimated population coverage[a] (%)	Geographical representativeness[b]	Hospital representativeness[c]	Isolate representativeness[d]	Blood culture rate (blood culture sets/ 1 000 patient-days)[e]
Austria	90	High	High	High	ND
Belgium	42[f]	High	Medium	High	115.7[f]
Bulgaria	45	Medium	Medium	Medium	12.8
Croatia	90	High	High	High	29.0
Cyprus	82	High	High	High	69.4
Czechia	70	High	High	High	18.2
Denmark	100	High	High	High	261.7
Estonia	100	High	High	High	40.2
Finland	84	High	High	High	195.8
France	0[f]	Low [f]	Low [f]	Low [f]	ND
Germany	40	High	Medium	High	ND
Greece	68	High	High	High	ND
Hungary	90	High	High	High	19.5
Iceland	100	High	High	High	72.0
Ireland	92	High	High	High	56.5
Italy	66	High	High	High	61.2
Latvia	90	High	High	Medium	24.8
Liechtenstein	40	Medium	Medium	Medium	2.1
Lithuania	100	High	High	High	8.8
Luxembourg	100	High	High	High	42.5
Malta	95	High	High	High	32.8
Netherlands	76	High	High	High	ND
Norway	94	High	High	High	80.9
Poland	21	Medium	Medium	High	55.1
Portugal	98	High	High	High	323.6
Romania	13	Low	Low	Low	39.7
Slovakia	54	High	High	High	30.6
Slovenia	99	High	High	High	44.7
Spain	28	Medium	High	High	606.6
Sweden	89	High	High	High	112.4

ND: no data available.

[a] *As estimated by the national focal points for AMR and/or operational contact points for AMR. Estimated national population coverage: mean population coverage (%) of laboratories reporting* Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Staphylococcus aureus, Enterococcus faecalis *and* Enterococcus faecium *to EARS-Net. Due to outliers in some countries,* Streptococcus pneumoniae *and* Acinetobacter *spp. are not included in the calculation.*

[b] *Geographical representativeness. High: all main geographical regions of the country are covered. Medium: most geographical regions of the country are covered. Low: only a few geographical areas of the country are covered.*

[c] *Hospital representativeness. High: the hospital selection is representative of the acute care hospital distribution in the country. Medium: the hospital selection is partly representative of the acute care hospital distribution in the country. Low: the hospital selection is insufficiently representative of the acute care hospital distribution in the country.*

[d] *Isolate representativeness. High: the isolate selection is representative of microorganisms causing invasive infections in the included hospitals. Medium: the isolate selection is partly representative of microorganisms causing invasive infections in the included hospitals. Low: the isolate selection is insufficiently representative of microorganisms causing invasive infections in the included hospitals.*

[e] *Blood culture rate (blood culture sets/1 000 patient-days): refers to the mean number of blood culture sets divided by the mean total of patient-days of hospitals served by laboratories that provided the blood culture sets performed, as reported for the following bacterial species:* Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Staphylococcus aureus, Enterococcus faecalis *and* Enterococcus faecium*, and multiplied by 1 000. The definition of a 'blood culture set' and a 'patient-day' might differ between countries and influence the estimate.*

[f] *Not including the country's* S. pneumoniae *network.*

Table 2. Bacterial species-antimicrobial group/agent combinations presented in this report for 2023

Bacterial species	Assessed antimicrobial group/agent resistance or specific resistance mechanism	Indicative antimicrobial agent(s)
Escherichia coli	Aminopenicillins	Ampicillin or amoxicillin
	Third-generation cephalosporins	Cefotaxime, ceftriaxone or ceftazidime
	Carbapenems	Imipenem or meropenem
	Fluoroquinolones	Ciprofloxacin, levofloxacin or ofloxacin
	Aminoglycosides	Gentamicin or tobramycin
	(New antibiotics and combinations)[a]	Cefiderocol, ceftazidime-avibactam, ceftolozane-tazobactam, imipenem-relebactam, or meropenem-vaborbactam
Klebsiella pneumoniae	Third-generation cephalosporins	Cefotaxime, ceftriaxone or ceftazidime
	Carbapenems	Imipenem or meropenem
	Fluoroquinolones	Ciprofloxacin, levofloxacin or ofloxacin
	Aminoglycosides	Gentamicin or tobramycin
	(New antibiotics and combinations) [a]	Cefiderocol, ceftazidime-avibactam, ceftolozane-tazobactam, imipenem-relebactam, or meropenem-vaborbactam
Pseudomonas aeruginosa	Piperacillin-tazobactam	Piperacillin-tazobactam
	Ceftazidime	Ceftazidime
	Carbapenems	Imipenem or meropenem
	Fluoroquinolones	Ciprofloxacin or levofloxacin
	Aminoglycosides	Tobramycin
	(New antibiotics and combinations) [a]	Cefiderocol, ceftazidime-avibactam, ceftolozane-tazobactam, imipenem-relebactam, or meropenem-vaborbactam
Acinetobacter species	Carbapenems	Imipenem or meropenem
	Fluoroquinolones	Ciprofloxacin or levofloxacin
	Aminoglycosides	Gentamicin or tobramycin
	(New antibiotics and combinations) [a]	Cefiderocol, ceftazidime-avibactam, ceftolozane-tazobactam, imipenem-relebactam, or meropenem-vaborbactam
Staphylococcus aureus	MRSA	Cefoxitin or oxacillin[b]
	Fluoroquinolones	Ciprofloxacin, levofloxacin or norfloxacin[c]
	Rifampicin	Rifampicin
Streptococcus pneumoniae	Penicillins	Penicillin or oxacillin[d]
	Third-generation cephalosporins	Cefotaxime or ceftriaxone
	Fluoroquinolones	Levofloxacin, norfloxacin or moxifloxacin[e]
	Macrolides	Azithromycin, clarithromycin or erythromycin
Enterococcus faecalis	High-level aminoglycoside resistance	Gentamicin
Enterococcus faecium	Aminopenicillins	Ampicillin or amoxicillin
	High-level aminoglycoside resistance	Gentamicin
	Vancomycin	Vancomycin

MRSA: meticillin-resistant Staphylococcus aureus.

[a] *Analysed for carbapenem-resistant gram-negative bacteria.*

[b] *MRSA is based on AST results for cefoxitin or, if unavailable, oxacillin. AST results reported for cloxacillin, dicloxacillin, flucloxacillin or meticillin are accepted as a marker for oxacillin resistance if oxacillin is not reported. If no phenotypic results are available, data from molecular confirmation tests (detection of* mecA *gene PCR or a positive PBP2A-agglutination test) are accepted as a marker for MRSA.*

[c] *AST results for norfloxacin are accepted if neither ciprofloxacin nor levofloxacin results are available.*

[d] *Penicillin results are based on penicillin or, if not available, oxacillin.*

[e] *AST results for norfloxacin are accepted if neither levofloxacin nor moxifloxacin results are available.*

Overview of EU/EEA country participation in EARS-Net

In 2024, all EU Member States and EEA countries reported data for 2023 to EARS-Net. Twenty (66.7%) of these 30 countries reported that their participating laboratories had a population coverage of over two-thirds of the national population, including 14 countries that reported having a national population coverage of 90.0% or more. However, eight countries reported data with a coverage of less than half of their population (Table 1). The data provided to EpiPulse by France was more limited in 2023 than in previous years and the data analysis was adjusted accordingly.

Twenty-one (70.0%) of the 30 participating countries indicated that their reported data had a high national representativeness in terms of three metrics: covered geographical areas, included acute care hospitals, and microorganisms that caused invasive infections in those hospitals. A further four countries reported that the representativeness was 'high' for two of the three metrics, and two countries reported representativeness as 'low' for all three metrics (Table 1).

In hospitals served by the laboratories that reported data to EARS-Net in 2023, the blood culture rate was reported by 25 countries. The reported blood culture rates (blood culture sets per 1 000 patient-days) varied widely among the countries. However, these varying estimates should be interpreted with caution since the definitions of a 'blood culture set' and a 'patient-day' may differ between and within countries.

In 2023, all but two countries reported isolate data for all eight bacterial species under surveillance by EARS-Net (*E. coli*, *K. pneumoniae*, *P. aeruginosa*, *Acinetobacter* spp., *S. pneumoniae*, *S. aureus*, *E. faecalis* and *E. faecium*), while one country (France) reported isolate data for only *S. pneumoniae,* and one country (Liechtenstein) reported isolate data for only *E. coli*, *K. pneumoniae*, *P. aeruginosa*, *S. pneumoniae*, *S. aureus* and *E. faecalis*.

Based on the laboratory identifiers provided by the countries, the number of laboratories participating in EARS-Net has increased since 2019, indicating that national AMR surveillance systems are being strengthened in the EU/EEA. For 2023, data were reported from 1 123 laboratories (935 when excluding France). Moreover, 763 laboratories were identified as having reported data for each year during the period 2019–2023.

As part of the pilot reporting of AST data for new antimicrobials, nine (30.0%) of the 30 reporting countries reported data on susceptibility to new antimicrobials for carbapenem-resistant gram-negative bacteria. These data were not included in the analyses since the data were not considered as representative of the EU/EEA.

Epidemiology of bacterial species under surveillance in EARS-Net in the EU/EEA

Compared to 2022, the total number of reported invasive isolates decreased from 396 900 to 373 770. However, when excluding isolates for France (except *S. pneumoniae* isolates), the number increased from 353 237 to 373 700 isolates.

Both 2020 and 2021 coincided with major COVID-19 pandemic-associated pressures on healthcare. Therefore, it is useful to also compare 2023 data with 2019 data (last year before the COVID-19 pandemic). To analyse changes in AMR percentage and estimated incidence at EU and EU/EEA level, we excluded countries which did not continuously report data to EARS-Net, as well as France for results other than *S. pneumoniae* due to recent changes in the reporting from the French surveillance system.

For bacteria (not taking AST results into account), the highest estimated EU/EEA incidence of invasive isolates from all reporting laboratories in 2023 was *E. coli* (71.4 per 100 000 population), followed by *S. aureus* (36.9 per 100 000 population), *K. pneumoniae* (24.2 per 100 000 population), *E. faecalis* (14.1 per 100 000 population), *E. faecium* (10.7 per 100 000 population), *P. aeruginosa* (10.5 per 100 000 population), *S. pneumoniae* (7.2 per 100 000 population) and *Acinetobacter* spp. (4.6 per 100 000 population). This ranking did not differ from the ranking in 2022. It is interesting to note that, compared to 2022, the largest increase in estimated incidence occurred for *S. pneumoniae* (+26.3%) which has now surpassed its estimated incidence for 2019 (6.9 per 100 000 population).

When comparing 2019 to 2023, the largest increases (>5%) in the estimated EU/EEA incidence of invasive isolates (per 100 000 population) were for *E. faecium* (+25.9%; 8.5 and 10.7, respectively), followed by *Acinetobacter* spp. (+21.1%; 3.8 and 4.6, respectively), *K. pneumoniae* (+18.0%; 20.5 and 24.2, respectively), *P. aeruginosa* (+11.7%; 9.4 and 10.5, respectively), and *E. faecalis* (+11.0%; 12.7 and 14.1, respectively). There was no decrease in the estimated EU/EEA incidence of invasive isolates for the bacteria covered by EARS-Net compared to 2019. However, this comparison obscured two more recent changes to the estimated incidence. For *Acinetobacter* spp., the estimated incidence of invasive isolates has decreased from 2021 to 2023 (-24.6%; 6.1 and 4.6, respectively). Whereas for *S. pneumoniae,* after a steep decrease in 2020 from 2019 (-46.4%: from 6.9 to 3.7), there was an increase from 2021 until 2023 (+100.0%; from 3.6 to 7.2) so that it exceeded the estimated incidence recorded for 2019 (6.9). These more recent patterns indicate that some of the most pronounced changes after 2019 continue to be reversed. Another development worth noting is that the estimated incidence of invasive isolates for *K. pneumoniae* ranged between 19.8

and 21.8 per 100 000 population between 2019 and 2022, but increased to 24.2 per 100 000 population in 2023.

For AMR, the situation reported by EU/EEA countries to EARS-Net for 2023 varied widely, depending on the bacterial species, antimicrobial group and geographical region, as demonstrated by varying AMR percentages and often also estimated incidence of bloodstream infections with AMR (Table 3b, Figures 1–10 and Country summaries). Overall, in 2023 more than 80% of the estimated EU (excluding the UK and excluding France for results other than *S. pneumoniae*) incidences of bloodstream infections with AMR under EARS-Net surveillance exceeded 1 per 100 000 population. Moreover, the results showed increases from 2019 to 2023 for almost two thirds (63.0%) of the combinations, ranging from +4.3 to +57.5% (Table 3a). In particular, for all AMR combinations for *K. pneumoniae,* for vancomycin resistance in *E. faecium* and for piperacillin-tazobactam resistance, ceftazidime resistance and carbapenem resistance in *P. aeruginosa*, there was a significantly increasing trend.

As of 2023, there are recommended EU targets on AMR to reduce the total EU incidence of meticillin-resistant *S. aureus* (MRSA), third-generation cephalosporin-resistant *E. coli* and carbapenem-resistant *K. pneumoniae* bloodstream infections by 15%, 10% and 5%, respectively, by 2030 against the baseline year 2019 [1]. In the data for 2023, the estimated total EU incidence of MRSA bloodstream infections was 4.64 per 100 000 population (country range 0–15.5). This was 17.6% lower than in 2019 (baseline year) and 0.15 per 100 000 population lower than the 2030 target of 4.79 per 100 000 population. For the EU overall, a statistically significant decreasing trend was detected between 2019 (baseline year) and 2023. The estimated total EU incidence of third-generation cephalosporin-resistant *E. coli* bloodstream infections was 10.35 per 100 000 population (country range 0–19.56) in 2023. This was 3.6% lower than in 2019 (baseline year) and 0.68 per 100 000 population higher than the 2030 target of 9.67 per 100 000 population. For the EU overall, no statistically significant trend was detected between 2019 (baseline year) and 2023. The estimated total EU incidence of carbapenem-resistant *K. pneumoniae* bloodstream infections was 3.97 per 100 000 population (country range 0.00–21.44) in 2023. This was 57.5% higher than in 2019 (baseline year) and 1.58 per 100 000 population higher than the 2030 target of 2.39 per 100 000 population. For the EU overall, a statistically significant increasing trend was detected between 2019 (baseline year) and 2023.

Overall, in 2023, the population-weighted EU/EEA (excluding the UK and excluding France for results other than *S. pneumoniae*) mean AMR percentages exceeded 10% in 85.2% of the combinations under regular surveillance. However, the pattern of change in the AMR percentages differed from the estimated EU incidence of bloodstream infections with AMR. Most of the bacterial species–antimicrobial combinations either had a significantly decreasing trend or no significant trend in the AMR percentage. The exceptions were carbapenem resistance in *K. pneumoniae*, as well as penicillin non-wild-type and macrolide resistance, including the combination of these two types of resistance, in *S. pneumoniae* (Table 3b).

In 2023, the two bacterial species with the highest estimated EU incidences of bloodstream infections with AMR were *E. coli* and *K. pneumoniae*. More than half of the *E. coli* isolates reported to EARS-Net, and more than a third of the *K. pneumoniae* isolates were resistant to at least one antimicrobial group under surveillance, and combined resistance to several antimicrobial groups was a frequent occurrence. Despite lower estimated EU incidences of *E. coli* bloodstream infections with AMR in 2023 than in 2019, these incidences have been increasing since 2021 and may be on their way towards reaching the 2019 levels. The estimated EU incidences of *K. pneumoniae* bloodstream infections with AMR also decreased in 2020, but have since increased and have now reached higher levels than in 2019 and showed a significantly increasing trend over 2019–2023. With one notable exception – carbapenem resistance in *K. pneumoniae* – both *E. coli* and *K. pneumoniae* saw either significantly decreasing trends in the EU/EEA population-weighted mean AMR percentages, or no significant trend. Among antimicrobial groups monitored for both species, the estimated EU incidences of bloodstream infections with AMR were, with one exception (carbapenem resistance) higher in *E. coli* than in *K. pneumoniae*. However, the EU/EEA population-weighted mean AMR percentages for the same groups were higher in *K. pneumoniae* than in *E. coli*.

In general, *P. aeruginosa* and *Acinetobacter* spp. exhibited lower estimated EU incidences of bloodstream infections with AMR than *E. coli* and *K. pneumoniae*. However, the estimated EU incidences of *P. aeruginosa* and *Acinetobacter* spp. bloodstream infections with carbapenem resistance were 2.01 and 2.98 per 100 000 population, respectively. In addition, there was a significantly increasing trend for carbapenem resistance, piperacillin-tazobactam resistance and ceftazidime resistance for *P. aeruginosa* bloodstream infections. Although no such trend was observed for *Acinetobacter* spp., the reported data showed that, compared to the high incidence reported for 2021, there has been a decrease in the last two years. This pattern for *Acinetobacter* spp. with AMR has also been observed for the EU/EEA population-weighted mean AMR percentages.

For most gram-negative bacteria under surveillance, the patterns of the estimated EU incidences of AMR bloodstream infections during 2019–2023 indicate that, with the exception of *Acinetobacter* spp., further increases may be expected. Conversely, the EU/EEA population-weighted mean AMR percentages for most gram-negative bacteria under surveillance showed significantly decreasing trends between 2019 and 2023. However, the AMR percentages remained at high levels. It is also interesting to note that for 2023 the EU/EEA population-weighted mean AMR percentages for some of the *P. aeruginosa* combinations decreased compared to 2022, whereas some *E. coli* combinations have increased since 2021.

For *S. aureus*, the estimated EU incidence of MRSA bloodstream infections decreased by 17.6% from 2019 (5.63 per 100 000 population) to 2023 (4.64 per 100 000 population) and showed a significantly decreasing trend during

2019–2023 (Table 3a). The reported data also showed a decrease and a significantly decreasing trend in the EU/EEA population-weighted mean MRSA percentage from 2019 (18.2%) to 2023 (15.8%) (Table 3b).

For *S. pneumoniae*, in addition to the considerable increase in the estimated EU/EEA incidence of invasive isolates in 2023 compared to 2021, the last five years have seen a significantly increasing trend in AMR. The EU/EEA population-weighted mean percentage of macrolide resistance and penicillin non-wild-type, including combined resistance in *S. pneumoniae*, has increased since 2019 (Table 3b). Moreover, the lower estimated EU incidences of *S. pneumoniae* bloodstream infections with AMR in 2020 and 2021, at the start of the COVID-19 pandemic, have not remained at the same level, and in 2023 they surpassed those of 2019.

E. faecium continued to be of concern in 2023. The results showed a significantly increasing trend in the estimated EU incidence of vancomycin-resistant *E. faecium* bloodstream infections over the last five years, although the last two years have shown slightly lower numbers, possibly indicating some improvement in the situation (Table 3a). However, the 2023 EU/EEA population-weighted mean percentage of vancomycin resistance in *E. faecium* (19.8%) remained within the range reported for the previous four years (19.7%–20.7%).

The reported AMR percentages, and often also the estimated incidences of bloodstream infections with AMR, varied widely among EU/EEA countries. Often the AMR percentages showed a north-to-south and west-to-east gradient. In general, the lowest AMR percentages were reported by countries in the north of Europe and the highest by countries in the south and east of Europe. For the estimated incidences of bloodstream infections with AMR, the same pattern was evident for *K. pneumoniae*, fairly evident for *P. aeruginosa, Acinetobacter* spp., *S. aureus*, but less evident for *E. coli, S. pneumoniae*, *E. faecalis* and *E. faecium*. Nevertheless, the highest incidences were generally reported from countries in the south or south-east of Europe.

For each bacterial species, country-specific information on the estimated incidence of antimicrobial-resistant bloodstream infections (including the recommended EU targets on AMR), the percentage of invasive isolates with AMR, data availability and the percentage of ICU patients is available in the country summaries. Results by age group and sex are available in the ECDC Surveillance Atlas of Infectious Diseases [2].

Discussion

In 2024, all EU/EEA countries reported data for 2023 to EARS-Net. Representativeness, as reported by the countries, was high for 70% of countries. This indicates that, although all EU/EEA countries are included in EARS-Net, progress is needed in some countries to improve surveillance representativeness.

This report showed that progress of the EU towards the EU targets on AMR varied, depending on the pathogen. For MRSA, a favourable decreasing trend in the estimated incidence of bloodstream infections was noted and the EU reduction target of 15% was already reached by 2023. For third-generation cephalosporin-resistant *E. coli,* despite a slightly lower incidence than in 2019 (baseline year) and a decrease in 2020 and 2021, the incidence of bloodstream infections has since been increasing and may be on its way to reaching pre-pandemic values. This indicates that further work needs to be done to reach the EU reduction target of 10%. For carbapenem-resistant *K. pneumoniae*, the incidence of bloodstream infections showed an increase of over 50% during the period 2019–2023, which means that, instead of progressing towards the EU reduction target of 5%, the situation in the EU has worsened since 2019 (baseline year). This increase indicates the need to rapidly strengthen prevention and control actions in the EU, as highlighted in the Council Recommendation [1].

Increases in the estimated EU incidences of bloodstream infections with resistant bacteria were observed not only for two of the above-mentioned AMR-pathogen combinations with an EU target, but also for many other bacteria and antimicrobial groups under surveillance, such as antimicrobial-resistant *K. pneumoniae* (other than carbapenem-resistant), vancomycin-resistant *E. faecium* and piperacillin-tazobactam-, ceftazidime-, and carbapenem-resistant *P. aeruginosa*. Moreover, for most gram-negative bacteria under surveillance, except for *Acinetobacter* spp., the recent changes in the estimated EU incidences of bloodstream infections with AMR indicate that, in the absence of stronger, swifter public health action, further increases may be expected in the coming years. On the other hand, for most gram-positive bacteria under surveillance, except for *S. pneumoniae*, the patterns indicated that decreases in AMR can be expected in the coming years.

Overall, AMR levels remained high in the EU/EEA in 2023, as in previous years, with many of the estimated EU incidences of antimicrobial-resistant bloodstream infections and most of the EU/EEA population-weighted mean AMR percentages for the bacterial species-antimicrobial group combinations under surveillance continuing to be elevated. Nevertheless, the AMR situation reported by EU/EEA countries varied widely, depending on the bacterial species, antimicrobial group and geographical region. The highest estimated incidences of antimicrobial-resistant bloodstream infections were generally reported from countries in the south or south-east of Europe and the highest AMR percentages were generally reported by countries in the south and east of Europe.

By providing an overview of the wide variability in the estimated incidences of bloodstream infections with AMR and AMR percentages across EU/EEA countries in 2023 (see Country summaries), the report suggests that there are further opportunities for significant AMR reduction through interventions to improve infection prevention and control (IPC) and antimicrobial stewardship practices. For carbapenem-resistant *K. pneumoniae* and other carbapenem-resistant Enterobacterales (CRE), the options for action are highlighted in the 2019 update of ECDC's rapid risk assessment on

CRE, including timely and appropriate diagnosis, high standards of IPC and antimicrobial stewardship [3].

Data for the years 2020 and 2021 coincided with the first years of the COVID-19 pandemic. Changes to human behaviour in 2020–2021 to control the pandemic, and then again in 2022 as the number of non-pharmaceutical interventions were reduced, may have modified the risk of infection with antimicrobial-resistant pathogens. However, unlike antimicrobial consumption in the EU/EEA [4-6], for AMR under EARS-Net surveillance there was no uniform pattern across the bacterial species. Some of the bacterial species, such as *Acinetobacter* spp. [7-9] and *S. pneumoniae* [8, 9], showed indications of having been affected by the COVID-19 pandemic and the actions taken during this time. However, these two bacterial species followed different patterns (i.e. increases for *Acinetobacter* spp. and decreases for *S. pneumoniae*, during 2020–2021) compared to 2019, followed by a reversal of these changes in 2022 and 2023. These changes point towards the importance of IPC in healthcare settings, as well as non-pharmaceutical interventions in the community.

When interpreting the EARS-Net data, it is important to be mindful of the structure of the surveillance system, including variations in national blood culture rates as well as changes in the national surveillance systems and in EARS-Net over time. An example of a limitation of EARS-Net surveillance is that the magnitude of the impact of Russia's war of aggression against Ukraine on AMR in the EU/EEA cannot be assessed using data regularly reported to EARS-Net. On 8 March 2022, ECDC published a report entitled 'Operational public health considerations for the prevention and control of infectious diseases in the context of Russia's aggression towards Ukraine' [10]. The report presents considerations for hospitalised patients in the EU/EEA, including recommendations that patients transferred from hospitals in Ukraine, or with a history of hospitalisation in Ukraine during the last 12 months, should be pre-emptively isolated and screened for carriage of multidrug-resistant organisms. Although it is not possible to follow through the data annually reported to ECDC, since 2022 there have been reports from EU/EEA countries of multidrug-resistant organisms being detected in patients having recently been hospitalised in Ukraine [11-13]. Despite these limitations, EARS-Net surveillance is able to reflect the overall AMR situation in the EU/EEA.

The European Health Union was created in 2020 to better protect the health of EU citizens [14]. This included strengthened mandates for ECDC and the European Medicines Agency (EMA), the creation of the European Health Emergency preparedness and Response Authority (HERA) and a new Regulation on serious cross-border threats to health that was adopted by the Council on 24 October 2022 [15]. Moreover, a large budget is available under the EU4Health programme (EUR 5.3 billion for the period 2021–2027), which is one of the main instruments for the European Health Union, dedicated to wider policy areas and including action on AMR.

At the global level, the Political Declaration of the High-Level Meeting on AMR at the United Nations (UN) General Assembly (September 2024) has also highlighted the importance of AMR as a health threat [16]. Moreover, the Declaration called for the establishment of an independent panel to collect evidence for action against AMR. The European Commission declared that it will be providing funds for the establishment of such a panel [17].

Public health implications

Estimates based on EARS-Net data from 2020 indicate that each year more than 35 000 people die in the EU/EEA as a direct consequence of antimicrobial-resistant infections [18]. Together with the poor progress towards the EU targets on AMR overall and, more particularly, the continued increase in the incidence of carbapenem-resistant *K. pneumoniae* bloodstream infections, the increases in many of the other estimated EU incidences of bloodstream infections with antimicrobial-resistant bacteria described in this report highlight the urgent need for intensified public health action against AMR.

The 'Council Recommendation on stepping up EU actions to combat antimicrobial resistance in a One Health approach' (2023/C 220/01) adopted in June 2023 encourages Member States to develop and implement national action plans against AMR, and highlights the need for them to allocate appropriate human and financial resources for the effective implementation of these plans [1]. The plans should include key elements, such as enhanced surveillance and strengthened IPC programmes in hospitals and other healthcare settings, integrated with antimicrobial stewardship programmes and good diagnostic practices.

Public health interventions to tackle AMR can have a significant positive impact on population health and future healthcare expenditure in the EU/EEA. Such interventions include IPC measures, starting with the promotion of better hand hygiene in healthcare to prevent transmission; antibiotic stewardship programmes (e.g. rapid testing of patients to discriminate viral from bacterial infections) and the promotion of prudent use of antibiotics, to prevent the development and selection of AMR. In addition, mass media campaigns can be useful to raise public awareness of AMR and the importance of the prudent use of antibiotics. In 2023, the Organisation for Economic Co-operation and Development (OECD) estimated that a mixed intervention package including enhanced hygiene, antibiotic stewardship programmes, mass media campaigns, and food handling practices would have the potential to prevent nearly 613 000 resistant infections and avoid more than 10 000 deaths each year in the EU/EEA. Moreover, the combined health expenditure reduction and productivity gains from such a package would be about three times higher than the average cost of implementing the package [19].

In the absence of stronger, and swifter public health action, it is unlikely that the EU will reach all its AMR targets by 2030. The consequence will be an increased number of infections with antimicrobially-resistant bacteria that will be more difficult to treat, leading to increasing challenges for patients and AMR-related deaths.

Table 3a. Estimated total incidence of bloodstream infections with resistance phenotype (number per 100 000 population) and trend, 2019–2023, as well as the percentage change 2019-2023, by bacterial species and antimicrobial group/agent, EU[a] (excluding the UK; excluding France for results other than *Streptococcus pneumoniae*)

Bacterial species	Antimicrobial group/agent	Estimated incidence[b] of isolates from bloodstream infections with resistance phenotype (n per 100 000 population)						
		2019 (baseline year)	2020	2021	2022	2023	Trend 2019-2023[c]	Change 2019–2023 (%)[d]
Escherichia coli	Aminopenicillin (amoxicillin/ampicillin) resistance	28.46	24.80	23.89	26.25	28.42	-	-0.1
	Third-generation cephalosporin (cefotaxime/ceftriaxone/ceftazidime) resistance	10.74	8.88	7.87	9.12	10.35	-	-3.6
	Carbapenem (imipenem/meropenem) resistance	0.20	0.10	0.08	0.12	0.14	-	-30.0
	Fluoroquinolone (ciprofloxacin/levofloxacin/ofloxacin) resistance	16.82	14.34	12.64	14.00	15.70	-	-6.7
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance[e]	7.17	6.16	5.17	5.76	6.59	-	-8.1
	Combined resistance to third-generation cephalosporins, fluoroquinolones, and aminoglycosides[e]	3.81	3.01	2.54	2.89	3.36	-	-11.8
Klebsiella pneumoniae	Third-generation cephalosporin (cefotaxime/ceftriaxone/ceftazidime) resistance	7.59	7.26	7.67	7.93	9.25	↑	+21.9
	Carbapenem (imipenem/meropenem) resistance	2.52	2.77	3.19	3.11	3.97	↑	+57.5
	Fluoroquinolone (ciprofloxacin/levofloxacin/ofloxacin) resistance	7.48	7.24	7.46	7.65	8.83	↑	+18.0
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance[e]	5.07	4.69	5.01	5.11	5.96	↑	+17.6
	Combined resistance to third-generation cephalosporins, fluoroquinolones, and aminoglycosides[e]	4.46	4.14	4.47	4.52	5.26	↑	+17.9
Pseudomonas aeruginosa	Piperacillin-tazobactam resistance	1.77	1.64	1.78	1.99	2.00	↑	+13.0
	Ceftazidime resistance	1.55	1.42	1.54	1.69	1.72	↑	+11.0
	Carbapenem (imipenem/meropenem) resistance	1.73	1.65	1.82	1.99	2.01	↑	+16.2
	Fluoroquinolone (ciprofloxacin/levofloxacin) resistance	2.02	1.74	1.82	1.94	1.94	-	-4.0
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance[f]	1.20	0.62	0.72	0.69	0.79	NA	-34.2
	Combined resistance to ≥3 antimicrobial groups (among piperacillin-tazobactam, ceftazidime, carbapenems, fluoroquinolones and aminoglycosides)[f]	1.20	0.75	0.93	1.02	1.05	NA	-12.5
***Acinetobacter* species**	Carbapenem (imipenem/meropenem) resistance	2.45	3.32	4.76	3.22	2.98	-	+21.6
	Fluoroquinolone (ciprofloxacin/levofloxacin) resistance	2.63	3.45	4.92	3.33	3.02	-	+14.8

Bacterial species	Antimicrobial group/agent	Estimated incidence[b] of isolates from bloodstream infections with resistance phenotype (n per 100 000 population)						
		2019 (baseline year)	2020	2021	2022	2023	Trend 2019-2023[c]	Change 2019–2023 (%)[d]
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance[e]	2.38	3.07	4.37	2.92	2.66	-	+11.8
	Combined resistance to carbapenems, fluoroquinolones and aminoglycosides[e]	2.20	2.93	4.17	2.74	2.55	-	+15.9
Staphylococcus aureus	MRSA[g]	5.63	4.86	4.41	4.72	4.64	↓	-17.6
Streptococcus pneumoniae	Penicillin non-wild-type[h]	0.72	0.47	0.51	0.63	0.76	-	+5.6
	Macrolide (azithromycin/clarithromycin/erythromycin) resistance	0.92	0.51	0.53	0.74	0.96	-	+4.3
	Combined penicillin non-wild-type and resistance to macrolides[h]	0.41	0.24	0.28	0.34	0.43	-	+4.9
Enterococcus faecalis	High-level gentamicin resistance	2.25	2.59	2.98	2.50	2.36	-	+4.9
Enterococcus faecium	Vancomycin resistance	1.85	2.09	2.57	2.47	2.30	↑	+24.3

NA: not applicable.

[a] For each individual EU Member State, a similar table is available as part of the country summaries.

[b] Incidence was estimated using the EARS-Net data reported to EpiPulse. Each de-duplicated isolate from a blood sample (>99% data) or cerebrospinal fluid sample (<1% data) was considered a proxy for a bloodstream infection.

[c] ↑ and ↓ indicate statistically significant increasing and decreasing trends, respectively; – indicates no statistically significant trend. NA: not applicable indicates that a significant change in data sources occurred during the period.

[d] The 'Council Recommendation on stepping up EU actions to combat antimicrobial resistance in a One Health approach', (2023/C 220/01), includes 2030 EU targets, with 2019 as the baseline year: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:JOC_2023_220_R_0001

[e] The aminoglycoside group includes only gentamicin and tobramycin from 2020 onwards.

[f] The aminoglycoside group includes only tobramycin from 2020 onwards.

[g] MRSA is based on AST results for cefoxitin or, if unavailable, oxacillin. AST results reported for cloxacillin, dicloxacillin, flucloxacillin or meticillin are accepted as a marker for oxacillin resistance if oxacillin is not reported. If no phenotypic results are available, data from molecular confirmation tests (detection of mecA *gene by PCR or a positive PBP2A-agglutination test) are accepted as a marker for MRSA.*

[h] Penicillin results are based on penicillin or, if unavailable, oxacillin. For S. pneumoniae*, the term penicillin non-wild-type is used in this report, referring to* S. pneumoniae *isolates reported by local laboratories as susceptible, increased exposure (I) or resistant (R) to penicillin, assuming MIC to benzylpenicillin above those of wild-type isolates (> 0.06 mg/L). The qualitative susceptibility categories (S/I/R) as reported by the laboratory are used, since quantitative susceptibility information is missing for a large part of the data.*

Table 3b. Total number of invasive isolates tested (n) and percentage of isolates with AMR phenotype (%) in the EU/EEA, by bacterial species and antimicrobial group/agent, population-weighted EU/EEA mean and trend (excluding the UK[a]; excluding France for results other than *Streptococcus pneumoniae*), 2019–2023

Bacterial species	Antimicrobial group/agent	2019		2020		2021		2022		2023		2023 EU/EEA country range[b]	Trend 2019–2023[c]
		n	%	n	%	n	%	n	%	n	%		
Escherichia coli	Aminopenicillin (amoxicillin/ampicillin) resistance	88 960	57.0	89 697	54.7	91 462	53.4	101 298	53.5	108 036	54.7	32.5–68.9	↓*
	Third-generation cephalosporin (cefotaxime/ceftriaxone/ceftazidime) resistance	118 306	16.8	120 200	15.8	125 295	14.9	136 859	15.4	146 382	16.2	5.6–37.3	↓*
	Carbapenem (imipenem/meropenem) resistance	114 626	0.4	117 786	0.2	120 826	0.2	132 752	0.2	142 744	0.3	0.0–1.8	↓*
	Fluoroquinolone (ciprofloxacin/levofloxacin/ofloxacin) resistance	118 584	26.2	120 803	25.1	125 566	23.3	136 273	23.3	146 415	24.0	10.1–42.9	↓*
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance[d]	117 851	11.4	118 315	11.6	122 632	10.3	133 662	10.3	143 280	10.9	4.5–28.4	↓*
	Combined resistance to third-generation cephalosporins, fluoroquinolones, and aminoglycosides[d]	116 444	6.6	116 682	6.2	121 215	5.6	131 184	5.5	140 844	5.9	1.3–17.6	↓*
Klebsiella pneumoniae	Third-generation cephalosporin (cefotaxime/ceftriaxone/ceftazidime) resistance	33 115	34.8	34 803	35.0	38 866	35.9	43 171	34.1	48 143	34.8	5.7–81.5	-
	Carbapenem (imipenem/meropenem) resistance	32 436	10.4	34 483	11.6	37 857	13.6	42 295	12.7	47 570	13.3	0.0–69.7	↑*
	Fluoroquinolone (ciprofloxacin/levofloxacin/ofloxacin) resistance	33 172	34.6	35 065	34.9	38 762	35.2	42 952	33.4	48 056	33.7	7.1–76.9	↓*
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance[d]	32 975	24.7	34 210	24.6	38 053	24.9	42 370	23.5	47 412	23.6	2.6–73.3	↓*
	Combined resistance to third-generation cephalosporins, fluoroquinolones, and aminoglycosides[d]	32 618	21.8	33 639	21.8	37 488	22.4	41 584	21.0	46 457	21.0	0.0–64.9	↓*
Pseudomonas aeruginosa	Piperacillin-tazobactam resistance	15 015	19.0	16 382	19.0	18 198	19.1	20 058	19.8	21 315	18.5	3.7–54.4	-
	Ceftazidime resistance	15 329	16.5	16 548	15.9	18 358	16.5	20 266	16.9	21 608	15.7	2.8–52.7	-
	Carbapenem (imipenem/meropenem) resistance	15 420	19.1	16 934	18.8	18 779	19.2	20 536	20.0	21 844	18.6	3.3–53.4	-
	Fluoroquinolone (ciprofloxacin/levofloxacin) resistance	15 561	21.6	16 840	20.4	18 704	19.6	20 467	19.4	21 861	17.9	5.9–52.0	↓*
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance[e]	15 466	13.4	9 821	10.2	11 276	9.7	15 278	9.5	16 809	9.5	0.0–46.1	NA
	Combined resistance to ≥3 antimicrobial groups (among piperacillin-tazobactam, ceftazidime, carbapenems, fluoroquinolones and aminoglycosides)[e]	14 530	14.4	9 145	14.6	10 676	13.5	14 525	14.5	16 071	13.1	1.6–49.5	NA

Bacterial species	Antimicrobial group/agent	2019		2020		2021		2022		2023		2023 EU/EEA country range[b]	Trend 2019–2023[c]
		n	%	n	%	n	%	n	%	n	%		
***Acinetobacter* species**	Carbapenem (imipenem/meropenem) resistance	4 722	41.8	6 815	44.0	10 569	46.6	8 575	42.1	8 843	40.1	0.0–95.8	↓
	Fluoroquinolone (ciprofloxacin/levofloxacin) resistance	4 700	45.8	6 719	47.4	10 511	49.5	8 583	44.6	8 734	42.4	0.0–96.6	↓*
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance[d]	4 697	40.8	6 614	42.1	10 282	45.7	8 445	39.0	8 570	36.7	0.0–92.4	↓*
	Combined resistance to carbapenems, fluoroquinolones and aminoglycosides[d]	4 540	38.0	6 483	39.7	10 102	43.0	8 168	37.0	8 413	35.2	0.0–91.5	↓*
Staphylococcus aureus	MRSA[f]	59 137	18.2	62 213	17.5	68 015	17.1	74 863	16.0	75 205	15.8	1.5–51.1	↓*
Streptococcus pneumoniae	Penicillin non-wild-type[g]	14 568	13.2	8 076	15.5	8 490	16.2	13 363	16.3	16 659	15.1	3.7–39.1	↑*
	Macrolide (azithromycin/clarithromycin/erythromycin) resistance	15 069	15.9	8 407	16.8	8 784	18.4	14 079	17.9	17 698	17.8	4.0–53.8	↑*
	Combined penicillin non-wild-type and resistance to macrolides[g]	14 102	8.0	7 782	8.9	8 166	9.8	12 825	9.7	16 029	9.2	0.0–26.9	↑*
Enterococcus faecalis	High-level gentamicin resistance	12 231	27.7	14 316	29.0	16 523	28.9	17 406	25.2	17 353	24.3	4.3–99.0	↓*
Enterococcus faecium	Vancomycin resistance	13 033	20.7	16 964	19.7	21 275	19.9	21 473	20.6	21 436	19.8	0.0–60.9	-

NA: not applicable.

[a] The population-weighted EU/EEA mean and trend, including 2019 UK data, can be found in previous Annual Epidemiological Reports.

[b] Lowest and highest national AMR percentage among reporting EU/EEA countries (n=29, with the exception of S. pneumoniae *where n=30).*

*[c] ↑ and ↓ indicate statistically significant increasing and decreasing trends, respectively, in the overall data; * indicates confirmation by a significant trend in the data that only includes laboratories reporting continuously for all five years; – indicates no statistically significant trend. NA: not applicable indicates that a significant change in data sources occurred during the period.*

[d] The aminoglycoside group includes only gentamicin and tobramycin from 2020 onwards.

[e] The aminoglycoside group includes only tobramycin from 2020 onwards.

[f] MRSA is based on AST results for cefoxitin or, if unavailable, oxacillin. AST results reported for cloxacillin, dicloxacillin, flucloxacillin or meticillin are accepted as a marker for oxacillin resistance if oxacillin is not reported. If no phenotypic results are available, data from molecular confirmation tests (detection of mecA *gene by PCR or a positive PBP2A-agglutination test) are accepted as a marker for MRSA.*

[g] Penicillin results are based on penicillin or, if unavailable, oxacillin. For S. pneumoniae*, the term penicillin non-wild-type is used in this report, referring to* S. pneumoniae *isolates reported by local laboratories as susceptible, increased exposure (I) or resistant (R) to penicillin, assuming MIC to benzylpenicillin above those of wild-type isolates (> 0.06 mg/L). The qualitative susceptibility categories (S/I/R) as reported by the laboratory are used, since quantitative susceptibility information is missing for a large part of the data.*

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Bacterial species-specific results

Escherichia coli

Epidemiology

For 2023, 29 EU/EEA countries reported 147 939 invasive isolates of *E. coli*. Among the countries that continuously reported data during 2019–2023 (excluding France, due to changes in the surveillance system), when comparing 2019 to 2023, there was an increase in the number of reported invasive *E. coli* isolates (+23.7%; 119 632 and 147 931, respectively). The estimated EU/EEA incidence of invasive *E. coli* isolates increased from 69.9 per 100 000 population in 2019 to 71.4 per 100 000 population in 2023.

Of all reported invasive isolates in 2023, 146 415 (99.0%) had AST results for fluoroquinolones, 146 382 (98.9%) for third-generation cephalosporins, 143 280 (96.9%) for aminoglycosides, 142 744 (96.5%) for carbapenems, and 108 036 (73.0%) for aminopenicillins (Table 3b).

In 2023, the highest estimated EU incidence of *E. coli* bloodstream infections by AMR phenotype was reported for aminopenicillins (28.42 per 100 000 population), followed by fluoroquinolones (15.7 per 100 000 population), third-generation cephalosporins (10.35 per 100 000 population), and aminoglycosides (6.59 per 100 000 population). Resistance to carbapenems was rare (0.14 per 100 000 population) (Table 3a). During the period 2019−2023, all the estimated EU incidence of *E. coli* bloodstream infections with resistance decreased, albeit without showing a significantly decreasing trend (Table 3a). Moreover, since the decrease seen in 2020 and 2021, the estimated EU incidences of bloodstream infections with AMR have been increasing. The result for the AMR target, the estimated incidence of third-generation cephalosporin-resistant *E. coli* bloodstream infections, was a 3.6% decrease in the estimated incidence against the baseline year 2019, and 0.68 per 100 000 population higher than the 2030 target of 9.67 per 100 000 population. For the target the country range was 0−19.56 per 100 000 population in 2023.

At EU/EEA level, more than half (53.5%) of the invasive *E. coli* isolates reported to EARS-Net for 2023 were resistant to at least one of the antimicrobial groups under surveillance (aminopenicillins, fluoroquinolones, third-generation cephalosporins, aminoglycosides and carbapenems) (Table 4). In 2023, the highest EU/EEA population-weighted mean AMR percentage was reported for aminopenicillins (54.7%), followed by fluoroquinolones (24.0%), third-generation cephalosporins (16.2%), and aminoglycosides (10.9%). Resistance to carbapenems remained rare (0.3%) (Table 3b). Between 2019 and 2023, there was a significant decreasing trend in the EU/EEA population-weighted mean percentage for aminopenicillin resistance, third-generation cephalosporin resistance, carbapenem resistance, fluoroquinolone resistance, and aminoglycoside resistance. When restricting the analysis to include only laboratories that continuously reported data for all five years, all trends remained significant (Table 3b). However, annual increases in EU/EEA-level AMR percentages were seen in 2023 compared to 2022 for aminopenicillins (+1.2%), third-generation cephalosporins (+0.8%), fluoroquinolones (+0.7%), aminoglycosides (+0.6%) and carbapenems (+0.1%). Similarly, annual increases were also seen for AMR percentages in 2022 compared to 2021 (aminopenicillins (+0.1%) and third-generation cephalosporins (+0.5%)) (Table 3b).

Resistance to multiple antimicrobial groups was common. Among the AMR phenotypes, resistance to aminopenicillins, both as single resistance and in combination with other antimicrobial groups, was the most common at EU/EEA level (Table 4). In 2023, the percentage of combined resistance, measured as resistance to third-generation cephalosporins, fluoroquinolones and aminoglycosides, was 5.9% (EU/EEA population-weighted mean) and this showed a statistically significant decreasing trend during the period 2019–2023. When the analysis was restricted to include only laboratories that continuously reported data for all five years (Table 3b), the decreasing trend remained. The estimated EU incidence of bloodstream infections with combined AMR, measured as resistance to third-generation cephalosporins, fluoroquinolones and aminoglycosides, was 3.36 per 100 000 population and this did not show a statistically significant trend during the period 2019–2023.

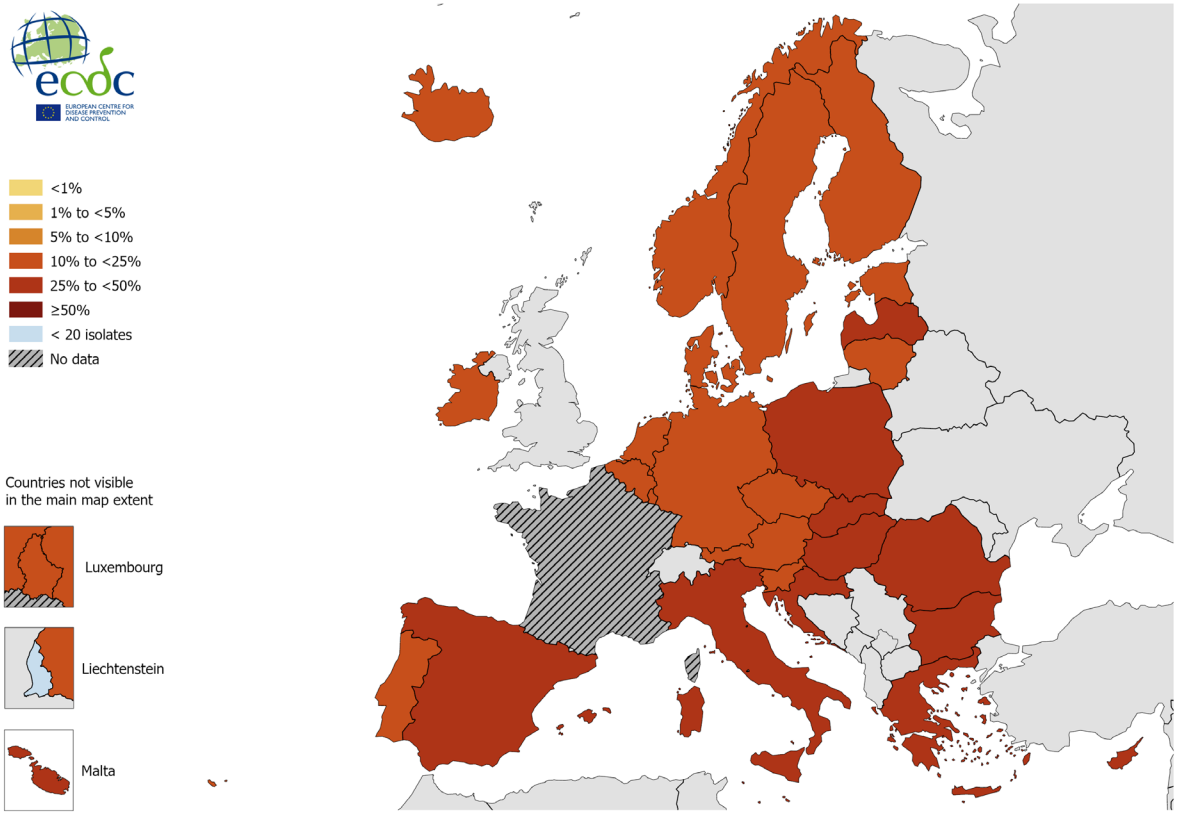
Except for carbapenem resistance, which remained low in all countries, large inter-country variations were noted for all the antimicrobial groups under surveillance (Table 3b), with generally higher AMR percentages reported from southern and eastern Europe than from northern Europe (Figures 1 and 3), although such a pattern was not always evident (Figure 2). For the estimated incidences of AMR bloodstream infections the pattern was less clear, although it did indicate that, apart from resistance to aminopenicillins, the highest estimated incidences were reported from countries in the south of Europe (see Country summaries).

Table 4. ***Escherichia coli.*** **Total number of invasive isolates tested (n = 99 378)[a] and AMR percentage (%) per phenotype, EU/EEA, 2023**

AMR pattern[b]	Number of isolates	Percentage of total[c]
Susceptible to all included antimicrobial groups[d]	**46 207**	**46.5**
Single resistance (to indicated antimicrobial group)		
Total (any single resistance)	**30 966**	**31.2**
Aminopenicillins	27 933	28.1
Fluoroquinolones	2 684	2.7
Other antimicrobial groups	349	0.4
Resistance to two antimicrobial groups		
Total (any two-group combinations)	**10 112**	**10.2**
Aminopenicillins + fluoroquinolones	5 602	5.6
Aminopenicillins + third-generation cephalosporins	2 644	2.7
Aminopenicillins + aminoglycosides	1 736	1.7
Other antimicrobial group combinations	130	0.1
Resistance to three antimicrobial groups		
Total (any three-group combinations)	**7 648**	**7.7**
Aminopenicillins + third-generation cephalosporins + fluoroquinolones	5 412	5.4
Aminopenicillins + fluoroquinolones + aminoglycosides	1 669	1.7
Other antimicrobial group combinations	567	0.6
Resistance to four antimicrobial groups		
Total (any four-group combinations)	**4 389**	**4.4**
Aminopenicillins + third-generation cephalosporins + fluoroquinolones + aminoglycosides	4 322	4.3
Other antimicrobial group combinations	67	0.1
Resistance to five antimicrobial groups		
Aminopenicillins + third-generation cephalosporins + fluoroquinolones + aminoglycosides + carbapenems	**56**	**0.1**

[a] Only isolates with complete susceptibility information for aminopenicillins (amoxicillin or ampicillin), third-generation cephalosporins (cefotaxime, ceftriaxone or ceftazidime), carbapenems (imipenem or meropenem), fluoroquinolones (ciprofloxacin, levofloxacin or ofloxacin) and aminoglycosides (gentamicin or tobramycin) were included in the analysis. This represented 67% (99 378/147 939) of all reported E. coli *isolates.*
[b] Only AMR combinations >1% of the total are specified.
[c] Not adjusted for population differences in the reporting countries.
[d] Aminopenicillins (amoxicillin or ampicillin), third-generation cephalosporins (cefotaxime, ceftriaxone or ceftazidime), carbapenems (imipenem or meropenem), fluoroquinolones (ciprofloxacin, levofloxacin or ofloxacin) and aminoglycosides (gentamicin or tobramycin).

Figure 1. ***Escherichia coli.*** **Percentage of invasive isolates resistant to fluoroquinolones (ciprofloxacin/levofloxacin/ofloxacin), by country, EU/EEA, 2023**



Administrative boundaries: © EuroGeographics. The boundaries and names shown on this map do not imply official endorsement or acceptance by the European Union. Map produced by ECDC on 13 September 2024

Figure 2. ***Escherichia coli.*** **Percentage of invasive isolates resistant to third-generation cephalosporins (cefotaxime/ceftriaxone/ceftazidime), by country, EU/EEA, 2023**

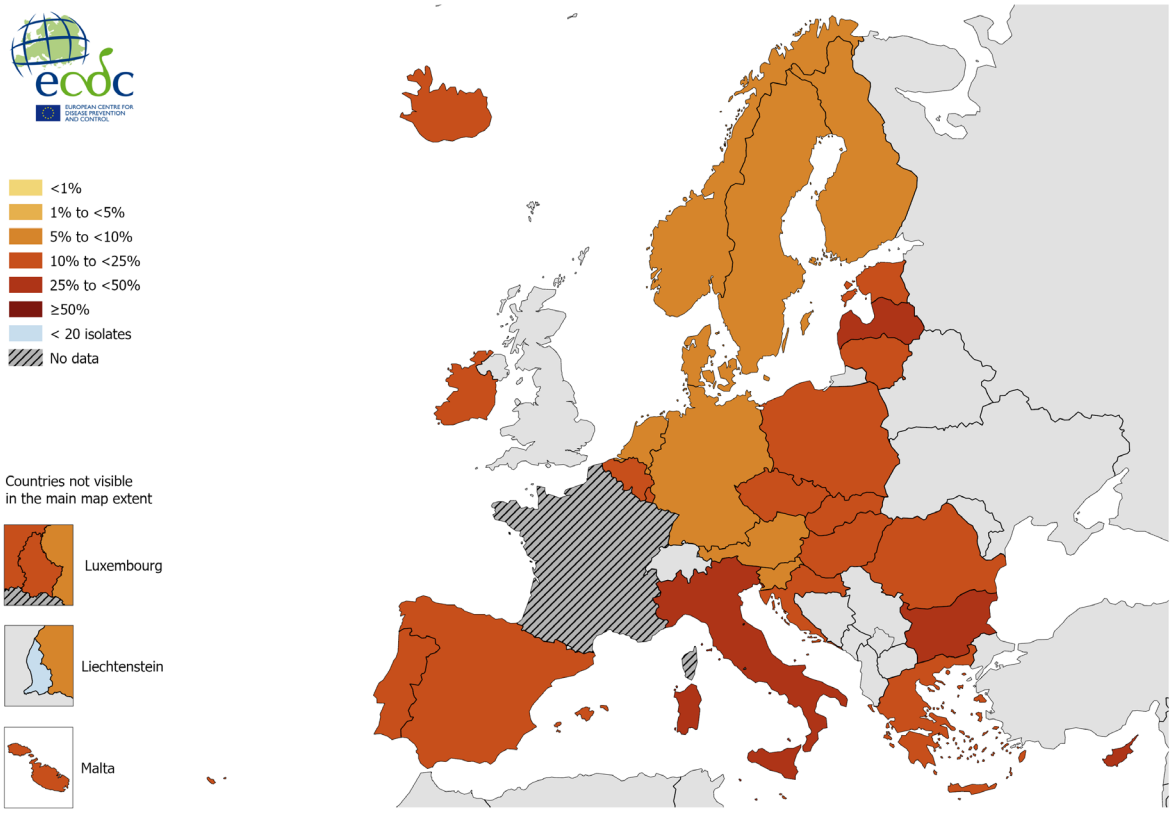


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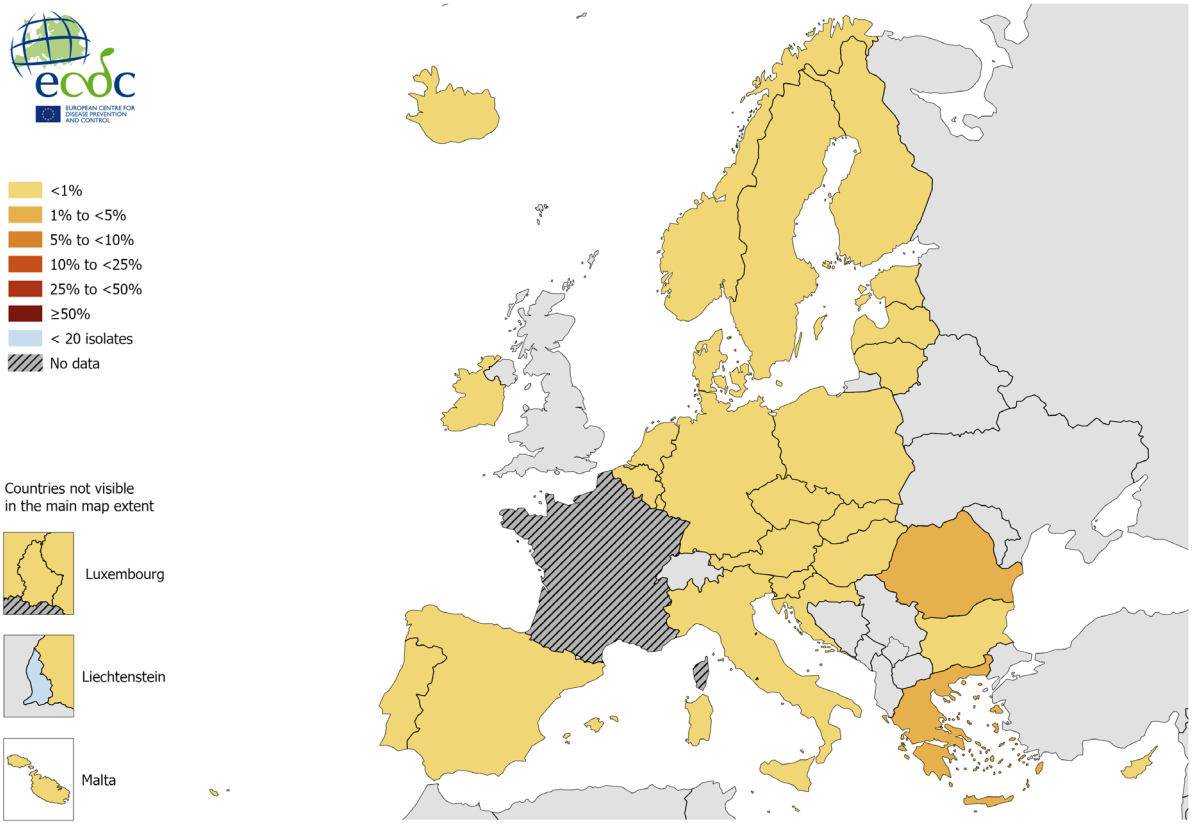
Figure 3. ***Escherichia coli*****. Percentage of invasive isolates resistant to carbapenems (imipenem/meropenem), by country, EU/EEA, 2023**



Discussion

E. coli is a major cause of bloodstream infections in Europe, and prompt access to effective antimicrobial treatment is essential to reduce the health-related and economic burden caused by *E. coli* infection. In ECDC's study of the EU/EEA health burden of AMR for the period 2016–2020, the largest burden of disease was caused by infections with third-generation cephalosporin-resistant *E. coli*, both in terms of the number of cases and the number of attributable deaths [1]. As antimicrobial-resistant *E. coli* infections commonly occur in the community, interventions to reduce the burden of infection should not be restricted to hospital settings but should also target primary and community care.

With a decrease of 3.6% compared to 2019 (baseline year), the estimated EU incidence of third-generation cephalosporin-resistant *E. coli* bloodstream infections for 2023 indicates that the EU has been progressing towards the agreed target of a 10% reduction in incidence by 2030 [2]. However, since the decrease seen in 2020 and 2021, the increase for all the estimated resistance incidences, and the absence of decreasing trends indicates that the progress may be slowing down and that the estimated incidences may be on their way to reaching the levels noted in 2019. This underlines the need for further efforts to improve antimicrobial stewardship and IPC.

Time-series analyses of EU/EEA population-weighted means for third-generation cephalosporin resistance and fluoroquinolone resistance in *E. coli* reported to EARS-Net for the years 2002–2018 have shown that, although AMR percentages increased substantially during the period, the increase was most prominent until around 2012, before becoming less pronounced [3]. A significantly declining EU/EEA trend was noted for both antimicrobial groups for the five-year period presented in this report (2019–2023). This was further underpinned by both the 2022 and 2023 EARS-Net EQA exercises, indicating that the under-reporting of decreased susceptibility towards fluroquinolones, noted in the 2021 EARS-Net EQA, was no longer present, and that in the 2022 and 2023 EARS-Net EQA there was over-reporting of resistance to ceftazidime [4, 5]. Nevertheless, the EU/EEA AMR percentages reported for 2023 remain high, and have increased compared to 2022.

The 2022 and 2023 EARS-Net EQA indicated an overestimation of third-generation cephalosporin resistance in *E. coli* and therefore caution should also be exercised when interpreting these results for the EU and the EU/EEA in this report [4, 5].

Use of broad-spectrum antimicrobials is a known risk factor for the colonisation and spread of antimicrobial-resistant Enterobacterales, including *E. coli*. Associations between national AMR percentages in *E. coli* and national antimicrobial consumption rates have been reported [6]. However, although data from ESAC-Net showed a considerable decrease in antimicrobial consumption in 2020 and 2021 compared to previous years and an increase for 2022 and 2023 [7], such a pattern is not as clearly reflected for the EU/EEA population-weighted mean AMR percentages for *E. coli* and *K. pneumoniae*. However, for *E. coli* the estimated EU incidences of bloodstream infections with AMR showed a pattern more similar to that reported by ESAC-Net.

Given that high levels of AMR have been reported in *E. coli* isolates from food-producing animals in Europe, including a low occurrence of isolates with carbapenemase production [8], ensuring cross-sectoral collaboration between the human, veterinary and food-production sectors is essential in a 'One Health' approach, which addresses AMR in both humans and food-producing animals. ECDC is working closely with the European Food Safety Authority (EFSA) and the European Medicines Agency (EMA) to better understand the interrelationships between antimicrobial use and AMR in humans and animals across Europe. To this end, in 2024, the three agencies produced the fourth joint inter-agency report on integrated analysis of antimicrobial agent consumption and occurrence of AMR in bacteria from humans and food-producing animals in the EU/EEA [6].

Carbapenem-resistant isolates remained rare among the invasive *E. coli* isolates included in EARS-Net. However, an increase in serious infections caused by carbapenem-resistant *E. coli* would have severe consequences on the burden of AMR in the EU/EEA. Carbapenem-resistant Enterobacterales (CRE) infections are associated with high mortality, primarily due to delays in the administration of effective treatment and the limited availability of treatment options. The 2019 update of ECDC's rapid risk assessment on CRE highlights the need for high standards in IPC, combined with adequate microbiological capacity, to detect and prevent further spread [9].

Carbapenem resistance is most often mediated by a range of carbapenemases and there are carbapenemase-producing isolates that test susceptible to meropenem and/or imipenem, based on clinical breakpoints. One example is OXA-244-producing *E. coli* which, in routine clinical microbiology laboratories may only be classified as extended-spectrum beta-lactamase-producing rather than carbapenemase-producing *E. coli*, unless specifically tested for OXA-48-like carbapenemases. An ECDC risk assessment on OXA-244-producing *E. coli* [10] indicated a pan-European problem, with a high risk of OXA-244-producing *E. coli* spreading further in the EU/EEA, given the rapid and simultaneous increase in multiple countries between 2016 and 2019. In addition, a study based on *E. coli* data from the EU/EEA in 2012–2020 collected by ECDC with a focus on another carbapenemase, New Delhi metallo-β-lactamase (NDM)-5, concluded that *E. coli* carrying the related gene $bla_{\text{NDM-5}}$ are spreading rapidly and could contribute to further carbapenem resistance in the coming years [11]. There is a risk that spread of carbapenemase-producing *E. coli* in the community may further contribute to the loss of carbapenems as options for treatment of multidrug-resistant *E. coli* infections. This highlights the need to further investigate the sources and routes of transmission for carbapenemase-producing *E. coli*.

To address the need and to complement the phenotypic-based surveillance data available from EARS-Net, the periodic carbapenem- and/or colistin-resistant Enterobacterales (CCRE) surveys have been incorporated into a network – the European Antimicrobial Resistance Genes Surveillance Network (EURGen-Net) [12]. The latest survey results will provide information on the prevalence and distribution of carbapenemases and contribute to a better understanding of the epidemiology of CRE in Europe and risk factors associated with CRE infection and colonisation. ECDC is also able, to a limited extent, to provide Member States with access to whole-genome sequencing services, primarily for investigating potential multi-country outbreaks. By way of example, these services were provided for a combined clonal and plasmid-mediated outbreak of carbapenemase-producing Enterobacterales (CPE) in Lithuania during the period 2019–2020 [13].

Klebsiella pneumoniae

Epidemiology

For 2023, 29 EU/EEA countries reported 48 741 invasive isolates of *K. pneumoniae*. Among the countries that continuously reported data during 2019–2023 (excluding France due to changes in the surveillance system), when comparing 2019 to 2023, there was an increase in the number of reported invasive *K. pneumoniae* isolates (+46.0%; 33 372 and 48 739, respectively). This includes an 11.9% increase in the number of reported *K. pneumoniae* isolates between 2022 and 2023. Between 2019 and 2022 the estimated EU/EEA incidence of invasive *K. pneumoniae* isolates ranged between 19.8 and 21.8 per 100 000 population. Since 2019, it has increased (+18.0%) from 20.5 per 100 000 population to 24.2 per 100 000 population in 2023, with an 11.0% increase in 2023 compared to 2022 (21.8 per 100 000 population).

Of all reported invasive isolates in 2023, 48 143 (98.8%) had AST results for third-generation cephalosporins, 48 056 (98.6%) for fluoroquinolones, 47 570 (97.6%) for carbapenems, and 47 412 (97.3%) for aminoglycosides (Table 3b).

In 2023, the highest estimated EU incidence of bloodstream *K. pneumoniae* infections by resistance phenotype was reported for third-generation cephalosporins (9.25 per 100 000 population), followed by fluoroquinolones (8.83 per 100 000 population), aminoglycosides (5.96 per 100 000 population), and carbapenems (3.97 per 100 000 population) (Table 3a). During the period 2019−2023, all the estimated EU incidences of *K. pneumoniae* bloodstream infections with AMR increased and showed significantly increasing trends (Table 3a). The estimated EU incidences of *K. pneumoniae* bloodstream infections with AMR, except carbapenem resistance, showed a decrease in 2020, but have since increased and are now at higher levels than in 2019. Moreover, in 2023 all the estimated EU incidences of *K. pneumoniae* bloodstream infections with AMR had increased compared to 2022. The result for the AMR target, the estimated EU incidence of carbapenem-resistant *K. pneumoniae* bloodstream infections, was a 57.5% increase in the estimated incidence against the baseline year 2019, and 1.58 per 100 000 population higher than the 2030 target of 2.39 per 100 000 population. The country range for the target was 0.00−21.44 per 100 000 population in 2023.

At EU/EEA level, more than a third (42.0%) of the invasive *K. pneumoniae* isolates reported to EARS-Net for 2023 were resistant to at least one of the antimicrobial groups under surveillance (fluoroquinolones, third-generation cephalosporins, aminoglycosides, and carbapenems) (Table 5). In 2023, the highest EU/EEA population-weighted mean AMR percentage was reported for third-generation cephalosporins (34.8%), followed by fluoroquinolones (33.7%), aminoglycosides (23.6%) and carbapenems (13.3%) (Table 3b). Between 2019 and 2023, there was a significantly increasing trend in the EU/EEA population-weighted mean percentage for carbapenem resistance. During this period, carbapenem-resistant *K. pneumoniae* showed the largest increase (+2.9%) in the EU/EEA population-weighted mean AMR percentage of all bacteria-antibiotic combinations under EARS-Net surveillance. At the same time, the EU/EEA trend for fluoroquinolone and aminoglycoside resistance decreased significantly. When the trend analysis was restricted to include only laboratories that continuously reported data, the EU/EEA trends for carbapenem, fluoroquinolone and aminoglycoside resistance remained statistically significant (Table 3b).

Single AMR was less commonly reported than AMR to two, three or four antimicrobial groups, with the most common AMR phenotype being combined resistance to third-generation cephalosporins, fluoroquinolones and aminoglycosides (Table 5). The EU/EEA population-weighted mean for combined resistance to fluoroquinolones, third-generation cephalosporins and aminoglycosides was 21.0% in 2023 and showed a statistically significant decreasing trend during the period 2019−2023 (Table 3b). When the analysis was restricted to laboratories that continuously reported data, this trend remained. However, the estimated EU incidence of the same combined resistance in *K. pneumoniae* bloodstream infections was 5.26 per 100 000 population, and showed a statistically significant increasing trend during the period 2019–2023.

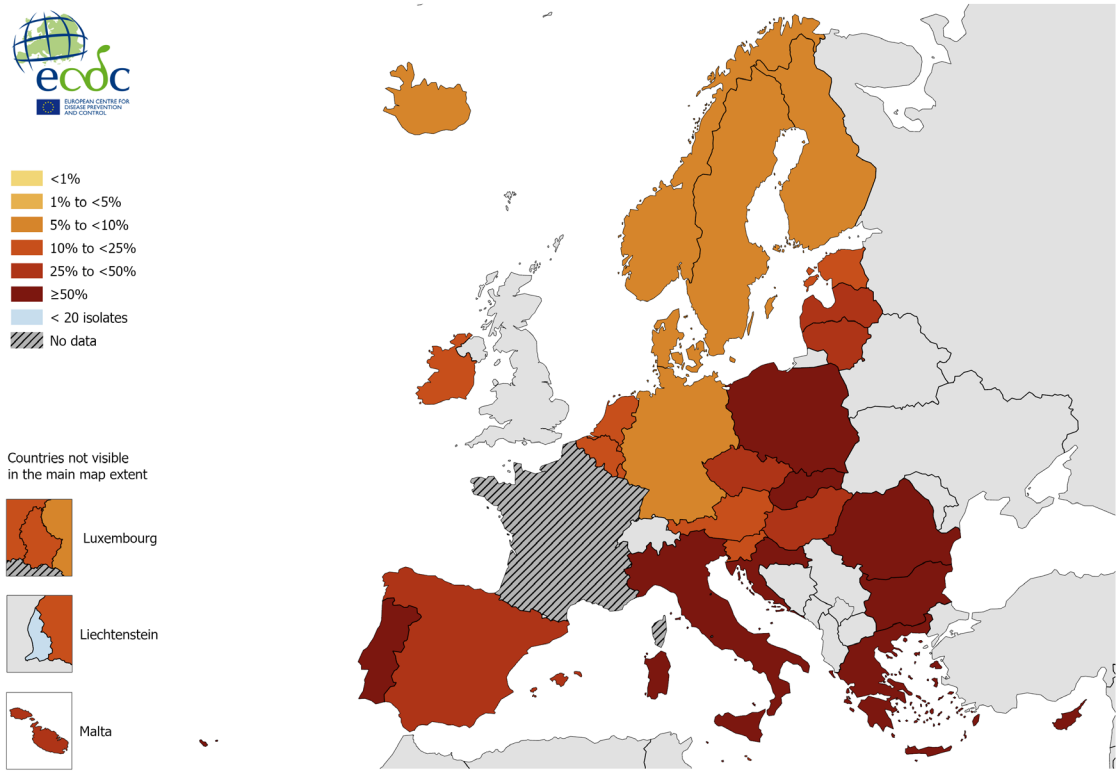
Large inter-country variations were noted for all antimicrobial groups under surveillance (Table 3b), with generally higher AMR percentages reported from southern and eastern Europe than from northern Europe (Figures 4 and 5). Nine countries reported carbapenem resistance percentages above 10.0% for *K. pneumoniae* [14]. The countries reporting the highest percentages of carbapenem resistance in *K. pneumoniae* were also generally among those reporting the highest AMR percentages for the other antimicrobial groups. For the estimated incidences of bloodstream infections with AMR, the pattern was similar.

Table 5. ***Klebsiella pneumoniae.*** **Total number of invasive isolates tested (n = 45 471)[a] and AMR percentage (%) per phenotype, EU/EEA, 2023**

AMR pattern[b]	Number of isolates	Percentage of total[c]
Susceptible to all included antimicrobial groups [d]	**26 353**	**58.0**
Single resistance (to indicated antimicrobial group)		
Total (any single resistance)	**3 770**	**8.3**
Third-generation cephalosporins	1 943	4.3
Fluoroquinolones	1 634	3.6
Other antimicrobial groups	193	0.4
Resistance to two antimicrobial groups		
Total (any two-group combinations)	**4 138**	**9.1**
Third-generation cephalosporins + fluoroquinolones	3 004	6.6
Third-generation cephalosporins + aminoglycosides	568	1.2
Other antimicrobial group combinations	566	1.2
Resistance to three antimicrobial groups		
Total (any three-group combinations)	**6 182**	**13.6**
Third-generation cephalosporins + fluoroquinolones + aminoglycosides	4 584	10.1
Third-generation cephalosporins + fluoroquinolones + carbapenems	1 530	3.4
Other antimicrobial group combinations	68	0.1
Resistance to four antimicrobial groups		
Third-generation cephalosporins + fluoroquinolones + aminoglycosides + carbapenems	**5 028**	**11.1**

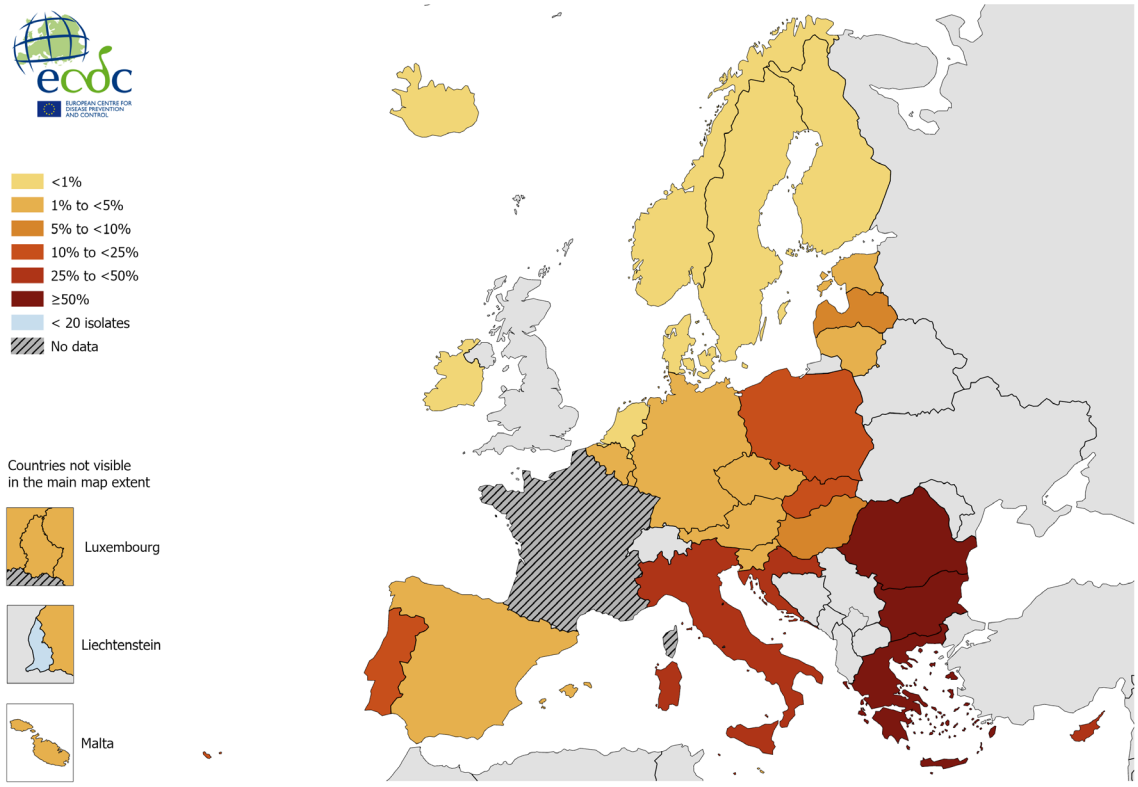
[a] Only isolates with complete susceptibility information for third-generation cephalosporins (cefotaxime, ceftriaxone or ceftazidime), carbapenems (imipenem or meropenem), fluoroquinolones (ciprofloxacin, levofloxacin or ofloxacin) and aminoglycosides (gentamicin or tobramycin) were included in the analysis. This represented 93% (45 471/48 741) of all reported K. pneumoniae *isolates.*
[b] Only AMR combinations >1% of the total are specified.
[c] Not adjusted for population differences in the reporting countries.
[d] Third-generation cephalosporins (cefotaxime, ceftriaxone or ceftazidime), carbapenems (imipenem or meropenem), fluoroquinolones (ciprofloxacin, levofloxacin or ofloxacin) and aminoglycosides (gentamicin or tobramycin).

Figure 4. ***Klebsiella pneumoniae*. Percentage of invasive isolates resistant to third-generation cephalosporins (cefotaxime/ceftriaxone/ceftazidime), by country, EU/EEA, 2023**



Administrative boundaries: © EuroGeographics. The boundaries and names shown on this map do not imply official endorsement or acceptance by the European Union. Map produced by ECDC on 13 September 2024

Figure 5. ***Klebsiella pneumoniae*. Percentage of invasive isolates resistant to carbapenems (imipenem/meropenem), by country, EU/EEA, 2023**



Administrative boundaries: © EuroGeographics. The boundaries and names shown on this map do not imply official endorsement or acceptance by the European Union. Map produced by ECDC on 13 September 2024

Discussion

The AMR situation with *K. pneumoniae* in the EU/EEA remains problematic. ECDC's study of the EU/EEA health burden of AMR for the period 2016–2020 showed that the largest burden of disease was caused by infections with third-generation cephalosporin-resistant *E. coli*, followed by MRSA and third-generation cephalosporin-resistant *K. pneumoniae*. Infections with these three antibiotic-resistant bacteria resulted in the largest health impact, generating 58.2% of the total burden, as measured in disability-adjusted life years (DALYs) [1].

Moreover, all the estimated EU incidences of resistant *K. pneumoniae* bloodstream infections increased significantly compared to 2019. This includes carbapenem-resistant *K. pneumoniae*, which increased by more than 50% compared to 2019 (baseline year). This is an indication that overall, the EU is not progressing towards the agreed target of a 5% reduction in incidence by 2030, compared to the baseline year 2019 [2]. Moreover, it highlights the urgent need for intensified public health action against carbapenem-resistant *K. pneumoniae*.

The 2021 EARS-Net EQA indicated that decreased carbapenem susceptibility in *K. pneumoniae* was probably over-reported in 2021 [15], and the EARS-Net 2023 EQA similarly indicated that carbapenem resistance may be over-reported [5]. This calls for some caution when interpreting the results in this report for the EU and the EU/EEA.

Nevertheless, the results show a significantly increasing trend in both the estimated EU incidences of carbapenem-resistant *K. pneumoniae* bloodstream infections as well as the EU/EEA population-weighted mean percentage for carbapenem resistance during the period 2019−2023. Carbapenem resistance was often combined with AMR to several other key antimicrobial groups, leading to a severely limited range of treatment options for serious infections caused by this type of bacteria. ECDC's studies of the AMR health burden found that even though the level of carbapenem-resistant *K. pneumoniae* was relatively low, the impact of AMR on the EU/EEA health burden is heavy because of the high level of attributable mortality caused by these infections [1,16]. In 2020, the number of deaths attributable to carbapenem-resistant *K. pneumoniae* in 2020 was estimated to be 4 076 [1].

The highest percentages and estimated incidences of carbapenem-resistant *K. pneumoniae* were observed in southern and eastern Europe, similar to the distribution of CPE reflected in a survey conducted by EURGen-Net [17]. Results from EURGen-Net also show that in several EU/EEA countries the situation deteriorated between 2010 and 2018 with regard to the spread of CPE [18]. Numerous reports on outbreaks with varying potential for, or recorded cross-border spread of CPE demonstrate the transmission potential in the healthcare systems of EU/EEA countries [18–20]. Outbreaks and clusters in EU/EEA countries also highlight the importance of detecting CPE early in settings with low incidence, due to high transmissibility [18–22].

CRE can be resistant to carbapenems resulting from a variety of mechanisms, but most frequently through production of carbapenemase enzymes. It is not possible to assess the overall presence and spread of CPE from the data available through EARS-Net, as some carbapenemases do not confer a fully carbapenem-resistant phenotype. One example is the OXA-48-like carbapenemase enzymes, which present a particular problem for laboratory detection because of their weak capacity to hydrolyse carbapenems [18].

In addition, a recent ECDC rapid risk assessment noted that since 2019 there have been more reports in the EU/EEA of *K. pneumoniae* isolates belonging to the ST23-K1 lineage that also exhibit carbapenemase genes [23]. This is worrying since the lineage is associated with hypervirulence and invasive infections, primarily hepatic abscesses that can occur in healthy individuals. Early detection of hypervirulent *K. pneumoniae*, as well as close cooperation between clinicians and public health services, and increased laboratory capacity for the detection of these isolates is needed to prevent spread among the patient population in the EU/EEA.

There is also a need for increased capacity in the EU/EEA to support outbreak investigations and surveillance with real-time whole genome sequencing in order to identify high-risk clones and implement enhanced control measures to avoid further spread [21, 22]. One initiative to address this need is the CCRE surveys (part of EURGen-Net) that will provide updated and more detailed information on the distribution of carbapenemase-producing *K. pneumoniae* in Europe [12]. It has been shown that it is possible to implement a modified version of the survey at national level to allow collection of near real-time data that is useful for IPC work [24].

As highlighted in the 2019 update of ECDC's rapid risk assessment on CRE, options for action include timely and appropriate diagnosis, high standards of IPC and antimicrobial stewardship [9]. Many EU/EEA countries have developed and implemented recommendations and guidance documents on multidrug-resistant Enterobacterales and/or CRE [25], indicating a trend towards nationally coordinated responses to this public health threat. To support countries, ECDC published a guidance document on how to prevent the entry and spread of CRE into healthcare settings in 2017. The guidance outlines evidence-based best practices for the prevention of CRE, including measures for intervention that can be adopted or adapted to local needs, depending on the availability of financial and structural resources [26].

It should be noted that the data reported on *K. pneumoniae* may have been affected by changes over time in the identification and nomenclature of *K. pneumoniae*. Species previously but no longer identified as *K. pneumoniae* are less often found to be resistant. As a result, the reported percentage of resistant *K. pneumoniae* in the EU/EEA may have increased over time. The size of the impact, in terms of changes in identification and nomenclature, is unknown.

Resistance to newly released antimicrobials has turned out to be a challenge for the optimal treatment of infections with CRE that are resistant to these new antimicrobials [27]. WHO sees a critical need for research and development of new antibiotics targeting both third-generation cephalosporin resistant and carbapenem-resistant Enterobacterales [28], to which both *E. coli and K. pneumoniae* belong. This highlights the need to also monitor for resistance to new antimicrobials. EARS-Net took steps in this direction in 2024 by piloting the inclusion of new antimicrobials in the data collection in 2024.

Pseudomonas aeruginosa

Epidemiology

For 2023, 29 EU/EEA countries reported 22 045 invasive isolates of *P. aeruginosa*. Among the countries that continuously reported data during 2019–2023 (excluding France due to changes in the surveillance system), when comparing 2019 to 2023, there was an increase in the number of reported *P. aeruginosa* (+41.1%; 15 620 and 22 045, respectively). This includes an increase from 2022 to 2023, when the number or reported invasive *P. aeruginosa* isolates increased by +6.4%. The estimated incidence of invasive *P. aeruginosa* isolates increased (+11.7%) from 9.4 per 100 000 population in 2019 to 10.5 per 100 000 population in 2023.

Of all reported invasive isolates in 2023, 21 861 (99.2%) had AST results for fluoroquinolones, 21 844 (99.1%) for carbapenems, 21 608 (98.0%) for ceftazidime, 21 315 (96.7%) for piperacillin-tazobactam and 16 809 (76.2%) for aminoglycosides (Table 3b).

In 2023, the highest estimated EU incidence of bloodstream *P. aeruginosa* infections by resistance phenotype was reported for carbapenems (2.01 per 100 000 population), followed by piperacillin-tazobactam (2.00 per 100 000 population), fluoroquinolones (1.94 per 100 000 population), ceftazidime (1.72 per 100 000 population), and aminoglycosides (0.79 per 100 000 population) (Table 3a). During the period 2019–2023, the estimated EU incidence of *P. aeruginosa* bloodstream infections with resistance to piperacillin-tazobactam, ceftazidime and carbapenems increased and showed significantly increasing trends (Table 3a).

In the EU/EEA, 32.2% of the invasive *P. aeruginosa* isolates reported to EARS-Net for 2023 were resistant to at least one of the antimicrobial groups under surveillance (piperacillin-tazobactam, fluoroquinolones, ceftazidime, aminoglycosides and carbapenems) (Table 6). The highest EU/EEA population-weighted mean AMR percentage in 2023 was reported for carbapenems (18.6%), followed by piperacillin-tazobactam (18.5%), fluoroquinolones (17.9%), ceftazidime (15.7%) and aminoglycosides (9.5%) (Table 3b). Between 2019 and 2023, the EU/EEA population-weighted mean AMR percentage trend decreased significantly for fluoroquinolones. When the analysis was restricted to include only laboratories that continuously reported data for all five years, the trend remained statistically significant (Table 3b). Moreover, compared to 2022, the 2023 EU/EEA population-weighted mean AMR percentages for fluoroquinolones, carbapenems, piperacillin-tazobactam and ceftazidime showed decreases.

For *P. aeruginosa* and aminoglycosides there was a considerable change in the analysis as of 2020 which could affect the results when compared with the period 2019, and the trend for this bacterial species antimicrobial group combination is therefore not calculated (Table 3a and Table 3b).

Resistance to two or more antimicrobial groups was common: found in 19.6% of all tested invasive isolates (Table 6). Between 2019 and 2023, the EU/EEA population-weighted mean percentage of combined resistance, defined as resistance to at least three of the antimicrobial groups under surveillance, was not calculated due to the considerable change in the analysis as of 2020 that could affect the results when compared with 2019 (Table 3b). The estimated EU incidence of combined resistance in *P. aeruginosa* bloodstream infections, measured as resistance to at least three of the antimicrobial groups under surveillance, was 1.05 per 100 000 population and this showed a decrease compared to 2019 (1.20 per 100 000 population), however a trend was not calculated, and the change should be interpreted with considerable caution, given the change in the analysis as of 2020.

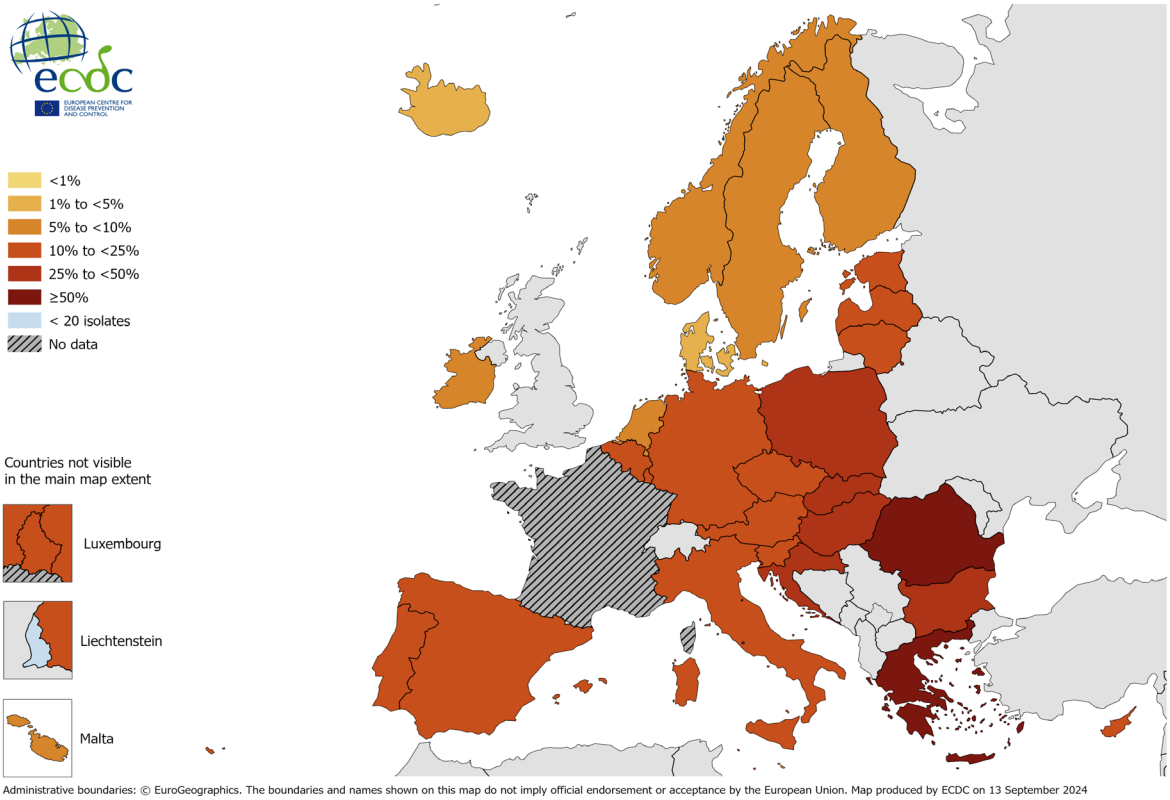
Large inter-country variations were noted for all antimicrobial groups (Table 3b), with reported AMR percentages generally higher from southern and eastern Europe than northern Europe (Figure 6) [14]. For the estimated incidences of bloodstream infections with AMR, the pattern was fairly similar.

Table 6. ***Pseudomonas aeruginosa.*** **Total number of invasive isolates tested (n = 16 092)[a] and AMR percentage (%) per phenotype, EU/EEA, 2023**

AMR pattern[b]	Number of isolates	Percentage of total[c]
Susceptible to all included antimicrobial groups[d]	**10 907**	**67.8**
Single resistance (to indicated antimicrobial group)		
Total (any single resistance)	**2 026**	**12.6**
Carbapenems	827	5.1
Fluoroquinolones	683	4.2
Piperacillin-tazobactam	313	1.9
Other antimicrobial groups	203	1.3
Resistance to two antimicrobial groups		
Total (any two group combinations)	**1 286**	**8.0**
Piperacillin-tazobactam + ceftazidime	676	4.2
Fluoroquinolones + carbapenems	239	1.5
Other antimicrobial group combinations	371	2.3
Resistance to three antimicrobial groups		
Total (any three group combinations)	**674**	**4.2**
Piperacillin-tazobactam + ceftazidime + carbapenems	282	1.8
Piperacillin-tazobactam + ceftazidime + fluoroquinolones	166	1.0
Other antimicrobial group combinations	226	1.4
Resistance to four antimicrobial groups		
Total (any four group combinations)	**425**	**2.6**
Piperacillin-tazobactam + fluoroquinolones + ceftazidime + carbapenems	208	1.3
Other antimicrobial group combinations	217	1.3
Resistance to five antimicrobial groups		
Piperacillin-tazobactam + fluoroquinolones + ceftazidime + aminoglycosides + carbapenems	**774**	**4.8**

[a] Only isolates with complete susceptibility information for piperacillin-tazobactam, ceftazidime, carbapenems (imipenem or meropenem), fluoroquinolones (ciprofloxacin or levofloxacin) and aminoglycosides (tobramycin) were included in the analysis. This represented 73% (16 092/22 045) of all reported P. aeruginosa isolates.
[b] Only AMR combinations >1% of the total are specified.
[c] Not adjusted for population differences in the reporting countries.
[d] Piperacillin-tazobactam, ceftazidime, carbapenems (imipenem or meropenem), fluoroquinolones (ciprofloxacin or levofloxacin) and aminoglycosides (tobramycin).

Figure 6. ***Pseudomonas aeruginosa.*** **Percentage of invasive isolates with resistance to carbapenems (imipenem/meropenem), by country, EU/EEA, 2023**



Discussion

EARS-Net data showed increasing trends in estimated EU incidences of *P. aeruginosa* bloodstream infections with AMR during the period 2019–2023. These trends were not reflected in the AMR percentages at EU/EEA level during the same period. Moreover, there was a decreasing trend noted for the EU/EEA fluoroquinolones resistance percentage. Nevertheless, high AMR percentages were observed in many countries, especially in the eastern and southern parts of Europe, and carbapenem resistance was common among the tested invasive isolates. As *P. aeruginosa* is intrinsically resistant to many antimicrobial agents, additional acquired resistance is further complicating the treatment of *P. aeruginosa* infections.

The 2022 EARS-Net EQA exercise showed an over-reporting of resistance towards levofloxacin in *P. aeruginosa* [4]. Whether this AMR overestimation remains is uncertain, since the 2023 EARS-Net EQA exercise did not include a *P. aeruginosa* isolate [5]. Some caution may still be called for when interpreting the results for *P. aeruginosa* and fluoroquinolones.

The public health implications of AMR in *P. aeruginosa* should not be ignored. Although the estimated EU incidences for *P. aeruginosa* bloodstream infections with AMR are the lowest among the gram-negative bacteria under EARS-Net surveillance, *P. aeruginosa* remains one of the major causes of healthcare-associated infection in Europe [29-30]. In addition, an ECDC report based on EARS-Net data estimated that in 2020 there were 67 638 infections with carbapenem-resistant *P. aeruginosa,* and 3 210 deaths attributable to the same bacterial species antimicrobial group combination [1].

An analysis based on 2016 EARS-Net data highlighted that countries reporting high percentages of *P. aeruginosa* and *Acinetobacter* spp. bloodstream infections among all reported bloodstream infections were also those where the percentage of isolates with acquired AMR in gram-negative bacteria was generally highest [31]. This finding is probably attributable to shared risk factors, such as a high consumption of broad-spectrum antimicrobials and varying IPC practices in healthcare [32]. Addressing these factors and implementing high standards of IPC in healthcare within these countries would probably have a positive impact, both on the burden of infections caused by bacteria with high levels of intrinsic AMR, such as *P. aeruginosa* and *Acinetobacter* spp., and on bacteria with acquired AMR.

At the global level, WHO has listed carbapenem-resistant *P. aeruginosa* as a pathogen of high priority that requires research and the development of new antibiotics [28].

Acinetobacter species

Epidemiology

For 2023, 28 EU/EEA countries reported 8 973 invasive isolates of *Acinetobacter* spp., with four EU/EEA countries each reporting fewer than 30 isolates, not including Liechtenstein or France as these two countries did not report any isolate to EpiPulse.

Among the countries that continuously reported data during 2019–2023 (excluding France due to changes in the surveillance system), when comparing 2019 to 2023, there was an increase in the number of reported invasive *Acinetobacter* spp. isolates (+84.6%; 4 860 and 8 973, respectively). However, compared to the highest number reported during 2019-2023 (2021 n=10 707) there was a decrease in 2023. Moreover, although there was an increase from 2022 to 2023, the number of reported invasive *Acinetobacter* spp. isolates rose by less than 2% (+1.7%; 8 826 and 8 973, respectively). The estimated EU/EEA incidence of invasive *Acinetobacter* spp. isolates increased (+21.1%) from 3.8 per 100 000 population in 2019 to 4.6 per 100 000 population in 2023. However, compared to the high incidence noted for 2021 (6.1 per 100 000 population) there was a 24.6% decrease in 2023.

Of all reported invasive isolates reported for 2023, 8 843 (98.6%) had AST results for carbapenems, 8 734 (97.3%) for fluoroquinolones, and 8 570 (95.5%) for aminoglycosides (Table 3b).

In 2023, the highest estimated EU incidence of *Acinetobacter* spp. bloodstream infections by resistance phenotype was reported for fluoroquinolones (3.02 per 100 000 population), followed by carbapenems (2.98 per 100 000 population), and aminoglycosides (2.66 per 100 000 population) (Table 3a). During the period 2019–2023, none of the estimated EU incidences of *Acinetobacter* spp. bloodstream infections with AMR showed a significant trend (Table 3a). However, compared to the high incidences seen in 2021 all had decreased, albeit not to the level noted for 2019.

More than two thirds (67.2%) of the invasive *Acinetobacter* spp. isolates reported by EU/EEA countries to EARS-Net for 2023 were resistant to at least one of the antimicrobial groups under surveillance (fluoroquinolones, aminoglycosides and carbapenems) (Table 7). The highest EU/EEA population-weighted mean AMR percentage in 2023 was reported for fluoroquinolones (42.4%), followed by carbapenems (40.1%) and aminoglycosides (36.7%) (Table 3b). Between 2019 and 2023, significant decreasing trends in AMR were detected for all the antimicrobial groups under surveillance in the EU/EEA (Table 3b). The trends remained statistically significant for fluoroquinolones and aminoglycosides when restricting the analysis to continuously reporting laboratories. Compared to the high numbers noted for 2021 there has been a decrease for all the antimicrobial groups in the last two years.

Resistance to one or two antimicrobial groups was considerably less common than combined resistance to all three groups under surveillance (Table 7). Between 2019 and 2023, the EU/EEA population-weighted mean percentage for combined resistance to carbapenems, fluoroquinolones and aminoglycosides increased (from 38.0% to 43.0% between 2019 and 2021) and then decreased in 2022 and 2023 to reach 35.2% in 2023. The estimated EU incidence of combined resistance in bloodstream infections, measured as resistance to carbapenems, fluoroquinolones and aminoglycosides, showed a similar pattern, reaching 2.55 per 100 000 population in 2023, with no statistically significant trend during the period 2019–2023. It is interesting to note that in 2023 the highest estimated incidence of combined resistance in bloodstream infections under EARS-Net surveillance at country level was for *Acinetobacter* spp. (19.15 per 100 000 population) (Country summaries).

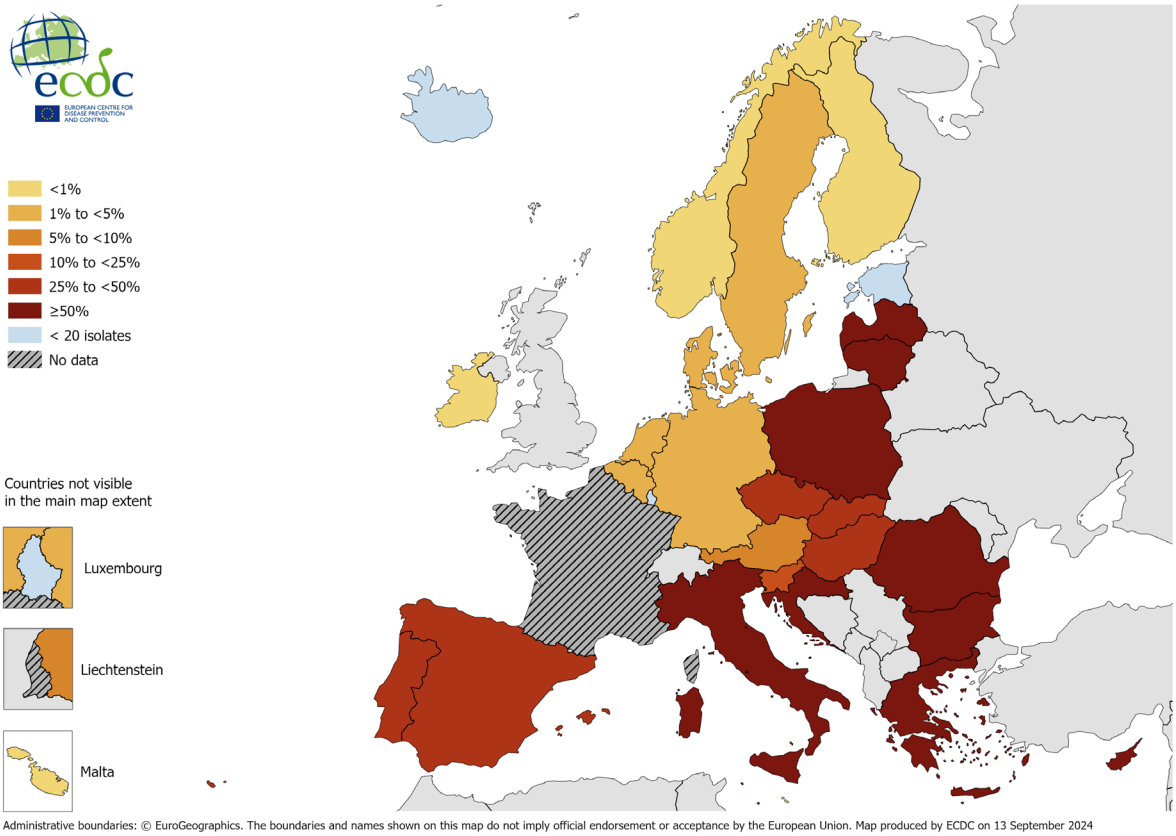
Large inter-country variations were noted for all antimicrobial groups (Table 3b), with higher AMR percentages generally reported from southern and eastern Europe than northern Europe (Country summaries and Figure 7). For the estimated incidences of bloodstream infections with AMR, the pattern was fairly similar (Country summaries).

Table 7. ***Acinetobacter*** **species. Total number of invasive isolates tested (n = 8 429)[a] and AMR percentage (%) per phenotype, EU/EEA, 2023**

AMR pattern[b]	Number of isolates	Percentage of total[c]
Susceptible to all included antimicrobial groups[d]	**2 764**	**32.8**
Single resistance (to indicated antimicrobial group)		
Total (any single resistance)	**166**	**2.0**
Resistance to two antimicrobial groups		
Total (any two-group combinations)	**522**	**6.2**
Fluoroquinolones + carbapenems	437	5.2
Other antimicrobial group combinations	85	1.0
Resistance to three antimicrobial groups		
Fluoroquinolones + aminoglycosides + carbapenems	**4 977**	**59.0**

[a] Only isolates with complete susceptibility information for carbapenems (imipenem or meropenem), fluoroquinolones (ciprofloxacin or levofloxacin) and aminoglycosides (gentamicin or tobramycin) were included in the analysis. This represented 94% (8 429/8 973) of all reported Acinetobacter *spp. isolates.*
[b] Only AMR combinations >1% of the total are specified.
[c] Not adjusted for population differences in the reporting countries.
[d] Carbapenems (imipenem or meropenem), fluoroquinolones (ciprofloxacin or levofloxacin) and aminoglycosides (gentamicin or tobramycin).

Figure 7. ***Acinetobacter*** **species. Percentage of invasive isolates with resistance to carbapenems (imipenem/meropenem), by country, EU/EEA, 2023**



Discussion

Of all the bacterial species under surveillance by EARS-Net, *Acinetobacter* spp. was the least commonly reported for 2023. A publication based on 2017–2021 EARS-Net data from laboratories that continuously reported over these five years showed an increase in reported isolates in 2020–2021. A major part of these isolates consisted of carbapenem-resistant infections in ICU patients, in the countries with carbapenem resistance percentages in *Acinetobacter* spp. exceeding 50% in 2018–2019 [34]. This development implied that the situation with *Acinetobacter* spp. in the EU/EEA had deteriorated and indicated the need for reinforced *Acinetobacter* spp. preparedness, and IPC in EU/EEA healthcare facilities. This need for action was further emphasised by ECDC's estimate that in 2020 3 656 deaths were attributable to carbapenem-resistant *Acinetobacter* spp. [1]. Overall, the results in 2023, for both the EU/EEA population-weighted mean AMR percentages and the estimated EU incidences of bloodstream infections with AMR, indicate that the efforts to improve the situation are having an effect. However, the estimated incidences of resistance are not yet at the levels they were at in 2019.

Acinetobacter spp., and multidrug-resistant strains in particular, are notoriously difficult to eradicate from the hospital environment once established, surviving on dry surfaces, readily contaminating healthcare providers' hands, and being spread by asymptomatic carriers [35]. Therefore, although the data reported to EARS-Net indicate that at EU and EU/EEA level, the previous deterioration in the *Acinetobacter* spp. situation may be improving, the fact that *Acinetobacter* spp. continue to display high EU/EEA population-weighted mean AMR percentages is of concern. In addition, the 2022 and the 2023 EARS-Net EQA both indicated that in EARS-Net resistance to aminoglycosides is under-reported, and this result should therefore be interpreted with some caution [4, 5].

The inter-country range in AMR percentages remains one of the widest ranges among all pathogens included in EARS-Net. In 2023, the percentage of invasive isolates resistant to at least one of the antimicrobial groups under surveillance (fluoroquinolones, aminoglycosides or carbapenems) ranged between 0.0% and 96.6%, depending on the reporting country. In general, the highest AMR percentages and estimated incidences of bloodstream infections with AMR were reported from southern and eastern Europe. The high levels of AMR in these countries are of great concern since the most frequently reported AMR phenotype was combined resistance to all three antimicrobial groups under surveillance, severely limiting options for patient treatment. It should be pointed out that *Acinetobacter* spp. are intrinsically resistant to many antimicrobial agents, and hence additional acquired AMR is further complicating treatment of *Acinetobacter* spp. infections.

ECDC's risk assessment on carbapenem-resistant *Acinetobacter baumannii* in healthcare settings highlights the need for increased efforts to face this significant threat to patients and healthcare systems in all EU/EEA countries. The document outlines options for reducing risks through clinical management; prevention of transmission in hospitals and other healthcare settings; prevention of cross-border transmission and improvement in the preparedness of EU/EEA countries. Options for response presented in the risk assessment include timely laboratory reporting, screening and pre-emptive isolation of high-risk patients, good IPC, rigorous environmental cleaning and disinfection, and antimicrobial stewardship programmes [36].

To further assist EU/EEA countries as well as Western Balkan countries and Türkiye in enhancing their capacities for detecting and controlling infections caused by carbapenem-resistant *A. baumannii* (CRAb), ECDC has expanded EURGen-Net to include the conducting of a genomic survey of CRAb in 2024–2025 [37].

WHO has listed carbapenem-resistant *A. baumannii* as a pathogen of critical priority in its global priority list of antibiotic-resistant bacteria, requiring research and the development of new antibiotics [28].

Staphylococcus aureus

Epidemiology

For 2023, 29 EU/EEA countries reported 77 543 invasive isolates of *S. aureus*. Among the countries that continuously reported data during 2019–2023 (excluding France due to changes in the surveillance system), when comparing 2019 to 2023, there was an increase in the number of reported *S. aureus* invasive isolates (+29.5%; 59 883 and 77 541, respectively). The estimated EU/EEA incidence of *S. aureus* invasive isolates during the same period showed a smaller increase (+4.2%), from 35.4 per 100 000 population to 36.9 per 100 000 population.

Of all reported invasive isolates in 2023, 77 543 (97.0%) had AST results or molecular confirmation test results available to determine MRSA status (Table 3b).

In 2023, the estimated EU incidence of MRSA bloodstream infections was 4.64 per 100 000 population (Table 3a). During the period 2019–2023, the estimated EU incidence of MRSA bloodstream infections showed a statistically significant decreasing trend (Table 3a). The result for the AMR target, the estimated EU incidence of MRSA bloodstream infections, was a 17.6% decrease in the estimated incidence between 2019 (baseline year) and 2023, from 5.63 to 4.64 cases per 100 000 population, and was 0.15 per 100 000 population lower than the 2030 target. The country range for the incidence of MRSA bloodstream infections was 0–15.5 per 100 000 population in 2023.

A little less than one fifth (18.5%) of the invasive *S. aureus* isolates reported by EU/EEA countries to EARS-Net for 2023 were resistant to at least one of the antimicrobial groups under surveillance (meticillin/MRSA, fluoroquinolones and rifampicin) (Table 8).

The EU/EEA population-weighted mean MRSA percentage was 15.8% in 2023. This denotes a significantly decreasing trend for the period 2019–2023, from 18.2% to 15.8%, a trend that remained statistically significant when the analysis was restricted to include only laboratories that continuously reported data for all five years (Table 3b). Moreover, the MRSA percentage either showed a statistically significant decreasing trend or no statistically significant trend (i.e. neither decreasing nor increasing) in most EU/EEA countries.

With MRSA, combined resistance to another antimicrobial group was quite common. The most common AMR combination was MRSA and resistance to fluoroquinolones (Table 8).

Large inter-country variations were noted for MRSA (Table 3b), with higher AMR percentages generally reported from southern and eastern Europe than northern Europe (Figure 8). For the estimated incidences of bloodstream infections with AMR, the pattern was fairly similar (Country summaries).

Table 8. ***Staphylococcus aureus.*** **Total number of invasive isolates tested (n = 54 022)[a] and AMR percentage (%) per phenotype, EU/EEA, 2023**

AMR pattern[b]	Number of isolates	Percentage of total[c]
Susceptible to all included antimicrobial groups[d]	**44 024**	**81.5**
Single resistance (to indicated antimicrobial group)		
Total (any single resistance)	**5 097**	**9.4**
Fluoroquinolones	2 735	5.1
Meticillin/MRSA	1 912	3.5
Other antimicrobial groups	450	0.8
Resistance to two antimicrobial groups		
Total (any two-group combinations)	**4 578**	**8.5**
Meticillin/MRSA + fluoroquinolones	4 419	8.2
Other resistance combinations	159	0.3
Resistance to three antimicrobial groups		
Meticillin/MRSA + fluoroquinolones + rifampicin	**323**	**0.6**

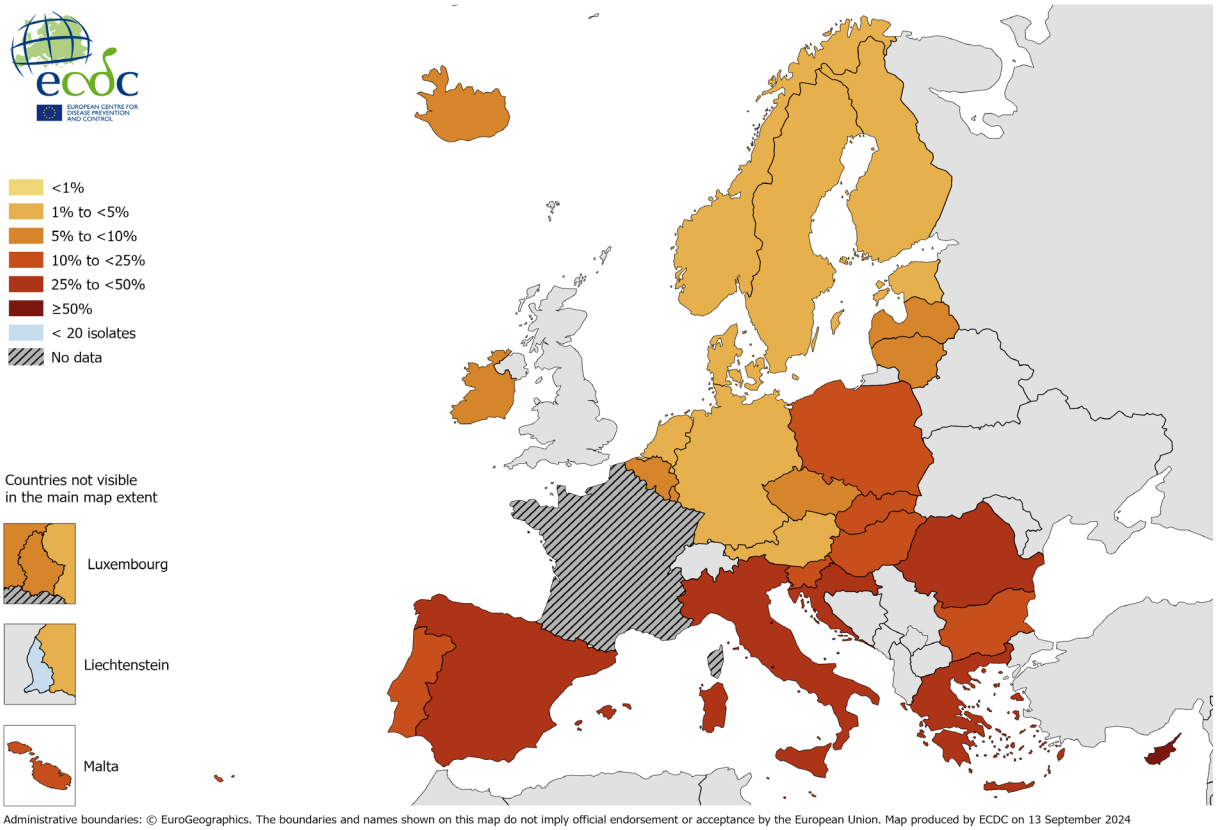
[a] *Only isolates with complete susceptibility information for MRSA, fluoroquinolones and rifampicin were included in the analysis. This represented 70% (54 022/77 543) of all reported* S. aureus *isolates. MRSA is based on AST results for cefoxitin, or if unavailable, oxacillin. AST results reported for cloxacillin, dicloxacillin, flucloxacillin or meticillin are accepted as a marker for oxacillin resistance if oxacillin is not reported. If no phenotypic results are available, data from molecular confirmation tests (detection of* mecA *gene by PCR or a positive PBP2A-agglutination test) are accepted as a marker for MRSA. For fluoroquinolones (ciprofloxacin or levofloxacin) AST results for norfloxacin are also accepted if neither ciprofloxacin nor levofloxacin results are available.*

[b] *Only AMR combinations >1% of the total are specified.*

[c] *Not adjusted for population differences in the reporting countries.*

[d] *MRSA, fluoroquinolones and rifampicin. MRSA is based on AST results for cefoxitin, or if unavailable, oxacillin. AST results reported for cloxacillin, dicloxacillin, flucloxacillin or meticillin are accepted as a marker for oxacillin resistance if oxacillin is not reported. If no phenotypic results are available, data from molecular confirmation tests (detection of* mecA *gene by PCR or a positive PBP2A-agglutination test) are accepted as a marker for MRSA. For fluoroquinolones (ciprofloxacin or levofloxacin) AST results for norfloxacin are also accepted if neither ciprofloxacin nor levofloxacin results are available.*

Figure 8. ***Staphylococcus aureus.*** **Percentage of invasive isolates resistant to meticillin (MRSA),[a] by country, EU/EEA, 2023**



[a] *For EARS-Net, MRSA is based on AST results for cefoxitin or, if unavailable, oxacillin. AST results reported for cloxacillin, dicloxacillin, flucloxacillin or meticillin are accepted as a marker for oxacillin resistance if oxacillin is not reported. If no phenotypic results are available, data from molecular confirmation tests (detection of* mecA *gene by PCR or a positive PBP2A-agglutination test) are accepted as a marker for MRSA.*

Discussion

The difference in trends for the number and the estimated incidence of reported *S. aureus* invasive isolates in the EU/EEA could be due to change over time in the national population coverages reported to EARS-Net. The difference indicates the importance of considering the effects of changes in the surveillance system when examining the number of reported isolates.

Several countries have developed and implemented national recommendations and guidance documents on preventing the spread of MRSA, focusing on improved IPC and prudent antimicrobial use [25]. In 2023, the estimated incidence of MRSA bloodstream infections also showed either no trend or a decreasing trend in most EU/EEA countries and a resulting decreasing trend for the EU overall. The MRSA percentage also showed no trend or a decreasing trend in most EU/EEA countries, and a resulting decreasing EU/EEA population-weighted mean MRSA percentage.

Despite this overall positive development, MRSA remains an important pathogen in Europe, with combined resistance to another antimicrobial group being quite common and high MRSA percentages still being observed in several countries. *S. aureus* is one of the most common causes of bloodstream infections, with a high burden in terms of morbidity and mortality [1,16].

In the ECDC study of the health burden of AMR in the EU/EEA for the period 2016–2020, the second largest burden of disease was caused by infections with MRSA [1]. Although the EU/EEA population-weighted MRSA percentage, as reported by EARS-Net, has overall been decreasing for many years, ECDC's study of the health burden of AMR reported an increase in estimated incidence of MRSA infections between 2007 and 2015. Further analysis of the age-group-specific incidence of MRSA infections found that this mainly related to infants and those aged 55 years or above [16]. A separate study based on EARS-Net data for the period 2005–2018 highlighted that the decrease in the percentage of MRSA among *S. aureus* bloodstream infections was mainly due to the increasing number of meticillin-susceptible *S. aureus* bloodstream infections. The seemingly conflicting results highlighted the need to improve surveillance of AMR by reporting not only AMR percentages, but also the incidence of infections with antimicrobial-resistant bacteria such as MRSA [38]. The estimation of the incidence of bloodstream infections with antimicrobial-

resistant bacteria has been added to this 2023 annual epidemiological report for EARS-Net for all bacterial species-antimicrobial group combinations under EARS-Net surveillance.

For MRSA, the estimated incidence of bloodstream infections for the EU overall showed a 17.6% decrease from 2019 to 2023. As a result, the EARS-Net data currently indicate that by 2023 the EU had already reached the agreed target of a 15% reduction in incidence by 2030 against 2019 (baseline year) [2].

Comprehensive MRSA strategies targeting all healthcare sectors are essential for slowing down the spread of MRSA in Europe. At present, monitoring of MRSA in animals and food is voluntary and only performed in a few countries. Nevertheless, this monitoring detected MRSA, mainly livestock-associated MRSA (LA-MRSA), in food and food-producing animals in 2021−2022 [8]. LA-MRSA poses a zoonotic risk, particularly for those in close contact with livestock. Although data collected through EARS-Net do not allow the identification of LA-MRSA isolates, an ECDC survey has documented increasing numbers of detections and geographical dispersion of LA-MRSA in humans in the EU/EEA during the period 2007–2013, highlighting the veterinary and public health significance of LA-MRSA as a 'One Health' issue [39].

WHO has listed MRSA as a pathogen of high priority in its global priority list of antibiotic-resistant bacteria, emphasising the significant treatment difficulties that can be critical in some populations [28].

Streptococcus pneumoniae

Epidemiology

For 2023, 30 EU/EEA countries reported 18 453 invasive isolates of *S. pneumoniae*. Among the countries that continuously reported data during the period 2019–2023, and when comparing 2019 to 2023, there was an increase in the number of reported *S. pneumoniae* invasive isolates (+17.7%; 15 608 and 18 375, respectively). More recently, between 2022 and 2023, the number of reported *S. pneumoniae* invasive isolates increased by +25.4% from n=14 653 to n=18 375. The estimated incidence of *S. pneumoniae* invasive isolates increased by +4.3% from 6.9 per 100 000 population in 2019 to 7.2 per 100 000 population in 2023. Compared to 2022, the estimated incidence increased by +26.3%. This means that the incidence has doubled since 2021 when it was 3.6 per 100 000 population.

Of the invasive isolates reported in 2023, 17 698 (95.9%) had AST results for macrolides and 16 659 (90.3%) had AST results for penicillins (Table 3b).

For this report, the term penicillin non-wild-type refers to *S. pneumoniae* isolates reported by local laboratories as 'susceptible, increased exposure' (I) or resistant (R) to penicillin, assuming an MIC for benzylpenicillin above that for the wild-type isolates (> 0.06 mg/L). The analysis was based on the qualitative susceptibility categories S/I/R, since quantitative susceptibility information was missing for a large part of the reported data.

In 2023, the highest estimated EU incidence of *S. pneumoniae* bloodstream infections by resistance phenotype was reported for macrolides (0.96 per 100 000 population), followed by penicillin non-wild-type (0.76 per 100 000 population) (Table 3a). During the period 2019–2023, the estimated EU incidences of bloodstream infections with resistant *S. pneumoniae* showed a decrease from 2019 to 2020 and then increased from 2021 to 2023. This resulted in the 2023 incidences exceeding those of 2019. There was no statistically significant trend for the EU overall (Table 3a). However, there are large inter-country variations in the pattern of incidence of resistant *S. pneumoniae* bloodstream infections over time (Country summaries).

More than one fifth (20.5%) of the invasive *S. pneumoniae* isolates reported by EU/EEA countries to EARS-Net for 2023 were resistant to at least one of the antimicrobial groups under surveillance (penicillins, third-generation cephalosporins, fluoroquinolones and macrolides) (Table 9). In 2023, the EU/EEA population-weighted mean percentage was 17.8% for macrolide resistance and 15.1% for penicillin non-wild-type (Table 3b). Between 2019 and 2023, the trend in the EU/EEA population-weighted mean percentage of macrolide resistance and penicillin non-wild-type resistance increased significantly, with percentages increasing from 15.9% to 17.8% and from 13.2% to 15.1%, respectively (Table 3b). These trends remained significant when the analysis was restricted to include only laboratories that continuously reported data for all five years.

The EU/EEA population-weighted mean percentage for combined penicillin non-wild-type and resistance to macrolides was 9.2% in 2023, with a significantly increasing trend during the period 2019−2023 (Table 3b). Moreover, the trend remained statistically significant when the analysis was restricted to include only laboratories that continuously reported data for all five years. Resistance to antimicrobial groups other than penicillin and macrolides was less common (Table 9). The estimated EU incidence of combined AMR (i.e. macrolide resistance and penicillin non-wild-type) in *S. pneumoniae* bloodstream infections, was 0.43 per 100 000 population in 2019 and showed no statistically significant trend during the period 2019–2023. However, the estimated EU incidence of combined resistance followed the same pattern as that noted for macrolides and penicillin non-wild-type.

Large inter-country variations were noted for all antimicrobial groups (Table 3b, Figure 9), with higher macrolide resistance and penicillin non-wild-type percentages generally reported from southern and eastern Europe than northern Europe. For the estimated incidences of bloodstream infections with resistant *S. pneumoniae*, this pattern was less evident.

Table 9. ***Streptococcus pneumoniae.*** **Total number of invasive isolates tested (n = 11 439)[a] and percentage non-wild-type/ AMR (%) per phenotype, EU/EEA, 2023**

AMR pattern[b]	Number of isolates	Percentage of total[c]
Susceptible to all included antimicrobial groups[d]	**9 098**	**79.5**
Single non-wild-type/resistance (to indicated antimicrobial groups)		
Total (any single resistance)	**1 487**	**13.0**
Macrolides	845	7.4
Penicillin non-wild-type[e]	607	5.3
Other antimicrobial groups	35	0.3
Non-wild-type/resistance to two antimicrobial groups		
Total (any two-group combinations)	**811**	**7.1**
Penicillin non-wild-type + macrolides	787	6.9
Other antimicrobial group combinations	24	0.2
Non-wild-type/resistance to three antimicrobial groups		
Total (any three-group combinations)	**40**	**0.3**
Non-wild-type/resistance to four antimicrobial groups		
Penicillin non-wild-type + third-generation cephalosporins + fluoroquinolones + macrolides	**3**	**<0.1**

[a] *Only isolates with complete susceptibility information for penicillins (based on penicillin or, if unavailable, oxacillin), third-generation cephalosporins (cefotaxime or ceftriaxone) and fluoroquinolones (levofloxacin or moxifloxacin - AST results for norfloxacin are also accepted if neither levofloxacin nor moxifloxacin results are available) and macrolides (azithromycin, clarithromycin or erythromycin) were included in the analysis. This represented 62% (11 439/18 453) of all reported* S. pneumoniae *isolates.*

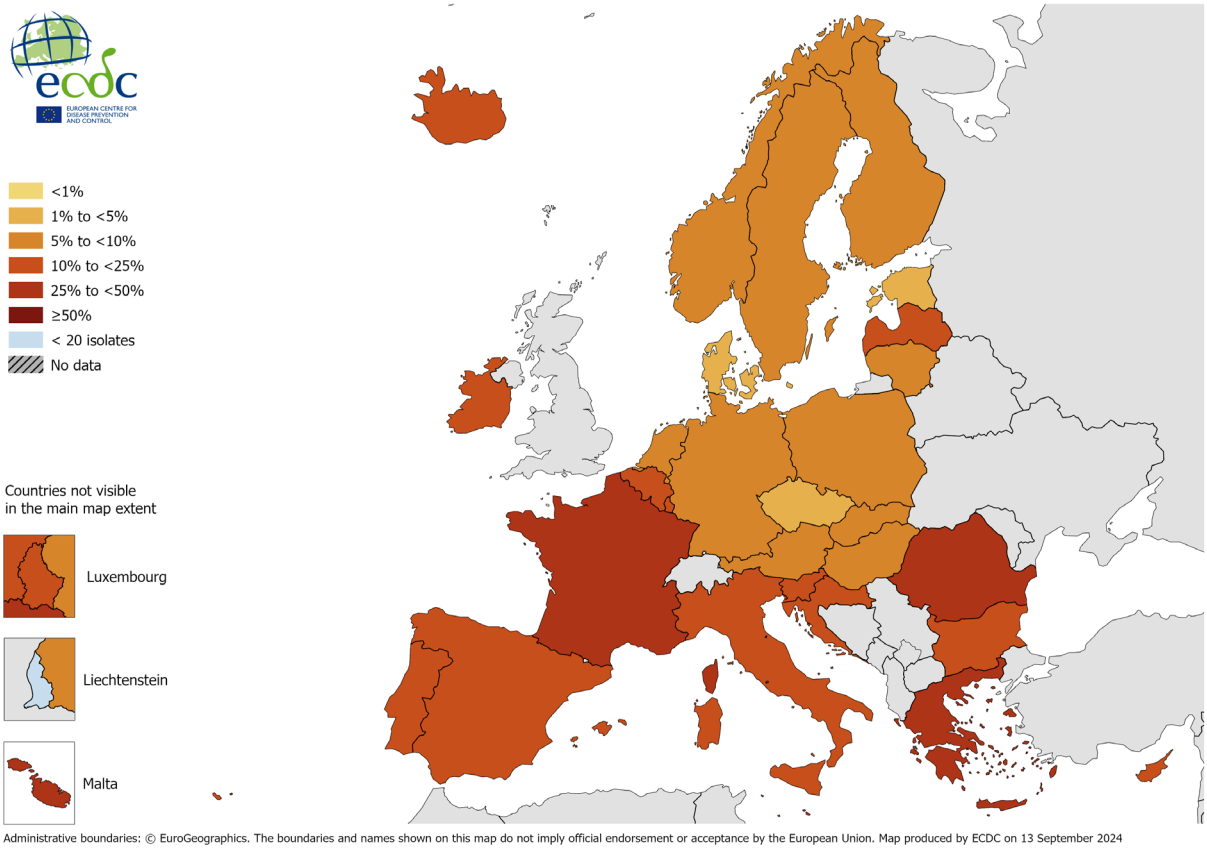
[b] *Only AMR combinations >1% of the total are specified.*

[c] *Not adjusted for population differences in the reporting countries.*

[d] *Penicillins (based on penicillin or, if unavailable, oxacillin), third-generation cephalosporins (cefotaxime or ceftriaxone) and fluoroquinolones (levofloxacin or moxifloxacin - AST results for norfloxacin are also accepted if neither levofloxacin nor moxifloxacin results are available) and macrolides (azithromycin, clarithromycin or erythromycin) were included in the analysis.*

[e] *For* S. pneumoniae*, the term penicillin non-wild-type is used in this report, referring to* S. pneumoniae *isolates reported by local laboratories as 'susceptible, increased exposure' (I) or resistant (R) to penicillin, assuming MIC for benzylpenicillin above that for wild-type isolates (> 0.06 mg/L). The qualitative susceptibility categories (S/I/R) as reported by the laboratory are used, since quantitative susceptibility information is missing for a large part of the data.*

Figure 9. *Streptococcus pneumoniae*. Percentage of penicillin[a] non-wild type[b] invasive isolates, by country, EU/EEA, 2023



[a] *Penicillin results are based on penicillin or, if unavailable, oxacillin.*

[b] *For* S. pneumoniae*, the term penicillin non-wild-type is used in this report, referring to* S. pneumoniae *isolates reported by local laboratories as 'susceptible, increased exposure' (I) or resistant (R) to penicillin, assuming MIC for benzylpenicillin above that for wild-type isolates (> 0.06 mg/L). The qualitative susceptibility categories (S/I/R) as reported by the laboratory are used, since quantitative susceptibility information is missing for a large part of the data.*

Discussion

Non-pharmaceutical interventions introduced to reduce severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission, and the lifting of these non-pharmaceutical interventions [40], could potentially have resulted in decreased circulation of pathogens in the community followed by an increase. This could explain the decrease in the number of invasive *S. pneumoniae* isolates and the estimated EU/EEA incidence of invasive isolates for 2020 and 2021 compared to 2019, and the subsequent increase in 2022 and 2023.

In addition to the increases for invasive *S. pneumoniae* isolates overall, there were also increasing trends in the population-weighted EU/EEA mean percentages for penicillin non-wild-type and macrolide resistance between 2019 and 2023. Moreover, the estimated EU incidences of bloodstream *S. pneumoniae* infections with resistance phenotype have been increasing since 2021 and now exceed those of 2019. However, there were large inter-country variations in AMR percentages in 2023 and in the estimated incidence pattern over time.

When considering the increasing estimated EU incidence of penicillin non-wild-type *S. pneumoniae* bloodstream infections and the increased EU/EEA population-weighted mean percentage for penicillin non-wild-type *S. pneumoniae*, it should be noted that the 2022 EARS-Net EQA indicated that reduced susceptibility to benzylpenicillin is under-reported in EARS-Net [4]. The 2023 EARS-Net EQA exercise did not include a *S. pneumoniae* isolate [5] and it is therefore unknown if this continues to be the case.

In parallel with EARS-Net, surveillance of invasive pneumococcal disease in the EU/EEA is covered by another surveillance network, the European Invasive Bacterial Disease Surveillance Network (EU-IBD), also coordinated by ECDC. This network collects additional data on invasive pneumococcal disease cases throughout the EU/EEA – for example data on outcome [41]. Data from this surveillance show that the percentage of resistance to penicillin was 2% and to erythromycin 18%, based on the reporting of antimicrobial susceptibility data by 10 countries in 2018 [41]. It is, however, difficult to compare data from the two surveillance systems due to differences – for example in the number of reporting countries.

Most EU/EEA countries have implemented routine immunisation for children with multivalent pneumococcal conjugated vaccines (PCVs). In some countries, high-risk adult groups, such as elderly people and immunocompromised individuals, are also targeted with the polysaccharide vaccine or with PCVs [42]. Changes in immunisation and serotype coverage of the PCVs available will probably have an impact on the epidemiology of *S. pneumoniae* in the EU/EEA, both in terms of changes in the age-specific incidence and potential serotype replacement. It is also conceivable that the COVID-19 pandemic and related public health interventions and changes in antibiotic consumption [43] may further affect *S. pneumoniae* epidemiology in the EU/EEA.

WHO has listed macrolide-resistant *S. pneumoniae* as a pathogen of medium priority in its global priority list of antibiotic-resistant bacteria, indicating moderate treatment difficulties that can be critical in some populations [28].

Enterococcus faecalis

Epidemiology

For 2023, 29 EU/EEA countries reported 28 482 invasive isolates of *E. faecalis*. The estimated EU/EEA incidence of invasive *E. faecalis* isolates increased (+11.0%) from 12.7 per 100 000 population in 2019 to 14.1 per 100 000 population in 2023. Between 2019 and 2021, the incidence increased to 14.6 per 100 000 population. However, since then it has decreased to its current level.

Of the invasive isolates reported, 17 353 (60.9%) had AST results for high-level gentamicin (Table 3b).

In 2023, the estimated EU incidence of *E. faecalis* bloodstream infections with high-level gentamicin resistance was 2.36 per 100 000 population) (Table 3a). During the period 2019−2023, the estimated EU incidence of high-level gentamicin-resistant *E. faecalis* bloodstream infections increased from 2019 (2.23 per 100 000 population) to 2021 (2.98 per 100 000 population) and then decreased until 2023. The results showed no significant trend in the EU (Table 3a).

In 2023, the EU/EEA population-weighted mean percentage of high-level gentamicin resistance in *E. faecalis* was 24.3%. This represents a decrease since 2019, when the percentage was 27.7%, and a smaller decrease compared to 2022, when the percentage was 25.2% (Table 3b). A significantly decreasing trend was noted for high-level gentamicin resistance during the period 2019–2023. The trend remained significant when the analysis was restricted to include only laboratories that continuously reported data for all five years.

Large inter-country variations were noted for high-level gentamicin resistance in *E. faecalis* (Table 3b). Although there were generally higher AMR percentages reported from southern and eastern Europe than from northern Europe there were exceptions (Country summaries). More information is provided in ECDC's Surveillance Atlas of Infectious Diseases [14]. For the estimated incidence of high-level gentamicin-resistant *E. faecalis* infections, this pattern was less evident.

Discussion

While the estimated incidence of invasive *E. faecalis* isolates increased, the EU/EEA population-weighted mean percentage of high-level gentamicin resistance has decreased significantly. At the same time, there was no trend in the estimated EU incidence of high-level gentamicin-resistant *E. faecalis* bloodstream infections, although there were indications of a decrease in the last two years. However, the estimated incidence of high-level gentamicin-resistant *E. faecalis* bloodstream infections remains higher than in 2019. This indicates that antimicrobial-resistant enterococci remain a major IPC challenge and an important cause of healthcare-associated infections in Europe. In addition to the fact that infections caused by resistant strains are difficult to treat, enterococci are also easily disseminated in healthcare settings.

Enterococcus faecium

Epidemiology

For 2023, 28 EU/EEA countries reported 21 594 invasive isolates of *E. faecium.*

Over the last five years, the number of reported invasive isolates of *E. faecium* at EU/EEA level from countries that continuously reported between 2019 and 2023 (excluding France due to changes in the surveillance system) increased by +64.3% from 13 140 in 2019 to 21 594 in 2023. However, this was a small decrease (-0.5%) compared to 2022 (n=21 700). The estimated EU/EEA incidence of invasive *E. faecium* isolates increased (+25.9%) from 8.5 per 100 000 population in 2019 to 10.7 per 100 000 population in 2023.

Of the invasive isolates reported in 2023, 21 436 (99.3%) had AST results for vancomycin (Table 3b).

In 2023, the estimated EU incidence of vancomycin-resistant *E. faecium* bloodstream infections was 2.30 per 100 000 population (Table 3a). During the period 2019–2023, the estimated EU incidence of vancomycin-resistant *E. faecium* bloodstream infections increased and showed a significantly increasing trend (Table 3a). However, compared to 2021 (2.57 per 100 000 population) and 2022 (2.47 per 100 000 population), the incidence decreased.

The EU/EEA population-weighted mean percentage of vancomycin resistance in *E. faecium* was 19.8% in 2023, representing a decrease since 2019 when the percentage was 20.7%. However, the percentage remained within the range reported for the previous four years (19.7%–20.7%). There was no significant trend.

More than nine-tenths (92.8%) of the invasive *E. faecium* isolates reported by all EU/EEA countries to EARS-Net for 2023 were resistant to at least one of the antimicrobial groups under surveillance (aminopenicillins, gentamicin (high-level resistance) and vancomycin) (Table 10).

AMR to two or more antimicrobial groups was common - seen in 58.8% of all tested invasive isolates (Table 10).

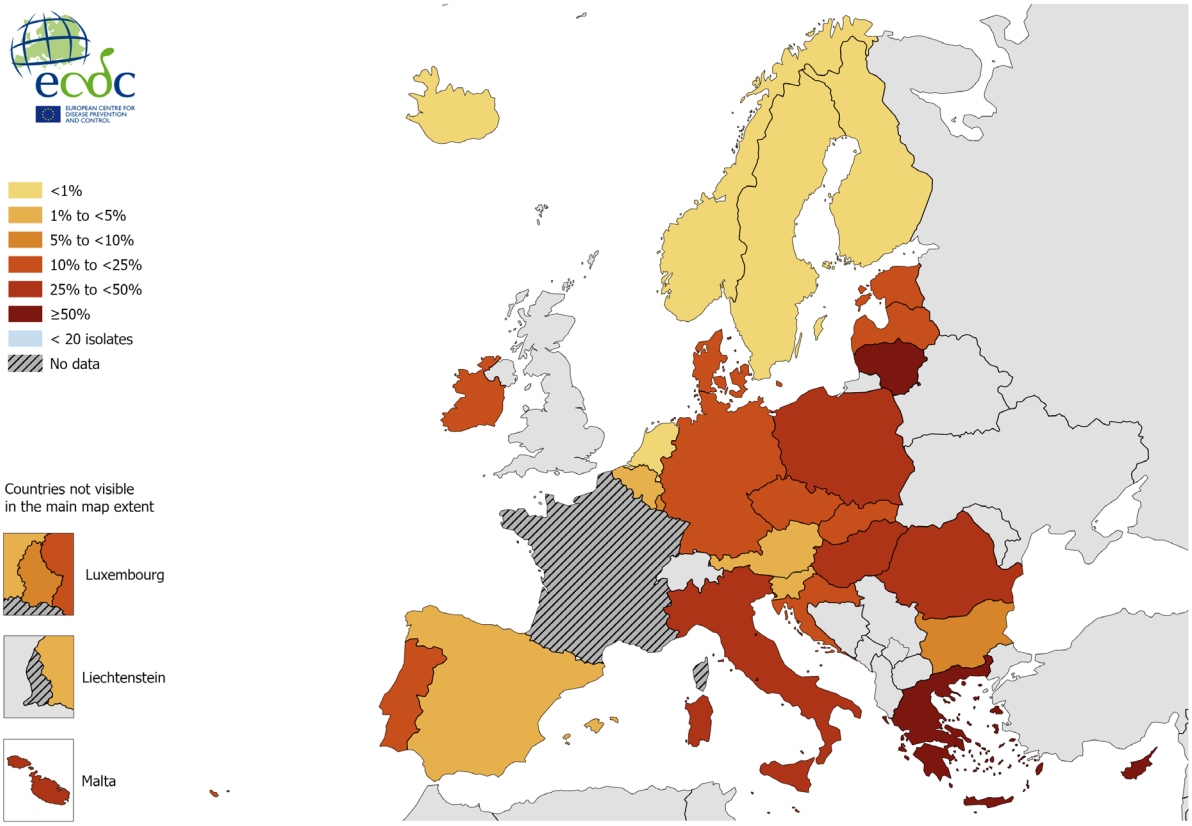
National percentages of vancomycin resistance ranged from 0.0% to 60.9% (Table 3b), with nine countries reporting percentages below 5% (Figure 10). The estimated incidence of vancomycin-resistant *E. faecium* bloodstream infections ranged from 0 to 10.48 per 100 000 population, with 10 countries reporting an estimated incidence below 0.50 per 100 000 population (Country summaries). High vancomycin-resistant *E. faecium* percentages were reported from countries in central, southern, and eastern Europe, as well as Ireland. For the estimated incidence of vancomycin-resistant *E. faecium* bloodstream infections, the pattern was similar.

Table 10. *Enterococcus faecium.* Total number of invasive isolates tested (n = 12 634)[a] and AMR percentage (%) per phenotype, EU/EEA, 2023

AMR pattern[b]	Number of isolates	Percentage of total[c]
Susceptible to all included antimicrobial groups[d]	**915**	**7.2**
Single resistance (to indicated antimicrobial group)		
Total (any single resistance)	**4 286**	**33.9**
Aminopenicillins	4 189	33.2
Other antimicrobial groups	97	0.8
Resistance to two antimicrobial groups		
Total (any two-group combinations)	**6 016**	**47.6**
Aminopenicillins + gentamicin (high level resistance)	4 704	37.2
Aminopenicillins + vancomycin	1 293	10.2
Other resistance combinations	19	0.2
Resistance to three antimicrobial groups		
Aminopenicillins + gentamicin (high level resistance) + vancomycin	**1 417**	**11.2**

[a] *Only isolates with complete susceptibility information for aminopenicillins (ampicillin or amoxicillin), gentamicin (high-level resistance) and vancomycin were included in the analysis. This represented 59% (12 634/21 594) of all reported* E. faecium *isolates.*
[b] *Only AMR combinations >1% of the total are specified.*
[c] *Not adjusted for population differences in the reporting countries.*
[d] *Aminopenicillins (ampicillin or amoxicillin), gentamicin (high-level resistance) and vancomycin.*

Figure 10. *Enterococcus faecium*. Percentage of invasive isolates resistant to vancomycin, by country, EU/EEA, 2023



Discussion

The increase in not only the estimated EU/EEA incidence of invasive *E. faecium* isolates, but also the estimated incidence of vancomycin-resistant *E. faecium* bloodstream infections in the EU compared to 2019 is a cause for concern. Although the last two years have shown slightly lower numbers, possibly indicating some improvement in the situation, the 2023 EU/EEA population-weighted mean percentage of vancomycin resistance remained within the range reported for the previous four years.

An ECDC study of the health burden of AMR in the EU/EEA estimated that the median number of infections and deaths attributable to vancomycin-resistant enterococci almost doubled between 2007 and 2015 [16]. A more recent ECDC study estimated that the number of these infections increased from 47 124 in 2016 to 117 866 in the EU/EEA in 2020, with a concomitant increase in the number of attributable deaths from 1 335 to 3 414 [1]. The rise in the estimated EU incidence of vancomycin-resistant *E. faecium* bloodstream infections in 2023 compared to 2020 contributes to a further increase in the health burden of vancomycin-resistant enterococci infections.

In addition, the significantly increasing trend in the estimated incidence of vancomycin-resistant *E. faecium* bloodstream infections observed at EU level and in several individual countries highlights the urgent need for closer monitoring to better understand the epidemiology, clonal diversity and risk factors associated with vancomycin-resistant *E. faecium* infection. Contrary to many other bacterial species–antimicrobial group combinations under surveillance by EARS-Net, the geographical pattern for vancomycin-resistant *E. faecium* was somewhat different, with high AMR levels reported from countries in central, southern and eastern Europe, as well as Ireland.

In addition to the fact that infections caused by vancomycin-resistant strains are difficult to treat, enterococci are also easily disseminated in healthcare settings. A recently published report confirmed that *Enterococcus* spp. continued to be a frequently observed healthcare-associated infection in European acute care hospitals in 2022–2023 and the same study reported high levels of vancomycin resistance in healthcare-associated infections with *E. faecium* [30]. The results of this report attest to the fact that high levels of antimicrobial-resistant enterococci remain a major infection control challenge in Europe.

Enterococci have intrinsic resistance to several antimicrobial classes, and any additional acquired AMR severely limits the number of treatment options. WHO has listed vancomycin-resistant *E. faecium* as a pathogen of high priority in its global priority list of antibiotic-resistant bacteria, indicating that research and the development of new antibiotics is required [28].

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Annex 1. Participating institutions

Country	Participating institutions	Web link
Austria	Federal Ministry of Social Affairs, Health, Care and Consumer Protection	www.sozialministerium.at
	Ordensklinikum Linz, Elisabethinen	www.ordensklinikum.at
Belgium	Sciensano	www.sciensano.be
Bulgaria	National Center of Infectious and Parasitic Diseases	https://ncipd.org/index.php?option=com_content&view=featured&Itemid=730&lang=en
Croatia	Reference Center for Antimicrobial Resistance Surveillance University Hospital for Infectious Diseases (Dr Fran Mihaljević), Zagreb	https://bfm.hr/referentni-centar-za-pracenje-rezistencijebakterija-na-antibotike/
Cyprus	Microbiology Department, Nicosia General Hospital	https://shso.org.cy/clinic/mikroviologiko/
Czechia	National Institute of Public Health	www.szu.cz
	National Reference Laboratory for Antibiotics	https://szu.cz/odborna-centra-a-pracoviste/centrum-epidemiologie-a-mikrobiologie/oddeleni-bakterialni-rezistence-na-antibiotika-a-sbirka-kultur/nrl-pro-antibiotika
Denmark	Statens Serum Institut	https://www.ssi.dk/
	Danish Study Group for Antimicrobial Resistance Surveillance (DANRES)	www.danmap.org
Estonia	Estonian Health Board	https://www.terviseamet.ee/et
	East-Tallinn Central Hospital	https://itk.ee/
	Tartu University Hospital	https://www.kliinikum.ee/partnerile/uhendlabor/
Finland	Finnish Institute for Health and Welfare, Department of Health Security	www.thl.fi
	Finnish Study Group for Antimicrobial Resistance (FiRe)	www.finres.fi
	Finnish Hospital Infection Program (SIRO)	https://thl.fi/en/web/infectious-diseases-and-vaccinations/diseases-and-disease-control/healthcare-associated-infections
France	Santé Publique France	www.santepubliquefrance.fr
	Since 2020:	
	Surveillance and Prevention of Antimicrobial RESistance in hospital settings (SPARES)	https://www.preventioninfection.fr/
	National Reference Centre for Pneumococci	www.cnr-pneumo.com
	Up to 2019:	
	French National Observatory for the Epidemiology of Bacterial Resistance to Antimicrobials (ONERBA) through three participating networks:	www.onerba.org
	Azay-Résistance	
	Île-de-France	
	Réussir	
Germany	Robert Koch Institute	www.rki.de
Greece	National Public Health Organization, Central Public Health Laboratory	https://eody.gov.gr/en/
	University of West Attica, Department of Public Health Policy, School of Public Health	https://php.uniwa.gr/en/homepage/
Hungary	National Public Health Center	www.oek.hu
Iceland	National University Hospital of Iceland	https://www.landspitali.is
	Centre for Health Security and Infectious Disease Control	https://www.landlaeknir.is
	Akureyri hospital	www.sak.is
Ireland	Health Protection Surveillance Centre	www.hpsc.ie
Italy	National Institute of Health	www.iss.it
Latvia	Disease Prevention and Control Center of Latvia	www.spkc.gov.lv
Liechtenstein	Liechtensteinisches Landesspital	https://www.landesspital.li/

Country	Participating institutions	Web link
	Laboratory Dr Risch[a]	https://www.risch.ch/de
	The Swiss Center for Antibiotic Resistance (ANRESIS)[b]	https://www.anresis.ch/
Lithuania	National Public Health Surveillance Laboratory	www.nvspl.lt
	Institute of Hygiene	www.hi.lt
Luxembourg	National Health Laboratory	https://lns.lu/
	Microbiology Laboratory, Centre Hospitalier de Luxembourg	https://www.chl.lu/fr/service/laboratoire-de-bacteriologie-microbiologie
Malta	Malta Mater Dei Hospital, Msida	https://healthservices.gov.mt/en/MDH/Pages/Home.aspx
Netherlands	National Institute for Public Health and the Environment	www.rivm.nl
Norway	University Hospital of North Norway	https://www.unn.no/fag-og-forskning/norm-norsk-overvakingssystem-for-antibiotikaresistens-hos-mikrober
	Norwegian Institute of Public Health	https://www.fhi.no/
	St Olav University Hospital, Trondheim	https://www.stolav.no/
Poland	National Medicines Institute, Department of Epidemiology and Clinical Microbiology	https://www.nil.gov.pl
	National Reference Centre for Susceptibility Testing	https://korld.nil.gov.pl
Portugal	National Institute of Health Doutor Ricardo Jorge	https://www.insa.min-saude.pt/
	Directorate-General of Health	https://www.dgs.pt/
Romania	National Institute of Public Health	www.insp.gov.ro
Slovakia	National Reference Centre for Antimicrobial Resistance	https://www.uvzsr.sk
	Public Health Authority of the Slovak Republic	https://www.uvzsr.sk
	Regional Public Health Authority Banska Bystrica	https://www.uvzsr.sk
Slovenia	National Institute of Public Health	www.nijz.si
	Medical Faculty, University of Ljubljana	https://imi.si/
	National Laboratory of Health, Environment and Food	https://www.nlzoh.si/
Spain	Health Institute Carlos lll	www.isciii.es
	National Centre for Microbiology	
	CIBERinfect	
Sweden	The Public Health Agency of Sweden	www.folkhalsomyndigheten.se

[a] *Liechtenstein uses Laboratory Dr Risch as a participating institution at national level.*
[b] *Liechtenstein uses the Swiss Center for Antibiotic Resistance as a participating institution at national level.*