

Epidemiological situation, laboratory capacity and preparedness for carbapenem-resistant *Acinetobacter baumannii* in Europe, 2019

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To update information on the epidemiological situation and national capacity for detection, surveillance and containment of carbapenem-resistant *Acinetobacter baumannii* (CRAb) in Europe, we performed a survey in 37 countries. Nine countries reported regional or inter-regional spread and seven an endemic situation. Laboratories with a reference function, surveillance systems, and a national containment plan for CRAb existed in 30, 23 and eight countries, respectively. A pan-European molecular survey would provide in-depth understanding of the CRAb epidemiology.

To better understand the current epidemiological situation of carbapenem-resistant *Acinetobacter baumannii* (CRAb) in Europe and the surveillance and control activities in individual countries, we conducted a survey in 37 countries. The main aims were (i) to update the information about the epidemiological stages of spread of CRAb in Europe, and (ii) to assess the current national capacity for laboratory detection, identification and characterisation, surveillance and containment of CRAb.

Terminology

Most nosocomial outbreaks are caused by *A. baumannii* sensu stricto (s.s.), which is characterised by its ability to survive long periods of time on dry surfaces [1], while outbreaks of other closely related species are rare. In this report and unless specified otherwise, 'A. baumannii', or 'Ab' as in CRAb, refer to *A. baumannii* s.s. as a species (and not the *A. calcoaceticus*-*A. baumannii* complex or the *A. baumannii* group).

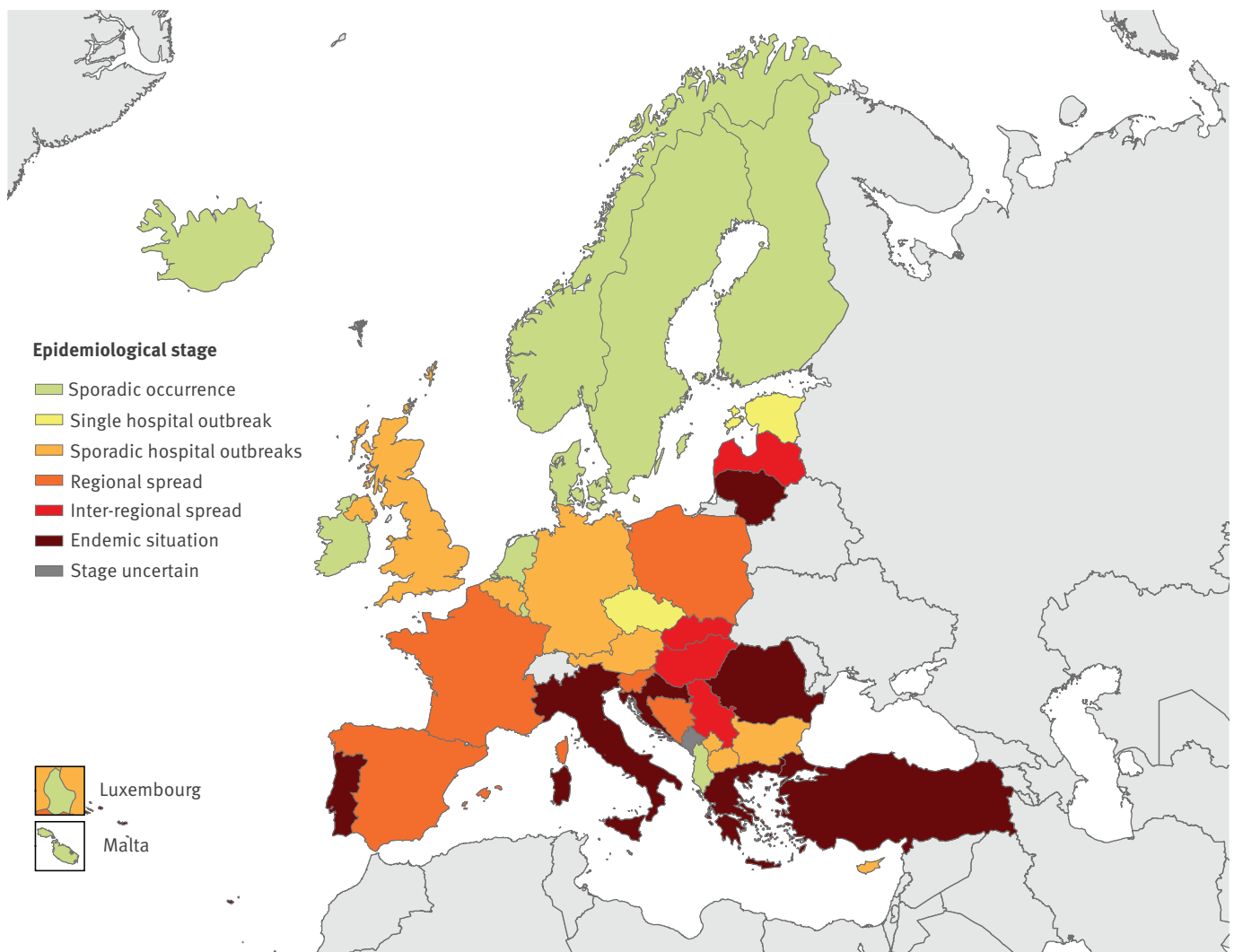
Epidemiological situation

A questionnaire using the EUSurvey online tool was sent to the EURGen-Net national coordinators from 37 countries in December 2019. The questions in this survey about the situation in 2019 were adapted from two previous assessments of CRAb in Europe, one in 2013 for that same year [2] and one in 2015 covering 2014 and the beginning of 2015. To assess the epidemiological stage of CRAb dissemination across each country, a previously used seven-stage scale (0, 1, 2a, 2b, 3, 4 and 5) was applied [3]. All contacted coordinators completed the survey, with individual answers received from the United Kingdom (UK) for England, Northern Ireland, Scotland and Wales. While the data for these four countries in the UK are shown separately in some of the tables of the current report, all analyses count the United Kingdom as a single country.

With regards to the epidemiological stage of spread in 2019, 10 countries reported sporadic, unrelated cases (*stage 1*), two reported single hospital outbreaks (*stage 2a*), eight reported sporadic hospital outbreaks (*stage 2b*), five reported regional spread (*stage 3*), four reported inter-regional spread (*stage 4*), and seven reported an endemic situation (*stage 5*). For one country the stage was uncertain. The epidemiological stages by country are shown in the Figure and a comparison with the results from previous similar surveys is provided in Table 1. Compared to the result of the 2015 survey, there was a decrease of the epidemiological stage in 13 countries, an identical stage in 16 countries, and an increase in five countries. No comparison could be made for three countries as no epidemiological stage was available from the 2015 study (Table 1).

FIGURE

Epidemiological situation of carbapenem-resistant *Acinetobacter baumannii*, assessment by national experts in European countries, 2019 (n = 37)



Administrative boundaries: EuroGeographics, UN-FAO.

National surveillance and notification of cases as well as control guidelines

A national system for surveillance of CRAB, either mandatory or voluntary, was in place in only 23 of the 37 countries (Table 2) with establishment of surveillance systems in only four additional countries since the previous survey, indicating that surveillance has not been further expanded and that attention and resources might have shifted away from CRAB, possibly with a focus on the spread of carbapenem-resistant Enterobacteriales in many European countries [3]. Notification of cases was mandatory or recommended in 14 countries compared to nine in the period 2014 to 2015.

Progress was made in developing national recommendations or guidelines on infection control measures for CRAB, with 15 countries having guidelines in 2019 compared to 12 countries in the 2014 to 2015 period. A national plan for containment of CRAB existed in eight countries; however, six of the seven CRAB endemic

countries did not have such a plan. National guidelines on phenotypic carbapenem susceptibility testing were present in 15 countries, whereas a national guideline on molecular characterisation of carbapenem resistance was available in only three countries. Ten countries had a national screening policy or guideline. For admission screening of patients to acute care hospitals, all of these guidelines recommended selective screening in high-risk situations (outbreaks) or of high-risk groups, for example after hospitalisation abroad. The survey did not include any questions regarding the laboratory capacity and microbiological methods used for screening.

National laboratory capacity

Collection of data on isolates analysed by standardised microbiological methods is crucial for a reliable assessment of the spread of CRAB. However, laboratories with a reference function for CRAB existed in only 30 of the 37 countries. Differentiation between *A. baumannii* s.s. and other closely related species, such as *A. pittii*, *A.*

TABLE 1

 Comparison of epidemiological stages of carbapenem-resistant *Acinetobacter baumannii* in European countries, 2013–2019 (n = 37)

Country	Epidemiological stage of spread of CRAB			Change between 2014–15 and 2019
	2013 [2]	2014–15 (previously unpublished)	2019	
Albania	Stage 1	Stage 1	Stage 1	→
Austria	Stage 1	Stage 1	Stage 2 ^b	↑
Belgium	Stage 3	Stage 2 ^b	Stage 2 ^b	→
Bosnia and Herzegovina ^a	Stage 1	Stage 3	Stage 3	→
Bulgaria	Stage 2 ^b	Stage 2 ^a	Stage 2 ^b	→
Croatia	Stage 5	Stage 5	Stage 5	→
Cyprus	Stage 3	Stage 4	Stage 2 ^a	↓
Czechia	Stage 4	Stage 2 ^b	Stage 2 ^b	→
Denmark	Stage 2 ^b	Stage 1	Stage 1	→
Estonia	Stage 2 ^a	Uncertain	Stage 2 ^a	NA
Finland	Stage 1	Stage 2 ^a	Stage 1	↓
France	Stage 3	Stage 2 ^b	Stage 3	↑
Germany	Stage 4	Stage 3	Stage 2 ^b	↓
Greece	Stage 5	Stage 5	Stage 5	→
Hungary	Stage 4	Stage 4	Stage 4	→
Iceland	Stage 0	Stage 1	Stage 1	→
Ireland	Stage 2a	Stage 1	Stage 1	→
Italy	Stage 5	Stage 5	Stage 5	→
Kosovo ^b	Stage 3	Stage 5	Stage 2 ^b	↓
Latvia	Stage 5	Stage 2 ^b	Stage 4	↑
Lithuania	Stage 5	Uncertain	Stage 5	NA
Luxembourg	Stage 1	Stage 0	Stage 1	↑
Malta	Stage 1	Stage 2 ^a	Stage 1	↓
Montenegro	Stage 0	Uncertain	Uncertain ^c	NA
Netherlands	Stage 1	Stage 2 ^a	Stage 1	↓
North Macedonia	Stage 1	Stage 1	Stage 2 ^b	↑
Norway	Stage 1	Stage 2 ^a	Stage 1	↓
Poland	Stage 2 ^b	Stage 4	Stage 3	↓
Portugal	Stage 4	Stage 5	Stage 5	→
Romania	Stage 2 ^b	Stage 5	Stage 5	→
Serbia	Stage 2 ^b	Stage 5	Stage 4	↓
Slovakia	Stage 4	Stage 4	Stage 4	→
Slovenia	Stage 2 ^a	Stage 4	Stage 3	↓
Spain	Stage 3	Stage 4	Stage 3	↓
Sweden	Stage 2 ^a	Stage 2 ^a	Stage 1	↓
Turkey	Stage 2 ^b	Stage 5	Stage 5	→
United Kingdom ^d	Stage 4	Stage 4	Stage 2 ^b	↓

CRAB: carbapenem-resistant *Acinetobacter baumannii*. NA: not applicable.

The epidemiological stages of carbapenem-resistant *Acinetobacter baumannii* are defined as follow: stage 0: no cases reported; stage 1: sporadic occurrence (epidemiologically-unrelated single cases); stage 2a: single hospital outbreak (two or more epidemiologically-associated cases with indistinguishable geno- or phenotype in a single institution); stage 2b: sporadic hospital outbreaks (unrelated hospital outbreaks with epidemiologically unrelated introduction or different strains, no autochthonous inter-institutional transmission reported); stage 3: regional spread (more than one epidemiologically-related hospital outbreak confined to hospitals that are part of the same region or health district, indicating regional autochthonous inter-institutional transmission); stage 4: inter-regional spread (multiple epidemiologically-related outbreaks occurring in different health districts, indicating inter-regional autochthonous inter-institutional transmission); stage 5: endemic situation (most hospitals in a country are repeatedly seeing cases admitted from autochthonous sources).

^a The results reported for Bosnia and Herzegovina only apply to the Republic of Srpska.

^b This designation is without prejudice to positions on status, and is in line with United Nations Security Council resolution 1244/99 and the International Court of Justice Opinion on the Kosovo declaration of independence.

^c *Acinetobacter* spp. and *Pseudomonas* spp. are becoming a major problem in Montenegro as they are frequently isolated and are increasingly resistant to carbapenems. However, a National Reference Laboratory for these bacteria does not exist and all answers in the manuscript are connected with that fact. Therefore, it was judged that a realistic picture of the situation cannot be presented.

^d The reported results are for the United Kingdom overall. The epidemiological stages vary among countries within the United Kingdom.

TABLE 2 A
National capacity for surveillance and containment of carbapenem-resistant *Acinetobacter baumannii*, European countries, 2019 (n = 37)

Country	NRL	Routine referral of suspected CRAB isolates to NRL	National system for surveillance	National recommendation or obligation for notification	National guideline on phenotypic carbapenem susceptibility testing	National guideline on molecular characterisation of carbapenem resistance	National recommendation or guideline on infection control measures for CRAB	National plan for containment of CRAB	National policy or guideline on screening
Albania	Yes	No	No	No	No	No	No	No	No
Austria	Yes	Subset of isolates	Voluntary	No	No	No	No	No	Selective screening
Belgium	Yes	Subset of isolates	Mandatory	Yes	Yes	No	For single cases and outbreaks	Yes	Selective screening
Bosnia and Herzegovina ^a	No	NA	No	No	No	No	No	No	No
Bulgaria	Yes	Subset of isolates	Voluntary	No	Yes	No	For single cases and outbreaks	In preparation	No
Croatia	No	NA	Mandatory	No	No	No	In preparation for single cases	No	Selective screening
Cyprus	No	NA	Voluntary	No	No	No	No	No	No
Czechia	Expert laboratory ^b	Subset of isolates	No	No	No	No	No	No	No
Denmark	Yes	All isolates	Mandatory	No	Yes	No	For single cases and outbreaks	Yes	Selective screening
Estonia	No	NA	No	In preparation	No	No	No	No	No
Finland	Expert laboratory ^b	Subset of isolates	Mandatory	Yes	No	Yes	For single cases and outbreaks	Yes	Selective screening
France	Yes	All isolates	Voluntary	No	Yes	No	No	No	No
Germany	Yes	Subset of isolates	Mandatory	Yes	No	No	For single cases and outbreaks	No	No
Greece	No	NA	Voluntary	Yes, for bacteraemias	No	No	For single cases and outbreaks	Yes	No
Hungary	Yes	Subset of isolates	Mandatory	Yes	Yes	No	For single cases and outbreaks	In preparation	Selective screening
Iceland	Expert laboratory ^b	All isolates	Mandatory	Yes	Yes	Yes	For single cases and outbreaks	Yes	Selective screening
Ireland	Yes	Subset of isolates	Mandatory	Yes	Yes	Yes	For single cases	No	No
Italy	Expert laboratory ^b	No	Voluntary	No	No	No	Yes ^c	No	No

CRAB: carbapenem-resistant *Acinetobacter baumannii*; NA: not applicable; NRL: national reference laboratory; UK: United Kingdom.

^a Results reported for Bosnia and Herzegovina only apply to Republic of Srpska.

^b An expert laboratory fulfils the role of a NRL.

^c Regional or local recommendations/guidelines apply.

^d This designation is without prejudice to positions on status, and is in line with United Nations Security Council resolution 1244/99 and the International Court of Justice Opinion on the Kosovo declaration of independence.

^e All organisms are isolated in one laboratory, which is interfaced with the surveillance unit.

^f There is a national system for surveillance of multidrug-resistant microorganisms, but not specifically for CRAB. It is an obligation to report these microorganisms through the Centers of Public Health to the National Institute of Public Health.

^g There is no national recommendation or guideline on infection control measures for CRAB, but World Health Organization guidelines are followed.

^h Guidelines available at institutional level.

ⁱ Part of the general policy on multidrug-resistant organisms.

TABLE 2B

National capacity for surveillance and containment of carbapenem-resistant *Acinetobacter baumannii*, European countries, 2019 (n = 37)

Country	NRL	Routine referral of suspected CRAB isolates to NRL	National system for surveillance	National recommendation or obligation for notification	National guideline on phenotypic carbapenem susceptibility testing	National guideline on molecular characterisation of carbapenem resistance	National recommendation or guideline on infection control measures for CRAB	National plan for containment of CRAB	National policy or guideline on screening
Kosovo ^d	Expert laboratory ^b	All isolates	No	No	No	No	No	No	No
Latvia	Expert laboratory ^b	No	Yes	Yes	No	No	No answer	No answer	No
Lithuania	Expert laboratory ^b	Subset of isolates	Mandatory	No	No	No	No	No	No
Luxembourg	Expert laboratory ^b	All isolates	No	No	No	No	No	No	No
Malta	Expert laboratory ^b	All isolates	Voluntary	Other ^e	No	No	Yes ^e	No	No
Montenegro	No	NA	No	No	No	No	No	No	No
The Netherlands	Expert laboratory ^b	No	No	No	No	No	Yes	No	No
North Macedonia	Expert laboratory ^b	No	Yes ^f	No	No	No	No ^g	No	No
Norway	Yes	All isolates	Mandatory	Yes	Yes	No	For single cases and outbreaks	Yes	Selective screening
Poland	Expert laboratory ^b	Subset of isolates	No	Yes	Yes	No	No	No	No
Portugal	Yes	Subset of isolates	Mandatory	Yes	Yes	No	In preparation	In preparation	No
Romania	Expert laboratory ^b	Subset of isolates	Voluntary	No	No	No	In preparation	No	No
Serbia	Yes	Subset of isolates	In preparation	No	No	No	No	No	No
Slovakia	No	NA	No	Yes	No	No	No	No	No
Slovenia	Expert laboratory ^b	No	No	No	Yes	No	No ^h	No	No

CRAB: carbapenem-resistant *Acinetobacter baumannii*; NA: not applicable; NR: national reference laboratory; UK: United Kingdom.

^a Results reported for Bosnia and Herzegovina only apply to Republic of Srpska.

^b An expert laboratory fulfils the role of a NRL.

^c Regional or local recommendations/guidelines apply.

^d This designation is without prejudice to positions on status, and is in line with United Nations Security Council resolution 1244/99 and the International Court of Justice Opinion on the Kosovo declaration of independence.

^e All organisms are isolated in one laboratory, which is interfaced with the surveillance unit.

^f There is a national system for surveillance of multidrug-resistant microorganisms, but not specifically for CRAB. It is an obligation to report these microorganisms through the Centers of Public Health to the National Institute of Public Health.

^g There is no national recommendation or guideline on infection control measures for CRAB, but World Health Organization guidelines are followed.

^h Guidelines available at institutional level.

ⁱ Part of the general policy on multidrug-resistant organisms.

TABLE 2CNational capacity for surveillance and containment of carbapenem-resistant *Acinetobacter baumannii*, European countries, 2019 (n = 37)

Country	NRL	Routine referral of suspected CRAB isolates to NRL	National system for surveillance	National recommendation or obligation for notification	National guideline on phenotypic carbapenem susceptibility testing	National guideline on molecular characterisation of carbapenem resistance	National recommendation or guideline on infection control measures for CRAB	National plan for containment of CRAB	National policy or guideline on screening
Spain	Expert laboratory ^b	Subset of isolates	In preparation	In preparation	Yes	No	In preparation	Yes	No
Sweden	Yes	All isolates	Voluntary	Yes	Yes	No	Yes	Yes	Selective screening
Turkey	Yes	No	Voluntary	Yes	Yes	No	For outbreaks	No	Selective screening
England	Yes	Subset of isolates	Voluntary	In preparation	Yes	No	For outbreaks	No	Yes
Northern Ireland	Yes	Subset of isolates	No	No	Yes	Do not know	Other ^h	No	No
Scotland	Yes	All isolates	Voluntary	Yes	Yes	No	For single cases and outbreaks	Yes	No
Wales	Yes	All isolates	In preparation	No	Yes	No	Other ⁱ	No	Selective screening

CRAB: carbapenem-resistant *Acinetobacter baumannii*; NA: not applicable; NRL: national reference laboratory; UK: United Kingdom.^a Results reported for Bosnia and Herzegovina only apply to Republic of Srpska.^b An expert laboratory fulfils the role of a NRL.^c Regional or local recommendations/guidelines apply.^d This designation is without prejudice to positions on status, and is in line with United Nations Security Council resolution 1244/99 and the International Court of Justice Opinion on the Kosovo declaration of independence.^e All organisms are isolated in one laboratory, which is interfaced with the surveillance unit.^f There is a national system for surveillance of multidrug-resistant microorganisms, but not specifically for CRAB. It is an obligation to report these microorganisms through the Centers of Public Health to the National Institute of Public health.^g There is no national recommendation or guideline on infection control measures for CRAB, but World Health Organization guidelines are followed.^h Guidelines available at institutional level.ⁱ Part of the general policy on multidrug-resistant organisms.

TABLE 3A

Methods used by national reference or expert laboratories for species identification, phenotypic carbapenem susceptibility testing and genotypic characterisation of carbapenem-resistant *Acinetobacter baumannii* (CRAB), European countries, 2019 (n = 37)

Country	Method for species determination				Method for phenotypic carbapenem susceptibility testing				Method for genotypic characterisation of carbapenem resistance							
	Biochemical	MALDI-TOF	PCR/gene sequencing	WGS	Automated system	Disc diffusion	Gradient test	Commercial broth microdilution	Agar dilution	In-house broth microdilution	PCR	Real-time PCR	Single-gene sequencing	WGS	Other	
Albania	Yes	No	No	No	Yes	Yes	Yes	No	No	No	Not performed	Not performed	No	No	Yes ^a	
Austria	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes	
Belgium	No	Yes	Yes	Yes	No	Yes	No	Yes	No	No	Yes	No	Yes	Yes	No	
Bosnia and Herzegovina ^b																
Bulgaria	Yes	No	Yes	No	No	Yes	No	Yes	No	No	Yes	No	No	No	No	
Croatia																
Cyprus																
Czechia	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	No	
Denmark	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	
Estonia																
Finland	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	
France	No	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	
Germany	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	No	
Greece																
Hungary	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	No	
Iceland	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes ^c	
Ireland	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No	
Italy ^d	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	No	
Kosovo ^e	Yes	No	No	No	Yes	Yes	Yes	Yes	No	No	Not performed	Not performed	Not performed	Not performed	Not performed	
Latvia	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	No	Yes	No	No	No	
Lithuania	No	Yes	No	No	No	Yes	No	Yes	No	No	Not performed	Not performed	Not performed	Not performed	Not performed	
Luxembourg	No	Yes	No	No	No	Yes	No	Yes	No	No	No	Yes	No	Yes	No	
Malta	No	Yes	No	No	Yes	No	No	No	No	No	Not performed	Not performed	Not performed	Not performed	Not performed	
Montenegro																
The Netherlands	No	Yes	No	No	Yes	No	No	No	No	No	Yes	No	No	No	Yes	
North Macedonia	Yes	No	No	No	Yes	Yes	Yes	No	No	No	No	Yes	No	No	No	
Norway	No	Yes	Yes	Yes	No	No	No	Yes	No	No	Yes	No	No	No	Yes	
Poland	Yes	No	No	No	No	Yes	Yes	No	No	Yes	Yes	No	No	No	No	
Portugal	No	Yes	Yes	No	No	Yes	No	No	No	Yes	Yes	No	Yes	Yes	No	

MALDI-TOF: matrix-assisted laser desorption/ionization-time of flight mass spectrometry; NRL: national reference laboratory; PCR: polymerase chain reaction; UK: United Kingdom; WGS: whole genome sequencing.

^a Commercial multiplex nucleic acid amplification methods.

^b Results reported for Bosnia and Herzegovina only apply to Republic of Srpska.

^c Commercial loop-mediated isothermal amplification.

^d Species determination, phenotypic and genotypic characterisation are not routinely performed but only upon request.

^e This designation is without prejudice to positions on status, and is in line with United Nations Security Council resolution 1244/99 and the International Court of Justice Opinion on the Kosovo declaration of independence.

TABLE 3B

Methods used by national reference or expert laboratories for species identification, phenotypic carbapenem susceptibility testing and genotypic characterisation of carbapenem-resistant *Acinetobacter baumannii* (CRAB), European countries, 2019 (n = 37)

Country	Method for species determination				Method for phenotypic carbapenem susceptibility testing						Method for genotypic characterisation of carbapenem resistance				
	Biochemical	MALDI-TOF	PCR/gene sequencing	WGS	Automated system	Disc diffusion	Gradient test	Commercial broth microdilution	Agar dilution	In-house broth microdilution	PCR	Real-time PCR	Single-gene sequencing	WGS	Other
Romania	Yes	Yes	Yes	No	No	Yes	No	No	No	No	Yes	No	Yes	No	No
Serbia	No	Yes	No	No	No	Yes	Yes	Yes	No	No	Yes	No	No	No	No
Slovakia						No NRL or expert laboratory									
Slovenia	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	No
Spain	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Sweden	No	Yes	No	Yes	No	No	No	Yes	No	No	No	No	No	Yes	No
Turkey	No	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No
England	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No	No
Northern Ireland						See UK – England									
UK															
Scotland	Yes	No	No	No	No	No	No	Yes	No	No		Not performed			
Wales	No	Yes	No	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	No

MALDI-TOF: matrix-assisted laser desorption/ionization-time of flight mass spectrometry; NRL: national reference laboratory; PCR: polymerase chain reaction; UK: United Kingdom; WGS: whole genome sequencing.

nosocomialis, *A. dijkshoorniae* or *A. seifertii*, has been considered difficult in the past, but has improved with the widespread availability of matrix-assisted laser desorption/ionization-time of flight mass spectrometry (MALDI-TOF/MS) method for species discrimination [4]. Widespread use of this technology in clinical laboratories is reflected in the answers indicating that, in 11 countries, all or nearly all clinical laboratories routinely use MALDI-TOF/MS for species identification; however, on the other end of the scale, experts from 13 countries reported that no or very few clinical laboratories in their country have access to MALDI-TOF/MS. In the national reference or expert laboratories, the most common method for species identification was MALDI-TOF/MS (n=22) followed by PCR / gene-sequencing (n=15).

The most frequently used methods for determination of phenotypic carbapenem susceptibility were disk diffusion (n=23), gradient tests (n=19) and commercial broth microdilution (n=17). European Committee on Antimicrobial Susceptibility Testing (EUCAST) breakpoints for susceptibility testing were used in all countries with a laboratory with reference function. Most national reference or expert laboratories (25 of 30 laboratories) reported that they perform genotypic characterisation of carbapenem resistance. The most commonly used methods were PCR (n=18) and whole genome sequencing (n=16).

Colistin susceptibility testing of *A. baumannii* isolates was performed in 25 of the 30 reference or expert laboratories with broth microdilution according to EUCAST recommendations (four laboratories did not use broth microdilution and the information was missing for one laboratory). Of the 25 laboratories using broth microdilution for colistin testing, nine tested all referred *A. baumannii* isolates for colistin susceptibility and the remaining 16 only tested a subset of isolates. The survey did not include questions regarding internal and external quality assessment in the laboratories. Detailed information on the laboratory capacity is provided in Table 3.

Ethical statement

This study did not involve personal data and ethical approval was thus not required. The release of the included national data was approved by the authors.

Discussion

CRAB poses a significant threat to patients and health-care systems in countries of the European Union (EU)/European Economic Area (EEA) [5] with an estimated 2,363 annual attributable deaths in 2015 [6]. According to 2018 data from the European Antimicrobial Resistance Surveillance Network (EARS-Net), nearly a third of invasive *Acinetobacter* spp. isolates in the EU/EEA are already resistant to carbapenems, limiting the availability of adequate treatment [7]. Several reports on outbreaks of CRAB in European countries have recently been published, possibly indicating increasing spread [8-12]. These outbreaks frequently affect intensive care

units, and morbidity and mortality are high. In the current study however, our results show that perception of the epidemiological situation of CRAB has not changed substantially since the last survey conducted in 2015. The extent of spread of CRAB appeared to be decreasing in some countries while it was increasing in other countries. The underlying reasons for these developments are not clear. On the one hand, decreasing epidemiological stages may reflect successful local or national control efforts. Control programmes were shown to be effective both in settings of high endemicity [13] and outbreaks [14,15]. On the other hand, the decrease in the epidemiological stage was not always confirmed by the carbapenem resistance rates in invasive isolates reported by EARS-Net or the Central Asian and European Surveillance of Antimicrobial Resistance network (CAESAR) [7,16]. Some countries reported a low epidemiological stage of spread of CRAB whereas EARS-Net showed that, in 2018, a high or very high proportion of *Acinetobacter* spp. invasive isolates in the same country were resistant to carbapenems [7]. One possible explanation for such discrepancies could be that local outbreaks of CRAB are driving the national resistance proportions in *Acinetobacter* spp. invasive isolates as reported to EARS-Net. In addition, two countries also mentioned increasing numbers of carbapenem-resistant isolates in *Acinetobacter* species other than *A. baumannii* s.s., e.g. *A. pittii* or *A. lwoffii* that were not included in this assessment of epidemiological stages but are included in the EARS-Net collection of data on *Acinetobacter* species. Finally, the epidemiological stages were determined by a self-assessment of the national representatives and might have been affected by unavailability of national surveillance data or reference laboratories in some countries, especially as differentiation between stages might be difficult without molecular typing results. The three surveys over time were also not always answered by the same national expert and it cannot be excluded that changes resulted from differences in subjective judgement.

An interest to participate in a European structured survey including the collection of CRAB isolates or whole genome sequencing data thereof as well as related epidemiological information was expressed by 32 countries. Such a survey would help identify successful clones and predominant lineages and the extent of their spread, provide a better understanding of predominant resistance mechanisms to carbapenems and other antimicrobials and allow conclusions on potential cross-border spread of CRAB.

EURGen-Net carbapenem-resistant *Acinetobacter baumannii* capacity survey group

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^a This designation is without prejudice to positions on status, and is in line with United Nations Security Council Resolution 1244/99 and the International Court of Justice Opinion on the Kosovo declaration of independence.

Conflict of interest

KLH and JT are members of PHE's Antimicrobial Resistance and Healthcare Associated Infections Reference Unit, which has received financial support for conference attendance, lectures, research projects, or contracted evaluations from numerous sources, including Accelerate Diagnostics, Achaogen Inc, Allegra Therapeutics, Amplex, AstraZeneca UK Ltd, AusDiagnostics, Basilea Pharmaceutica, Becton Dickinson Diagnostics, bioMérieux, Bio-Rad Laboratories, British Society for Antimicrobial Chemotherapy, Cepheid, Check-Points B.V., Cubist Pharmaceuticals, Department of Health, Enigma Diagnostics, the European Centre for Disease Prevention and Control, Food Standards Agency, GenePOC, GlaxoSmithKline Services Ltd, Helperby Therapeutics, Henry Stewart Talks, International Health Management Associates Ltd, Innovate UK, Kalidex Pharmaceuticals, Melinta Therapeutics, Merck Sharpe and Dohme, Meiji Seika Pharma Co Ltd, Mobidiag, Momentum Biosciences Ltd, Neom Biotech, NIHR, Nordic Pharma Ltd, Norgine Pharmaceuticals, Paratek, Rabiotech Rx, Rempex Pharmaceuticals Ltd, Roche, Rokitan Ltd, Smith and Nephew UK Ltd, Shionogi and Co Ltd, Tetrphase Pharmaceuticals, Trius Therapeutics, VenatoRx Pharmaceuticals, Wockhardt Ltd, and the World Health Organization.

Authors' contributions

F. Lötsch, B. Albiger, D.L. Monnet, M. Struelens, A. Kohlenberg: design and implementation of the survey, compilation of information received from individual countries and preparation of European overview, drafting and reviewing the manuscript;

H. Seifert: design of the survey and review of the manuscript;

EURGen-Net carbapenem-resistant *Acinetobacter baumannii* capacity survey group: compilation and analysis of national data from laboratories and surveillance databases, validation of national data included in the manuscript and review of the manuscript.

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