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Laboratory surveillance of *Enterobacter* spp. *Serratia* spp. and *Citrobacter* spp. bacteraemia in England, Wales and Northern Ireland: 2017

Health Protection Report
Volume 12 Number 37
19 October 2017

Laboratory surveillance of *Enterobacter* spp., *Serratia* spp. and *Citrobacter* spp. bacteraemia in England, Wales and Northern Ireland: 2017

These analyses are based on *Enterobacter* spp., *Serratia* spp. and *Citrobacter* spp. bloodstream infections in England, Wales and Northern Ireland during 2009 to 2017. The data were extracted on 18 September 2018 from Public Health England's voluntary surveillance database, the Secondary Generation Surveillance System (SGSS). Data for Wales and Northern Ireland were extracted separately (DataStore on 12 Feb 2018 and CoSurv on 15 May 2018, respectively) for inclusion in the geographical and species analyses.

Rates of laboratory reported bacteraemia were calculated using mid-year resident population estimates for the respective year and geography [1]. Geographical analyses were based on the patient's residential postcode. Where this information was unknown, the postcode of the patient's General Practitioner was used. Failing that, the postcode of the reporting laboratory was used. Cases in England were further assigned to one of nine local PHE Centres (PHECs), formed from the administrative local authority boundaries [2].

The following report will look at the trends and geographical distribution of *Enterobacter* spp., *Serratia* spp. and *Citrobacter* spp. bacteraemia rates. Cases are further broken down by bacterial species and by patient age and sex. Single-agent antimicrobial susceptibility trends since 2015 are reported for England and Northern Ireland based on SGSS AMR and CoSurv data, respectively. Multi-drug antimicrobial resistance trends since 2015 are reported for England, based on SGSS AMR data. A web appendix is available featuring the findings of this report including only data submitted to SGSS from laboratories in England.

Data presented here for earlier years may differ from those in previous publications due to the inclusion of late reports; also, in 2017, *Enterobacter aerogenes* was reclassified as belonging to the genus *Klebsiella* [3].

Key Points

- the overall rate of *Enterobacter* spp. bacteraemia in England, Wales and Northern Ireland was 3.5 per 100,000 population (n=2,150) in 2017, an increase of 8% from 3.3 per 100,000 population in 2009
- the overall rate of *Serratia* spp. bacteraemia in England, Wales and Northern Ireland was 1.9 per 100,000 population (n=1,143) in 2017, an increase of 4% from 1.8 per 100,000 population in 2009
- the overall rate of *Citrobacter* spp. bacteraemia in England, Wales and Northern Ireland was 1.9 per 100,000 population (n=1,147) in 2017, an increase of 48% from 1.3 per 100,000 population in 2009
- in England, the North East region had the highest reported incidence rate of *Enterobacter* spp. and *Serratia* spp. in 2017 (4.2 per 100,000 population and 2.4 per 100,000 population, respectively)
- in England, Yorkshire and Humber region had the lowest reported incidence rate of *Enterobacter* spp. and *Serratia* spp. in 2017 (2.7 per 100,000 population and 1.3 per 100,000 population, respectively)
- rates of *Enterobacter* spp., *Serratia* spp. and *Citrobacter* spp. were higher in the elderly (aged ≥75) compared with other age groups; overall bacteraemia rates were also higher in males vs. females, which was more pronounced in the elderly
- cefotaxime and ceftazidime had among the highest percentage of resistant isolates for all three genera. Ceftazidime resistance has continued to increase since 2015 for tested *Enterobacter* spp. and *Serratia* spp. isolates (24% to 28% and 11% to 14%, respectively). Ceftazidime resistance has decreased since 2015 for tested *Citrobacter* spp. isolates (14% to 10%).
- cefotaxime resistance has continued to increase since 2015 for all three genera. The percent resistant for tested *Enterobacter* spp. isolates increased from 22% to 31% and for *Serratia* spp. isolates from 13% to 17%. The increase in resistance for *Citrobacter* spp. isolates was smaller, from 11% to 13%
- multi-drug resistance for these three genera remains relatively uncommon (5% or less for all presented combinations)

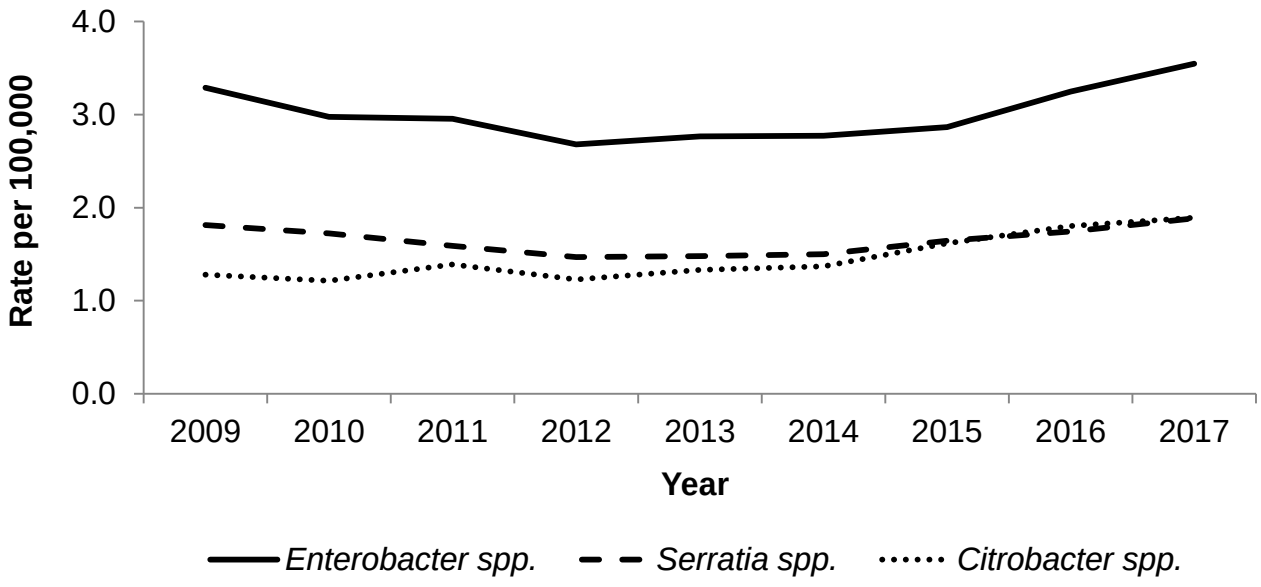
Trends

Figure 1 shows trends in the annual rate (per 100,000 population) of laboratory-reported bacteraemia by genus between 2009 and 2017 for England, Wales and Northern Ireland.

From 2009 to 2012 there was a decreasing trend observed for all three genera. Since 2013 there has been an incline in bacteraemia rates across genera, with various peaks in the annual increase. For *Serratia* and *Citrobacter* spp., the greatest annual increase was between 2014 and 2015 (10% and 18%, respectively). For *Enterobacter* spp. it was a 13% increase between 2015 and 2016. Annual increases between 2016 and 2017 were lower than the previous year for *Enterobacter* spp. and *Citrobacter* spp. The rate of *Enterobacter* spp. bacteraemia increased the most (9%), from 3.2 per 100,000 to 3.5 per 100,000. The rates of *Citrobacter* spp. bacteraemia and *Serratia* spp. bacteraemia increased by 5%, from 1.8 per 100,000 to 1.9 per 100,000 and 8% from 1.7 per 100,000 to 1.9 per 100,000, respectively.

Overall trends mirror those seen in the rates of monomicrobial and polymicrobial bacteraemia and/or fungaemia notifications for England, Wales and Northern Ireland. Rates for monomicrobials and polymicrobials have shown steady increases from 2014 [4]. This may be partly because of more extensive laboratory reporting in England following the transition from LabBase2 to SGSS in October 2014.

Figure 1. *Enterobacter* spp., *Serratia* spp., and *Citrobacter* spp. bacteraemia rate per 100,000 population (England, Wales and Northern Ireland): 2009 to 2017



Geographic distribution

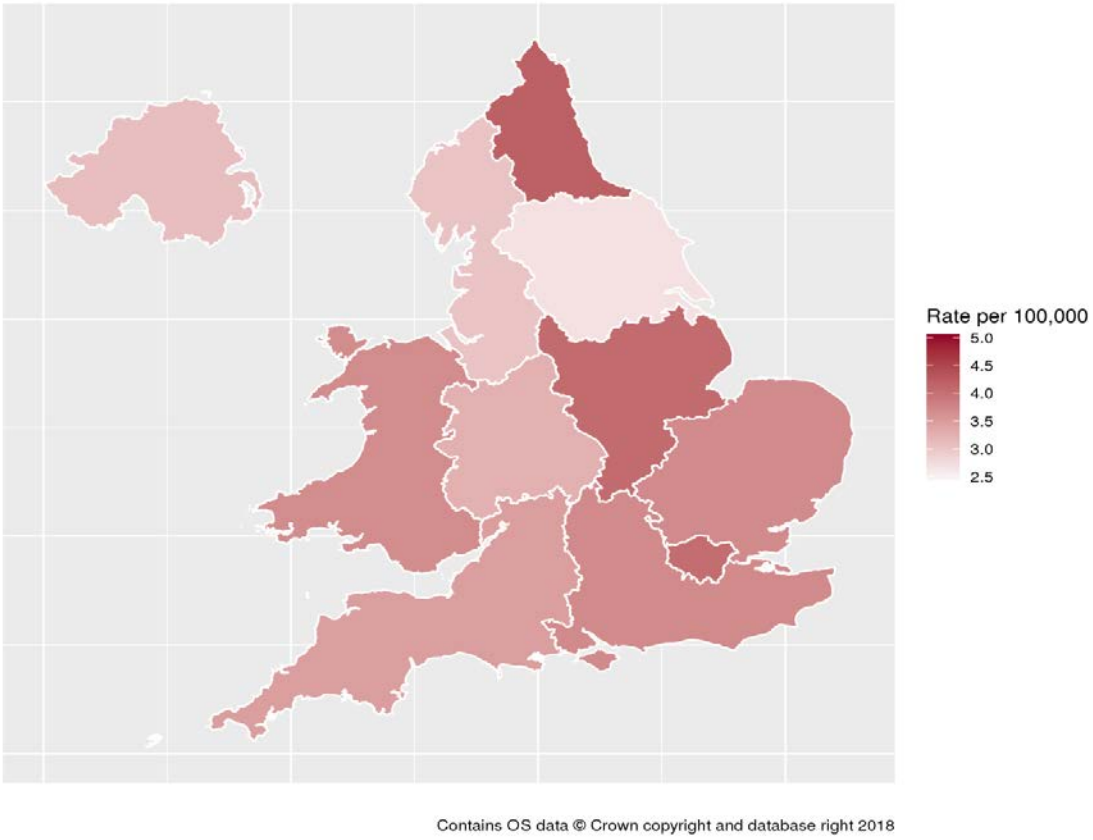
In 2017, the combined rate of reported *Enterobacter* spp. bacteraemia for England, Wales and Northern Ireland was 3.5 per 100,000 population; an increase of 9% from 2016 (see table 1a). Individually, Northern Ireland and Wales decreased in 2017 compared with 2016 (Northern Ireland 19% and Wales 7%). England with the aforementioned introduction of SGSS, has had steady increases since 2015 and a 11% increase from 2016.

Within England, there was variation among the nine PHECs as well. All PHECs had higher rates in 2017 compared to 2013. The highest rate of *Enterobacter* spp. bacteraemia in 2017 was in the North East (4.2 per 100,000) (see figure 2a). Following that was East Midlands (4.1 per 100,000) and London (4.0 per 100,000). The lowest rate of *Enterobacter* spp. bacteraemia in 2017 was in Yorkshire and Humber (2.7 per 100,000). Yorkshire and Humber has reported the lowest rate since 2013.

Table 1a. Rate of *Enterobacter* spp. bacteraemia reports per 100,000 population by PHE Centre (England, Wales and Northern Ireland): 2013 to 2017

		Rate per 100,000				
Region	**PHE Centre**	**2013**	**2014**	**2015**	**2016**	**2017**
North of England	North East	2.5	2.6	2.9	3.6	4.2
	Yorkshire and Humber	2.1	1.7	2.3	2.6	2.7
	North West	2.9	2.8	2.8	2.9	3.0
Midlands and East of England	West Midlands	2.7	2.9	2.6	2.9	3.3
	East Midlands	3.2	3.0	3.7	3.7	4.1
	East of England	2.7	2.8	2.9	3.4	3.7
London	London	3.0	2.8	2.9	3.3	4.0
South of England	South West	2.6	2.8	2.7	3.2	3.5
	South East	2.3	2.6	2.8	3.3	3.7
England		2.7	2.7	2.8	3.2	3.6
Northern Ireland		3.4	3.9	3.1	3.8	3.1
Wales		3.7	4.0	3.7	4.0	3.7
England, Wales and Northern Ireland		**2.8**	**2.8**	**2.9**	**3.2**	**3.5**

Figure 2a. Geographical distribution of *Enterobacter* spp. bacteraemia rates per 100,000 population (England, Wales and Northern Ireland): 2017



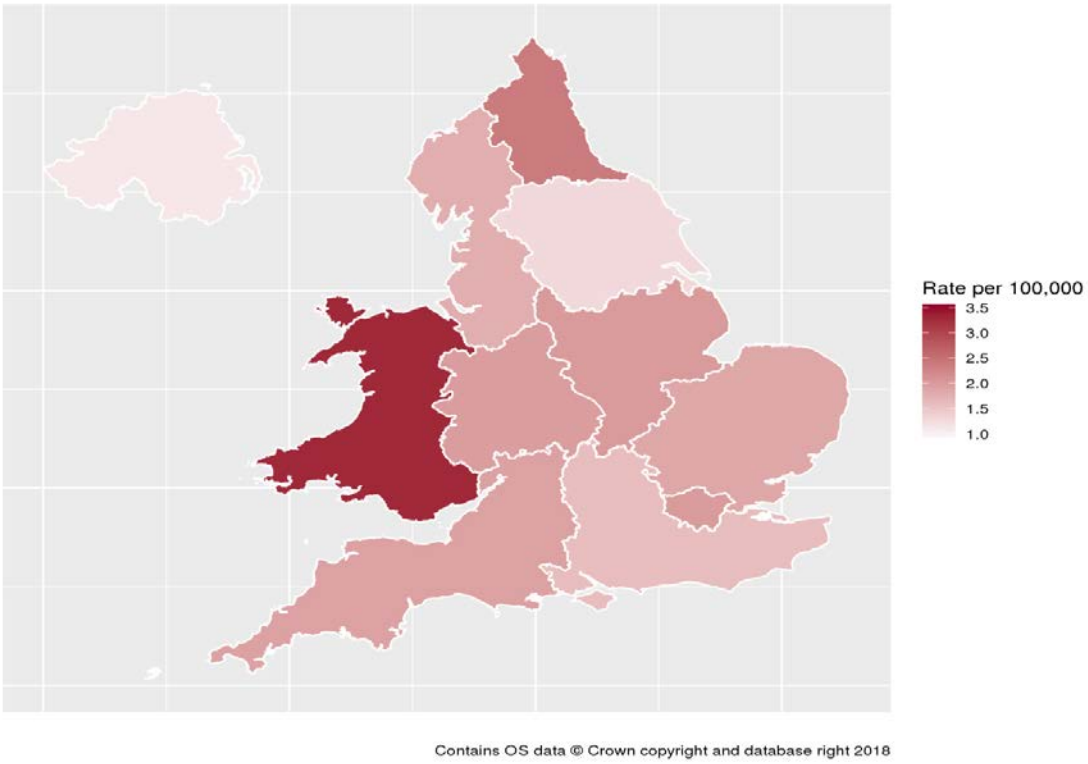
The combined rate of reported *Serratia* spp. bacteraemia for England, Wales and Northern Ireland was 1.9 per 100,000 population; an increase of 8% from 2016 (see table 1b). Individually, Northern Ireland saw a large decrease in 2017 compared with 2016 (37%), while England had a 9% increase from 2016 and has shown steady increases since 2015.

There was variation among the nine PHECs in England as well. In 2017, the highest rate was reported by the North East (2.4 per 100,000) and the lowest rate by Yorkshire and Humber (1.3 per 100,000) (see figure 2b). While rates in the North West have remained relatively stable over the past 5 years, all other PHECs reported higher rates in 2017 compared to 2013. The greatest increases in 2017 from 2013 were seen for the PHECs in the Midlands and East of England region (East of England 75%, West Midlands 54% and East Midlands 52%).

Table 1b. Rate of *Serratia* spp. bacteraemia reports per 100,000 population by PHE Centre (England, Wales and Northern Ireland): 2013 to 2017

		Rate per 100,000				
Region	**PHE Centre**	**2013**	**2014**	**2015**	**2016**	**2017**
North of England	North East	2.1	1.8	2.2	1.9	2.4
	Yorkshire and Humber	0.9	1.0	1.1	1.5	1.3
	North West	1.8	1.8	1.7	2.0	1.8
Midlands and East of England	West Midlands	1.3	1.3	1.3	1.8	2.0
	East Midlands	1.3	1.1	1.4	1.4	2.0
	East of England	1.1	1.7	1.4	1.5	1.9
London	London	1.5	1.8	1.8	1.7	2.0
South of England	South West	1.5	1.5	1.5	1.7	1.9
	South East	1.2	1.1	1.6	1.6	1.6
England		1.4	1.4	1.5	1.7	1.8
Northern Ireland		2.0	1.4	1.9	1.8	1.1
Wales		3.1	2.5	3.4	2.7	3.3
England, Wales and Northern Ireland		**1.5**	**1.5**	**1.6**	**1.7**	**1.9**

Figure 2b. Geographical distribution of *Serratia* spp. bacteraemia rates per 100,000 population (England, Wales and Northern Ireland): 2017



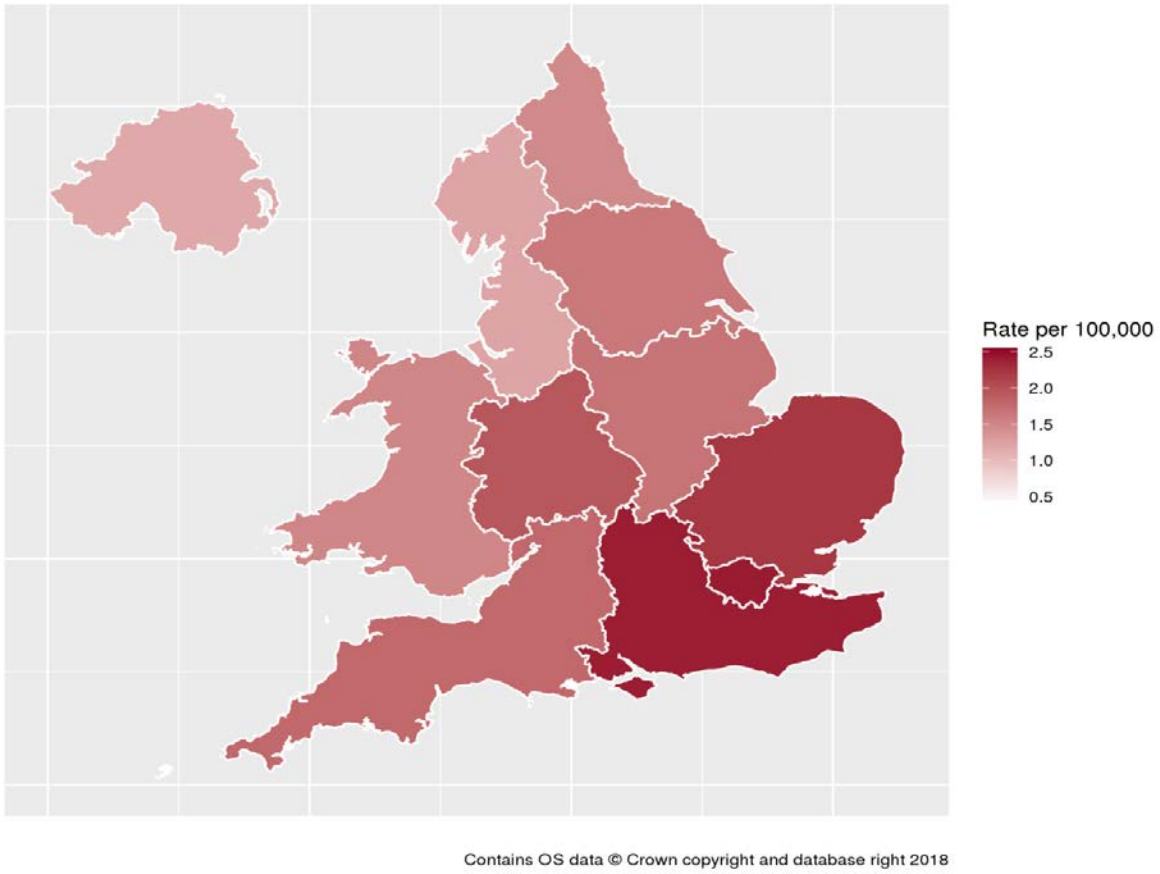
The combined rate of reported *Citrobacter* spp. bacteraemia for England, Wales and Northern Ireland was 1.9 per 100,000; an increase of 5% since 2016. Individually, Wales decreased in 2017 compared with 2016 (21%) and returned to the rate they had maintained consistently from 2013 to 2015. Northern Ireland remained relatively consistent at 1.2 per 100,000 and England saw a 7% increase from 2016.

There was variation among the nine PHECs in England as well. All PHECs have higher rates in 2017 compared to 2013; however, the greatest increases during this time period have been seen in the South East (85%), Yorkshire and Humber (63%) and London (52%). London and South East reported the highest rates in 2017 (2.4 per 100,000 for both). North West reported the lowest rate (1.2 per 100,000). North West has reported the lowest rate of *Citrobacter* spp. bacteraemia since 2015.

Table 1c. Rate of *Citrobacter* spp. bacteraemia reports per 100,000 population by PHE Centre (England, Wales and Northern Ireland): 2013 to 2017

		Rate per 100,000				
Region	**PHE Centre**	**2013**	**2014**	**2015**	**2016**	**2017**
North of England	North East	1.0	1.1	1.8	1.5	1.5
	Yorkshire and Humber	1.0	0.9	1.7	1.3	1.6
	North West	1.1	1.2	1.2	1.3	1.2
Midlands and East of England	West Midlands	1.8	1.7	1.7	1.8	1.9
	East Midlands	1.2	1.3	1.6	1.6	1.7
	East of England	1.6	1.6	1.7	1.9	2.2
London	London	1.6	1.7	1.8	2.2	2.4
South of England	South West	1.2	1.5	1.9	2.0	1.8
	South East	1.3	1.3	1.6	2.2	2.4
England		1.3	1.4	1.6	1.8	1.9
Northern Ireland		0.7	0.8	1.1	1.2	1.2
Wales		1.5	1.6	1.5	1.9	1.5
England, Wales and Northern Ireland		**1.3**	**1.4**	**1.6**	**1.8**	**1.9**

Figure 2c. Geographical distribution of *Citrobacter* spp. bacteraemia rates per 100,000 population (England, Wales and Northern Ireland): 2017



It is important to note that there are differences in the way data are collected between the three countries. In England and Northern Ireland, microbiology laboratories electronically report clinically significant isolates to SGSS or CoSurv, respectively. In Wales, data are collected by extraction from a single laboratory information system used by all the microbiology laboratories. The system extracts all positive blood cultures, including those not thought to be clinically significant.

Differences exist that may account for the variation observed between regions as well. These include completeness of reporting, local outbreaks, as well as different resident populations and distribution of specialist care units.

Species distribution

The total number of *Enterobacter* spp. bacteraemia reports increased by 10% from 2016 to 2017 (1,953 isolates in 2016 to 2,149 isolates in 2017). Due to the recent reclassification of *Enterobacter aerogenes* as *Klebsiella aerogenes;* overall isolate numbers for *Enterobacter* spp. are lower from those previously reported. As in previous years, about 90% of reported *Enterobacter* spp. bacteraemia isolates were identified to species level (see table 2a). The most predominant species remains *E. cloacae,* presented here as part of the *E. cloacae complex* (87.1%). Distinction between members of the complex is not always reliable; however, of those that were identified, species included *E. absuriae*, *E. ludwigii*, and *E. kobei*.

Table 2a. Reports of *Enterobacter* spp. bacteraemia by species (England, Wales and Northern Ireland): 2013 to 2017

	2013		2014		2015		2016		2017	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
***Enterobacter* spp.**	**1,625**	**100**	**1,644**	**100**	**1,712**	**100**	**1,953**	**100**	**2,149**	**100**
E. amnigenus	7	0.4	4	0.2	11	0.6	6	0.3	5	0.2
E. cancerogenus	0	0.0	1	0.1	0	0.0	2	0.1	1	0.1
*E. cloacae complex**	1,388	85.5	1,419	86.3	1,505	87.9	1,718	87.9	1,873	87.1
E. gergoviae	7	0.4	4	0.2	7	0.4	5	0.3	4	0.2
E. hormaechei	0	0.0	0	0.0	0	0.0	0	0.0	22	1.0
E. intermedius	0	0.0	1	0.1	0	0.0	0	0.0	1	0.1
E. sakazakii	28	1.7	13	0.8	6	0.3	2	0.1	3	0.1
Enterobacter spp., other named	46	2.8	56	3.4	24	1.4	26	1.3	32	1.5
Enterobacter spp., species not recorded	149	9.2	146	8.9	159	9.3	194	9.9	208	9.6

*****Species of the *Enterobacter cloacae* complex reported: *E. absuriae*, *E. cloacae* (predominant), *E. ludwigii*, and *E. kobei*

The total number of *Serratia* spp. bacteraemia reports increased by 9% from 2016 to 2017 (1,051 isolates in 2016 to 1,143 isolates in 2017). Since 2016, identification to species level has continued to improve for *Serratia* spp. bacteraemia isolates and 97% of reports in 2017 were identified (see table 2b). The most predominant species remains *S. marcescens* (88.2%).

Table 2b. Reports of *Serratia* spp. bacteraemia by species (England, Wales and Northern Ireland): 2013 to 2017

	2013		2014		2015		2016		2017	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
***Serratia* spp.**	**869**	**100**	**889**	**100**	**982**	**100**	**1,051**	**100**	**1,143**	**100**
S. ficaria	1	0.1	1	0.1	0	0.0	0	0.0	0	0.0
S. fonticola	8	0.9	3	0.3	2	0.2	7	0.7	5	0.4
S. liquefaciens	73	8.4	74	8.3	86	8.8	87	8.3	86	7.5
S. marcescens	735	84.6	755	85.0	836	85.1	919	87.3	1,008	88.2
S. odorifera	6	0.7	2	0.2	7	0.7	4	0.4	7	0.6
S. plymuthica	1	0.1	0	0.0	2	0.2	0	0.0	0	0.0
S. proteamaculas	1	0.1	0	0.0	1	0.1	0	0.0	0	0.0
S. rubidaea	0	0.0	1	0.1	5	0.5	1	0.1	3	0.3
S. ureilytica	0	0.0	0	0.0	0	0.0	3	0.3	1	0.1
Serratia spp., other named	10	1.2	20	2.3	2	0.2	0	0.0	1	0.1
Serratia spp., species not recorded	34	3.9	33	3.7	41	4.2	30	2.9	32	2.8

The total number of *Citrobacter* spp. bacteraemia reports increased by 6% from 2016 to 2017 (1,087 isolates in 2016 to 1,147 isolates in 2017). 94% of reported *Citrobacter* spp. bacteraemia isolates were identified to species level in 2017 (see table 2c). The most predominant species remain *C. diversus,* which accounted for 54.4% of identified species in 2017 and *C. freundii,* which accounted for 32.9% of identified species in 2017.

Table 2c. Reports of *Citrobacter* spp. bacteraemia by species (England, Wales and Northern Ireland): 2013 to 2017

	2013		2014		2015		2016		2017	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
***Citrobacter* spp.**	**782**	**100**	**812**	**100**	**966**	**100**	**1,087**	**100**	**1,147**	**100**
C. amalonaticus	3	0.4	4	0.5	5	0.5	5	0.5	3	0.3
C. braakii	2	0.3	4	0.5	28	2.9	30	2.8	33	2.9
C. diversus	405	51.8	369	45.4	478	49.5	559	51.4	624	54.4
C. farmeri	0	0.0	2	0.3	4	0.4	4	0.4	0	0.0
C. freundii	245	31.3	303	37.3	336	34.8	355	32.7	378	32.9
C. koseri	8	1.0	5	0.6	6	0.6	9	0.8	9	0.8
C. sedlakii	0	0.0	0	0.0	1	0.1	1	0.1	2	0.2
C. werkmanii	0	0.0	0	0.0	4	0.4	1	0.1	1	0.1
C. youngae	0	0.0	1	0.1	3	0.3	7	0.6	9	0.8
Citrobacter spp., other named	58	7.4	53	6.5	37	3.8	40	3.6	18	1.5
Citrobacter spp., species not recorded	61	7.8	71	8.8	64	6.7	76	7.0	70	6.1

The increased use of automated diagnostic technology (MALDI-TOF) has enhanced the capability of laboratories to distinguish species over time. In 2017, species of *Enterobacter hormaechei* were reported.

Among the most frequently reported monomicrobial bacteraemia and/or fungaemia in England, Wales and Northern Ireland for 2017, *Enterobacter cloacae* featured as the 13th most reported species (accounting for only 0.9% of monomicrobial infections however) and *Serratia marcescens* as the 17th most reported pathogen (accounting for 0.6% of monomicrobial infections) [4].

Age and sex distribution

Figures 3a-c show age and sex-specific bacteraemia rates of *Enterobacter* spp., *Serratia* spp. and *Citrobacter* spp. in 2017. All genera show higher rates among the older age groups (≥65 years), particularly in the elderly (aged ≥75 years). Higher rates were also seen amongst the youngest age group (<1 years) for *Enterobacter* spp. and *Serratia* spp. bacteraemia infections.

Across all genera, the overall rate of infection was higher among males than females. This was most pronounced in the older age groups, with the largest disparity among patients aged ≥75 years (2.9-fold higher for *Enterobacter* spp., 3.0-fold higher for *Serratia* spp. and 4.4-fold higher for *Citrobacter* spp.)

Figure 3a. *Enterobacter* spp. bacteraemia rates by age and sex (England, Wales and Northern Ireland): 2017

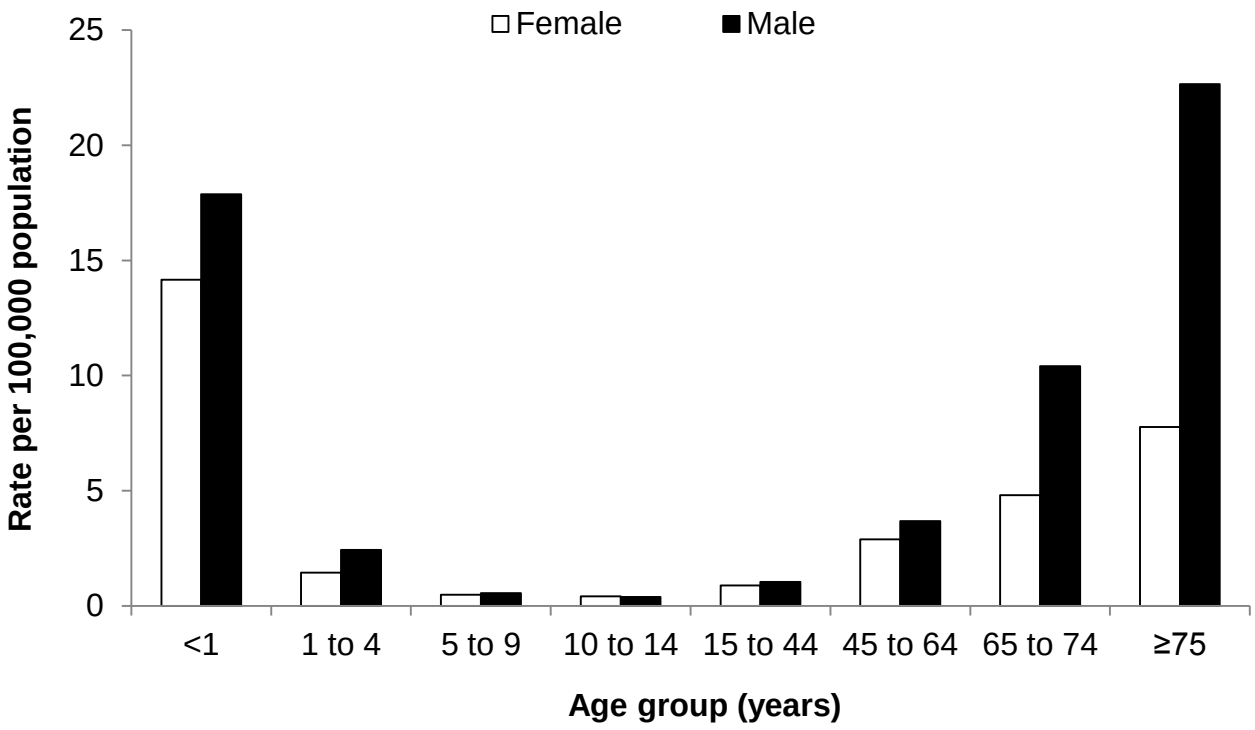


Figure 3b. *Serratia* spp. bacteraemia rates by age and sex (England, Wales and Northern Ireland): 2017

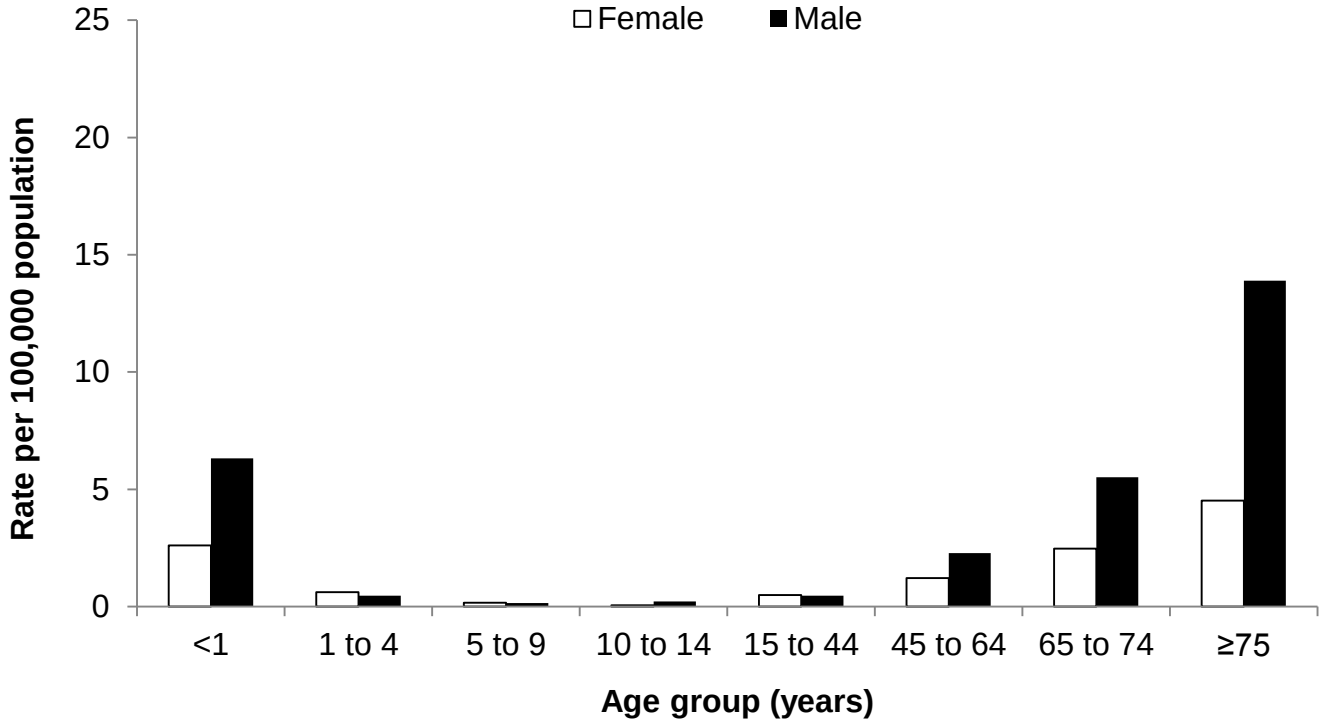
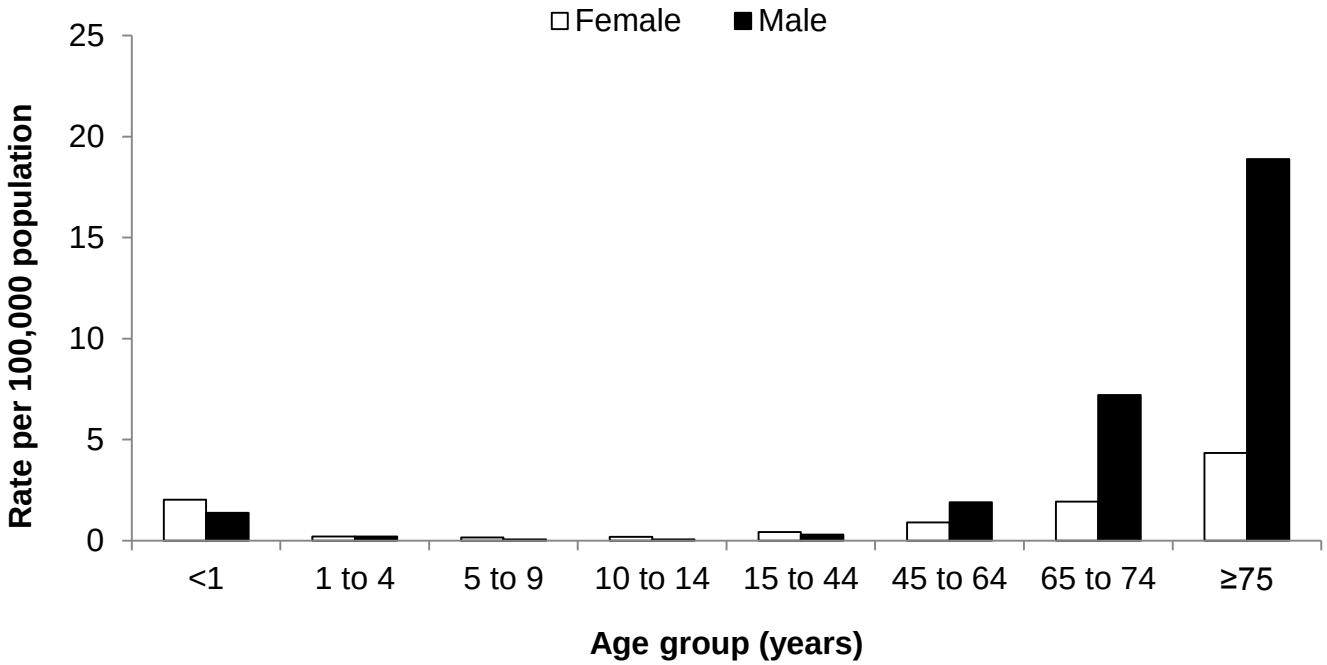


Figure 3c. *Citrobacter* spp. bacteraemia rates by age and sex (England, Wales and Northern Ireland): 2017



Antimicrobial resistance: England and Northern Ireland

Tables 3a-c present antibiotic susceptibility trends from tested *Enterobacter* spp., *Serratia* spp. and *Citrobacter* spp. isolates from 2015 to 2017 for England and Northern Ireland. In 2017, the number of *Enterobacter* spp. isolates tested for susceptibility to different antibiotics ranged from 880 for tobramycin to 2,053 for gentamicin. The percentage of resistant *Enterobacter* spp. isolates was highest for cefotaxime (31%), ceftazidime (28%) and piperacillin/tazobactam (18%) (see table 3a) . Single-agent antimicrobial resistance rates have remained relatively stable for *Enterobacter spp.* since 2015. The greatest increases in resistance observed from 2015 are for cefotaxime (22% to 31%) and ceftazidime (24% to 28%), probably reflecting selection of strains hyper-producing ampC β-lactamase. Decreased resistance from 2015 was observed for tobramycin (9% to 6%). Isolates within the *Enterobacter cloacae* complex that can produce IMI carbapenemases have been sporadically identified in AMRHAI submissions since 2010 [5]. In 2017, resistance to meropenem remained very low (1%) and ertrapenem resistance remained stable at 6%.

In 2017, the number of *Serratia* spp. isolates tested for susceptibility to different antibiotics ranged from 417 for tobramycin to 1,006 for gentamicin. The percentage of resistant *Serratia* spp. isolates was highest for cefotaxime (17%), tobramycin (15%) and ceftazidime (14%) (see table 3b). Resistance to ceftazidime and cefotaxime has increased since 2015 (11% to 14% and 13% to 17%, respectively). Tobramycin resistance decreased from 2016 (18% to 15%). Resistance to amikacin remains low (4%) however, the percentage of isolates that have tested as having “reduced susceptibility” has tripled since 2015.

In 2017, the number of *Citrobacter* spp. isolates tested for susceptibility to different antibiotics ranged from 407 for tobramycin to 1,047 for gentamicin. The percentage of resistant *Citrobacter* spp. isolates was highest for cefotaxime (13%), ceftazidime (10%) and piperacillin/tazobactam (6%) (see table 3c) . Single-agent antimicrobial resistance rates have remained relatively stable since 2015. Ceftazidime and piperacillin/tazobactam resistance have decreased since 2015 (14% to 10% and 9% to 6%, respectively). Overall resistance for *Citrobacter* spp. isolates remains low in comparison to the other genera.

Table 3a. Antibiotic susceptibility* for *Enterobacter* spp. bacteraemia in England and Northern Ireland: 2015 to 2017

	2015			2016			2017		
Antimicrobial agent	**S (%)**	**I (%)**	**R (%)**	**S (%)**	**I (%)**	**R (%)**	**S (%)**	**I (%)**	**R (%)**
Gentamicin	94	<1	6	95	<1	5	95	<1	5
Ciprofloxacin	94	1	5	94	1	5	94	2	5
Ceftazidime	75	1	24	73	2	25	69	2	28
Cefotaxime	76	1	22	75	1	24	67	2	31
Meropenem	99	1	1	99	1	<1	98	1	1
Ertrapenem	92	4	5	91	4	5	91	3	6
Tobramycin	90	1	9	92	1	7	94	<1	6
Amikacin	99	1	1	99	1	1	99	1	<1
Piperacillin\tazobactam	82	2	16	81	2	17	80	2	18

*__S__ = susceptible; __I__ = intermediate (reduced susceptibility); __R__ = resistant

Table 3b. Antibiotic susceptibility* for *Serratia* spp. bacteraemia in England and Northern Ireland: 2015 to 2017

	2015			2016			2017		
Antimicrobial agent	**S (%)**	**I (%)**	**R (%)**	**S (%)**	**I (%)**	**R (%)**	**S (%)**	**I (%)**	**R (%)**
Gentamicin	98	<1	1	98	<1	2	98	<1	2
Ciprofloxacin	94	2	4	95	2	3	94	2	4
Ceftazidime	88	1	11	89	2	9	85	1	14
Cefotaxime	85	2	13	84	1	15	81	2	17
Meropenem	99	<1	<1	100	<1	0	100	<1	<1
Ertrapenem	99	<1	1	99	0	1	99	<1	1
Tobramycin	75	11	14	71	11	18	74	11	15
Amikacin	92	3	4	88	8	5	86	10	4
Piperacillin\tazobactam	91	1	8	91	1	8	90	1	9

* __S__ = susceptible; __I__ = intermediate (reduced susceptibility); __R__ = resistant

Table 3c. Antibiotic susceptibility* for *Citrobacter* spp. bacteraemia in England and Northern Ireland: 2015 to 2017

	2015			2016			2017		
Antimicrobial agent	**S (%)**	**I (%)**	**R (%)**	**S (%)**	**I (%)**	**R (%)**	**S (%)**	**I (%)**	**R (%)**
Gentamicin	96	<1	3	97	0	3	97	<1	3
Ciprofloxacin	97	<1	3	97	1	2	97	<1	3
Ceftazidime	86	<1	14	89	2	9	89	1	10
Cefotaxime	87	2	11	90	1	9	87	<1	13
Meropenem	100	<1	0	100	0	0	100	<1	<1
Ertrapenem	99	1	<1	100	<1	0	100	<1	<1
Tobramycin	94	0	6	95	<1	4	93	1	5
Amikacin	99	1	0	99	<1	<1	98	1	<1
Piperacillin\tazobactam	90	1	9	91	1	8	92	2	6

* **S** = susceptible; **I** = intermediate (reduced susceptibility); **R** = resistant

Tables 4a-c show multi-drug resistance testing results for *Enterobacter* spp.*, Citrobacter* spp. and *Serratia* spp. for England from 2015 to 2017. This analysis examined four classes of antibiotics: third-generation cephalosporins (any of cefotaxime, ceftazidime, ceftriaxone or cefpodoxime), a fluoroquinolone (ciprofloxacin), carbapenems (meropenem) and an aminoglycoside (gentamicin).

Multi-drug resistance in general for these three genera is relatively uncommon (5% or less for all presented combinations). The highest reported resistance in 2017 is for *Enterobacter* spp. isolates tested for the combination of gentamicin and third generation cephalosporins, as well as ciprofloxacin and third generation cephalosporins (both 4%). Multi-drug resistance to a combination of all four antibiotics remains rare (<1%).

Table 4a. Multi-drug antimicrobial testing and resistance summary* for *Enterobacter* spp. bacteraemia (England): 2015 to 2017

	2015			2016			2017		
Antimicrobial combinations	**S (%)**	**I (%)**	**R (%)**	**S (%)**	**I (%)**	**R (%)**	**S (%)**	**I (%)**	**R (%)**
Gentamicin and ciprofloxacin	97	<1	3	97	1	2	97	1	2
Gentamicin and 3rd gen cephalosporin†	94	<1	5	95	<1	4	95	<1	4
Gentamicin and meropenem	99	<1	<1	100	<1	<1	99	<1	<1
Ciprofloxacin and 3rd gen cephalosporin†	95	1	4	96	1	4	95	1	4
Ciprofloxacin and meropenem	99	<1	<1	100	<1	<1	99	<1	<1
3rd gen cephalosporin† and meropenem	99	1	1	99	1	<1	98	1	1
Gentamicin, ciprofloxacin, 3rd gen cephalosporin† and meropenem	99	<1	<1	100	<1	<1	100	<1	<1

* **S** = susceptible; **I** = intermediate (reduced susceptibility); **R** = resistant
† cefotaxime, ceftazidime, ceftriaxone, cefpodoxime

Table 4b. Multi-drug antimicrobial testing and resistance summary* for *Serratia* spp. bacteraemia (England): 2015 to 2017

	2015			2016			2017		
Antimicrobial combinations	**S (%)**	**I (%)**	**R (%)**	**S (%)**	**I (%)**	**R (%)**	**S (%)**	**I (%)**	**R (%)**
Gentamicin and ciprofloxacin	100	<1	<1	99	<1	1	100	0	<1
Gentamicin and 3rd gen cephalosporin†	99	<1	1	98	<1	1	99	<1	1
Gentamicin and meropenem	100	<1	<1	100	0	0	100	0	0
Ciprofloxacin and 3rd gen cephalosporin†	97	1	2	98	1	2	96	1	3
Ciprofloxacin and meropenem	100	0	<1	100	0	0	100	<1	<1
3rd gen cephalosporin† and meropenem	99	<1	<1	100	0	0	100	<1	<1
Gentamicin, ciprofloxacin, 3rd gen cephalosporin† and meropenem	100	0	<1	100	0	0	100	0	0

* **S** = susceptible; **I** = intermediate (reduced susceptibility); **R** = resistant
† cefotaxime, ceftazidime, ceftriaxone, cefpodoxime

Table 4c. Multi-drug antimicrobial testing and resistance summary* for *Citrobacter* spp. bacteraemia (England): 2015 to 2017

	2015			2016			2017		
Antimicrobial combinations	**S (%)**	**I (%)**	**R (%)**	**S (%)**	**I (%)**	**R (%)**	**S (%)**	**I (%)**	**R (%)**
Gentamicin and ciprofloxacin	99	<1	1	99	0	1	99	<1	1
Gentamicin and 3rd gen cephalosporin†	98	<1	2	99	0	1	98	<1	1
Gentamicin and meropenem	100	<1	0	100	0	0	100	<1	<1
Ciprofloxacin and 3rd gen cephalosporin†	98	<1	2	99	1	1	99	<1	1
Ciprofloxacin and meropenem	100	0	0	100	0	0	100	<1	<1
3rd gen cephalosporin† and meropenem	100	<1	0	100	0	0	100	<1	<1
Gentamicin, ciprofloxacin, 3rd gen cephalosporin† and meropenem	100	0	0	100	0	0	100	<1	<1

* **S** = susceptible; **I** = intermediate (reduced susceptibility); **R** = resistant
† cefotaxime, ceftazidime, ceftriaxone, cefpodoxime

Microbiology services

For advice on treatment of antibiotic-resistant infections caused by these opportunistic pathogens, laboratories should contact the Medical Microbiologists at PHE's Bacteriology Reference Department in Colindale (colindalemedmicro@phe.gov.uk). For reference services, including species identification and confirmation of sensitivity testing results, laboratories should contact PHE's Antimicrobial Resistance and Healthcare Associated Infections (AMRHAI) Reference Unit in London [6].

Acknowledgements

These reports are only possible thanks to the weekly contributions from microbiology colleagues in laboratories across England, Wales, and Northern Ireland, without whom there would be no surveillance data. Support from colleagues within Public Health England, the PHE AMRHAI Reference Unit, Public Health Wales and Health and Social Care (HSC) Public Health Agency (Northern Ireland) is particularly valued in the preparation of the report. Feedback and specific queries about this report are welcome via hcai.amrdepartment@phe.gov.uk.

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Public Health England, Wellington House, 133-155 Waterloo Road, London SE1 8UG Tel: 020 7654 8000 www.gov.uk/phe
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Queries relating to this document should be directed to:
HCAI and AMR Department,
National Infection Service, PHE Colindale,
61 Colindale Avenue, London NW9 5EQ.
hcai.amrdepartment@phe.gov.uk

Published: October 2018
PHE publications
gateway number: 2018534

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