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Laboratory surveillance of *Proteus*, *Morganella*, and *Providencia* bacteraemia in England, Wales and Northern Ireland: 2018

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These analyses are based on *Proteus* spp., *Morganella* spp., and *Providencia* spp. blood stream infections in England, Wales, and Northern Ireland during the ten-year period of 2009 to 2018. The data were extracted on 10 October 2019 from Public Health England's voluntary surveillance database, Secondary Generation Surveillance System (SGSS). Data for Wales and Northern Ireland were extracted separately (DataStore on 23 July 2019 and CoSurv on 27 April 2019, respectively) for inclusion in the geographical and species analyses.

Rates of laboratory reported bacteraemia were calculated using the mid-year resident population estimates. 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 boundaries of administrative local authorities.

This report includes the analyses of trends, age, sex, and geographical distribution of cases of *Proteus* spp., *Morganella* spp., and *Providencia* spp. bacteraemia in England, Wales, and Northern Ireland. Single-agent antimicrobial susceptibility trends since 2015 are for England and Northern Ireland based on SGSS AMR and CoSurve 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.

The data presented here may differ from data in previous publications due to inclusion of late reports.

Key points

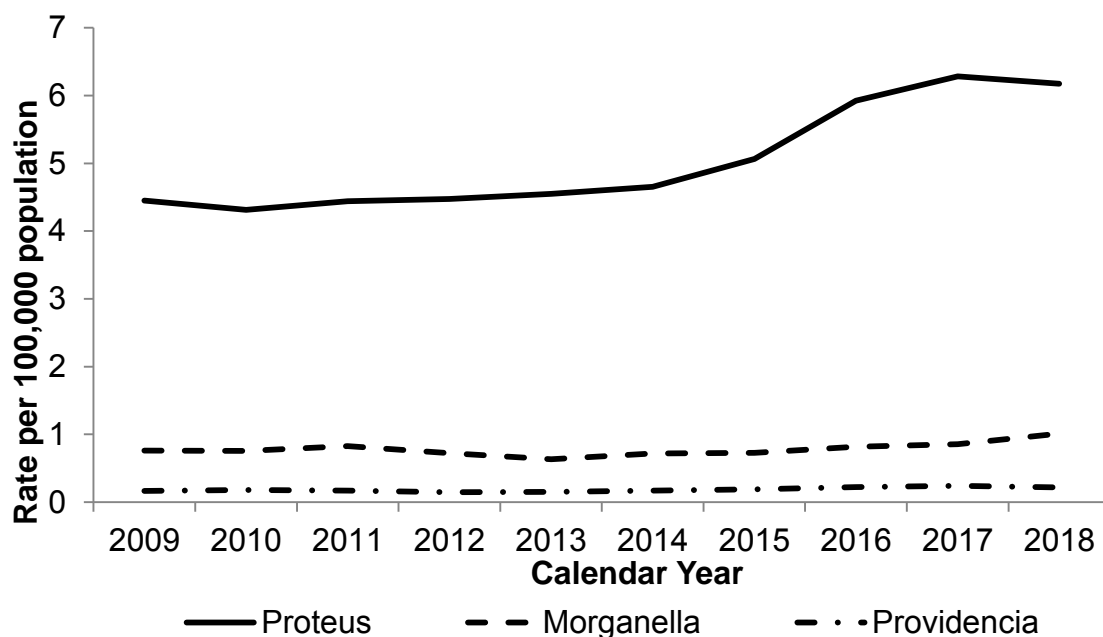
- in England, Wales, and Northern Ireland, the overall rate of *Proteus* spp. bacteraemia was 6.2 per 100,000 population (n=3,767) in 2018; this has increased 37.7% from 4.5 per 100,000 population (n=2,538) in 2009
- in England, Wales, and Northern Ireland, the overall rate of *Morganella* spp. bacteraemia was 1.0 per 100,000 (n=618) in 2018; this is a slight increase from a rate of 0.8 per 100,000 population (n=433) in 2009
- in England, Wales, and Northern Ireland, the overall rate of *Providencia* spp. bacteraemia was 0.21 per 100,000 population (n=132) in 2018; this rate has increased 24% from 0.17 per 100,000 population (n=95) in 2009
- in England, the Yorkshire and Humber PHE Centre had the highest reported incidence rate of *Proteus* spp. in 2018: 7.0 per 100,000 population
- in England, the South East PHE Centre had the highest reported incidence rate of *Morganella* spp. in 2018: 1.3 per 100,000 population
- in England, the East of England PHE Centre had the highest report incidence rate of *Providencia* spp. in 2018: 0.4 per 100,000 population
- the highest rates of *Proteus* spp., *Morganella* spp., and *Providencia* spp. were seen amongst the ≤ 75 age group; bacteraemia rates were also higher in males vs females in this age group
- compared to 2015, the percentage of *Proteus mirabilis* bacteraemia cultures showing resistance to gentamycin, cefotaxime and piperacillin/tazobactam has increased in 2018
- compared to 2015, the percentage of *Morganella morganii* bacteraemia cultures showing resistance to piperacillin/tazobactam, cefotaxime, ciprofloxacin and tobramycin has increased in 2018
- compared to 2015, the percentage of *Providencia stuartii* bacteraemia cultures showing resistance to ciprofloxacin, ceftazidime, cefotaxime, and gentamicin has increased in 2018

Trends

In England, Wales, and Northern Ireland, the overall rate of *Proteus* spp. bacteraemia in 2018 was 6.2 per 100,000 population (n=3,767). This was a 37.7% increase compared to 4.5 per 100,000 population (n=2,538; Figure 1), and a 1.6% decrease compared to 6.3 per 100,000 population (n=3,810) in 2017. 2018 was the first year since 2010 where a year-on-year increase in rates was not observed. In England, Wales, and Northern Ireland, the overall rate of *Morganella* spp. bacteraemia in 2018 was 1.0 per 100,000 population (n=618), showing a slight increase since 2009 (0.8 per 100,000 population; n=433; Figure 1). In England, Wales, and Northern Ireland, the overall rate of *Providencia* spp. bacteraemia was 0.22 per 100,000 population (n=132), a 30% increase from 0.17 per 100,000 population (n=95) in 2009.

Proteus mirabilis accounted for 1.8% of monomicrobial bloodstream infections (BSI: all reported bacteraemia and/or fungaemia) in 2018, making it the eighth most commonly reporting cause of monomicrobial BSI [1].

Figure 1. *Proteus* spp., *Morganella* spp., and *Providencia* spp. bacteraemia rate per 100,000 population (England, Wales, and Northern Ireland): 2009 to 2018

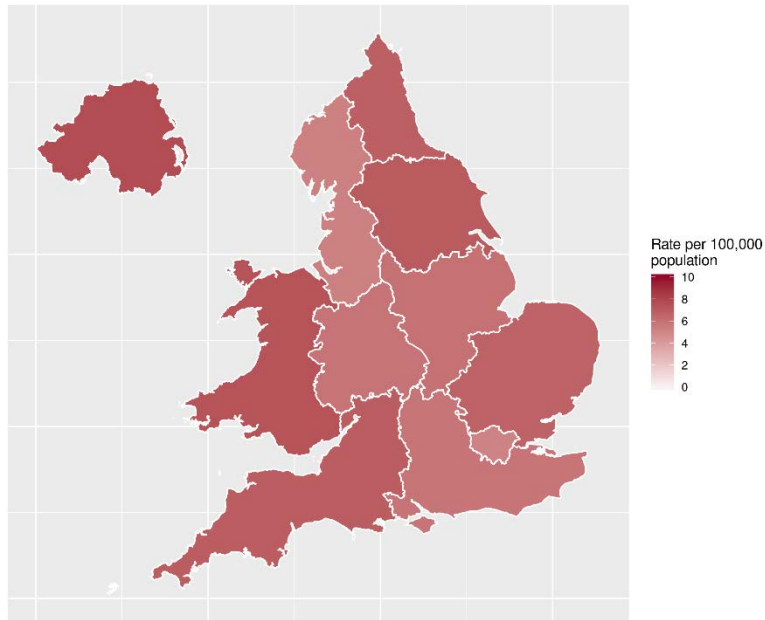


Geographic distribution

Yorkshire and Humber had the highest reported incidence rate of *Proteus* spp. bacteraemia in England in 2018 of 7.0 per 100,000 population. London had the lowest rate of *Proteus* spp. bacteraemia in England in 2018, with 5.2 per 100,000 population (Figure 2a). For Northern Ireland and Wales, rates of *Proteus* spp. bacteraemia were 7.7 and 7.4 per 100,000 population in 2018, respectively. All PHE Centres have seen an increase in bacteraemia rates in the past 5 years, since 2014 (Table 1a). The largest increase in *Proteus* spp. bacteraemia rates has been observed in the Yorkshire and Humber PHE Centre (64.9% between 2014 and 2018; Table 1a). Compared to 2017, decreases in *Proteus* spp. bacteraemia rates were observed in 6 of 9 PHE Centres in England (Table 1a) as well as Northern Ireland, which had the largest decrease in bacteraemia rates between 2017 and 2018 (17.6%; Table 1a).

While rates in NI have decreased in 2018 to background rates, the local epidemiological investigation in 2017 identified no specific groups where there was an increase in incidence. Similarly, no clustering of cases were identified which could explain an increase in rates. The local surveillance systems will continue to monitor this situation for trends and clustering to take appropriate actions.

Figure 2a. Geographical distribution of *Proteus* spp. bacteraemia rates per 100,000 population (England, Wales and Northern Ireland): 2018



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Table 1a. *Proteus* spp. bacteraemia per 100,000 population by region (England, Wales, Northern Ireland): 2014 to 2018

Region	PHE Centre	Rate per 100,000 population				
		2014	2015	2016	2017	2018
London	London	4.4	4.3	5.5	5.5	5.2
Midlands and East of England	West Midlands	4.7	5.1	5.6	6.2	5.9
	East Midlands	4.5	5.2	6.1	6.0	6.0
	East of England	5.4	5.3	6.6	7.8	6.7
North of England	North East	5.8	5.4	7.1	6.8	6.8
	Yorkshire and Humber	4.3	4.4	5.8	5.3	7.0
	North West	4.1	5.2	5.3	5.5	5.3
South of England	South West	4.4	5.4	6.1	6.3	6.9
	South East	4.0	4.7	5.4	6.3	5.8
England		4.5	4.9	5.8	6.1	6.1
Northern Ireland		5.8	5.9	7.4	9.4	7.7
Wales		6.4	6.9	7.1	7.4	7.4
England, Wales & Northern Ireland		4.7	5.1	5.9	6.3	6.2

The South East England PHE Centre had the highest reported incidence rate of *Morganella* spp. bacteraemia in 2018, which was 1.3 per 100,000 population. This was followed by Yorkshire and Humber and London PHE Centres, with rates of 1.11 and 1.08 per 100,000 population respectively. The North East had the lowest rate of *Morganella* spp. bacteraemia in 2018 of 0.6 per 100,000 population (Figure 2b). All PHE Centres saw increases in *Morganella* spp. bacteraemia rates except the North East in the five-year period between 2014 and 2018 inclusive, with an overall increase of 41.3% for all regions combined (Table 1b). The largest increase in *Morganella* spp. bacteraemia rates during this period was observed in Yorkshire and Humber (148.6% between 2014 and 2018; Table 1b).

Figure 2b. Geographical distribution of *Morganella* spp. bacteraemia rates per 100,000 population (England, Wales and Northern Ireland): 2018

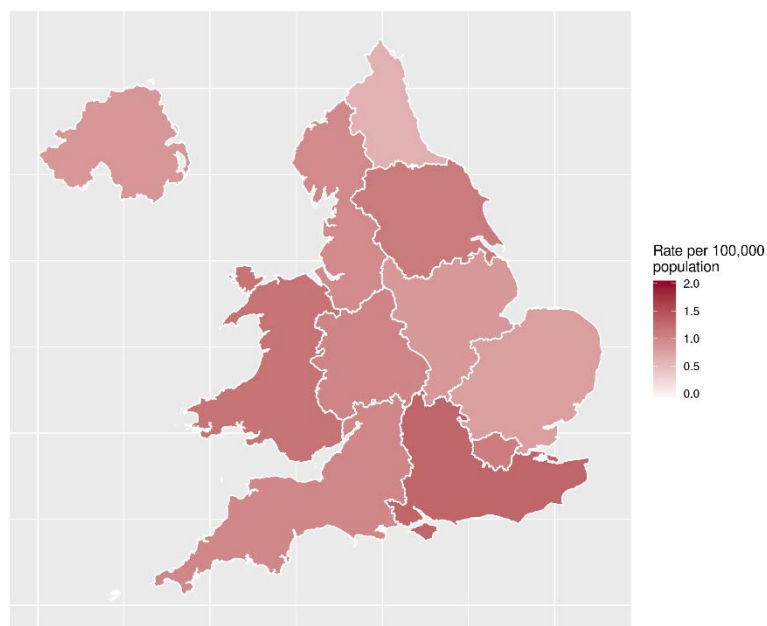


Table 1b. *Morganella* spp. bacteraemia per 100,000 population by region (England, Wales, Northern Ireland): 2014 to 2018

Region	PHE Centre	Rate per 100,000 population				
		2014	2015	2016	2017	2018
London	London	0.9	0.8	1.0	0.9	1.1
Midlands and East of England	West Midlands	0.8	0.8	0.9	0.8	1.0
	East Midlands	0.6	0.9	0.9	1.0	0.8
	East of England	0.7	0.5	0.5	0.7	0.8
North of England	North East	0.7	0.4	0.8	1.0	0.6
	Yorkshire and Humber	0.4	0.6	0.8	0.7	1.1
	North West	0.7	0.7	0.8	0.9	1.0
South of England	South West	0.8	0.7	0.8	0.8	1.0
	South East	0.7	0.9	0.9	1.0	1.3
England		0.7	0.7	0.8	0.8	1.0
Northern Ireland		0.5	0.5	0.6	0.8	0.9
Wales		0.9	1.2	0.8	1.1	1.2
England, Wales & Northern Ireland		0.7	0.7	0.8	0.9	1.0

The East of England PHE Centre had the highest rate of *Providencia* spp. bacteraemia in 2018, which was 0.36 per 100,000 population. This was followed by London and East Midlands, with *Providencia* spp. bacteraemia rates of 0.31 and 0.27 per 100,000 population in 2018 respectively. In 2018, the lowest rate was observed in the North East and Yorkshire and Humber, with rates of 0.11 and 0.14 per 100,000 population, respectively (Figure 2c). *Providencia* spp. bacteraemia rates largely remained stable between 0.1 and 0.2 per 100,000 population across all regions of England, Wales, and Northern Ireland from 2014 to 2018 inclusive, with the exception of Wales in 2015, with a rate of 0.4 (Table 1c).

Figure 2c. Geographical distribution of *Providencia* spp. bacteraemia rates per 100,000 population (England, Wales and Northern Ireland): 2018

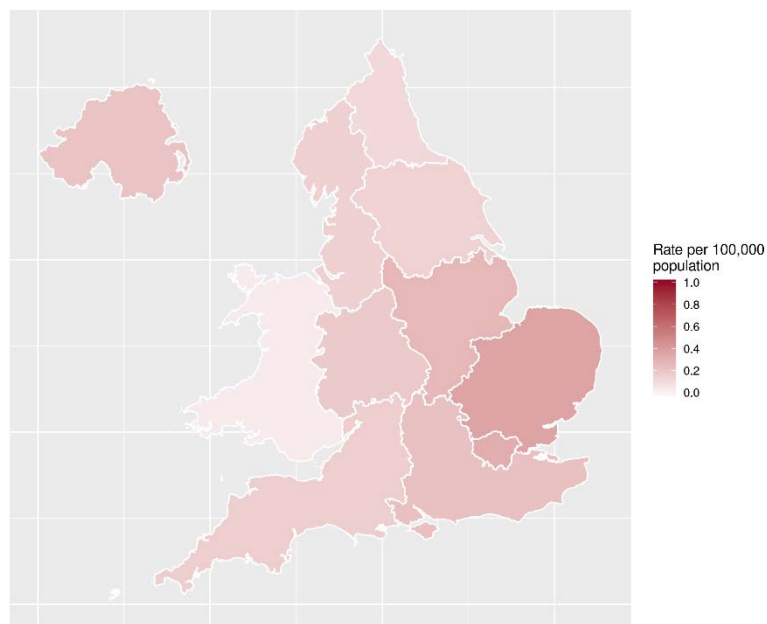


Table 1c. *Providencia* spp. bacteraemia per 100,000 population by region (England, Wales, Northern Ireland): 2014 to 2018

Region	PHE Centre	Rate per 100,000 population				
		2014	2015	2016	2017	2018
London	London	0.2	0.3	0.4	0.5	0.3
Midlands and East of England	West Midlands	0.3	0.0	0.1	0.2	0.2
	East Midlands	0.1	0.2	0.2	0.1	0.3
	East of England	0.2	0.1	0.3	0.3	0.4
North of England	North East	0.1	0.2	0.2	0.1	0.1
	Yorkshire and Humber	0.1	0.1	0.1	0.1	0.1
	North West	0.1	0.1	0.2	0.2	0.2
South of England	South West	0.1	0.1	0.2	0.2	0.2
	South East	0.2	0.3	0.2	0.3	0.2
England		0.2	0.2	0.2	0.2	0.2
Northern Ireland		0.2	0.1	0.2	0.1	0.2
Wales		0.2	0.4	0.2	0.2	0.0
England, Wales & Northern Ireland		0.7	0.2	0.2	0.2	0.2

Species distribution

In 2018, 93.9% of *Proteus* spp. bacteraemia isolates were identified to the species level (Table 2a). This proportion was similar to previous years. In 2018, *Proteus mirabilis* was the most common species, accounting for 91.3% of bacteraemia. This was followed by *P. vulgaris* (2.3%). The number of reported blood isolates has increased steadily from 2014 to 2018, with a 36.6% increase in this five-year period. However, compared to 2017, the number of reported blood isolates saw a 1.1% decrease (Table 2a).

Table 2a. Reports of *Proteus* spp. bacteraemia by species (England, Wales, Northern Ireland): 2014-2018

	2014		2015		2016		2017		2018	
	No.	%	No.	%	No.	%	No.	%	No.	%
<i>P. hauseri</i>	0	0.0	0	0.0	2	0.1	8	0.2	7	0.2
<i>P. mirabilis</i>	2480	90.0	2688	88.8	3164	88.7	3426	89.9	3440	91.3
<i>P. penneri</i>	6	0.2	3	0.1	12	0.3	9	0.2	7	0.2
<i>P. vulgaris</i>	87	3.2	87	2.9	101	2.8	89	2.3	85	2.3
<i>Proteus</i> spp., other named	1	0.0	4	0.1	2	0.1	3	0.1	2	0.1
<i>Proteus</i> spp., sp. not recorded	183	6.6	244	8.1	288	8.1	275	7.2	226	6.0
<i>Proteus</i> spp.	2757	100	3026	100	3569	100	3810	100	3767	100

In 2018, all *Morganella* spp. bacteraemia isolates were identified at the species level. *Morganella morganii* accounted for 100% of bacteraemia (Table 2b). Since 2017, 100% of all *Morganella* spp. isolates have been identified.

Table 2b. Reports of *Morganella* spp. bacteraemia by species (England, Wales, Northern Ireland): 2014-2018

	2014		2015		2016		2017		2018	
	No.	%	No.	%	No.	%	No.	%	No.	%
<i>M. morganii</i>	425	100	435	100	491	100	519	100	618	100
<i>Morganella</i> spp., sp not recorded	-	-	1	0	2	0	-	-	-	-
<i>Morganella</i> spp.	425	100	436	100	493	100	519	100	618	100

In 2018, 97% of *Providencia* spp. bacteraemia isolates were identified at the species level. The predominant species was *P. rettgeri*, which accounted for 53.8% of *Providencia* spp. bacteraemia isolates in 2018, followed by *P. stuartii* (42.4%; Table 2c). The number of reported blood isolates has increased from 2014 to 2018, with an increase of 29.4% over this five-year period.

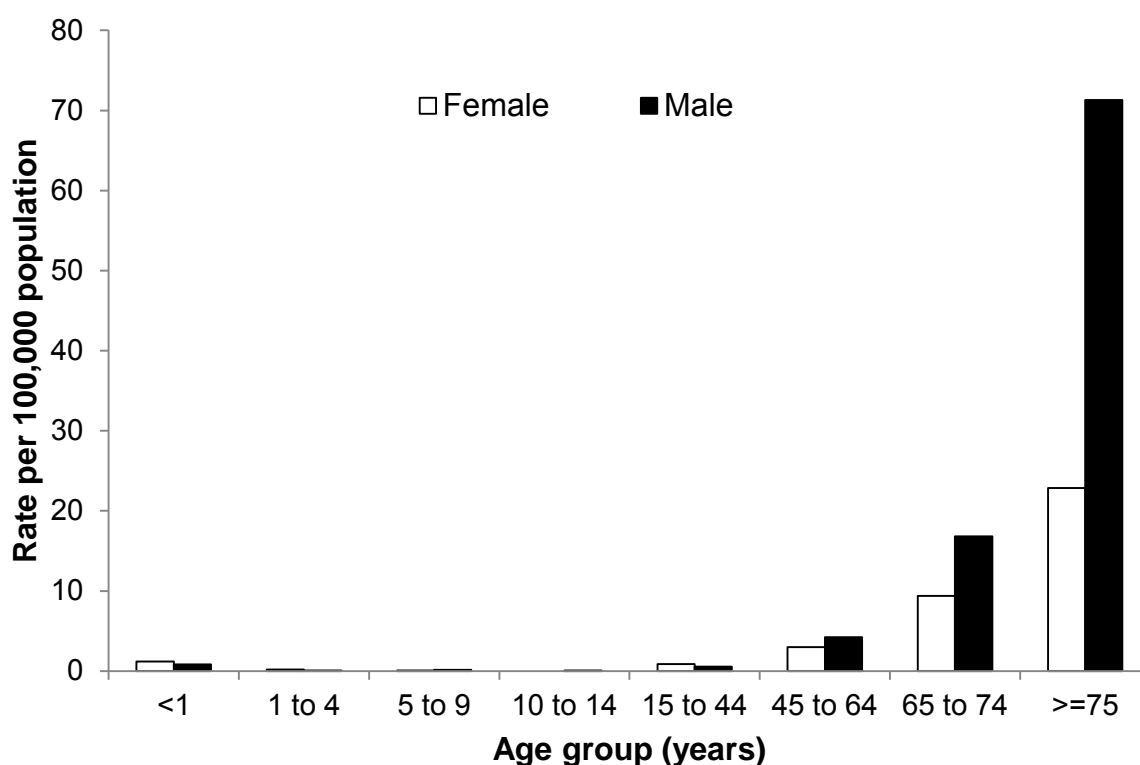
Table 2c. Reports of *Providencia* spp. bacteraemia by species (England, Wales, Northern Ireland): 2014-2018

	2014		2015		2016		2017		2018	
	No.	%	No.	%	No.	%	No.	%	No.	%
<i>P. alcalifaciens</i>	1	1.0	5	4.5	3	2.3	2	1.4	1	0.8
<i>P. rettgeri</i>	46	45.1	43	38.4	64	48.1	74	50.3	71	53.8
<i>P. rustigianii</i>	1	1.0	0	0.0	0	0.0	0	0.0	0	0.0
<i>P. stuartii</i>	45	44.1	64	57.1	60	45.1	67	45.6	56	42.4
<i>Providencia</i> spp., other named	4	3.9	0	0.0	0	0.0	0	0.0	0	0.0
<i>Providencia</i> spp., sp. not recorded	5	4.9	0	0.0	6	4.5	4	2.7	4	3.0
<i>Providencia</i> spp.	102	100	112	100	133	100	147	100	132	100

Age and sex distribution

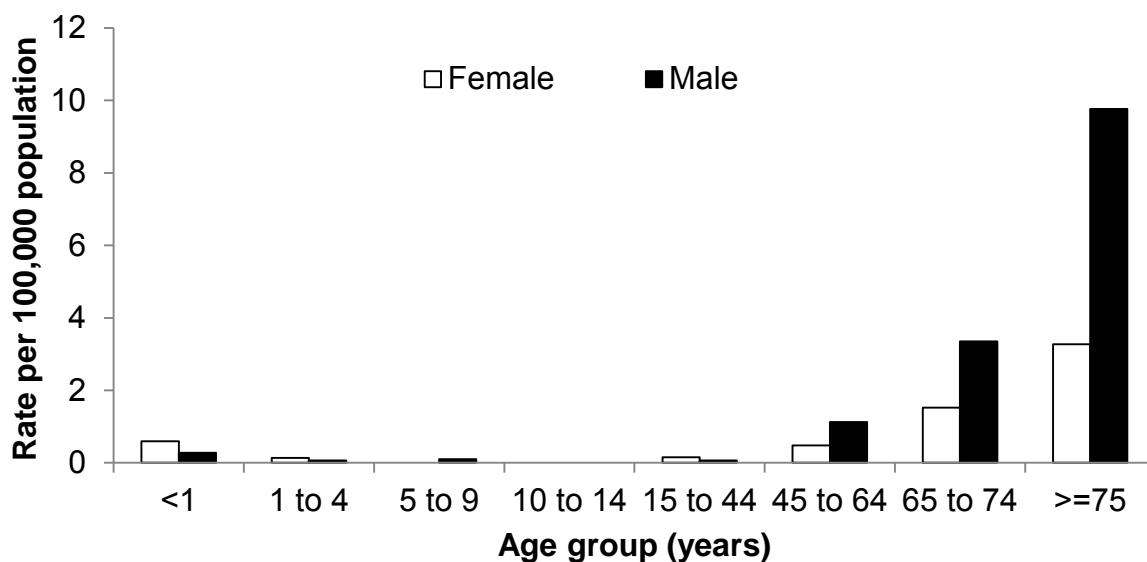
Distribution of *Proteus* spp. bacteraemia for England, Wales, and Northern Ireland by age and sex in 2018 can be seen in Figure 3a. The highest rate of *Proteus* spp. bacteraemia was observed in males aged 75 years or older (71.3 per 100,000 population) followed by females aged 75 years or older (22.8 per 100,000 population). Females had slightly higher rates of *Proteus* spp. bacteraemia than males in people under 45 years; these rates were 1.2 compared to 0.8 per 100,000 among those <1 year, and 0.9 compared to 0.5 per 100,000 among those between 15 and 44. This trend was reversed for those over 45 years, with higher rates observed in males. There were few cases reported among those 1 to 14 years old.

Figure 3a. *Proteus* spp. bacteraemia rates per 100,000 population by age and sex (England, Wales, Northern Ireland): 2018



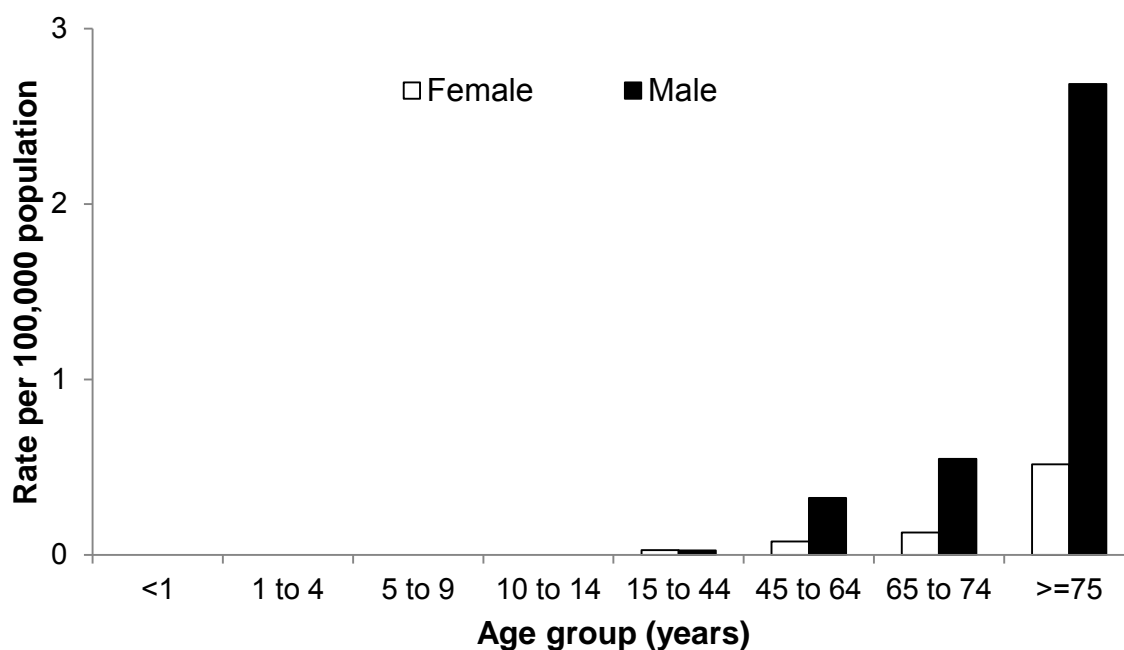
Distribution of *Morganella* spp. bacteraemia for England, Wales, and Northern Ireland by age and sex in 2018 can be seen in Figure 3b. The highest rate of *Morganella* spp. bacteraemia was observed in males 75 years or older (9.8 per 100,000 population), followed by males between 65 and 74 years old and females 75 years and older (3.3 per 100,000 population). Females had slightly higher rates of *Morganella* spp. bacteraemia than males under 45 years of age, with this trend reversing among those older than 45 years of age.

Figure 3b. *Morganella* spp. bacteraemia rates per 100,000 population by age and sex (England, Wales, Northern Ireland): 2018



Distribution of *Providencia* spp. bacteraemia for England, Wales, and Northern Ireland by age and sex for 2018 can be seen in Figure 3c. The highest rate of *Providencia* spp. bacteraemia was observed in males 75 years or older (2.7 per 100,000 population), followed by males between 65 and 74 years and females 75 years and older (0.5 per 100,000 population). There were no reported cases of *Providencia* spp. bacteraemia among those under 15 years of age. Bacteraemia rates were higher in males than in females, with the greatest gender-disparity in those aged 75 or older with a five-fold difference between males (2.7 per 100,000 population) and females (0.5 per 100,000 population).

Figure 3c. *Providencia* spp. bacteraemia rates per 100,000 population by age and sex. (England, Wales, Northern Ireland): 2018



Antimicrobial resistance: England and Northern Ireland

The percentage of *Proteus mirabilis* and *Proteus vulgaris* isolates with susceptibility test results reported in 2018 ranged from 67-100% and 7.5-100% for key antimicrobials (Table 3a and 3b), respectively. The percentage of resistant *P. mirabilis* bacteraemia isolates reported was ampicillin/amoxicillin (33%), gentamicin (10%), cefotaxime (2%), ceftazidime (1%), ciprofloxacin (6%), piperacillin/tazobactam (1%), tobramycin (7%), ertapenem (<1%), and meropenem (<1%) (Table 3a). The percentage of resistant *P. vulgaris* isolates reported was ampicillin/amoxicillin (93%), gentamicin (2%), cefotaxime (11%), ceftazidime (10%), ciprofloxacin (4%), piperacillin/tazobactam (0%), tobramycin (0%), ertapenem (1%), and meropenem (0%) (Table 3b). Single-agent antimicrobial resistance rates have remained stable for *P. mirabilis* since 2015. For *P. vulgaris* bacteraemia, increased resistance was observed against ceftazidime (2% to 10%), cefotaxime (2% to 11%), ertapenem (0% to 1%), and decreased resistance was observed against tobramycin (8% to 0%), gentamicin (6% to 2%), and ciprofloxacin (5% to 4%) since 2015. It should be noted that the number of *P. vulgaris* isolates tested for single-antimicrobial resistance each year is relatively small, hence the variation between years should be interpreted with caution.

The percentages of *Morganella morganii* isolates with susceptibility test results reported in 2018 ranged from 1.3-100% for key antimicrobials (Table 3c). The percentage of resistant *M. morganii* bacteraemia isolates reported was ampicillin/amoxicillin (99%), gentamicin (10%), cefotaxime (23%), ceftazidime (18%), ciprofloxacin (16%), piperacillin/tazobactam (6%), tobramycin (9%), ertapenem (<1%), and meropenem (<1%). Single-agent antimicrobial resistance rates have remained largely stable for most key antibiotics since 2015. Increased resistance was observed against piperacillin/tazobactam (3% to 6%), cefotaxime (16% to 23%), and tobramycin (5% to 9%). EUCAST report intrinsic resistance to ampicillin/amoxicillin in *M. morganii* (2)

The percentages of *Providencia stuartii* isolates with susceptibility test results reported in 2018 range from 8.3-98% for key antimicrobials (Table 3d). The percentage of resistant *P. stuartii* bacteraemia isolates reported was ampicillin/amoxicillin (92%), gentamicin (58%), cefotaxime (5%), ceftazidime (11%), ciprofloxacin (13%), piperacillin/tazobactam (4%), tobramycin (84%), ertapenem (2%), and meropenem (2%). For *P. stuartii* increases in antimicrobial resistance were observed for ciprofloxacin (8% to 13%), ceftazidime (4% to 11%), cefotaxime (3% to 5%), and

gentamicin (52% to 58%) since 2015. The high resistance seen with ampicillin/amoxicillin is expected due to possession of chromosomal β -lactamases in *P. stuartii* [2,3]. It should be noted that the number of *Providencia* spp. isolates tested for single-antimicrobial resistance each year is relatively small, hence the variation between years should be interpreted with caution.

Table 3a. Antimicrobial susceptibility* for *Proteus mirabilis* bacteraemia (England and Northern Ireland): 2015 to 2018

Antimicrobial agent	2015			2016			2017			2018		
	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)
Gentamicin	92.23	0.88	6.89	90.23	1.20	8.57	90.71	1.34	7.95	88.56	1.68	9.76
Ciprofloxacin	91.93	1.87	6.20	92.11	1.40	6.49	92.19	1.34	6.47	92.40	1.44	6.15
Ceftazidime	98.09	0.93	0.98	97.69	1.20	1.11	98.24	0.94	0.82	98.04	0.69	1.26
Cefotaxime	97.53	0.57	1.91	97.14	0.81	2.05	98.09	0.52	1.39	97.83	0.27	1.90
Meropenem	100.00	0.00	0.00	99.82	0.11	0.07	99.93	0.03	0.03	99.97	0.00	0.03
Ertapenem	99.57	0.38	0.05	99.70	0.09	0.21	99.92	0.00	0.08	99.81	0.07	0.11
Tobramycin	90.47	2.18	7.35	89.36	2.66	7.98	88.48	4.22	7.30	90.86	1.77	7.37
Ampicillin\Amoxicillin	66.18	0.09	33.73	66.57	0.04	33.40	67.14	0.00	32.86	66.66	0.00	33.34
Amikacin	98.42	1.10	0.48	97.82	1.51	0.67	96.80	2.51	0.69	98.38	1.39	0.24
Piperacillin\Tazobactam	98.27	0.95	0.78	97.88	1.04	1.08	97.05	1.69	1.26	97.84	0.82	1.34

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

Table 3b. Antimicrobial susceptibility* for *Proteus vulgaris* bacteraemia (England and Northern Ireland): 2015 to 2018

Antimicrobial agent	2015			2016			2017			2018		
	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)
Gentamicin	94.20	0.00	5.80	98.78	0.00	1.22	98.80	0.00	1.20	96.34	1.22	2.44
Ciprofloxacin	93.94	1.52	4.55	98.75	0.00	1.25	100.00	0.00	0.00	96.34	0.00	3.66
Ceftazidime	94.64	3.57	1.79	91.18	5.88	2.94	95.71	1.43	2.86	90.00	0.00	10.00
Cefotaxime	93.02	4.65	2.33	90.00	5.00	5.00	90.00	2.50	7.50	84.78	4.35	10.87
Meropenem	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00
Ertapenem	97.96	2.04	0.00	100.00	0.00	0.00	100.00	0.00	0.00	98.67	0.00	1.33
Tobramycin	87.50	4.17	8.33	97.22	2.78	0.00	96.88	3.13	0.00	100.00	0.00	0.00
Ampicillin\Amoxicillin	7.94	0.00	92.06	8.00	0.00	92.00	8.45	0.00	91.55	7.50	0.00	92.50
Amikacin	100.00	0.00	0.00	96.15	3.85	0.00	100.00	0.00	0.00	100.00	0.00	0.00
Piperacillin\Tazobactam	98.48	0.00	1.52	100.00	0.00	0.00	98.73	0.00	1.27	100.00	0.00	0.00

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

Table 3c. Antimicrobial susceptibility* for *Morganella morganii* bacteraemia (England and Northern Ireland): 2015 to 2018

Antimicrobial agent	2015			2016			2017			2018		
	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)
Gentamicin	90.26	0.26	9.49	89.03	0.42	10.55	86.90	1.41	11.69	88.23	1.37	10.41
Ciprofloxacin	85.25	2.68	12.06	83.84	4.31	11.85	82.25	5.85	11.90	82.14	2.21	15.65
Ceftazidime	77.09	6.19	16.72	82.56	2.31	15.13	76.42	2.85	20.73	78.77	2.97	18.26
Cefotaxime	78.41	5.29	16.30	84.13	2.78	13.10	78.99	1.56	19.46	75.37	2.05	22.58
Meropenem	100.00	0.00	0.00	99.56	0.22	0.22	99.79	0.21	0.00	99.83	0.00	0.17
Ertapenem	99.68	0.32	0.00	99.24	0.25	0.50	99.76	0.24	0.00	99.81	0.00	0.19
Tobramycin	94.08	0.66	5.26	88.17	1.78	10.06	83.00	3.50	13.50	88.32	2.55	9.12
Ampicillin\Amoxicillin	1.93	0.00	98.07	2.06	0.00	97.94	0.87	0.00	99.13	1.27	0.00	98.73
Amikacin	100.00	0.00	0.00	99.32	0.00	0.68	96.39	3.31	0.30	98.35	0.94	0.71
Piperacillin\Tazobactam	94.09	2.42	3.49	95.00	1.52	3.48	91.32	2.39	6.29	92.39	1.21	6.40

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

Table 3d. Antimicrobial susceptibility* for *Providencia stuartii* bacteraemia (England and Northern Ireland): 2015 to 2018

Antimicrobial agent	2015			2016			2017			2018		
	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)
Gentamicin	41.38	6.90	51.72	42.37	8.47	49.15	33.90	3.39	62.71	38.00	4.00	58.00
Ciprofloxacin	91.53	0.00	8.47	88.89	1.85	9.26	86.21	5.17	8.62	87.50	0.00	12.50
Ceftazidime	96.23	0.00	3.77	91.67	2.08	6.25	97.96	0.00	2.04	86.84	2.63	10.53
Cefotaxime	97.44	0.00	2.56	92.00	4.00	4.00	100.00	0.00	0.00	95.24	0.00	4.76
Meropenem	98.25	1.75	0.00	98.04	0.00	1.96	100.00	0.00	0.00	97.96	0.00	2.04
Ertapenem	95.65	0.00	4.35	95.24	0.00	4.76	98.00	2.00	0.00	97.67	0.00	2.33
Tobramycin	3.85	7.69	88.46	10.00	10.00	80.00	11.11	3.70	85.19	10.53	5.26	84.21
Ampicillin\Amoxicillin	1.85	0.00	98.15	9.62	0.00	90.38	7.27	0.00	92.73	8.33	0.00	91.67
Amikacin	97.87	0.00	2.13	94.12	0.00	5.88	100.00	0.00	0.00	94.59	0.00	5.41
Piperacillin\Tazobactam	96.55	0.00	3.45	98.25	0.00	1.75	96.08	1.96	1.96	96.00	0.00	4.00

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

Tables 4a-d show the multi-drug resistance of *Proteus mirabilis*, *Proteus vulgaris*, *Morganella* spp., and *Providencia stuartii* respectively to third-generation cephalosporins, gentamicin or ciprofloxacin. Multi-drug resistance is rare (<1%), with the exceptions of *Proteus mirabilis* and *Providencia stuartii* resistance for gentamicin and ciprofloxacin, and *Morganella* spp. resistance to combinations of gentamicin and ciprofloxacin, gentamicin and 3rd generation cephalosporins, and ciprofloxacin and 3rd generation cephalosporins.

Table 4a. Multi-drug antimicrobial resistance testing and resistance summary* for *Proteus mirabilis* bacteraemia (England): 2015 to 2018

Antimicrobial agent	2015		2016		2017		2018	
	No. Tested	R (%)	No. Tested	R (%)	No. Tested	R (%)	No. Tested	R (%)
Gentamicin and Ciprofloxacin	2217	2	2709	2	2930	2	2882	2
Gentamicin and 3rd Generation Cephalosporins*	2218	<1	2726	1	2962	1	2918	1
Gentamicin and Meropenem	2157	<1	2635	<1	2871	<1	2846	<1
Ciprofloxacin and 3rd Generation Cephalosporins*	2187	1	2694	1	2937	1	2924	1
Ciprofloxacin and Meropenem	2122	<1	2600	<1	2854	<1	2841	<1
3rd Generation Cephalosporins* and Meropenem	2143	<1	2643	<1	2920	<1	2917	<1

*Cefotaxime, Ceftazidime, Ceftriaxone, Cefpodoxime

Table 4b. Multi-drug antimicrobial resistance testing and resistance summary* for *Proteus vulgaris* bacteraemia (England): 2015 to 2018

Antimicrobial agent	2015		2016		2017		2018	
	No. Tested	R (%)	No. Tested	R (%)	No. Tested	R (%)	No. Tested	R (%)
Gentamicin and Ciprofloxacin	64	2	74	<1	78	<1	80	<1
Gentamicin and 3rd Generation Cephalosporins*	64	<1	75	<1	79	<1	78	1
Gentamicin and Meropenem	63	<1	72	<1	79	<1	79	<1
Ciprofloxacin and 3rd Generation Cephalosporins*	61	<1	73	<1	78	<1	79	<1
Ciprofloxacin and Meropenem	61	<1	70	<1	77	<1	78	<1
3rd Generation Cephalosporins* and Meropenem	62	<1	73	<1	78	<1	76	<1

*Cefotaxime, Ceftazidime, Ceftriaxone, Cefpodoxime

Table 4c. Multi-drug antimicrobial resistance testing and resistance summary* for *Morganella* spp. bacteraemia (England): 2015 to 2018

Antimicrobial agent	2015		2016		2017		2018	
	No. Tested	R (%)	No. Tested	R (%)	No. Tested	R (%)	No. Tested	R (%)
Gentamicin and Ciprofloxacin	366	5	448	7	462	6	546	8
Gentamicin and 3rd Generation Cephalosporins*	365	5	450	3	468	4	557	4
Gentamicin and Meropenem	370	<1	440	<1	455	<1	545	<1
Ciprofloxacin and 3rd Generation Cephalosporins*	358	6	443	4	459	5	558	5
Ciprofloxacin and Meropenem	363	<1	432	<1	443	<1	541	<1
3rd Generation Cephalosporins* and Meropenem	362	<1	435	<1	454	<1	562	<1

*Cefotaxime, Ceftazidime, Ceftriaxone, Cefpodoxime

Table 4d. Multi-drug antimicrobial resistance testing and resistance summary* for *Providencia stuartii* bacteraemia (England): 2015 to 2018

Antimicrobial agent	2015		2016		2017		2018	
	No. Tested	R (%)	No. Tested	R (%)	No. Tested	R (%)	No. Tested	R (%)
Gentamicin and Ciprofloxacin	57	7	52	4	56	7	44	9
Gentamicin and 3rd Generation Cephalosporins*	55	4	50	2	53	2	46	9
Gentamicin and Meropenem	55	<1	48	2	50	<1	46	<1
Ciprofloxacin and 3rd Generation Cephalosporins*	56	4	50	2	54	<1	43	7
Ciprofloxacin and Meropenem	56	<1	46	2	51	<1	43	<1
3rd Generation Cephalosporins* and Meropenem	55	<1	46	2	51	<1	46	<1

*Cefotaxime, Ceftazidime, Ceftriaxone, Cefpodoxime

For treatment or antibiotic-resistance advice of these opportunistic pathogens or reference services (species identification, molecular comparison, and confirmation of susceptibility testing results), laboratories may contact the Medical Microbiologists at PHE's Bacteriology Reference Department at Colindale on colindalemedmicro@phe.gov.uk and PHE's Antimicrobial Resistance and Healthcare Associated Infections (AMRHAI) Reference Unit in London [4].

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