Laboratory surveillance of paediatric bacterial bloodstream infections and antimicrobial resistance in England: 2018 to 2022

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Note: Throughout this report reference is made to numbered appendices. These refer to the data tables in the spreadsheet accompanying the report which are accessible from the same web page as the report. A full list of these data tables is given at the end of this report in section 7.

1. Introduction

This is the second edition of a series of health protection reports highlighting trends in laboratory-reported incidence and antimicrobial resistance (AMR) of bacterial bloodstream infections (BSI) in the paediatric population (0 to 17 year olds inclusive) in England. This report covers the years between 2018 and 2022. It should be viewed as supplementary to the English Surveillance Programme for Antimicrobial Utilisation and Resistance (ESPAUR) report 2022 to 2023 (1). Paediatric data is included in the main ESPAUR report, and further AMR data by age group is provided here.

This report is based upon ESPAUR methodology (1). Please note that the frequency of some organisms causing BSIs in children is very low, which can limit resistance trend interpretation. For this reason, resistance rates for certain antimicrobial and organism combinations are not graphically displayed where the number of infection episodes was below 20 for that age group and year. Data reference tables featuring the BSI rates and susceptibility data behind the findings in this report can all be found in the data tables spreadsheet accompanying this report.

In the AMR BSI section, frequently reported BSI-causing organisms (see appendices 11 to 15 in the accompanying data tables) for each age group were used to report AMR rates for specified antimicrobials (defined for each organism in Table 3 of the Methods section). While AMR for coagulase-negative staphylococci (CoNS) and *Micrococcus* spp. are reported for infants (up to 3 months old), this is not reported for older children as reports are less likely to be clinically relevant. However, CoNS and *Micrococcus* spp. remain the most frequently reported organisms detected from blood samples across all age groups and are therefore included in the BSI rates (see Caveats section).

The age groups used in the rates of laboratory-reported BSI rates and antimicrobial susceptibility trends differ slightly due to incidence, and therefore susceptibility testing numbers are low for some age groups (outlined in Table 2 of the Methods section).

This report was originally published in December 2023 but was updated in November 2024 to address data quality issues identified after publication. These issues predominately impacted the number and rate of BSIs, which have been rectified in this version of the report. Re-classification of *Streptococcus* spp. and some minor changes to antibiotic groupings have led to small changes in resistance rates but these have not impacted overall trends.

2. Main points

2.1 Bloodstream infection rates

Main results were that:

- bloodstream infection (BSI) reports in all paediatric age groups in England increased between 2018 (n=13,851) and 2022 (n=17,267), with a 23.3% increase in the overall rate (0 to 17 year olds; rate 117.8 to 145.3 per 100,000 population between 2018 and 2022), mainly driven by increases in reports of CoNS and *Micrococcus* spp. (34.9% combined increase), oral and other streptococci (16.4% increase), Group A *Streptococcus* (GAS; 60.0% increase), *Bacillus* spp. (47.9% increase), and *Klebsiella pneumoniae* (56.7% increase); all increasing by over 100 reported BSIs from 2018 to 2022.
- the increase in CoNS and *Micrococcus* spp. occurred predominantly in age groups outside of infancy (≥1 year olds) where reports are less likely to be clinically relevant
- there was a decrease in BSI counts and rates in almost all age groups in 2020, likely due to the impact of non-pharmaceutical interventions and disruptions to elective healthcare during the COVID-19 pandemic; this decrease did not occur in 0 to 3 day old neonates
- the rate of BSI was highest in under 1 year olds (1,263.6 per 100,000 population in 2022), followed by 1 to 4 year olds (193.8 per 100,000 population in 2022)
- the rate of BSI increase between 2018 and 2022 was highest in 1 to 4 years old (40.2%), followed by 5 to 17 years old (32.2%)

2.2 Antimicrobial resistance

Main results were that:

- group B streptococci (GBS) bacteraemia strains diagnosed in infants up to 3 months old remain highly susceptible to the first-line treatment, penicillin
- data from neonates 0 to 3 days old indicated an increase in GBS resistance to clindamycin from 23.0% (n=56 per 244 tested) in 2018 to 32.9% (n=53 per 161 tested) in 2022 and macrolides from 28.1% (n=89 per 317 tested) in 2018 to 40.7% (n=83 per 204 tested)
- between 2018 to 2022, GAS was universally susceptible to penicillin and resistance to specified antibiotics (clindamycin, macrolides and glycopeptides) remained low (<7%) in children over 3 months old
- *Enterococcus faecalis* ampicillin/amoxicillin, glycopeptides, and linezolid resistances were low (<5%) across all age groups
- meticillin-resistant *Staphylococcus aureus* (MRSA) comprised ≤10% of *S. aureus* BSI isolates in all age groups

- among meticillin-sensitive *S. aureus* (MSSA) isolates in 3 month to 4 year old children, resistance to macrolides and clindamycin increased from 17.1% (n=36 per 210 tested) in 2018 to 23.9% (n=54 per 226 tested) in 2022 and from 9.9% (n=17 per 171 tested) in 2018 to 20.6% (n=40 per 194 tested) in 2022, respectively
- *Streptococcus pneumoniae* resistance to penicillin remained low (<3%) throughout the period in 3-months to 4 years old children, except in 2021 (6.4%)
- *Escherichia coli* BSI resistance to co-amoxiclav remained high across all age groups, ranging from 28.3% to 46.6% over the 2018 to 2022 period, while resistance to third-generation cephalosporins, ciprofloxacin, and gentamicin ranged from 7.0% to 21.1%, 4.5% to 20.8%, and 5.4% to 16.7%, respectively, and resistance to piperacillin with tazobactam at less than 15% and amikacin less than 5%
- *E. coli* meropenem resistance was low (peaking at 1.1%) in all paediatric age groups between 2018 and 2022
- in 3 months to 4 years old children, there were concerning patterns of *K. pneumoniae* resistance to multiple antibiotics, peaking in 2021 to 2022: piperacillin with tazobactam (31.7% in 2022), third-generation cephalosporins (38.8% in 2021), gentamicin (19.6% in 2021), and ciprofloxacin (31.5% in 2022)
- *Listeria* sp. BSI were rare in children older than one month, and no amoxicillin resistance was reported in *Listeria* sp. isolates

2.3 Caveats

Please note the following caveats for this report:

- the overall frequency of BSI in the paediatric population was low; caution should therefore be taken when interpreting resistance rates due to small sample sizes and resistance rates are not reported where the number tested was <20 samples
- the COVID-19 pandemic affected the general case-mix of hospital patients during much of 2020 and 2021, this has likely impacted trends for the 5-year period
- clinical data is not captured in the UKHSA laboratory reporting surveillance system used in this report, and thus clinical significance of blood culture isolates cannot be determined
- locally performed antibiotic susceptibility results, reported here, have not been confirmed by UKHSA's national reference laboratory

3. Results

3.1 Incidence of bloodstream infections

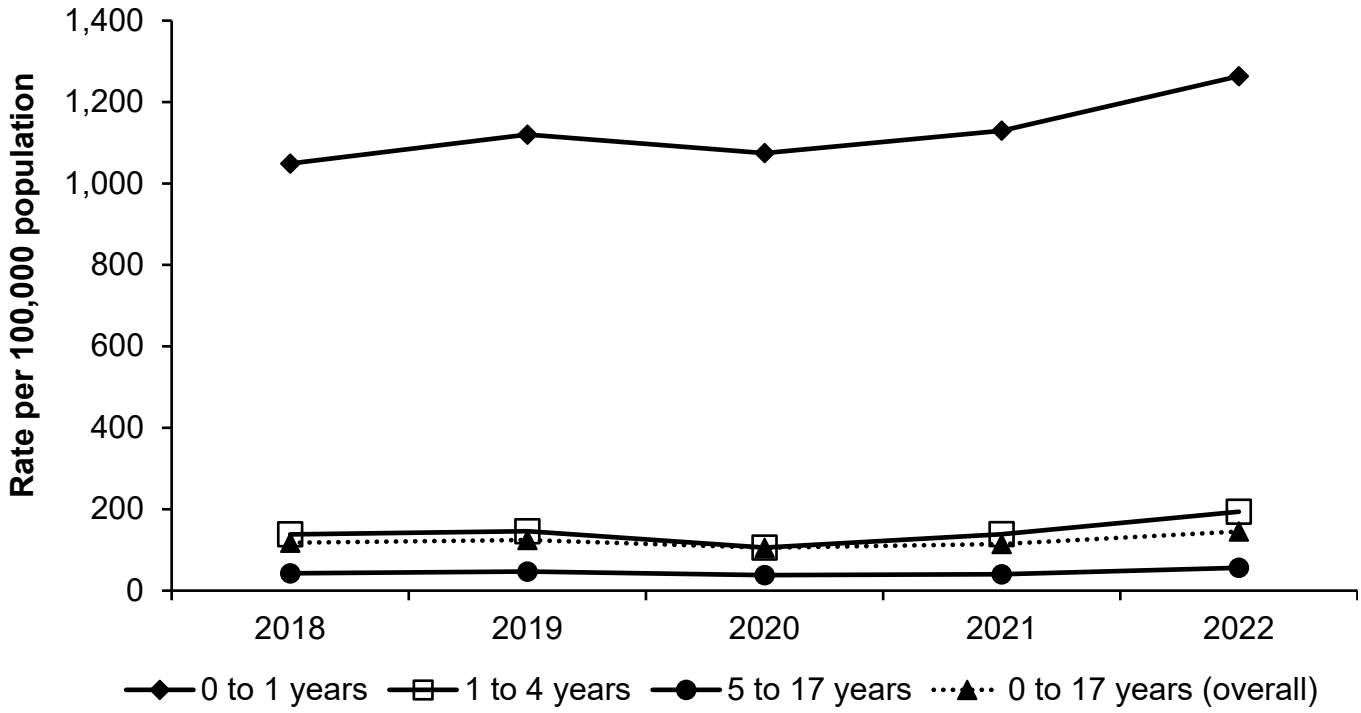
Overall rates of bloodstream infections (BSIs) in England increased between 2018 and 2022 for all paediatric age groups (Figure 1 and Appendix 1 of the accompanying data tables), from 117.8 to 145.3 overall per 100,000 population (an increase of 23.3%). This represents a total of 17,267 bacterial BSIs in children aged 0 to 17 years old in 2022. The increase occurred predominantly in coagulase-negative *Staphylococcus* (CoNS) and *Micrococcus* spp. when broken down by organism. There was a 34.9% combined increase in reports of CoNS and *Micrococcus* spp. between 2018 and 2022, particularly in the older age groups (≥1 year old). In individuals without an indwelling intravascular catheter, recovery of CoNS and *Micrococcus* spp. most frequently represents blood culture contamination, as opposed to a clinically relevant infection. Compared to infants (<1 year old), children and young people with a BSI are less likely to have an indwelling intravascular catheter, and therefore blood culture results with these 2 organisms in 1 to 17 year olds are less likely to represent clinically relevant infections. There was also an increase in reported Group A *Streptococcus* (GAS; 60.0% increase), corresponding with a national surge of GAS infection in 2022, *Enterococcus faecium* (75.3% increase) and *Klebsiella pneumoniae* (56.7% increase), between 2018 and 2022. Other organisms such as oral and other streptococci (16.4% increase (*Streptococcus* spp. in groups S*. anginosus, S. bovis, S. mitis, S. mutans, S. salivarius,* and *S. sanguinis*) and *Bacillus* spp. (47.9% increase) rose from 2018 to 2022, contributing to the overall increasing rate of paediatric BSIs. A breakdown of the most commonly isolated organisms is provided in appendices 11 to 16 of the accompanying data tables and provides the structure for resistance rates described below.

BSI rates were higher each year in infants aged under 1 years old than other paediatric age groups; the rate increased from 1,049.0 to 1,263.6 per 100,000 population (an increase of 20.5%) between 2018 and 2022. Large increases in the BSI rate occurred for children aged 1 to 4 years old (40.2% increase; 138.2 to 193.8 per 100,000 population) and 5 to 17 year olds (32.2% increase, 42.4 to 56.1 per 100,000 population). The BSI rate decreased in 2020 compared to 2018 across most age groups, before subsequently surpassing 2018 rates in 2022 (Figure 1 and Appendix 1 of the accompanying data tables). In <1 year olds in 2022, half of the BSI episodes occurred in infants that were older than one month (n=3,785), and half in infants younger than one month (with 19.7% occurring in 0 to 3 day olds, n=1,483, and 30.1% in 4 day to 1 month olds, n=2,268). The number of BSI episodes remained relatively stable from 2018 to 2022 in 0 to 3 day olds (n=1,537 to 1,483) however rose by 13.9% in the 4 day to 1 month olds (n=1,991 to n=2,268) and rose by 22.5% in 1 month to <1 year olds (n=3,089 to 3,785) (see Appendix 1).

The 5 most commonly isolated organisms by age group in 2022 were:

- 0 to 3 days old: CoNS and *Micrococcus* spp. (n=708), Group B Streptococcus (GBS; n=219), *Escherichia coli* (n=107), oral and other streptococci (n=90) and *Staphylococcus aureus* (n=33) (Appendix 12 of the accompanying data tables)
- 4 days to <1 months old: CoNS and *Micrococcus* spp. (n=1,276), *E. coli* (n=167), *S. aureus* (n=114), oral and other streptococci (n=107) and GBS (n=87) (Appendix 13)
- 1 month to <1 year old: CoNS and *Micrococcus* spp. (n=1,760), *E. coli* (n=312), oral and other streptococci (n=289), *S. aureus* (n=180) and *Enterococcus faecalis* (n=122) (Appendix 14)
- 1 to 4 years old: CoNS and *Micrococcus* spp. (n=2,077), oral and other streptococci (n=498), GAS (n=263), *S. aureus* (n=200), and *Streptococcus pneumoniae* (n=188) (Appendix 15)
- 5 to 17 years old: CoNS and *Micrococcus* spp. (n=2,110), *S. aureus* (n=366), oral and other streptococci (n=317), GAS (n=205) and *E. coli* (n=193) (Appendix 16)

Figure 1. Figure 1. BSI rates per 100,000 paediatric population for each paediatric age group (aged 0 to 17 years) in England: 2018 to 2022



3.2 Antimicrobial resistance of bloodstream infections

3.2.1 Neonates (0 to 3 day olds)

3.2.1.1 Gram-positive bloodstream infections

E. faecalis resistance to the specified antibiotics (ampicillin/amoxicillin, glycopeptides, and linezolid) was low (<5%) over the 2018 to 2022 period (Figure 2a and Appendix 2).

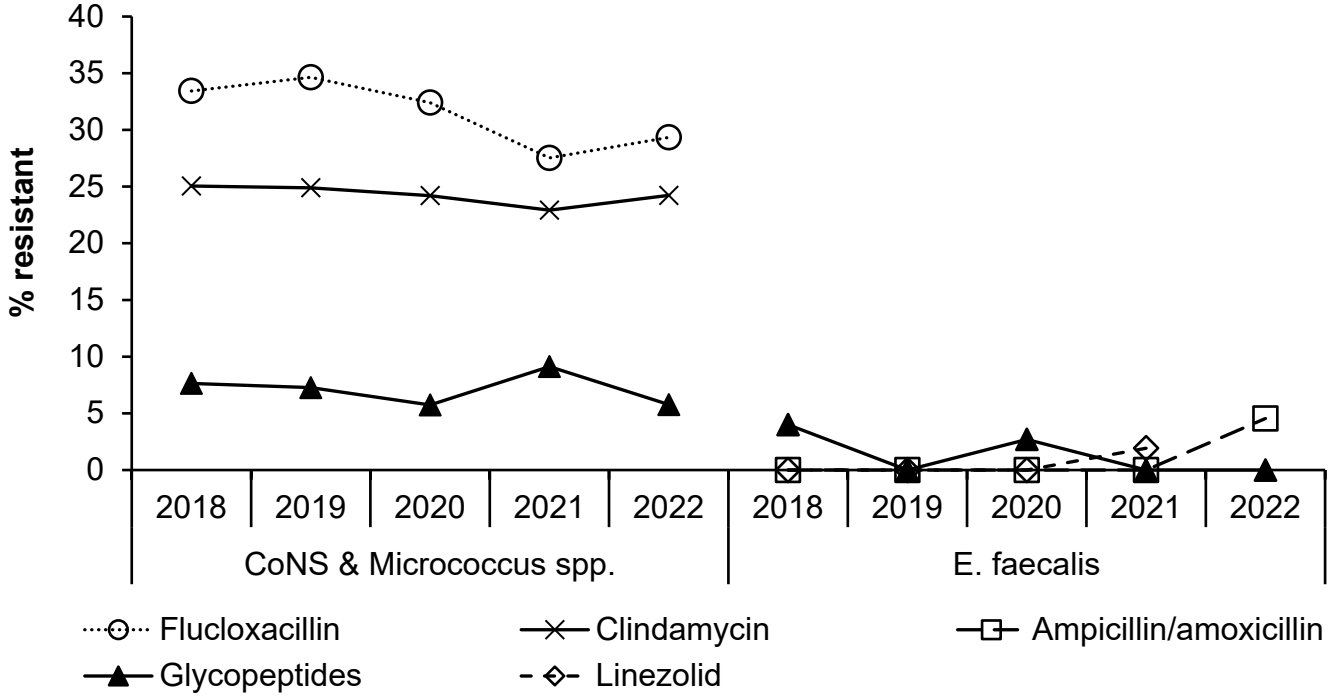
Small numbers of *S. aureus* BSI were reported (an average of 34 episodes annually from 2018 to 2022); resistance to meticillin (meticillin-resistant *S. aureus*, MRSA) remained low and stable between 2018 (6.7%, n=2 per 30 tested) and 2022 (6.1%, n=2 per 33 tested) (Figure 2b and Appendix 2 of the accompanying data tables). Low numbers of meticillin-susceptible *S. aureus* (MSSA) BSIs were reported, however a third (33.3%, n=11 per 33 tested) of MSSA BSI isolates were resistant to macrolides in 2022, in comparison to 10.7% (n=3 per 28 tested) in 2018, which differs to the wider population in England where MSSA resistance to macrolides remained stable over the same period (17.0% to 20.0% in 2022) (1). In MSSA reports, resistance to all other commonly used antibiotics (glycopeptides, clindamycin, co-trimoxazole, mupirocin and fusidic acid) remained below 16% (Figure 2b, Appendix 2). Mupirocin or glycopeptide resistance was not detected in MSSA isolates reported between 2018 and 2022. Further interpretation of resistance amongst MRSA isolates was not evaluated due to the low (≤3) annual number of isolates.

GBS remained susceptible to the first-line treatment, penicillin. Resistance to clindamycin and macrolides increased between 2018 and 2022 (Figure 2c and Appendix 2). Clindamycin resistance increased from 23.0% (n=56 per 244 tested) in 2018 to 32.9% (n=53 per 161 tested) in 2022. Macrolide resistance increased from 28.1% (n=89 per 317 tested) in 2018 to 40.7% (n=83 per 204 tested) in 2022.

Oral and other streptococci resistance to macrolides was 45.6% (n=26 per 57 tested) in 2018 and 58.3% (n=14 per 24 tested) in 2022. Clindamycin resistance was 4.8% (n=4 per 83 tested) in 2018 and 25.5% (n=13 per 51 tested) in 2022. Resistance to penicillin was <10%, with 6.5% resistance to penicillin in 2022 (n=4 per 62 tested). There was one isolate reported resistant to teicoplanin between 2018 and 2022 (Figure 2c and Appendix 2).

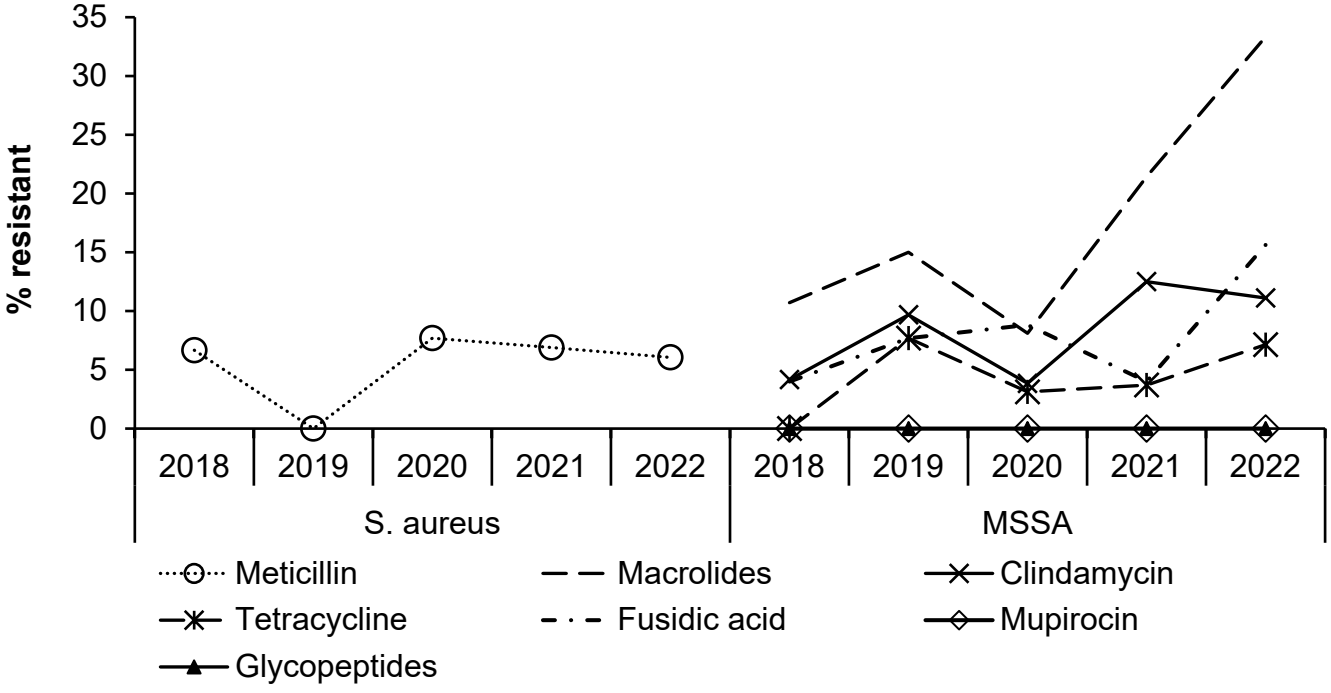
Figure 2. AMR of Gram-positive BSI for children aged 0 to 3 days in England, 2018 to 2022 for: (a) CoNS and *Micrococcus* spp. and *E. faecalis* (b) *S. aureus* (all) and MSSA (c) GBS and oral and other streptococci

2a. AMR of Gram-positive BSI for children aged 0 to 3 days in England, 2018 to 2022 for CoNS and *Micrococcus* spp. and *E. faecalis* [note 1]



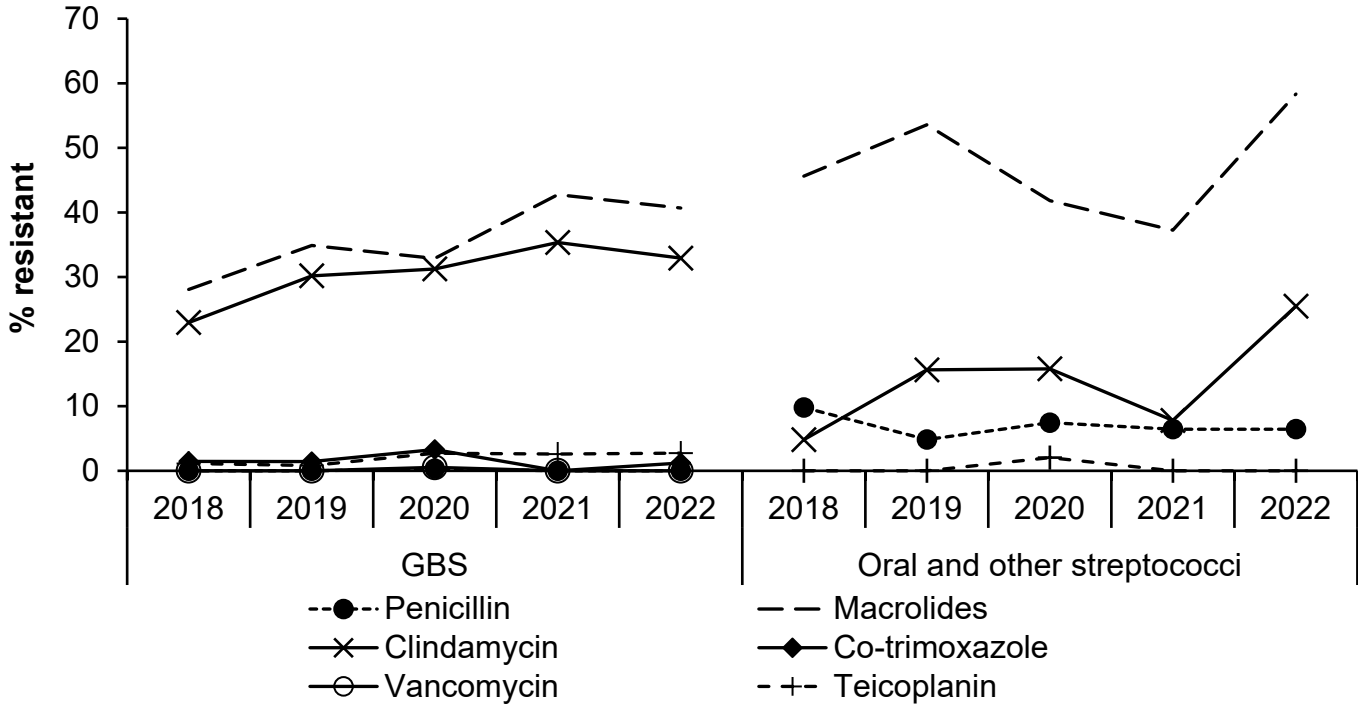
Note 1: Resistance not displayed for *E. faecalis* for linezolid in 2022 due to low (<20) numbers of reported BSIs tested for resistance.

2b. AMR of Gram-positive BSI for children aged 0 to 3 days in England, 2018 to 2022 for *S. aureus* (all) and MSSA [note 2]



Note 2: Resistance not displayed for MRSA due to low (<20) numbers of reported BSIs, and for MSSA (co-trimoxazole, 2018 to 2022)), due to low (<20) numbers of reported BSIs tested for resistance.

2c. AMR of Gram-positive BSI for children aged 0 to 3 days in England, 2018 to 2022 for GBS and oral and other streptococci [note 3]



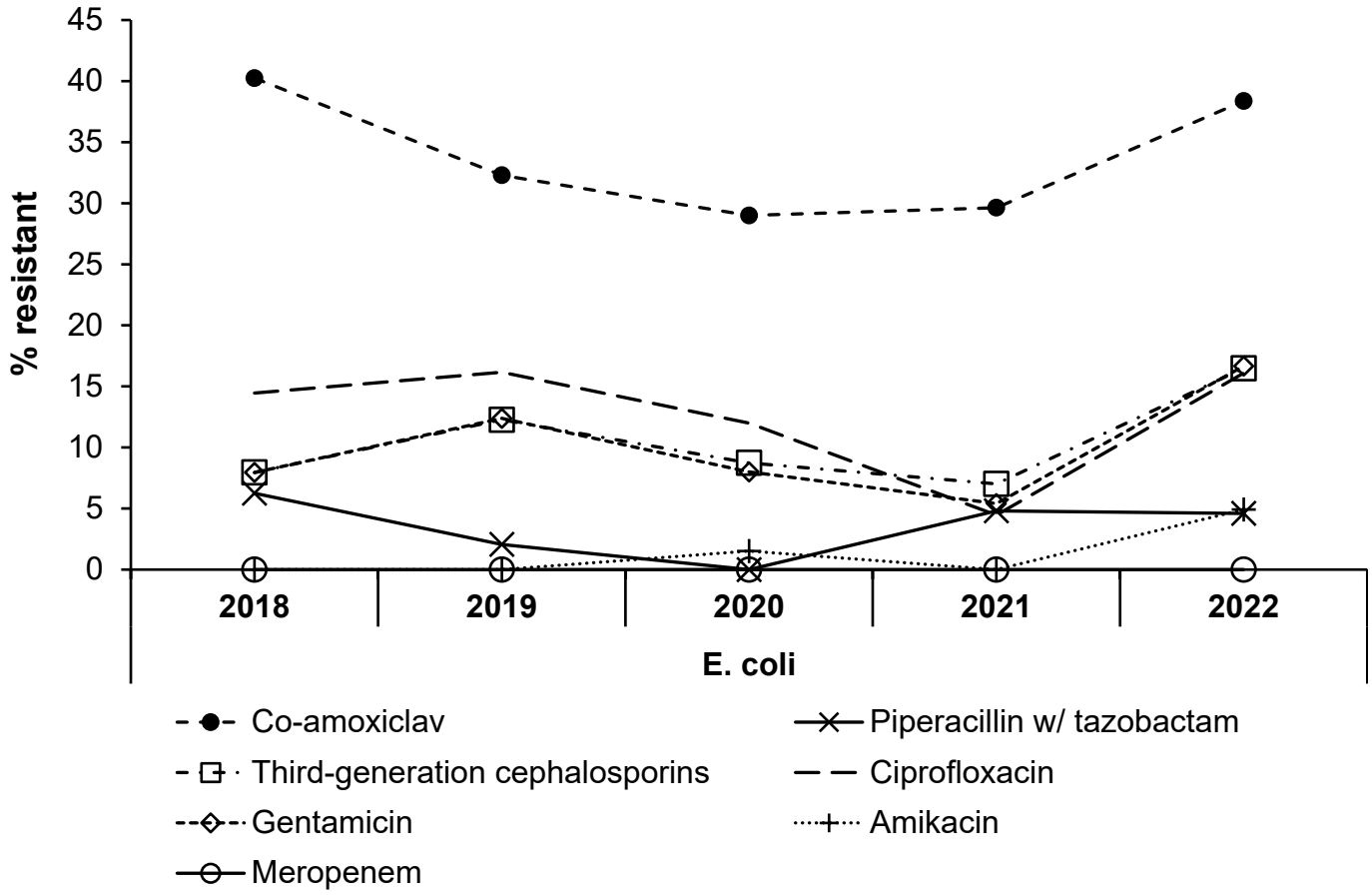
Note 3: Resistance to co-trimoxazole not displayed for oral and other streptococci due to low (<20) numbers of reported BSIs tested for resistance.

3.2.1.2 Gram-negative bloodstream infections

E. coli resistance to co-amoxiclav was 40.2% (n=33 per 82 tested) in 2018 and 38.4% (n=33 per 86 tested) in 2022. *E. coli* resistance to third-generation cephalosporins was 8.0% (n=7 per 88 tested) in 2018 and 16.5% (n=15 per 91 tested) in 2022 (Figure 3 and Appendix 3). Resistance to piperacillin with tazobactam was low (<7%) and stable over the period.

Ciprofloxacin resistance was stable over the period, with reported resistance at 14.5% (n=12 per 83 tested) in 2018 and 16.1% (n=14 per 87 tested) in 2022. Gentamicin resistance was 8.0% (n=7 per 88 tested) in 2018 and 16.7% (n=15 per 90 tested) in 2022. Amikacin resistance remained stable and low (<5%) over the 2018 to 2022 period. Meropenem resistance was not detected in this age group between 2018 and 2022.

Figure 3. AMR of Gram-negative BSI for children aged 0 to 3 days in England, 2018 to 2022 for *E. coli*



3.2.2 Neonates and infants (4 days to 3 months old)

3.2.2.1 Gram-positive bloodstream infections

E. faecalis resistance has remained stable and low (<4%) over the 2018 to 2022 period for all specified antibiotics (ampicillin/amoxicillin, linezolid, and glycopeptides) (Figure 4a and Appendix 4 of the accompanying data tables).

CoNS and *Micrococcus* spp. resistance to flucloxacillin remained high and stable between 2018 (71.7%, n=1,169 per 1,631 tested) and 2022 (68.4%, n=1,174 per 1,717 tested) (Figure 4a and Appendix 4). Glycopeptide resistance decreased between 2018 (23.4%, n=262 per 1,118 tested) and 2022 (17.1%, n=195 per 1,139 tested). There was an increase in clindamycin resistance, from 33.1% in 2018 (n=423 per 1,278 tested) to 38.7% (n=569 per 1,470 tested).

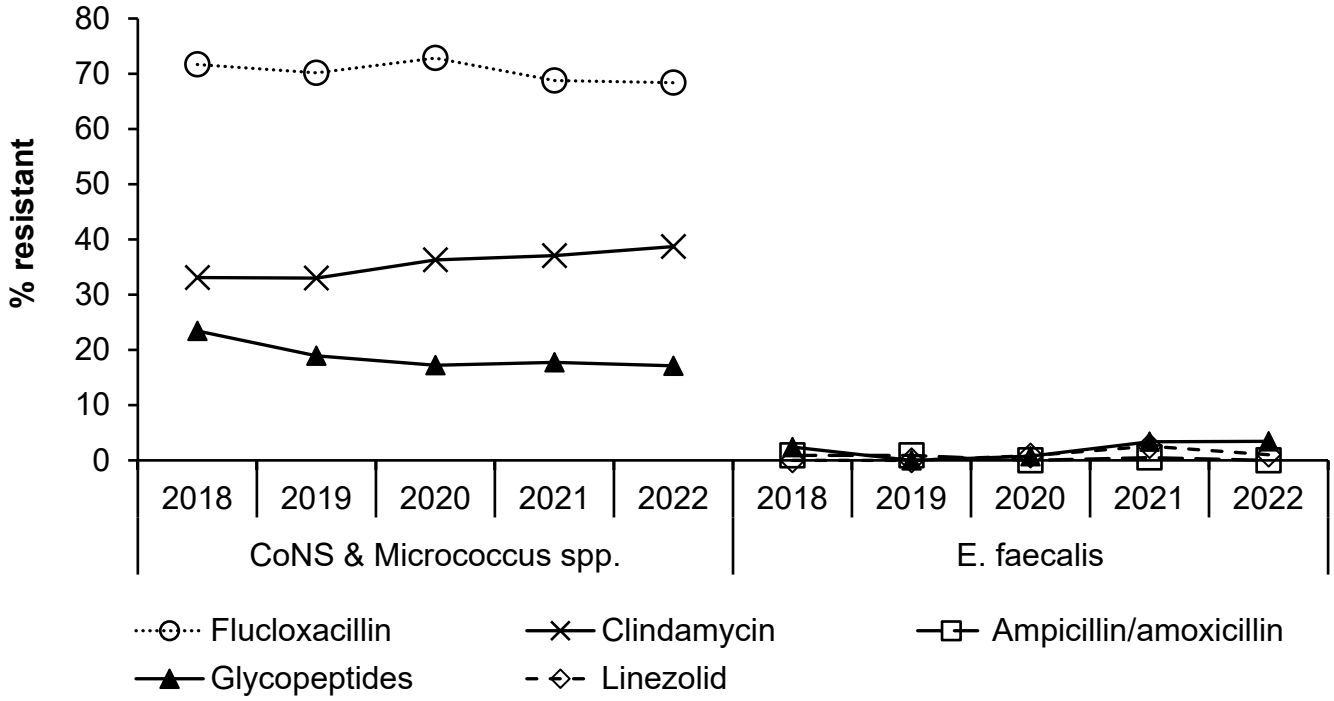
GBS remained universally susceptible to the first-line treatment, penicillin, and vancomycin (with zero resistant isolates reported between 2018 and 2022) (Figure 4c and Appendix 4). Clindamycin and macrolide resistances increased between 2018 and 2022; from 33.5% (n=54 per 161 tested) in 2018 to 37.5% (n=42 per 112 tested) in 2022 for clindamycin, and between 38.0% (n=73 per 192 tested) in 2018 to 42.9% (n=63 per 147 tested) in 2022 for macrolides.

In BSIs detected in neonates and infants aged 4 days to 3 months old, *S. aureus* resistance to meticillin (MRSA) increased from 2.1% (n=4 per 190 tested) in 2018 to 7.0% (n=14 per 201 tested) in 2020 before decreasing to 5.6% (n=11 per 196 tested) in 2022 (Figure 4b and Appendix 4). MSSA resistance to macrolides and clindamycin increased over the 2018 to 2022 period; from 10.5% (n=19 per 181 tested) in 2018 to 18.7% (n=35 per 187 tested) in 2022 for macrolides, and from 8.7% (n=13 per 150 tested) in 2018 to 17.0% (n=27 per 159 tested) in 2022 for clindamycin. In reports of MSSA, resistance to glycopeptides, co-trimoxazole, tetracycline, and mupirocin was low (<5%) over the period. Resistance to fusidic acid remained stable between 2018 and 2022 (7.8%, n=13 per 166 tested in 2018 and 9.1%, n=16 per 176 tested in 2022). Further interpretation of resistance amongst MRSA isolates was not evaluated due to the low (≤20) annual number of isolates.

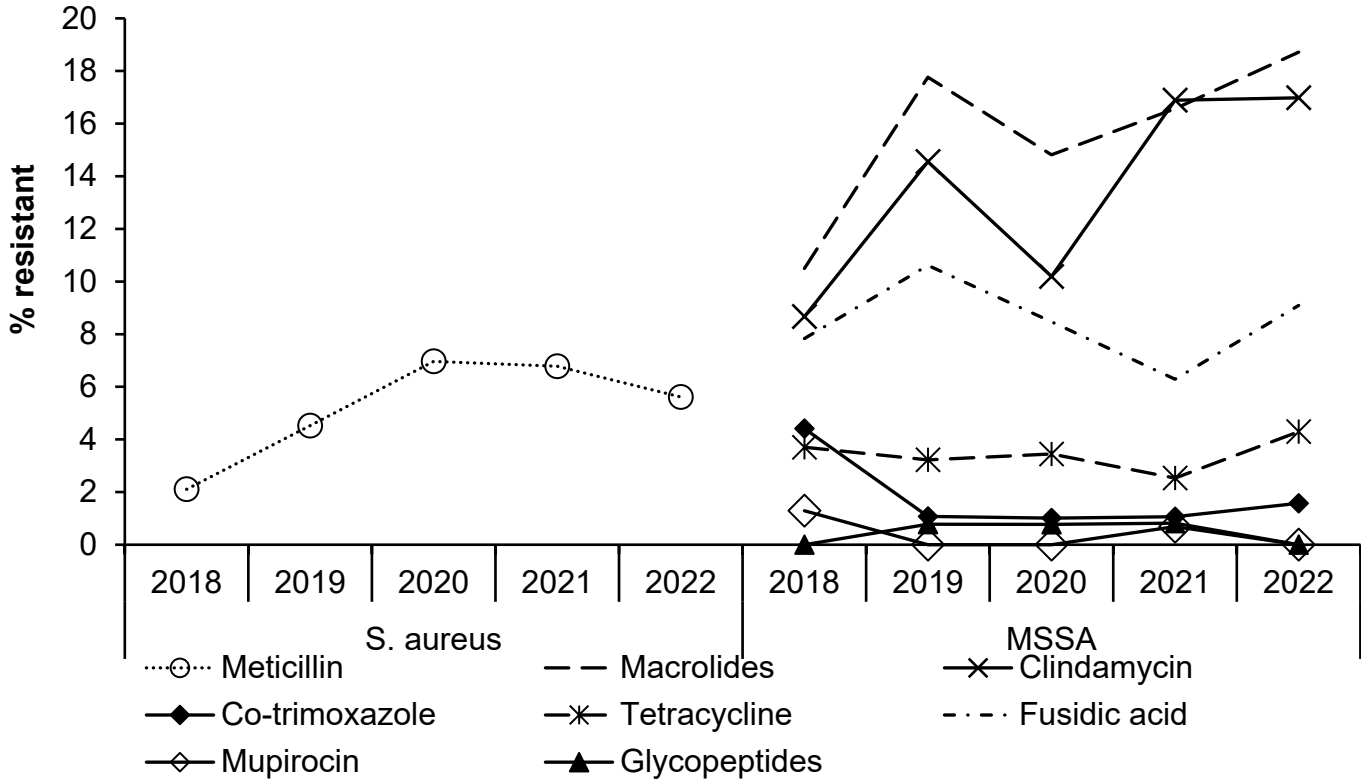
Oral and other streptococci resistance to penicillin decreased from 19.1% (n=31 per 162 tested) in 2018 to 10.4% (n=17 per 163 tested) in 2022 (Figure 4c and Appendix 4). Resistance to macrolides was high but remained stable between 2018 and 2022 (51.0%, n=52 per 102 tested in 2018 and 51.9%, n=40 per 77 tested in 2022). Resistance to clindamycin was also stable at 9.2% (n=11 per 119 tested) in 2018 and 9.7% (n=12 per 124 tested) in 2022. Oral and other streptococci resistance to teicoplanin has remained stable and low (<4%) over 2018 to 2022. There were low annual numbers (≤20) of oral and other streptococci tested for co-trimoxazole resistance.

Figure 4. AMR of Gram-positive BSI for children aged 4 days to 3 months in England, 2018 to 2022 for: (a) CoNS and *Micrococcus* spp. and *E. faecalis* (b) *S. aureus* (all) and MSSA (c) GBS and oral and other streptococci

4a. AMR of Gram-positive BSI for children aged 4 days to 3 months in England, 2018 to 2022 for CoNS and *Micrococcus* spp. and *E. faecalis*

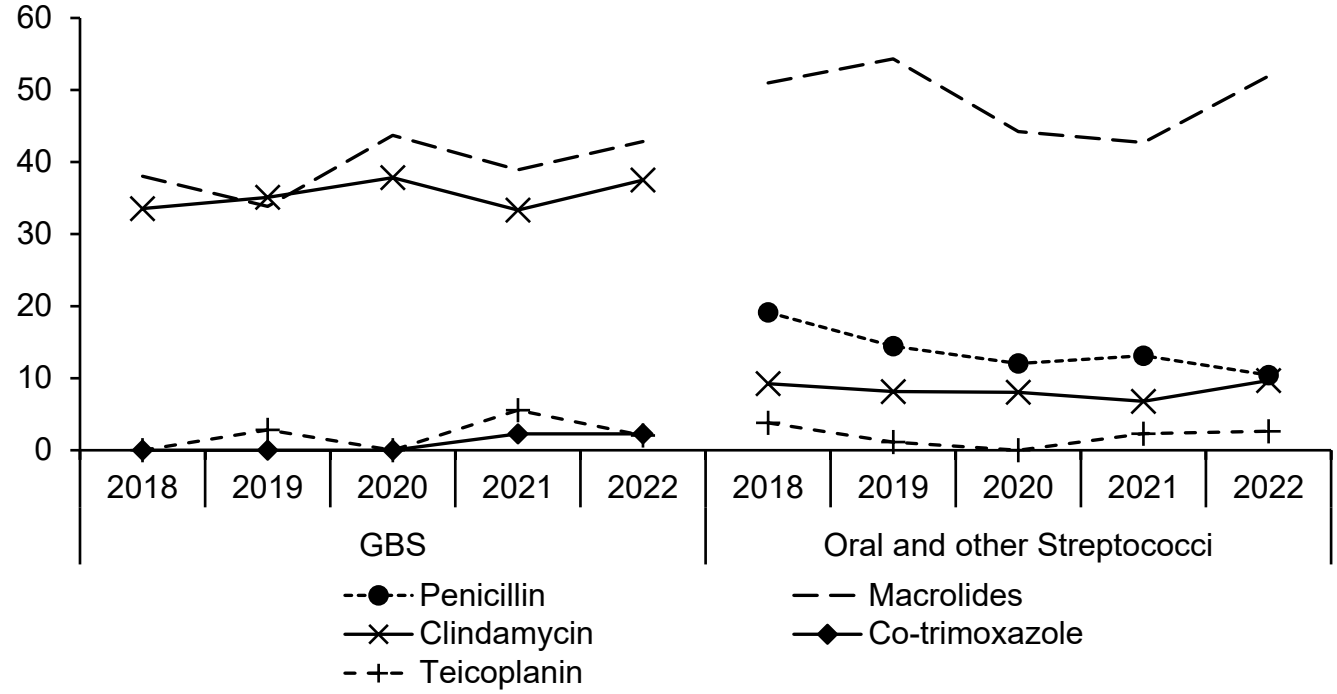


4b. AMR of Gram-positive BSI for children aged 4 days to 3 months in England, 2018 to 2022 for *S. aureus* (all) and MSSA [note 1]



Note 1: Resistance not displayed for MRSA due to low (<20) numbers of reported BSIs.

4c. AMR of Gram-positive BSI for children aged 4 days to 3 months in England, 2018 to 2022 for GBS and oral and other streptococci [note 2]



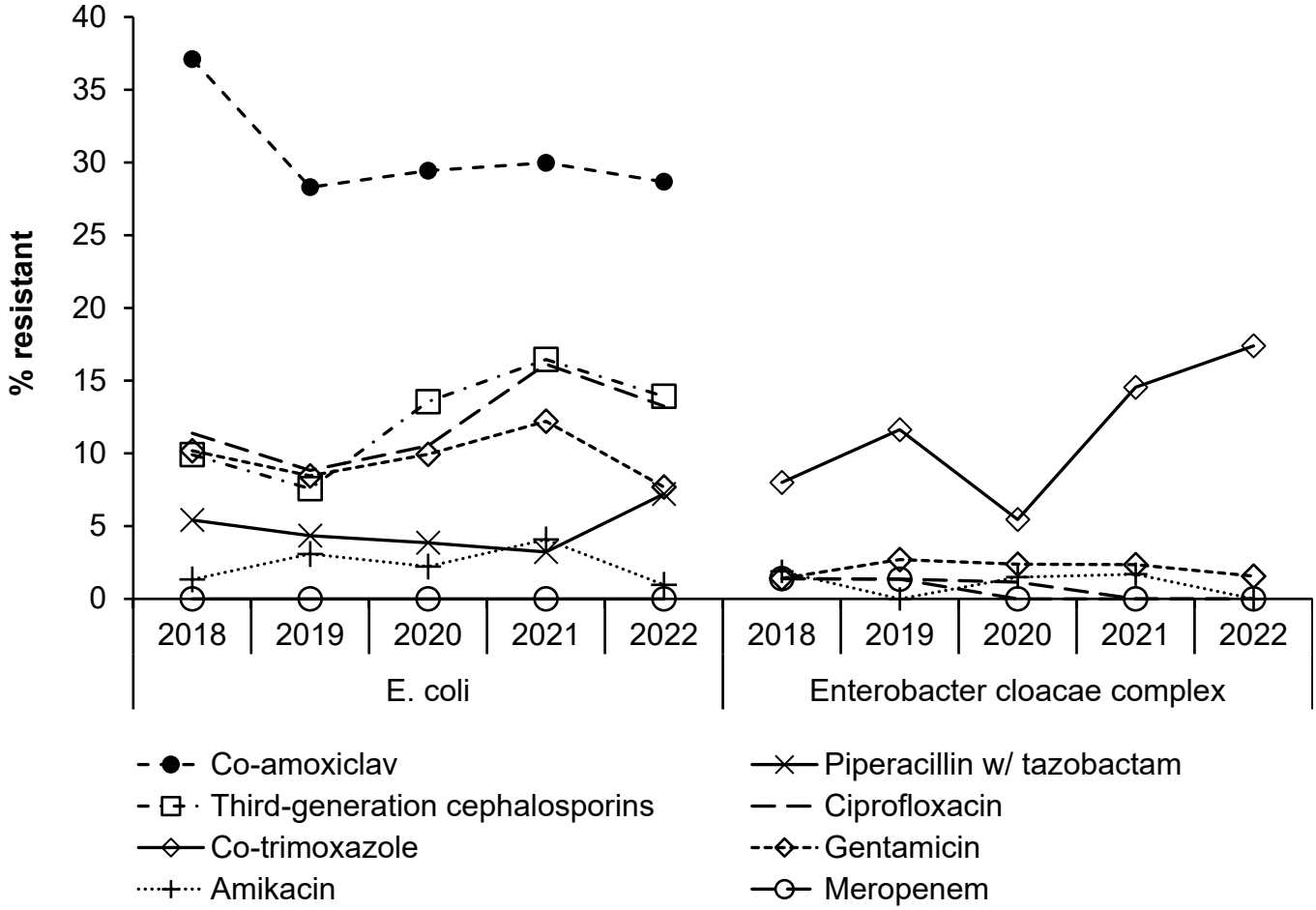
Note 2: Resistance not displayed for oral and other streptococci (co-trimoxazole) due to low (<20) numbers of reported BSIs tested for resistance.

3.2.2.2 Gram-negative bloodstream infections

E. coli resistance to co-amoxiclav ranged between 37.1% in 2018 (n=115 per 310 tested) to 28.7% in 2022 (n=84 per 293 tested). Resistance to third-generation cephalosporins has increased over the 5-year period, from 9.9% (n=33 per 333 tested) in 2018 to 13.9% (n=44 per 316 tested) (Figure 5 and Appendix 5 of the accompanying data tables). Resistance to piperacillin with tazobactam remained below 10% (7.2%, n=21 per 291 tested in 2023). Resistance to gentamicin ranged between a low of 7.7% (n=24 per 312 tested) in 2022 and a high of 12.2% (n=47 per 385 tested) in 2021, and resistance to amikacin remained low (<5%) with 1.0% resistance in 2022 (n=2 per 206 tested). Meropenem resistance was not detected in *E. coli* between 2018 and 2022.

Enterobacter cloacae complex resistance to ciprofloxacin, gentamicin, amikacin, and meropenem remained stable and low (<3%) between 2018 and 2022 (Figure 5 and Appendix 5). Resistance to co-trimoxazole increased from 8.0% (n=4 per 50 tested) in 2018 to 17.4% (n=8 per 46 tested) in 2022.

Figure 5. AMR of Gram-negative BSI for children aged 4 days to 3 months in England, 2018 to 2022 for *E. coli* and *Enterobacter cloacae* complex



3.2.3 Infants and children (3 months to 4 years)

3.2.3.1 Gram-positive bloodstream infections

In infants and children aged 3 months to 4 years old, there was a low prevalence of resistance in *E. faecalis* to ampicillin/amoxicillin, glycopeptides, and linezolid (<5%) (Figure 6a and Appendix 6 of the accompanying data tables). *E. faecium* resistance to ampicillin/amoxicillin was common throughout the period at 90.6% (n=48 per 53 tested) in 2018 and 81.8% (n=54 per 66 tested) in 2022 (Figure 6a and Appendix 6). Resistance to vancomycin and teicoplanin ranged from a minimum of 9.0% (n=6 per 62 tested) and 9.4% (n=6 per 64 tested) in 2019 to a maximum of 25.9% (n=15 per 58 tested) and 28.6% (n=14 per 49 tested) in 2018, with resistance 16.2% (n=12 per 74 tested) and 16.7% (n=12 per 72 tested) in 2022, respectively. Resistance to linezolid was low (<5%) throughout the period.

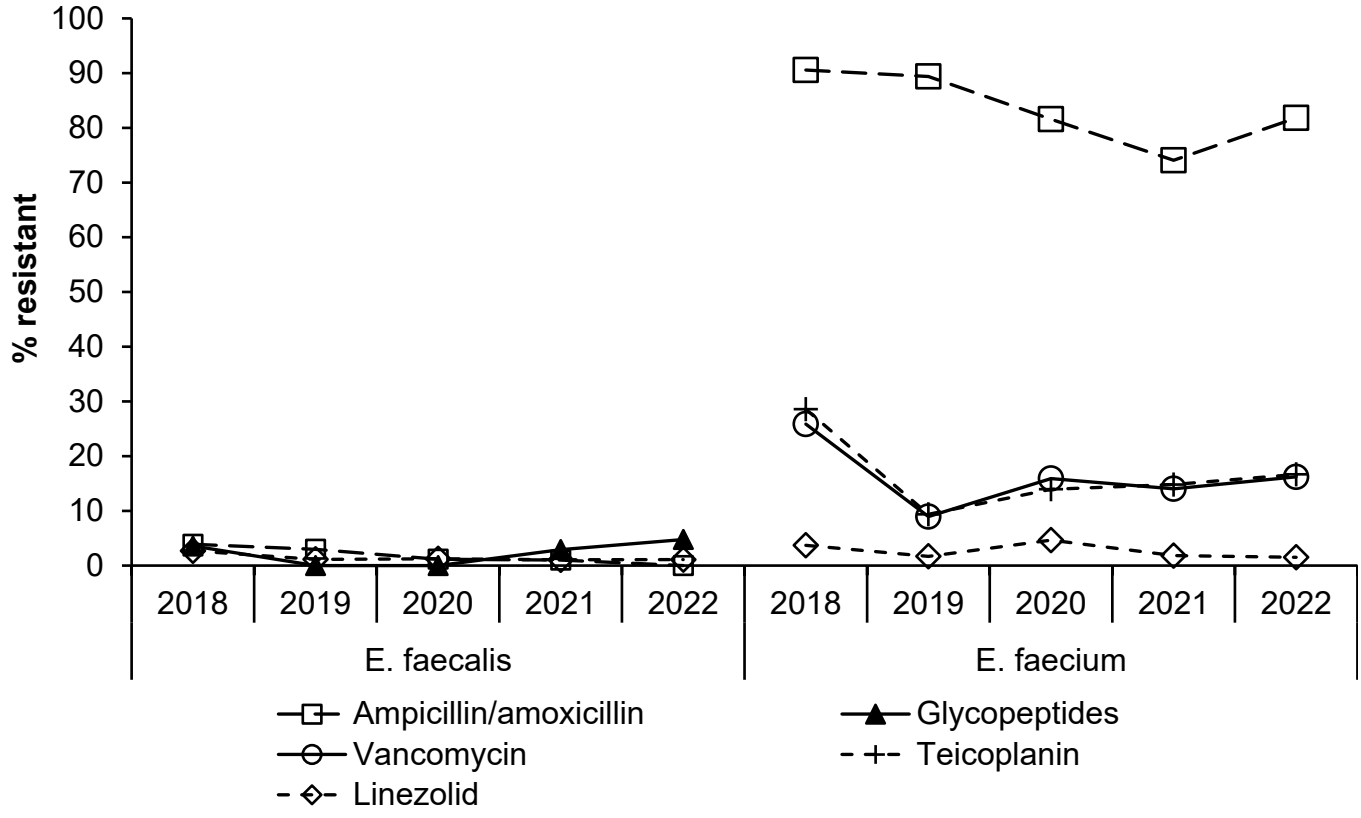
S. aureus resistance to meticillin (MRSA) was 8.0% (n=18 per 226 tested) in 2018 and 10.0% (n= 23 per 230 tested) in 2022 (Figure 6b and Appendix 6). MSSA resistance to macrolides and clindamycin increased from 17.1% (n=36 per 210 tested) in 2018 to 23.9% (n=54 per 226 tested) in 2022 and from 9.9% (n=17 per 171 tested) in 2018 to 20.6% (n=40 per 194 tested) in 2022, respectively (Figure 6b and Appendix 6). Resistance to co-trimoxazole, tetracycline, mupirocin, and glycopeptides remained low (<5%) throughout the period. MSSA resistance to fusidic acid remained relatively stable at 18.8% (n=36 per 192 tested) in 2018 and 14.1% (n=30 per 213 tested) in 2022. Further interpretation of resistance amongst MRSA isolates was not evaluated due to the low (<25) annual number of isolates.

Between 2018 and 2022, resistance to penicillin, teicoplanin, or vancomycin in GAS was not detected. GAS co-trimoxazole resistance remained low (<6%) and generally stable. Resistance to macrolides and clindamycin was also low (<5%) from 2018 to 2020 and in 2022; numbers tested were low in 2021 (<20) and therefore no resistance is reported for this year (Figure 6c and Appendix 6). Trends and demographics of GAS are discussed in more detail in the seasonal and annual reports (2, 3, 4).

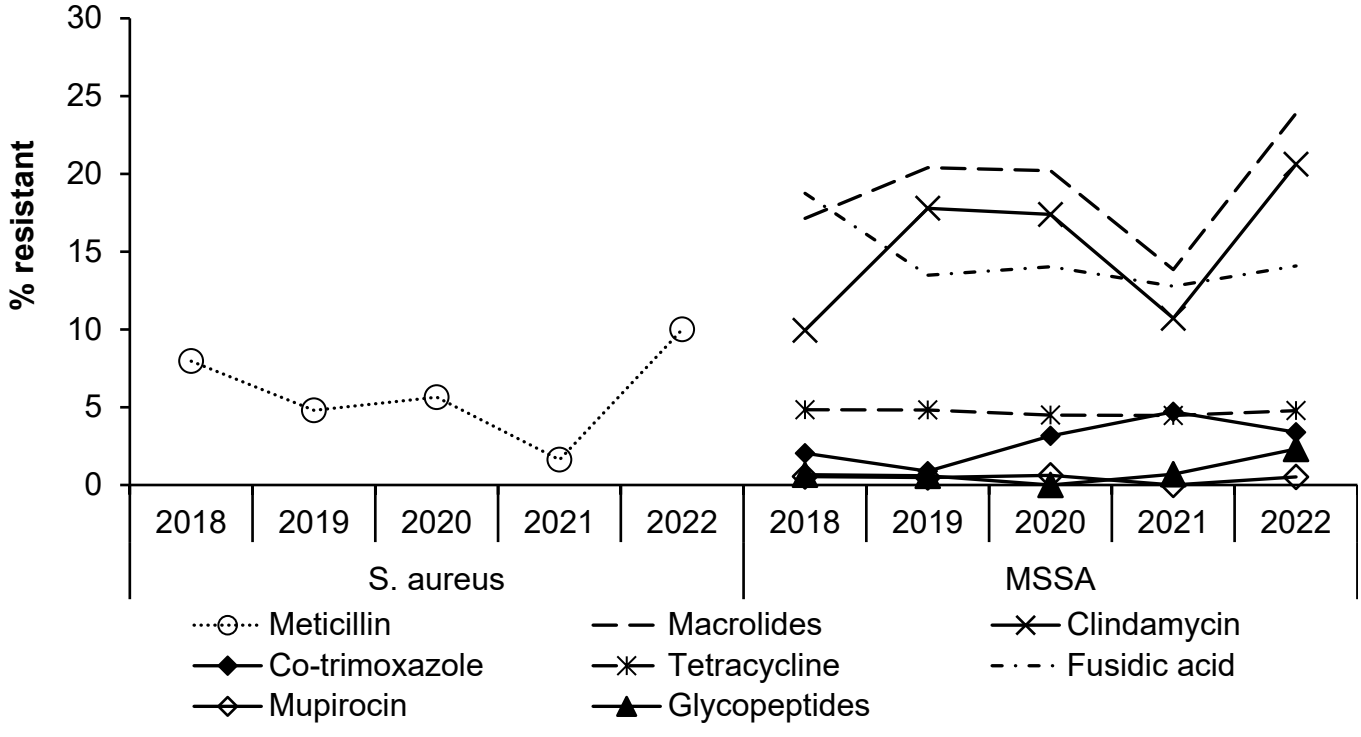
S. pneumoniae resistance to penicillin remained low (<7%) throughout the 5-year period (2.1%, n=4 per 188 tested in 2018; 2.1%, n=4 per 189 tested, in 2022) (Figure 6c and Appendix 6). Resistance to both macrolides and clindamycin remained low and stable over the 5-year period (<10%); macrolide resistance was 7.0% (n=14 per 199 tested) in 2018 and 7.7% (n=16 per 208 tested) in 2022 while clindamycin resistance was 3.2% (n=2 per 63 tested) in 2018 and 4.8% (n=4 per 84 tested) in 2022.

Figure 6. AMR of Gram-positive BSI for children aged 3 months to 4 years in England, 2018 to 2022 for: (a) *E. faecalis* and *E. faecium* (b) *S. aureus* (all) and MSSA(c) GAS, *S. pneumoniae* and oral and other streptococci

6a. AMR of Gram-positive BSI for children aged 3 months to 4 years in England, 2018 to 2022 for: *E. faecalis* and *E. faecium*

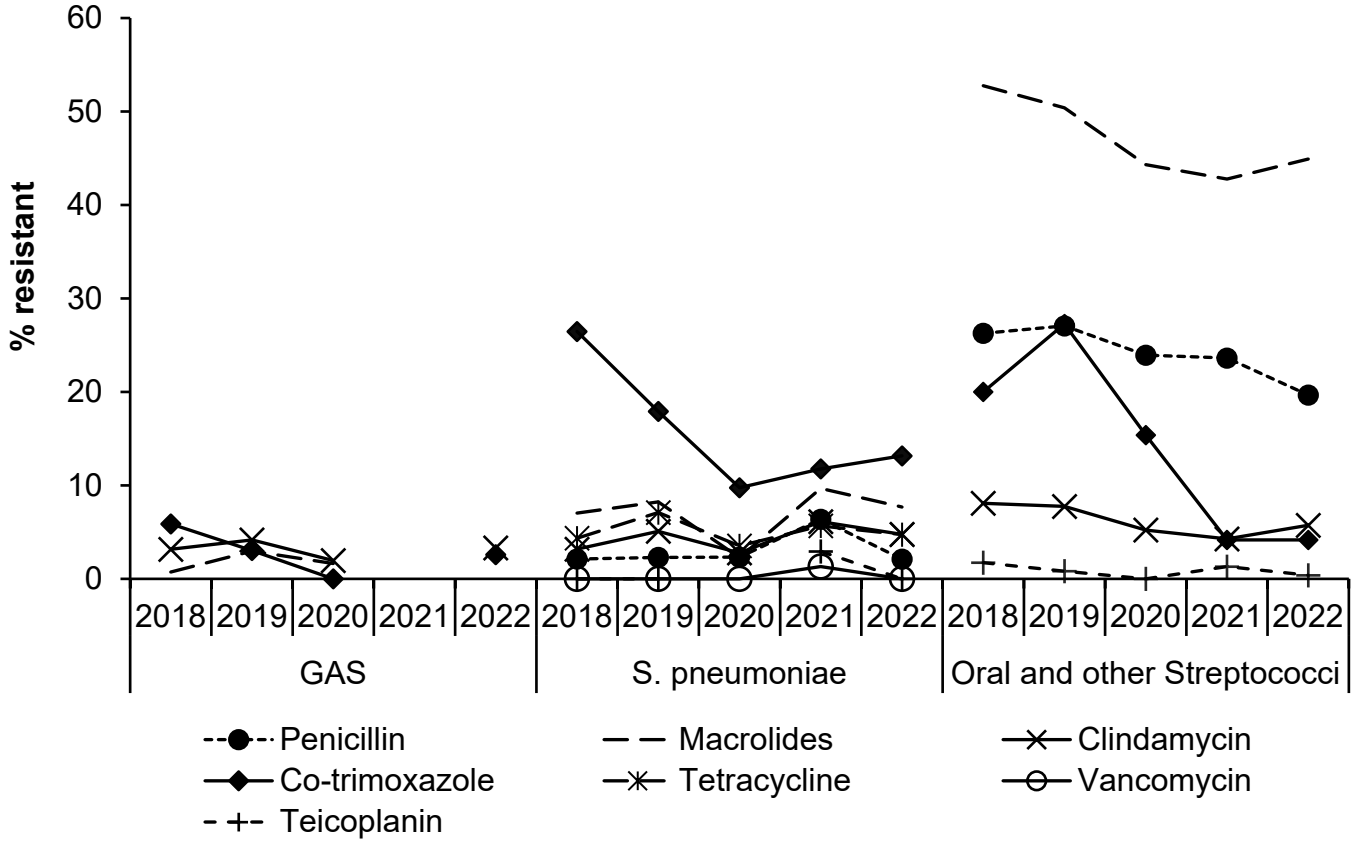


6b. AMR of Gram-positive BSI for children aged 3 months to 4 years in England, 2018 to 2022 for *S. aureus* (all) and MSSA [note 1]



Note 1: Resistance not displayed for MRSA due to low (<25) numbers of reported BSIs.

6c. AMR of Gram-positive BSI for children aged 3 months to 4 years in England, 2018 to 2022 for GAS [note 2], *S. pneumoniae* [note 3] and oral and other streptococci



Note 2: Resistance not displayed for GAS (teicoplanin [2020 and 2021]) and in 2021 due to low (<20) numbers of reported BSIs tested for resistance.

Note 3: Resistance not displayed for *S. pneumoniae* (teicoplanin [2020]) due to low (<20) numbers of reported BSIs tested for resistance.

3.2.3.2 Gram-negative bloodstream infections

Overall, *E. coli* resistance to the specified remained broadly stable between 2018 to 2022 in 3 months to 4 years old infants and children (Figure 7a and Appendix 7 of the accompanying data tables). *E. coli* resistance to amikacin was low (<5%) over the period, ranging from a minimum of 0.0% in 2018 (n=0 per 112 tested) to a maximum of 4.1% in 2019 (n=5 per 122 tested). Third-generation cephalosporin resistance was stable at 17.5% (n=28 per 160 tested) in 2018 and 17.9% (n=32 per 179 tested) in 2022. Resistance to co-amoxiclav ranged from a peak of 46.6% (n=83 per 178 tested) in 2019 to a low of 36.6% (n=63 per 172 tested) in 2022. Resistance to piperacillin with tazobactam and ciprofloxacin was also stable over the period; 13.0% (n=20 per 154 tested) resistance in 2018 and 14.9% (n=25 per 168 tested) resistance in 2022 for piperacillin with tazobactam, and 17.9% (n=28 per 156 tested) resistance in 2018 and 14.3% (n=25 per 175 tested) resistance in 2022 for ciprofloxacin. Resistance to meropenem was low (≤1.1%), with only 3 isolates reported resistant over the period (1 in 2018 and 2 in 2020).

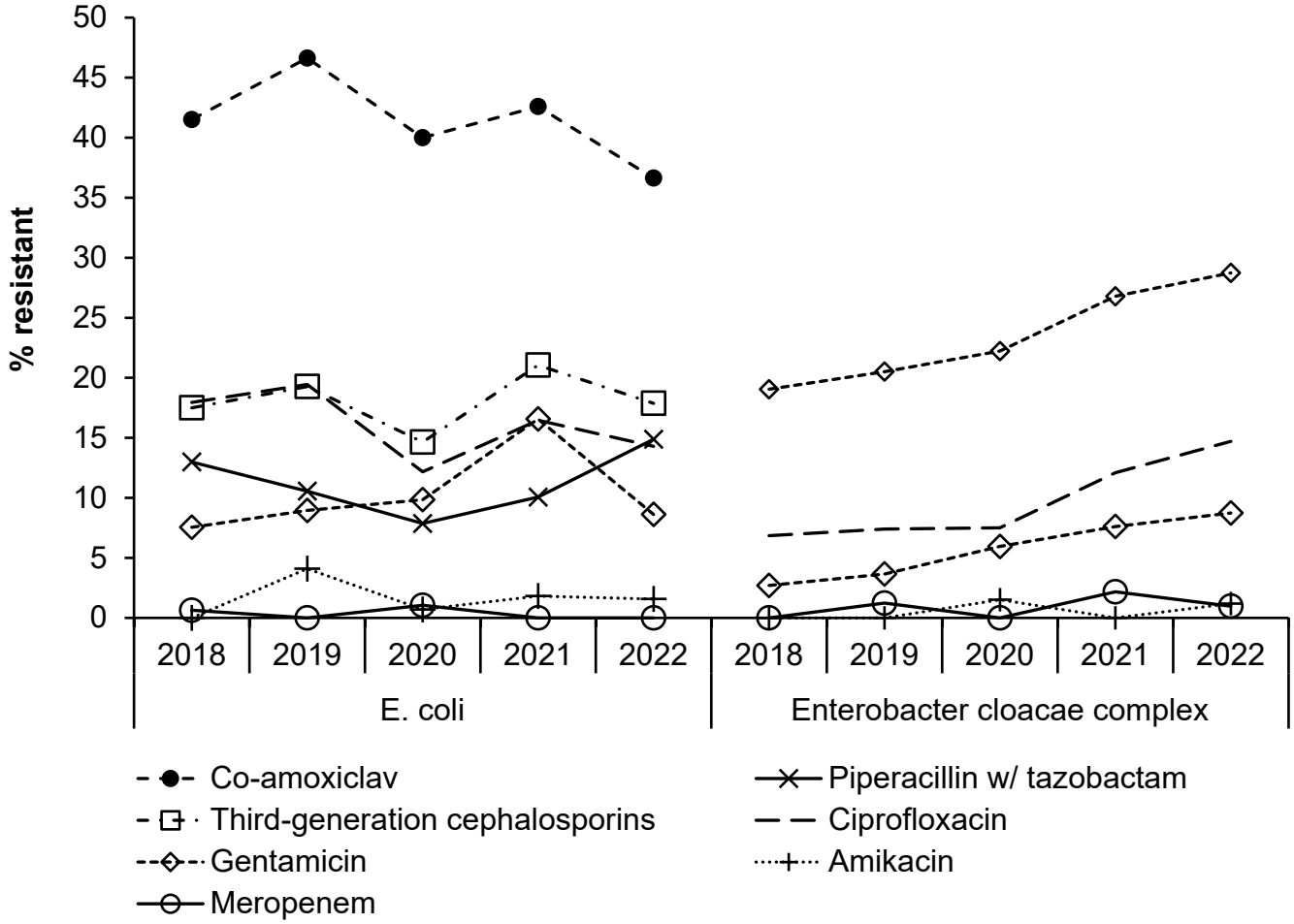
Enterobacter cloacae complex resistance to gentamicin increased from 2.7% (n=2 per 74 tested) in 2018 to 8.7% (n=9 per 103 tested) in 2022 (Figure 7a and Appendix 7). Resistance to amikacin was low (<2%) throughout the period. Resistance to co-trimoxazole increased from 19.0% (n=8 per 42 tested) in 2018 to 28.7% (n=25 per 87 tested) in 2022. Resistance to ciprofloxacin increased from 6.8% (n=5 per 73 tested) in 2018 to 14.7% (n=15 per 102 tested) in 2022. Meropenem resistance was low (≤2.2%).

K. pneumoniae resistance to gentamicin ranged from 11.6% (n=8 per 69 tested) in 2018 to a peak of 19.6% (n=20 per 102 tested) in 2021, with resistance at 15.2% (n=17 per 112 tested) in 2022 (Figure 7b and Appendix 7) Amikacin resistance ranged from 0.0% (n=0 per 86 tested) in 2019, to 7.3% (n=6 per 82 tested) in 2021, with resistance at 5.9% (n=5 per 85 tested) in 2022. Third-generation cephalosporin resistance ranged from a minimum of 19.4% (n=18 per 93 tested) in 2020 to a maximum of 38.8% (n=40 per 103 tested) in 2021. Co-amoxiclav resistance was 39.6% (n=40 per 101 tested) in 2022, and resistance to piperacillin with tazobactam and ciprofloxacin was 31.7% and 31.5%, respectively, in 2022. Resistance to meropenem ranged from 0.9% in 2019 to 5.9% in 2021, with a maximum of 6 resistant isolates (in 2021) reported per year during the period.

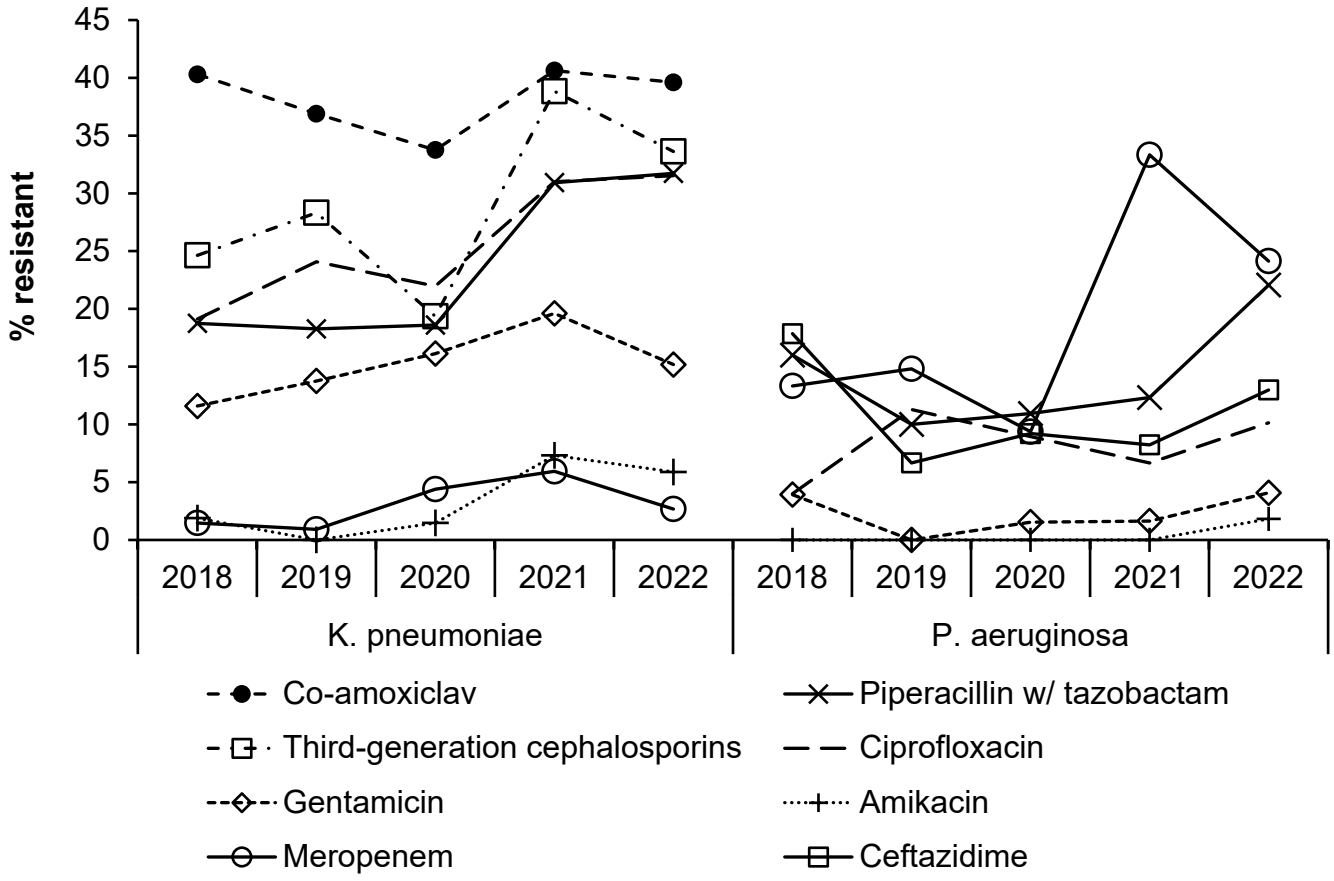
P. aeruginosa resistance to gentamicin was low (<5%) during this period, with no more than 2 resistant isolates reported per year (Figure 7b and Appendix 7). Amikacin resistance was also low (<2%), with only one resistant isolate reported in this period, in 2022 (1.8% resistance, n=1 per 55 tested). Resistance to ceftazidime ranged from a minimum of 6.7% (n=5 per 75 tested) in 2020 to a maximum of 17.9% (n=10 per 56 tested) in 2018, with resistance at 13.0% (n=10 per 77 tested) in 2022. Piperacillin with tazobactam resistance ranged from 10.0% (n=6 per 60 tested) in 2019 to 22.1% (n=15 per 68 tested) in 2022. Ciprofloxacin resistance ranged from 4.0% (n=2 per 50 tested) in 2018 to 11.3% (n=7 per 62 tested) in 2019 with resistance at 10.1% (n=7 per 69 tested) in 2022. Meropenem resistance ranged from 9.4% (n=3 per 32 tested) in 2020 to 33.3% (n=11 per 33 tested) in 2021, with resistance at 24.1% (n=7 per 29 tested) in 2022.

Figure 7. AMR of Gram-negative BSI for children aged 3 months to 4 years in England, 2018 to 2022 for: (a) *E. coli* and *Enterobacter cloacae* complex (b) *K. pneumoniae* and *P. aeruginosa*

7a. AMR of Gram-negative BSI for children aged 3 months to 4 years in England, 2018 to 2022 for *E. coli* and *Enterobacter cloacae* complex



7b. AMR of Gram-negative BSI for children aged 3 months to 4 years in England, 2018 to 2022 for *K. pneumoniae* and *P. aeruginosa*



3.2.4 Children (5 to 17 years)

3.2.4.1 Gram-positive bloodstream infections

Between 2018 and 2022, *E. faecalis* resistance to ampicillin/amoxicillin, glycopeptides, and linezolid was stable and low (<5%) (Figure 8a and Appendix 8 of the accompanying data tables). *E. faecium* resistance to ampicillin/amoxicillin was high between 81.4% to 92.1% over the period, while resistance to linezolid remained below <9%. *E. faecium* vancomycin resistance was 22.5% (n=9 per 40 tested) in 2018 and 27.8% (n=15 per 54 tested) in 2022, similar to resistance rates to teicoplanin.

S. aureus resistance to meticillin was stable between 2018 (5.0%, n=16 per 320 tested) and 2022 (5.1%, n=16 per 316 tested) in children aged 5 to 17 years old (Figure 8b and Appendix 8). MSSA resistance to macrolides increased over the 2018 to 2022 period; from 15.1% (n=46 per 305 tested) in 2018 to 20.1% (n=62 per 309 tested) in 2022. Clindamycin and fusidic acid resistance were stable over the 2018 to 2022 period; clindamycin resistance was 12.3% (n=32 per 260 tested) in 2018 and 13.3% (n=35 per 263 tested) in 2022, fusidic acid resistance was 13.4% (n=38 per 283 tested) in 2018 and 12.5% (n=35 per 280 tested) in 2022. MSSA resistance to co-trimoxazole, tetracycline, mupirocin, and glycopeptides was low (<5%) during the period. Further interpretation of resistance amongst MRSA isolates was not evaluated due to the low (<20) annual number of isolates.

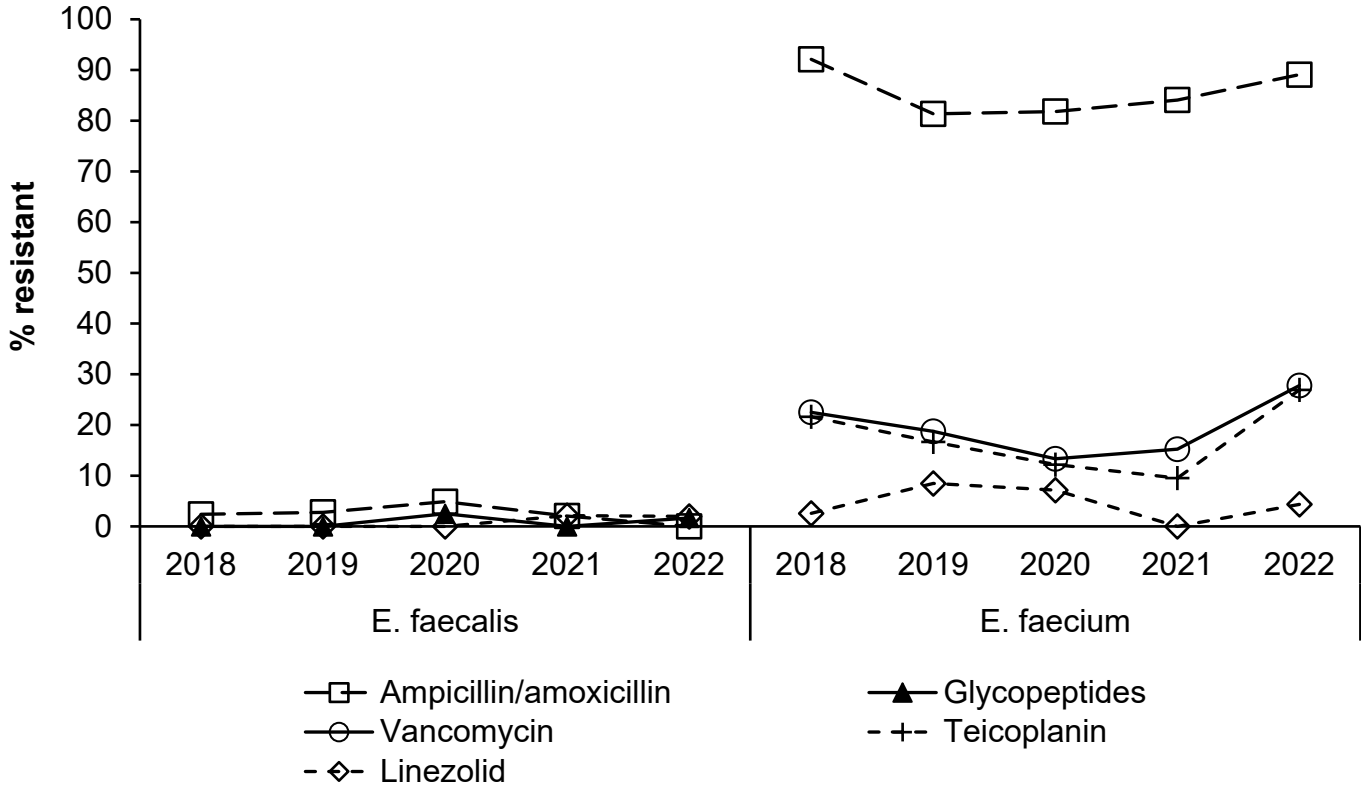
GAS resistance to penicillin, clindamycin, co-trimoxazole, and glycopeptides remained low between 2018 and 2022, with no resistance reported to penicillin and vancomycin, and resistance below 7% for teicoplanin and clindamycin. There were low numbers of isolates tested for resistance to co-trimoxazole, however resistance was 11.1% in 2022 (n=7 per 63 tested) (Appendix 8 of the accompanying data tables). Macrolide resistance was 4.0% (n=4 per 101 tested) in 2018 and 6.3% (n=10 per 160 tested) in 2022. The low numbers of GAS BSI isolates (<20) tested in 2021 complicates the interpretation of trends and makes resistance estimates for that year difficult to assess.

S. pneumoniae resistance to penicillin was 2.9% (n=2 per 69 tested) in 2018 and 6.7% (n=4 per 60 tested) in 2022. Macrolide resistance was 8.1% (n=6 per 74 tested) in 2018 and 8.3% (n=5 per 60 tested) in 2022. Between 2018 and 2022, co-trimoxazole resistance fluctuated between 9.5% and 25.0% (Figure 8c and Appendix 8). Resistance to tetracycline was stable and low (<4%) over the period.

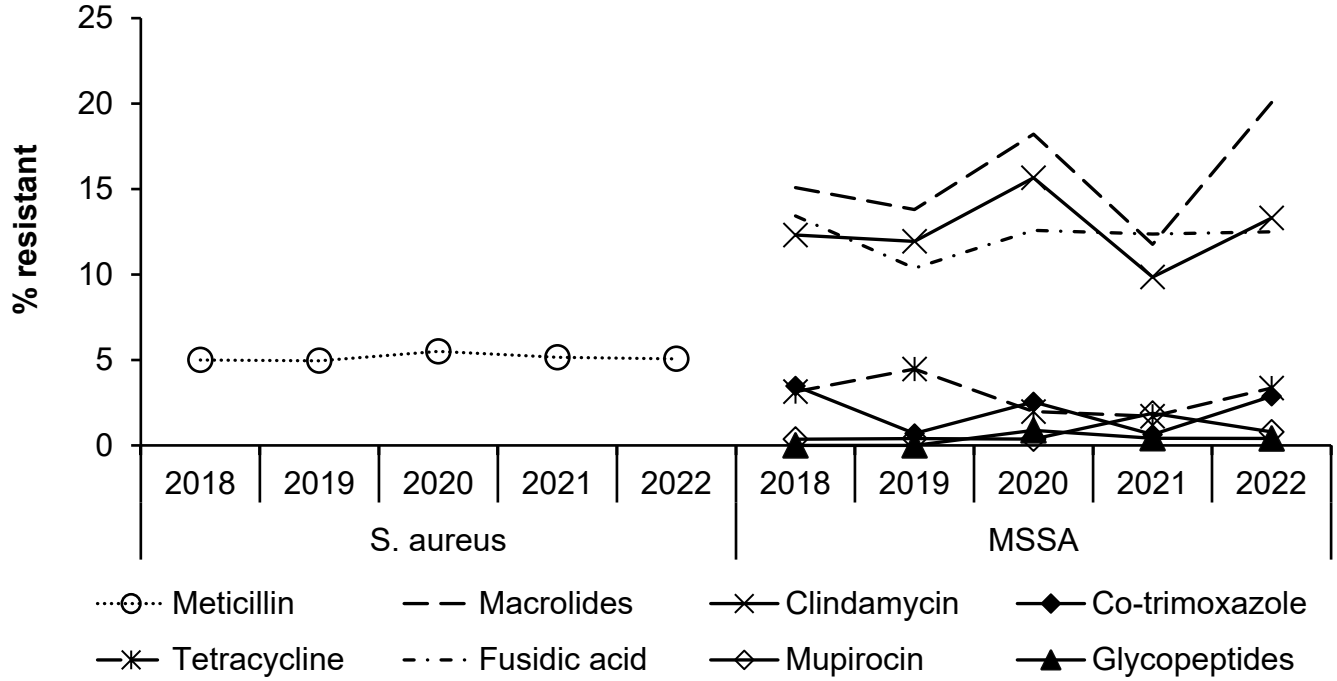
Oral and other streptococci resistance to macrolides decreased from 52.3% (n=78 per 149 tested) in 2018 to 35.0% (n=36 per 103 tested) in 2022 (Figure 8c and Appendix 8). Teicoplanin resistance was stable and low (<2%) over the period. Penicillin resistance fluctuated between 15.0% (n=37 per 246 tested) in 2022 and 19.0% (n=48 per 252 tested) in 2018.

Figure 8. AMR of Gram-positive BSI for children aged 5 to 17 years in England, 2018 to 2022 for: (a) *E. faecalis* and *E. faecium* (b) *S. aureus* (all) and MSSA and (c) *S. pneumoniae* and oral and other streptococci

8a. AMR of Gram-positive BSI for children aged 5 to 17 years in England, 2018 to 2022 for *E. faecalis* and *E. faecium*

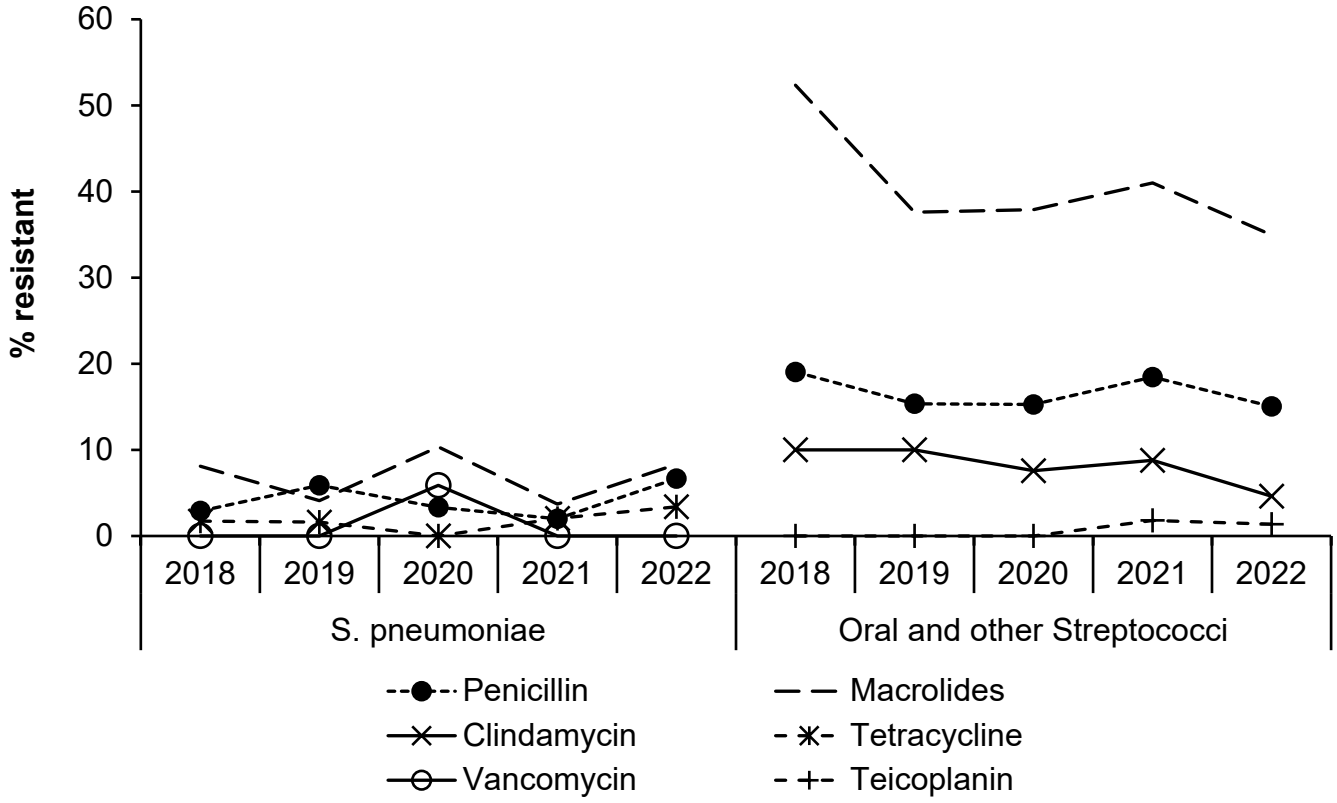


8b. AMR of Gram-positive BSI for children aged 5 to 17 years in England, 2018 to 2022 for *S. aureus* (all) and MSSA [note 1]



Note 1: Resistance not displayed for MRSA due to low (<20) numbers of reported BSIs.

8c. AMR of Gram-positive BSI for children aged 5 to 17 years in England, 2018 to 2022 for *S. pneumoniae* [note 2] and oral and other streptococci [note 3]



Note 2: Resistance not displayed for S. pneumoniae (clindamycin and teicoplanin [2018 to 2022]) and co-trimoxazole [2020]) due to low (<20) numbers of reported BSIs tested for resistance.

Note 3: Resistance not displayed for oral and other streptococci (co-trimoxazole [2018 to 2020]) due to low (<20) numbers of reported BSIs tested for resistance.

3.2.4.2 Gram-negative bloodstream infections

In children aged 5 to 17 years old, *E. coli* gentamicin resistance increased from 6.6% (n=12 per 181 tested) in 2018 to 12.4% (n=22 per 178 tested) in 2022 (Figure 9a and Appendix 9 of the accompanying data tables). *E. coli* resistance to amikacin was low (<4%) over the period. Third-generation cephalosporin resistance increased from 9.8% (n=18 per 184 tested) in 2018 to 17.4% (n=32 per 184 tested) in 2022. Resistance to co-amoxiclav was stable, ranging from a peak of 42.4% (n=64 per 151 tested) in 2020 to a low of 34.1% (n=57 per 167 tested) in 2019. Resistance to piperacillin with tazobactam was 7.6% (n=13 per 170 tested) in 2018 and 11.0% (n=18 per 164 tested) in 2022. Ciprofloxacin resistance was stable at 19.0% (n=34 per 179 tested) in 2018 and 20.8% (n=37 per 178) in 2022. Meropenem resistance was low (<1%) each year, with a total of 4 resistant isolates reported across the period.

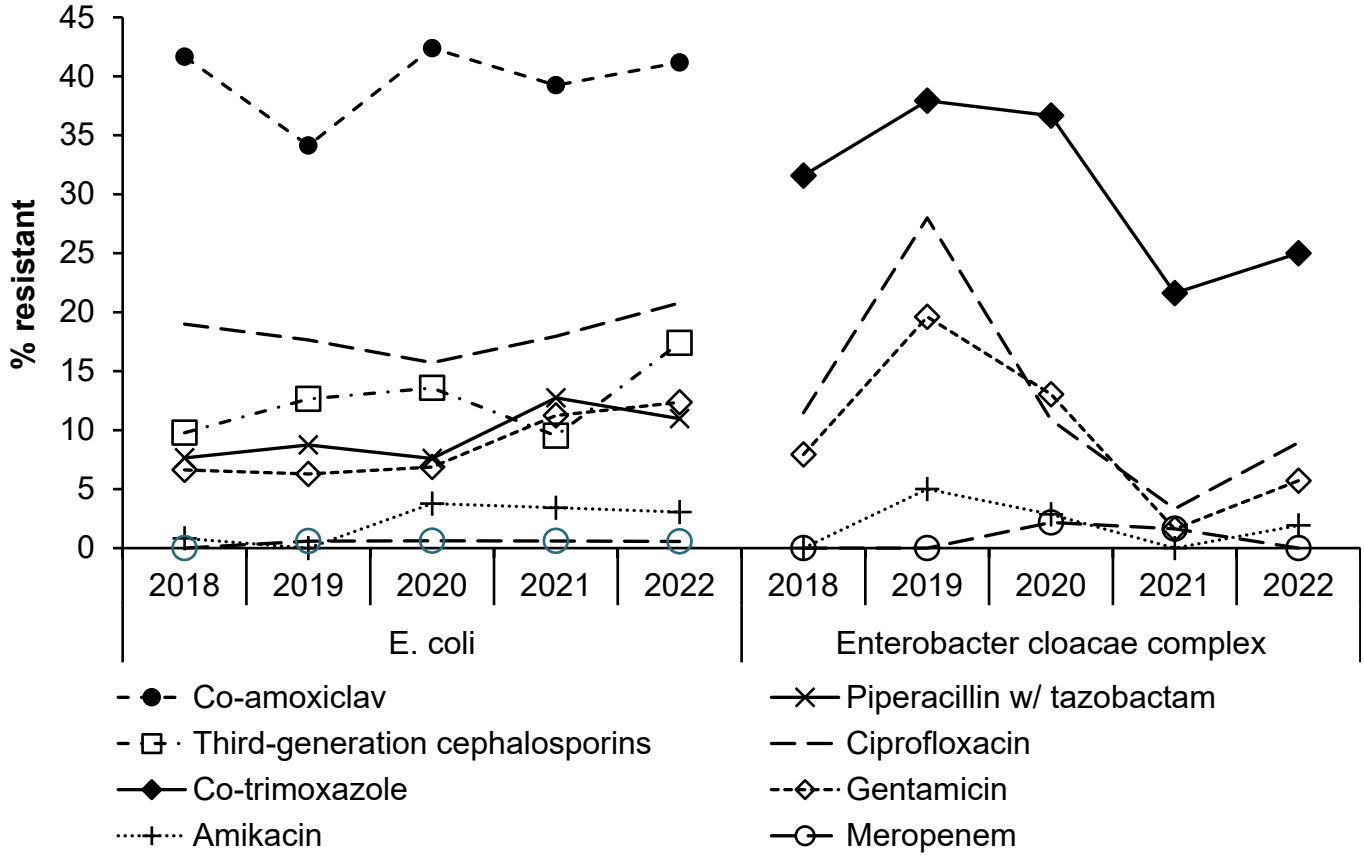
Enterobacter cloacae complex resistance to gentamicin ranged from 1.6% (n=1 per 62 tested) in 2021 to 19.6% (n=10 per 51 tested) in 2019, with resistance at 5.7% (n=4 per 70 tested) in 2022 (Figure 9a and Appendix 9). Resistance to amikacin was low (≤5%) throughout the period. Resistance to co-trimoxazole ranged from 21.6% (n=8 per 37 tested) in 2021 to 37.9% (n=11 per 29 tested) in 2019, with resistance at 25.0% (n=12 per 48 tested). Resistance to ciprofloxacin ranged from 3.3% (n=2 per 60 tested) in 2021 to 28.0% (n=14 per 50 tested) in 2019, with resistance at 9.0% (n=6 per 67 tested) in 2022. Meropenem resistance was low (<3%).

K. pneumoniae resistance to gentamicin was stable between 11.8% and 15.9% over the 2018 to 2022 period (Figure 9b and Appendix 9). Amikacin resistance was low (<3%) and stable. Third-generation cephalosporin resistance was also broadly stable between 23.1% (n=12 per 52 tested) in 2018 and 22.4% (n=17 per 76 tested) in 2022. Co-amoxiclav resistance was 36.0% (n=18 per 50 tested) in 2018 and 35.2% (25 per 71 tested) in 2022, peaking at 44.4% resistance (n=24 per 54 tested) in 2020. Piperacillin with tazobactam resistance increased from 18.4% (n=9 per 49 tested) in 2018 and 26.4% (n=19 per 72 tested) in 2022. Ciprofloxacin resistance increased from 14.8% (n=8 per 54 tested) in 2018 to 28.0% (n=21 per 75 tested) in 2022. Meropenem resistance was low (≤4%).

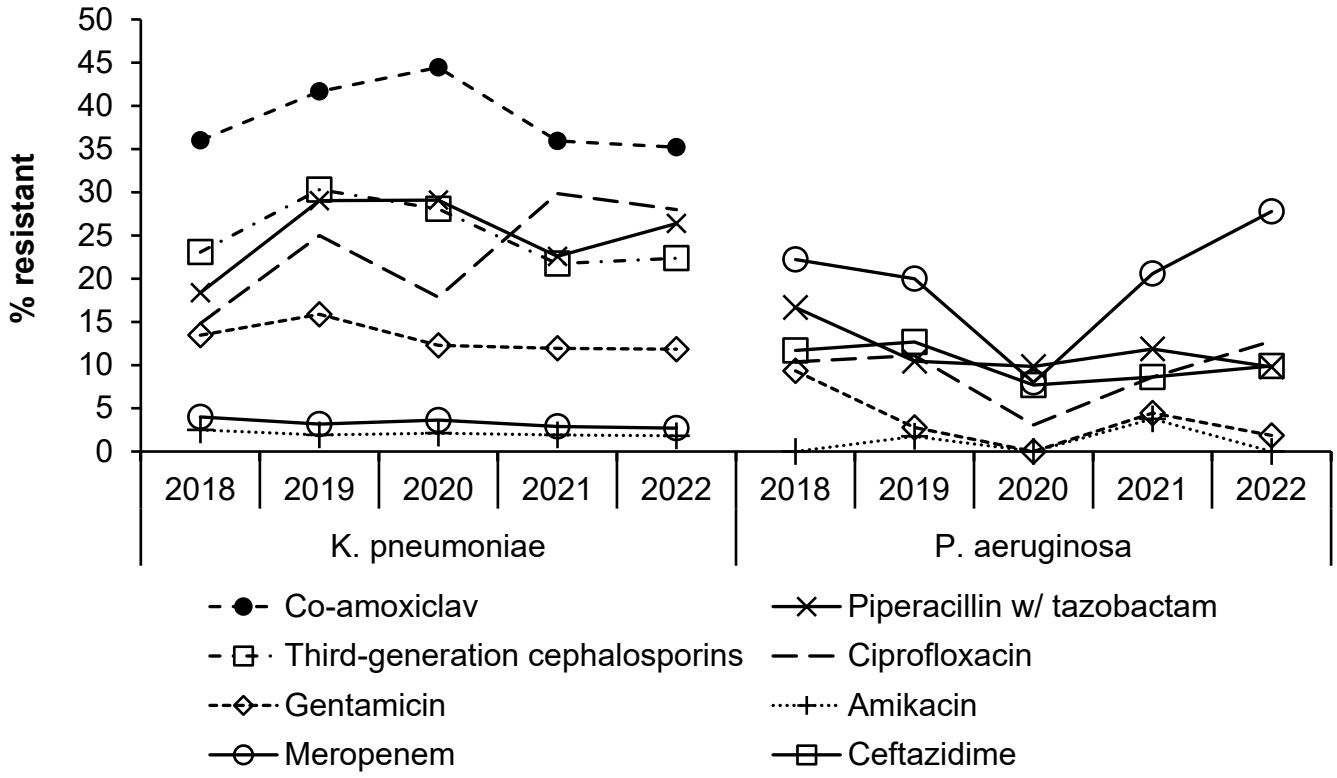
Finally, *P. aeruginosa* resistance to gentamicin and amikacin was low (<5%, other than gentamicin in 2018 which was 9.3%) over the 2018 to 2022 period (Figure 9b and Appendix 9). Ceftazidime resistance declined slightly from 11.7% (n=9 per 77 tested) in 2018 to 9.9% (n=9 per 91 tested) in 2022, with a minimum of 7.7% (n=5 per 65 tested) in 2020. Piperacillin with tazobactam resistance decreased from 16.7% (n=12 per 72 tested) in 2018 to 9.8% (n=9 per 92 tested) in 2022. Ciprofloxacin resistance was 10.4% (n=8 per 77 tested) in 2018 and 12.8% (n=12 per 94 tested) in 2022. Meropenem resistance was broadly stable from 22.2% (n=10 per 45 tested) in 2018 to 27.8% (n=10 per 36 tested) in 2022, however decreased to 8.0% in 2020 when lower test numbers we reported (n=2 resistant per 25 tested).

Figure 9. AMR of Gram-negative BSI for children aged 5 to 17 years in England, 2018 to 2022 for: (a) *E. coli* and *Enterobacter cloacae* complex (b) *K. pneumoniae* and *P. aeruginosa*

9a. AMR of Gram-negative BSI for children aged 5 to 17 years in England, 2018 to 2022 for *E. coli* and *Enterobacter cloacae* complex



9b. AMR of Gram-negative BSI for children aged 5 to 17 years in England, 2018 to 2022 for *K. pneumoniae* and *P. aeruginosa*



3.3 *Listeria* sp.

Listeria sp. has been included in this report due to its occurrence in infants <6 weeks of age. This report does not include isolation of *Listeria* sp. from sample types other than blood cultures.

3.3.1 Bloodstream infection rates of *Listeria* sp. in paediatric population (0 to 17 years)

While infants <6 weeks of age (as well as the immunosuppressed in other age groups) are particularly vulnerable to *Listeria*, the number of cases of *Listeria* sp. BSI was low in the paediatric population (Table 1). The highest number of cases was in the 0 to 3 days old neonates across the period – this number has been broadly stable between 2018 and 2022 with a peak of 11 BSIs in 2020, however, small numbers make meaningful trend interpretation difficult. Between 2018 and 2020, there were no reports of *Listeria* sp. BSI in 4 days to 1 month old neonates and infants. In 2021 there were 3 reported BSIs and 2 in 2022. Annual reports of all reported *Listeria monocytogenes* infections are available at Listeria monocytogenes: surveillance reports (5).

Table 1. BSI incidence (aged 0 to 17 years) for *Listeria* sp. in England: 2018 to 2022 (n stands for number)

Age category	2018 (n)	2019 (n)	2020 (n)	2021 (n)	2022 (n)
0 to 3 days	9	3	11	8	8
4 days to <1 month	0	0	0	4	1
1 month to <1 years	1	0	0	0	0
1 to 4 years	0	0	0	1	0
5 to 17 years	0	0	0	0	0
Total (0 to 17 years)	10	3	11	13	9

3.3.2 AMR of *Listeria* sp. in paediatric population (0 to 17 years)

There was no reported resistance to amoxicillin in *Listeria* sp. isolates in children aged 0 to 17 years between 2018 and 2022. During this period, 3 isolates were resistant to co-trimoxazole out of 24 tested.

4. Data sources and methods

This report focuses on the paediatric population (0 to 17 years). The age groups used in the rates of laboratory-reported BSI rates and antimicrobial susceptibility trends differ slightly due to susceptibility testing being low for some (smaller) age groups (Table 2).

Table 2. Age categories used in the analysis for BSI rates and AMR of BSI

Age category for BSI rates	Age category for AMR of BSI
0 to 3 days	0 to 3 days
4 days to <1 month 1 month to <1 years 1 to 4 years	4 days to 3 months 3 months to 4 years
5 to 17 years	5 to 17 years

This report is based upon ESPAUR methodology (1). In summary, voluntary surveillance data on the antibiotic susceptibility of organism causing bacteraemia was obtained from SGSS (Second Generation Surveillance System) for the period 2018 to 2022. The SGSS is a national database maintained by UK Health Security Agency (UKHSA) that contains laboratory data supplied electronically by approximately 98% of hospital microbiology laboratories in England. SGSS comprises 2 modules, a communicable disease reporting (CDR; formerly CoSurv/LabBase2) module and an antimicrobial resistance (AMR; formerly AmSurv) module. The CDR module includes antimicrobial susceptibility test results for bloodstream isolates, although any test results suppressed from clinical reports by the sending laboratories are not captured when the data is submitted. In contrast, the AMR module contains more comprehensive antibiogram information as it includes results for all antibiotics tested (including results suppressed from clinical reports) for isolates from all clinical sources. The AMR trends included within this report use data from the AMR module and the rates of laboratory reported BSI from the CDR module; as this data is provided on a voluntary basis, case ascertainment will have been incomplete. However, ascertainment of notifiable infections, such as invasive GAS, will be high.

In previous ESPAUR reports (6), hospital microbiology laboratories have reported antimicrobial susceptibility test results as ‘susceptible’, ‘intermediate’ or ‘resistant’. These categories were previously defined as follows:

1. Susceptible: a bacterial strain is said to be susceptible to a given antibiotic when its growth is inhibited in vitro by a concentration of the drug that is associated with a high likelihood of therapeutic success.
2. Intermediate: a bacterial strain is said to be intermediate when the concentration of antibiotic required to inhibit its growth in vitro is associated with an uncertain therapeutic outcome at standard antibiotic doses. It implies that an infection due to the isolate may be

appropriately treated in body sites where the antibiotic is physically concentrated or when a high dosage of drug can be used.

3. Resistant: a bacterial strain is said to be resistant to a given antibiotic when the concentration required to inhibit its growth in vitro is associated with a high likelihood of therapeutic failure.

The breakpoint criteria for categorising clinical isolates as susceptible, intermediate or resistant to individual antibiotics have changed over time. As noted in the ESPAUR report 2019, in 2019 the EUCAST definitions were amended to rename the ‘intermediate’ category to ‘susceptible, increased exposure’ (with an adjusted increased dose), as the antibiotic should still work for treatment (6). The definition changes cannot be retrospectively applied.

As patients may have more than one positive blood culture taken, blood cultures taken from the same patient that yielded growth of the same pathogen during a rolling 14-day period from the initial positive blood culture were regarded as comprising the same episode of infection and were de-duplicated, retaining the worst-case scenario susceptibility result for each antibiotic tested (resistant > intermediate > susceptible).

Rates of laboratory-reported bacteraemia per 100,00 were calculated using the relevant year’s Office for National Statistics (ONS) mid-year resident population estimates for England as the denominator (7). At the time of analysis, there was no 2022 mid-year population estimate, therefore, the 2021 mid-year population estimate was used as a proxy. All reported BSI episodes to SGSS were included in calculating reported BSI rates. The percentage increases were calculated using non-rounded rates and episodes.

The AMR BSI section includes the most frequently reported BSI-causing bacteria for each age group (appendices 11 to 15 of the accompanying data tables) and specified antibiotics for each organism (defined in Table 3).

Table 3. Organisms and specified antibiotics included in the AMR analysis by age category

Organisms	0 to 3 days	4 days to 3 months	3 months to 4 years	5 to 17 years
CoNS and *Micrococcus* spp.	- Glycopeptides - Clindamycin - Flucloxacillin	- Glycopeptides - Clindamycin - Flucloxacillin	Organism not included for age group	Organism not included for age group
E. faecalis	- Ampicillin/amoxicillin - Linezolid - Glycopeptides	- Ampicillin/amoxicillin - Linezolid - Glycopeptides	- Ampicillin/amoxicillin - Linezolid - Glycopeptides	- Ampicillin/amoxicillin - Linezolid - Glycopeptides
E. faecium	Organism not included for age group	Organism not included for age group	- Ampicillin/amoxicillin - Linezolid - Teicoplanin - Vancomycin	- Ampicillin/amoxicillin - Linezolid - Teicoplanin - Vancomycin
GAS	Organism not included for age group	Organism not included for age group	- Penicillin - Co-trimoxazole - Clindamycin - Tetracycline - Macrolides - Teicoplanin - Vancomycin	- Penicillin - Co-trimoxazole - Clindamycin - Tetracycline - Macrolides - Teicoplanin - Vancomycin
GBS	- Penicillin - Clindamycin - Co-trimoxazole - Macrolides	- Penicillin - Clindamycin - Co-trimoxazole - Macrolides	Organism not included for age group	Organism not included for age group

Organisms	0 to 3 days	4 days to 3 months	3 months to 4 years	5 to 17 years
	- Teicoplanin - Vancomycin	- Teicoplanin - Vancomycin		
S. aureus	- Meticillin	- Meticillin	- Meticillin	- Meticillin
MRSA	- Glycopeptides - Co-trimoxazole - Clindamycin - Macrolides - Tetracycline - Mupirocin - Fusidic acid	- Glycopeptides - Co-trimoxazole - Clindamycin - Macrolides - Tetracycline - Mupirocin - Fusidic acid	- Glycopeptides - Co-trimoxazole - Clindamycin - Macrolides - Tetracycline - Mupirocin - Fusidic acid	- Glycopeptides - Co-trimoxazole - Clindamycin - Macrolides - Tetracycline - Mupirocin - Fusidic acid
MSSA	- Glycopeptides - Co-trimoxazole - Clindamycin - Macrolides - Tetracycline - Mupirocin - Fusidic acid	- Glycopeptides - Co-trimoxazole - Clindamycin - Macrolides - Tetracycline - Mupirocin - Fusidic acid	- Glycopeptides - Co-trimoxazole - Clindamycin - Macrolides - Tetracycline - Mupirocin - Fusidic acid	- Glycopeptides - Co-trimoxazole - Clindamycin - Macrolides - Tetracycline - Mupirocin - Fusidic acid
Listeria sp.	- Amoxicillin - Co-trimoxazole - Meropenem - Moxifloxacin	- Amoxicillin - Co-trimoxazole - Meropenem - Moxifloxacin	- Amoxicillin - Co-trimoxazole - Meropenem - Moxifloxacin	- Amoxicillin - Co-trimoxazole - Meropenem - Moxifloxacin

Organisms	0 to 3 days	4 days to 3 months	3 months to 4 years	5 to 17 years
S. pneumoniae	Organism not included for age group	Organism not included for age group	- Penicillin - Clindamycin - Co-trimoxazole - Macrolides - Tetracycline - Teicoplanin - Vancomycin	- Penicillin - Clindamycin - Co-trimoxazole - Macrolides - Tetracycline - Teicoplanin - Vancomycin
Oral and other streptococci	- Teicoplanin - Penicillin - Clindamycin - Co-trimoxazole - Macrolides	- Teicoplanin - Penicillin - Clindamycin - Co-trimoxazole - Macrolides	- Teicoplanin - Penicillin - Clindamycin - Co-trimoxazole - Macrolides	- Teicoplanin - Penicillin - Clindamycin - Co-trimoxazole - Macrolides
E. coli	- Amikacin - Meropenem - Co-amoxiclav - Third-generation cephalosporins - Gentamicin - Piperacillin with tazobactam - Ciprofloxacin	- Amikacin - Meropenem - Co-amoxiclav - Third-generation cephalosporins - Gentamicin - Piperacillin with tazobactam - Ciprofloxacin	- Amikacin - Meropenem - Co-amoxiclav - Third-generation cephalosporins - Gentamicin - Piperacillin with tazobactam - Ciprofloxacin	- Amikacin - Meropenem - Co-amoxiclav - Third-generation cephalosporins - Gentamicin - Piperacillin with tazobactam - Ciprofloxacin

Organisms	0 to 3 days	4 days to 3 months	3 months to 4 years	5 to 17 years
Enterobacter cloacae complex	Organism not included for age group	- Amikacin - Gentamicin - Ciprofloxacin - Co-trimoxazole - Meropenem	- Amikacin - Gentamicin - Ciprofloxacin - Co-trimoxazole - Meropenem	- Amikacin - Gentamicin - Ciprofloxacin - Co-trimoxazole - Meropenem
K. pneumoniae	Organism not included for age group	Organism not included for age group	- Amikacin - Meropenem - Co-amoxiclav - Third-generation cephalosporins - Gentamicin - Piperacillin with tazobactam - Ciprofloxacin	- Amikacin - Meropenem - Co-amoxiclav - Third-generation cephalosporins - Gentamicin - Piperacillin with tazobactam - Ciprofloxacin
P. aeruginosa	Organism not included for age group	Organism not included for age group	- Amikacin - Meropenem - Third-generation cephalosporins (ceftazidime) - Gentamicin - Piperacillin with tazobactam - Ciprofloxacin	- Amikacin - Meropenem - Third-generation cephalosporins (ceftazidime) - Gentamicin - Piperacillin with tazobactam - Ciprofloxacin

The antimicrobials included in the antimicrobial susceptibility reporting are clinically important in the treatment of Gram-positive or Gram-negative paediatric infections. The following antimicrobial groupings were used:

- flucloxacillin (comprised of meticillin, cefoxitin, and flucloxacillin)
- Meticillin (comprised of meticillin and cefoxitin)
- third-generation cephalosporins (comprised of cefotaxime, ceftazidime, ceftriaxone, and cefpodoxime; except for *Pseudomonas* spp. where only ceftazidime was included)
- glycopeptides (comprised of teicoplanin and vancomycin)
- macrolides (comprised of azithromycin, clarithromycin, and erythromycin)

Several organism species were grouped together during data processing:

- CoNS with *Micrococcus* spp. because they form part of the normal skin flora and are common contaminants of blood cultures
- oral and other streptococci , comprises the Streptococcus spp. in groups *S. anginosus, S. bovis, S. mitis, S. mutans, S. salivarius,* and *S. sanguinis*.
- *Enterobacter cloacae* complex includes *Enterobacter asburiae, Enterobacter bugandensis, Enterobacter cloacae, Enterobacter cloacae complex, Enterobacter hormaechei, Enterobacter kobei, Enterobacter xianfangensis*, and unspeciated *Enterobacter* spp. (approximately 1.2% in 2022)
- all *Listeria* sp.
- *S. aureus* includes MRSA, MSSA and *S. aureus* that did not have a resistant, susceptible, or intermediate test result to meticillin and cefoxitin in SGSS
- MRSA is any *S. aureus* isolate that had a resistant test result to meticillin or cefoxitin in SGSS
- MSSA is any *S. aureus* isolate that had a susceptible or intermediate test result to meticillin or cefoxitin in SGSS and did not have a resistant result to either antimicrobial

5. Acknowledgements

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Feedback and specific queries about this report are welcome and can be sent to hcai.amrdepartment@ukhsa.gov.uk

6. References

1. UKHSA (2023) 'English surveillance programme for antimicrobial utilisation and resistance (ESPAUR) report 2022 to 2023'
2. UKHSA (2023) 'Group A streptococcal infections: tenth update on seasonal activity in England'
3. UKHSA (2023) 'Group A streptococcal infections: eleventh update on seasonal activity in England'
4. UKHSA (2014) 'Pyogenic and non-pyogenic streptococcal bacteraemia: annual data from voluntary surveillance'
5. UKHSA (2015) 'Listeria monocytogenes: surveillance reports'
6. UKHSA (2019) 'ESPAUR report 2018 to 2019'
7. ONS (2022) 'Mid-year population estimates for England, Wales and Northern Ireland'
8. UKHSA (2014) 'Antimicrobial Resistance and Healthcare Associated Infections (AMRHAI) Reference Unit'

7. Appendices

Throughout this report reference is made to numbered appendices. These refer to the data tables in the spreadsheet accompanying the report which can be found on the same web page as the report. They are:

Figures

Appendix 1. Data reference table for figure 1: bloodstream infection rates per 100,000 paediatric population (aged 0 to 17 years old) in England: 2018 to 2022

Appendix 2. Data reference table for figure 2: AMR of Gram-positive bloodstream infection for children aged 0 to 3 days old in England: 2018 to 2022

Appendix 3. Data reference table for figure 3: AMR of Gram-negative bloodstream infection for children aged 0 to 3 days old in England: 2018 to 2022

Appendix 4. Data reference table for figure 4: AMR of Gram-positive bloodstream infection for children aged 4 days to 3 months old in England: 2018 to 2022

Appendix 5. Data reference table for figure 5: AMR of Gram-negative bloodstream infection for children aged 4 days to 3 months old in England: 2018 to 2022

Appendix 6. Data reference table for figure 6: AMR of Gram-positive bloodstream infection for children aged 3 months to 4 years old in England: 2018 to 2022

Appendix 7. Data reference table for figure 7: AMR of Gram-negative bloodstream infection for children aged 3 months to 4 years old in England: 2018 to 2022

Appendix 8. Data reference table for figure 8: AMR of Gram-positive bloodstream infection for children aged 5 to 17 years old in England: 2018 to 2022

Appendix 9. Data reference table for figure 9: AMR of Gram-negative bloodstream infection for children aged 5 to 17 years old in England: 2018 to 2022

Accessory tables

Appendix 10. Data reference: Percentage resistance to key antibiotics for Listeria spp. in paediatric population in England: 2018 to 2022

Appendix 11. Data reference: Breakdown of bloodstream infection organisms with counts of 20 and over in 0 to 17 years old in England in 2018 and 2022

Appendix 12. Data reference: Breakdown of bloodstream infection organisms with counts of 20 and over in 0 to 3 days old in England in 2018 and 2022

Appendix 13. Data reference: Breakdown of bloodstream infection organisms with counts of 20 and over in 4 day to <1 month old in England in 2018 and 2022

Appendix 14. Data reference: Breakdown of bloodstream infection organisms with counts of 20 and over in 1 month to <1 year old in England in 2018 and 2022

Appendix 15. Data reference: Breakdown of bloodstream infection organisms with counts of 20 and over in 1 to 4 years old in England in 2018 and 2022

Appendix 16. Data reference: Breakdown of bloodstream infection organisms with counts of 20 and over in 5 to 17 years old in England in 2018 and 2022

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