

7. Susceptibility of Enterobacteriaceae to ampicillin, cefalexin and co-amoxiclav

Various combinations of susceptibility of Enterobacteriaceae to ampicillin, cefalexin and co-amoxiclav may be observed, depending on the species and resistance mechanisms involved. The following descriptions are a guide to indicate whether observed phenotypes are likely to be anomalous.

Ampicillin	Phenotype		Comment
	Co-amoxiclav	Cefalexin	
S	S	S	Wild type phenotype for <i>E. coli</i> , <i>P. mirabilis</i> , <i>Salmonella</i> spp. and <i>Shigella</i> spp. Exceptional phenotype for other common species, but occurs in around 2-5% of <i>Enterobacter</i> spp. via mutational loss of AmpC chromosomal β -lactamase inducibility.
S	S	R	Uncommon but occurs in <i>E. coli</i> permeability mutants, conferring low level/borderline susceptibility (zone sizes of all may be reduced compared with susceptible isolates). Such mutants should also be resistant to cefoxitin and cefuroxime, though not to third-generation cephalosporins.
S	R	S	Unlikely phenotype. May arise if a <i>Citrobacter freundii</i> or <i>Enterobacter</i> spp. has anomalous AmpC inducibility such that (atypically) cefalexin and ampicillin do not induce AmpC whereas clavulanate does induce. If seen in <i>E. coli</i> , refer to a Reference Laboratory.
S	R	R	Uncommon pattern mostly seen in <i>Providencia</i> spp., but also rarely in <i>Enterobacter</i> spp. and <i>C. freundii</i> isolates. Reflects a situation where clavulanate and cefalexin are strong inducers but ampicillin (for whatever reason) fails to induce as strongly as normally occurs for these species. If seen in other genera or species, refer to a Reference Laboratory.
R	S	S	Low-level penicillinase producer. Wild phenotype of <i>Klebsiella</i> spp., <i>Citrobacter koseri</i> , <i>Citrobacter amalonaticus</i> and <i>Escherichia hermannii</i> . Occurs also for isolates of <i>E. coli</i> , <i>P. mirabilis</i> , <i>Salmonella</i> spp. and <i>Shigella</i> spp. that have low or moderate expression of acquired plasmid-mediated penicillinases.

Phenotype			Comment
Ampicillin	Co-amoxiclav	Cefalexin	
R	S	R	Wild type pf <i>P. vulgaris</i> , <i>P. penneri</i> and <i>C. diversus</i> , reflecting activity of chromosomal β -lactamases. May arise for <i>E. coli</i> , <i>Klebsiella</i> spp. <i>P. mirabilis</i> , <i>Salmonella</i> spp. and <i>Shigella</i> spp. with high-level expression of acquired penicillinases, in which case co-amoxiclav zone, though implying susceptibility, is likely to be borderline. May be a low to moderate-level ESBL producer (most or all ESBLs are inhibited by clavulanate, and confer resistance to cefalexin). Not, however, a reliable identification of ESBL production by itself.
R	R	S	May be high-level penicillinase producer, overwhelming co-amoxiclav but leaving cefalexin as borderline susceptible see above also for ampicillin R, co-amoxiclav S cefalexin R. Also arises in <i>E. coli</i> , <i>Klebsiella</i> spp. and <i>P. mirabilis</i> that have acquired penicillinases that are naturally resistant to inhibition by clavulanate (e.g. OXA types, which account for 1-5% of ampicillin resistance in <i>E. coli</i>) or which have undergone mutations that confer inhibitor resistance (e.g. inhibitor resistant TEM types, sometimes called IRT enzymes).
R	R	R	Wild phenotype of <i>Enterobacter</i> spp., <i>C. freundii</i> , <i>Serratia</i> spp., <i>Morganella morganii</i> , <i>Providencia</i> spp. owing to inducible AmpC β -lactamases. May arise in <i>E. coli</i> , <i>Klebsiella</i> spp., <i>P. mirabilis</i> , <i>C. koseri</i> , <i>C. amalonaticus</i> and <i>E. hermannii</i> owing to strongly expressed acquired penicillinases or ESBLs or to acquired (plasmid-mediated) AmpC enzymes.