



BSAC Methods for Antimicrobial Susceptibility Testing

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## Preface

Since the *Journal of Antimicrobial Chemotherapy* Supplement containing the BSAC standardized disc susceptibility testing method was published in 2001, there have been various changes to the recommendations and these have been posted on the BSAC website (<http://www.bsac.org.uk>). One major organizational change has been the harmonisation of MIC breakpoints in Europe.

In 2002 the BSAC agreed to participate with several other European national susceptibility testing committees, namely CA-SFM (Comité de l'Antibiogramme de la Société Française de Microbiologie, France), the CRG (Commissie Richtlijnen Gevoeligheidsbepalingen (The Netherlands), DIN (Deutsches Institut für Normung, Germany), NWGA (Norwegian Working Group on Antimicrobials, Norway) and the SRGA (Swedish Reference Group of Antibiotics, Sweden), in a project to harmonize antimicrobial breakpoints, including previously established values that varied among countries. This work is being undertaken by the European Committee on Antimicrobial Susceptibility Testing (EUCAST) with the support and collaboration of the national committees, and is funded by the European Union, the European Society for Clinical Microbiology and Infectious Diseases (ESCMID) and the national committees, including the BSAC. The review process includes application of more recent techniques, such as pharmacodynamic analysis, and current data, where available, on susceptibility distributions, resistance mechanisms and clinical outcomes as related to *in vitro* tests. There is extensive discussion between EUCAST and the national committees, including the BSAC Working Party on antimicrobial susceptibility testing, and wide consultation on proposals. In the interest of international standardization of susceptibility testing, and the need to update older breakpoints, these developments are welcomed by the BSAC.

The implication of such harmonization is that over time some MIC breakpoints will change slightly and these changes will be reflected, where necessary, in corresponding changes to zone diameter breakpoints in the BSAC disc diffusion method. It is appreciated that changes in the method require additional work for laboratories in changing templates and laboratory information systems, and that the wider use of 'intermediate' categories will add complexity. Nevertheless the benefits of international standardization are considerable, and review of some older breakpoints is undoubtedly warranted.

In line with the European consensus EUCAST MIC breakpoints are defined as follows:

- Clinically resistant: level of antimicrobial susceptibility which results in a high likelihood of therapeutic failure
- Clinically susceptible: level of antimicrobial susceptibility associated with a high likelihood of therapeutic success
- Clinically intermediate: a level of antimicrobial susceptibility associated with uncertain therapeutic effect. It implies that an infection due to the isolate may be appropriately treated in body sites where the drugs are physically concentrated or when a high dosage of drug can be used; it also indicates a buffer zone that should prevent small, uncontrolled, technical factors from causing major discrepancies in interpretation.

The presentation of MIC breakpoints (mg/L) has also been amended to avoid the theoretical 'gap' inherent in the previous system as follows:

MIC  $\leq$  (as previously) MIC breakpoint concentration = organism is susceptible

MIC  $>$  (previously  $\geq$ ) MIC breakpoint concentration = organism is resistant

In practice, this does result in changes to breakpoint systems based on two-fold dilutions. However, the appearance of the tables will change, e.g. R  $\geq 16$ , S  $\leq 8$  will change to R  $> 8$ , S  $\leq 8$ .

EUCAST MIC breakpoints have to date been agreed for the following agents and are available on the EUCAST web site ([www.eucast.org](http://www.eucast.org)):

**Cephalosporins:** cefazolin, cefepime, cefotaxime, ceftazidime, ceftriaxone, cefuroxime

**Carbapenems:** ertapenem, imipenem, meropenem

**Monobactams:** aztreonam

**Fluoroquinolones:** ciprofloxacin, levofloxacin, moxifloxacin, norfloxacin, ofloxacin

**Aminoglycosides:** amikacin, gentamicin, netilmicin, tobramycin

**Glycopeptides:** teicoplanin, vancomycin

**Other agents:** linezolid, daptomycin, tigecycline

## Disc Diffusion Method for Antimicrobial Susceptibility Testing

### 1. Preparation of plates

- 1.1 Prepare Iso-Sensitest agar (ISA) (see list of suppliers) or media shown to have the same performance as ISA, according to the manufacturer's instructions. Supplement media for fastidious organisms with 5% defibrinated horse blood or 5% defibrinated horse blood and 20 mg/L  $\beta$ -nicotinamide adenine dinucleotide (NAD) as indicated in Table 1. Use Columbia agar with 2% NaCl for methicillin/oxacillin susceptibility testing of staphylococci.

Table 1: Media and supplementation for antimicrobial susceptibility testing of different groups of organisms

Organisms	Medium
Enterobacteriaceae	ISA
<i>Pseudomonas</i> spp.	ISA
<i>Stenotrophomonas maltophilia</i>	ISA
Staphylococci (tests other than methicillin/oxacillin)	ISA
<i>Staphylococcus aureus</i> (tests using cefoxitin to detect methicillin/oxacillin/cefoxitin resistance)	ISA
Staphylococci (tests using methicillin or oxacillin for the detection of methicillin/oxacillin/cefoxitin resistance)	Columbia agar ( <i>see suppliers</i> ) with 2% NaCl <sup>1</sup>
Enterococci	ISA
<i>Streptococcus pneumoniae</i>	ISA + 5% defibrinated horse blood <sup>2</sup>
$\alpha$ -Haemolytic streptococci	ISA + 5% defibrinated horse blood + 20 mg/L NAD
$\beta$ -Haemolytic streptococci	ISA + 5% defibrinated horse blood <sup>2</sup>
<i>Moraxella catarrhalis</i>	ISA + 5% defibrinated horse blood <sup>2</sup>
<i>Haemophilus</i> spp.	ISA + 5% defibrinated horse blood + 20 mg/L NAD
<i>Neisseria gonorrhoeae</i>	ISA + 5% defibrinated horse blood <sup>2</sup>
<i>Neisseria meningitidis</i>	ISA + 5% defibrinated horse blood <sup>2</sup>
<i>Pasteurella multocida</i>	ISA + 5% defibrinated horse blood + 20 mg/L NAD
<i>Bacteroides fragilis</i> , <i>Bacteroides thetaiotaomicron</i> , <i>Clostridium perfringens</i>	ISA + 5% defibrinated horse blood + 20 mg/L NAD
<i>Campylobacter</i> spp.	ISA + 5% defibrinated horse blood <sup>2</sup>
Coryneform organisms	ISA + 5% defibrinated horse blood + 20 mg/L NAD

<sup>1</sup> See Section 8.

<sup>2</sup> ISA supplemented with 5% defibrinated horse blood + 20mg/L NAD may be used.



- 1.2 Pour sufficient molten agar into sterile Petri dishes to give a depth of 4 mm  $\pm$  0.5 mm (25 mL in 90 mm diameter Petri dishes).
- 1.3 Dry the surface of the agar to remove excess moisture before use. The length of time needed to dry the surface of the agar depends on the drying conditions, e.g. whether a fan-assisted drying cabinet or 'still air' incubator is used, whether plates are dried before storage and storage conditions. **It is important that plates are not over dried.**
- 1.4 Store the plates in vented plastic boxes at 8-10°C prior to use. Alternatively the plates may be stored at 4-8°C in sealed plastic bags. Plate drying, method of storage and storage time should be determined by individual laboratories as part of their quality assurance programme. In particular, quality control tests should confirm that excess surface moisture is not produced and that plates are not over-dried.

## 2. Selection of control organisms

- 2.1 The performance of the tests should be monitored by the use of appropriate control strains (see section on control of antimicrobial susceptibility testing). The control strains listed (Tables 2a, 2b) include susceptible strains that have been chosen to monitor test performance and resistant strains that can be used to confirm that the method will detect a mechanism of resistance.
- 2.2 Store control strains at  $-70^{\circ}\text{C}$  on beads in glycerol broth. Non-fastidious organisms may be stored at  $-20^{\circ}\text{C}$ . Two vials of each control strain should be stored, one for an 'in-use' supply, the other for archiving.
- 2.3 Every week subculture a bead from the 'in-use' vial on to appropriate non-selective media and check for purity. From this pure culture, prepare one subculture on each of the following 5 days. For fastidious organisms that will not survive on plates for 5/6 days, subculture the strain daily for no more than 6 days.

Table 2a: Susceptible control strains or control strains with low-level resistance that have been chosen to monitor test performance of antimicrobial susceptibility testing

Organism	Strain		Characteristics
	Either	Or	
<i>Escherichia coli</i>	NCTC 12241 (ATCC 25922)	NCTC 10418	Susceptible
<i>Staphylococcus aureus</i>	NCTC 12981 (ATCC 25923)	NCTC 6571	Susceptible
<i>Pseudomonas aeruginosa</i>	NCTC 12934 (ATCC 27853)	NCTC 10662	Susceptible
<i>Enterococcus faecalis</i>	NCTC 12697 (ATCC 29212)		Susceptible
<i>Haemophilus influenzae</i>	NCTC 11931		Susceptible
<i>Streptococcus pneumoniae</i>	NCTC 12977 (ATCC 49619)		Low-level resistant to penicillin
<i>Neisseria gonorrhoeae</i>	NCTC 12700 (ATCC 49226)		Low-level resistant to penicillin
<i>Pasteurella multocida</i>	NCTC 8489		Susceptible
<i>Bacteroides fragilis</i>	NCTC 9343 (ATCC 25285)		Susceptible
<i>Bacteroides thetaiotaomicron</i>	ATCC 29741		Susceptible
<i>Clostridium perfringens</i>	NCTC 8359 (ATCC 12915)		Susceptible

Table 2b: Control strains with a resistance mechanism that can be used to confirm that the method will detect resistance.

Organism	Strain	Characteristics
<i>Escherichia coli</i>	NCTC 11560	TEM-1 $\beta$ -lactamase-producer
<i>Staphylococcus aureus</i>	NCTC 12493	<i>MecA</i> positive, methicillin resistant
<i>Haemophilus influenzae</i>	NCTC 12699 (ATCC 49247)	Resistant to $\beta$ -lactams ( $\beta$ -lactamase-negative)

### 3. Preparation of inoculum

The inoculum should give semi-confluent growth of colonies after overnight incubation. Use of an inoculum that yields semi-confluent growth has the advantage that an incorrect inoculum can easily be observed. A denser inoculum will result in reduced zones of inhibition and a lighter inoculum will have the opposite effect. The following methods reliably give semi-confluent growth with most isolates.

**NB.** Other methods of obtaining semi-confluent growth may be used if they are shown to be equivalent to the following.

### 3.1 Comparison with a 0.5 McFarland standard

#### 3.1.1 *Preparation of the 0.5 McFarland standard*

Add 0.5 mL of 0.048 M BaCl<sub>2</sub> (1.17% w/v BaCl<sub>2</sub> · 2H<sub>2</sub>O) to 99.5 mL of 0.18 M H<sub>2</sub>SO<sub>4</sub> (1% w/v) with constant stirring. Thoroughly mix the suspension to ensure that it is even. Using matched cuvettes with a 1 cm light path and water as a blank standard, measure the absorbance in a spectrophotometer at a wavelength of 625 nm. The acceptable absorbance range for the standard is 0.08-0.13. Distribute the standard into screw-cap tubes of the same size and volume as those used in growing the broth cultures. Seal the tubes tightly to prevent loss by evaporation. Store protected from light at room temperature. Vigorously agitate the turbidity standard on a vortex mixer before use. Standards may be stored for up to six months, after which time they should be discarded. Prepared standards can be purchased (See list of suppliers), but commercial standards should be checked to ensure that absorbance is within the acceptable range as indicated above.

#### 3.1.2 *Inoculum preparation by the growth method* (for non-fastidious organisms, e.g. Enterobacteriaceae, *Pseudomonas* spp. and staphylococci)

Touch at least four morphologically similar colonies (when possible) with a sterile loop. Transfer the growth into Iso-Sensitest broth or an equivalent that has been shown not to interfere with the test. Incubate the broth, with shaking at 35-37°C, until the visible turbidity is equal to or greater than that of a 0.5 McFarland standard.

#### 3.1.3 *Inoculum preparation by the direct colony suspension method* (the method of choice for fastidious organisms, i.e. *Haemophilus* spp., *Neisseria gonorrhoeae*, *Neisseria meningitidis*, *Moraxella catarrhalis*, *Streptococcus pneumoniae*, α and β-haemolytic streptococci, *Clostridium perfringens*, *Bacteroides fragilis*, *Bacteroides thetaiotaomicron*, *Campylobacter* spp., *Pasteurella multocida* and Coryneform organisms).

Colonies are taken directly from the plate into Iso-Sensitest broth (or equivalent) or sterile distilled water. The density of the suspension should match or exceed that of a 0.5 McFarland standard.

**NB.** With some organisms production of an even suspension of the required turbidity is difficult and growth in broth, if possible, is a more satisfactory option.

#### 3.1.4 *Adjustment of the organism suspension to the density of a 0.5 McFarland standard*

Adjust the density of the organism suspension to equal that of a 0.5 McFarland standard by adding sterile distilled water. To aid comparison, compare the test and standard suspensions against a white background with a contrasting black line.

**NB.** Suspension should be used within 15 min.

#### 3.1.5 *Dilution of suspension in distilled water before inoculation*

Dilute the suspension (density adjusted to that of a 0.5 McFarland standard) in distilled water as indicated in Table 3.

Table 3: Dilution of the suspension (density adjusted to that of a 0.5 McFarland standard) in distilled water

Dilute 1:100	Dilute 1:10	No dilution
$\beta$ -Haemolytic streptococci	Staphylococci	<i>Neisseria gonorrhoeae</i>
Enterococci	<i>Serratia</i> spp.	<i>Campylobacter</i> spp.
Enterobacteriaceae	<i>Streptococcus pneumoniae</i>	
<i>Pseudomonas</i> spp.	<i>Neisseria meningitidis</i>	
<i>Stenotrophomonas maltophilia</i>	<i>Moraxella catarrhalis</i>	
<i>Acinetobacter</i> spp.	$\alpha$ -haemolytic streptococci	
<i>Haemophilus</i> spp.	<i>Clostridium perfringens</i>	
<i>Pasteurella multocida</i>	Coryneform organisms	
<i>Bacteroides fragilis</i>		
<i>Bacteroides thetaiotaomicron</i>		

**NB.** These suspensions should be used within 15 min of preparation.

### 3.2 Photometric standardization of turbidity of suspensions

A photometric method of preparing inocula was described by Moosdeen *et al* (1988)<sup>1</sup> and from this the following simplified procedure has been developed. The spectrophotometer must have a cell holder for 100 x 12 mm test tubes. A much simpler photometer would also probably be acceptable. The 100 x 12 mm test tubes could also be replaced with another tube/cuvette system if required, but the dilutions would need to be recalibrated.

3.2.1 Suspend colonies (touch 4-5 when possible) in 3 mL distilled water or broth in a 100 x 12 mm glass tube (note that tubes are not reused) to give just visible turbidity. It is essential to get an even suspension.

**NB.** These suspensions should be used within 15 min of preparation.

3.2.2 Zero the spectrophotometer with a sterile water or broth blank (as appropriate) at a wavelength of 500 nm and measure the absorbance of the bacterial suspension.

3.2.3 From table 4 select the volume to transfer (with the appropriate fixed volume micropipette) to 5 mL sterile distilled water.

3.2.4 Mix the diluted suspension to ensure that it is even

**NB.** Suspension should be used within 15 min. of preparation

Table 4: Dilution of suspensions of test organisms according to absorbance reading

Organisms	Absorbance reading at 500 nm	Volume ( $\mu$ L) to transfer to 5 mL sterile distilled water
Enterobacteriaceae	0.01 - 0.05	250
Enterococci	>0.05 - 0.1	125
<i>Pseudomonas</i> spp.	>0.1 - 0.3	40
Staphylococci	>0.3 - 0.6	20
	>0.6 - 1.0	10
<i>Haemophilus</i> spp.	0.01 - 0.05	500
Streptococci	>0.05 - 0.1	250
Miscellaneous fastidious Organisms	>0.1 - 0.3	125
	>0.3 - 0.6	80
	>0.6 - 1.0	40

**NB.** As spectrophotometers may differ, it may be necessary to adjust the dilutions slightly to achieve semi-confluent growth with any individual set of laboratory conditions.

### 3.3 Direct antimicrobial susceptibility testing of urine specimens and blood cultures

Direct susceptibility testing is not advocated as the control of inoculum is very difficult. Direct testing is, however, undertaken in many laboratories in order to provide more rapid test results. The following methods have been recommended by laboratories that use the BSAC method and will achieve the correct inoculum size for a reasonable proportion of infected urines and blood cultures. If the inoculum is not correct (i.e. growth is not semi-confluent) or the culture is mixed, the test must be repeated.

#### 3.3.1 Urine specimens

##### 3.3.1.1 Method 1

Thoroughly mix the urine specimen, then place a 10  $\mu$ L loop of urine in the centre of the susceptibility plate and spread evenly with a dry swab.

##### 3.3.1.2 Method 2

Thoroughly mix the urine specimen, then dip a sterile cotton-wool swab in the urine and remove excess by turning the swab against the inside of the container. Use the swab to make a cross in the centre of the susceptibility plate and spread evenly with another sterile dry swab. If only small numbers of organisms are seen in microscopy, the initial cotton-wool swab may be used to inoculate and spread the susceptibility plate.

#### 3.3.2 Positive blood cultures

The method depends on the Gram reaction of the infecting organism.

##### 3.3.2.1 Gram-negative bacilli.

Using a venting needle, place one drop of the blood culture in 5 mL of sterile water, then dip a sterile cotton-wool swab in the suspension and remove excess by turning the swab against the inside of the container. Use the swab to spread the inoculum evenly over the surface of the susceptibility plate.

##### 3.3.2.2 Gram-positive organisms.

It is not always possible accurately to predict the genera of Gram-positive organisms from the Gram's stain. However, careful observation of the

morphology, coupled with clinical information, should make an “educated guess” correct most of the time.

Staphylococci and enterococci.

Using a venting needle, place three drops of the blood culture in 5 mL of sterile water, then dip a sterile cotton-wool swab in the suspension and remove excess by turning the swab against the inside of the container. Use the swab to spread the inoculum evenly over the surface of the susceptibility plate.

Pneumococci, “viridans” streptococci and diphtheroids.

Using a venting needle, place one drop of the blood culture in the centre of a susceptibility plate, and spread the inoculum evenly over the surface of the plate.

#### 4. Inoculation of agar plate

Use the adjusted suspension within 15 min to inoculate plates by dipping a sterile cotton-wool swab into the suspension and remove the excess liquid by turning the swab against the side of the container. Spread the inoculum evenly over the entire surface of the plate by swabbing in three directions. Allow the plate to dry before applying discs.

**NB.** If inoculated plates are left at room temperature for extended times before the discs are applied, the organism may begin to grow, resulting in reduced zones of inhibition. Discs should therefore be applied to the surface of the agar within 15 min of inoculation.

#### 5. Antimicrobial discs

Refer to interpretation tables 6-23 for the appropriate disc contents for the organisms tested.

##### 5.1 Storage and handling of discs.

Loss of potency of agents in discs will result in reduced zones of inhibition. To avoid loss of potency due to inadequate handling of discs the following are recommended:

- 5.1.1 Store discs in sealed containers with a desiccant and protected from light (this is particularly important for some light-susceptible agents such as metronidazole, chloramphenicol and the quinolones).
- 5.1.2 Store stocks at -20°C except for drugs known to be unstable at this temperature. If this is not possible, store discs at <8°C.
- 5.1.3 Store working supplies of discs at <8°C.
- 5.1.4 To prevent condensation, allow discs to warm to room temperature before opening containers.
- 5.1.5 Store disc dispensers in sealed containers with an indicating desiccant.
- 5.1.6 Discard discs on the expiry date shown on the side of the container.

##### 5.2 Application of discs

Discs should be firmly applied to the dry surface of the inoculated susceptibility plate. The contact with the agar should be even. A 90 mm plate will accommodate six discs without unacceptable overlapping of zones.

## 6. Incubation

If the plates are left for extended times at room temperature after discs are applied, larger zones of inhibition may be obtained compared with zones produced when plates are incubated immediately. Plates should therefore be incubated within 15 min of disc application.

### 6.1 Conditions of incubation

Incubate plates under conditions listed in table 5.

Table 5: Incubation conditions for antimicrobial susceptibility tests on various organisms

Organisms	Incubation conditions
Enterobacteriaceae	35-37°C in air for 18-20 h
<i>Acinetobacter</i> spp.	35-37°C in air for 18-20 h
<i>Pseudomonas</i> spp.	35-37°C in air for 18-20 h
<i>Stenotrophomonas maltophilia</i>	30°C in air for 18-20 h
Staphylococci (other than methicillin/oxacillin/cefoxitin)	35-37°C in air for 18-20 h
<i>Staphylococcus aureus</i> using cefoxitin for the detection of methicillin/oxacillin/cefoxitin resistance	35°C in air for 18-20 h
Staphylococci using methicillin or oxacillin to detect resistance	30°C in air for 24 h
<i>Moraxella catarrhalis</i>	35-37°C in air for 18-20 h
$\alpha$ -Haemolytic streptococci	35-37°C in 4-6% CO <sub>2</sub> in air for 18-20 h
$\beta$ -Haemolytic streptococci	35-37°C in air for 18-20 h
Enterococci	35-37°C in air for 24 h <sup>1</sup>
<i>Neisseria meningitidis</i>	35-37°C in 4-6 % CO <sub>2</sub> in air for 18-20 h
<i>Streptococcus pneumoniae</i>	35-37°C in 4-6 % CO <sub>2</sub> in air for 18-20 h
<i>Haemophilus</i> spp.	35-37°C in 4-6 % CO <sub>2</sub> in air for 18-20 h
<i>Neisseria gonorrhoeae</i>	35-37°C in 4-6 % CO <sub>2</sub> in air for 18-20 h
<i>Pasteurella multocida</i>	35-37°C in 4- 6% CO <sub>2</sub> in air for 18-20 h
Coryneform organisms	35-37°C in 4-6% CO <sub>2</sub> in air for 18-20 h
<i>Campylobacter</i> spp.	35-37°C in microaerophilic conditions for 18-20 h
<i>Bacteroides fragilis</i> , <i>Bacteroides thetaiotaomicron</i> , <i>Clostridium perfringens</i>	35-37°C in 10% CO <sub>2</sub> /10% H <sub>2</sub> /80% N <sub>2</sub> for 18-20 h (anaerobic cabinet or jar)

<sup>1</sup>It is essential that plates are incubated for at least 24 h before reporting a strain as susceptible to vancomycin or teicoplanin.

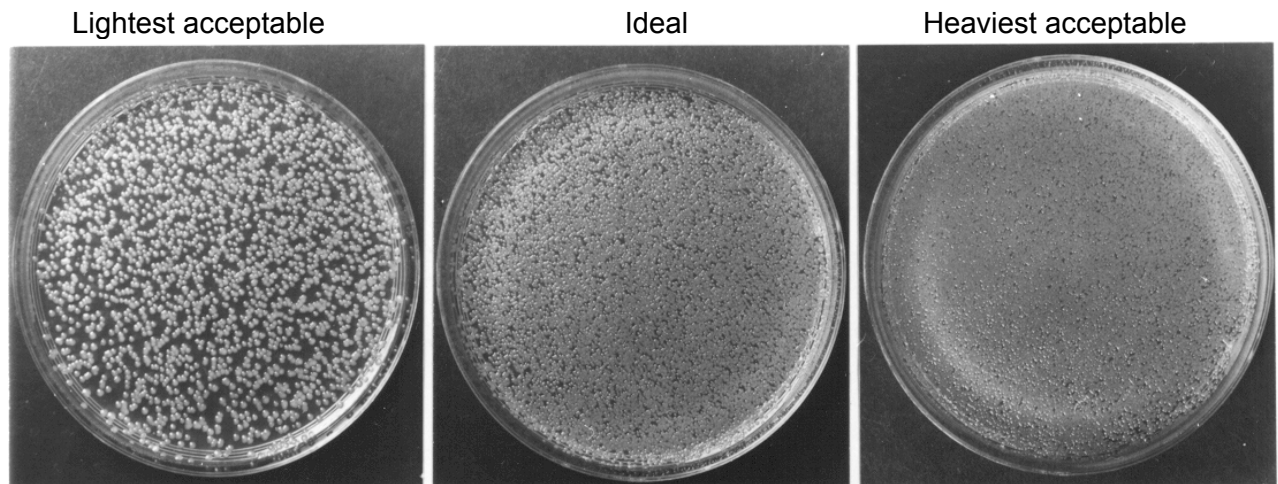
**NB.** Stacking plates too high in the incubator may affect results owing to uneven heating of plates. The efficiency of heating of plates depends on the incubator and the racking system used. Control of incubation, including height of plate stacking, should therefore be part of the laboratory's Quality Assurance programme.

## 7. Measuring zones and interpretation of susceptibility

### 7.1 Acceptable inoculum density

The inoculum should give semi-confluent growth of colonies on the susceptibility plate, within the range illustrated in Figure 1.

Figure 1: Acceptable inoculum density range for a Gram-negative rod



### 7.2 Measuring zones

- 7.2.1 Measure the diameters of zones of inhibition to the nearest millimetre (zone edge should be taken as the point of inhibition as judged by the naked eye) with a ruler, callipers or an automated zone reader.
- 7.2.2 Tiny colonies at the edge of the zone, films of growth as a result of the swarming of *Proteus* spp. and slight growth within sulphonamide or trimethoprim zones should be ignored.
- 7.2.3 Colonies growing within the zone of inhibition should be subcultured and identified and the test repeated if necessary.
- 7.2.4 When using cefoxitin for the detection of methicillin/oxacillin/cefoxitin resistance in *S. aureus*, measure the obvious zone, taking care to examine zones carefully in good light to detect minute colonies that may be present within the zone of inhibition (see Figure 3)
- 7.2.5 Confirm that the zone of inhibition for the control strain falls within the acceptable ranges in Tables 20-23 before interpreting the test (see section on control of the disc diffusion method).

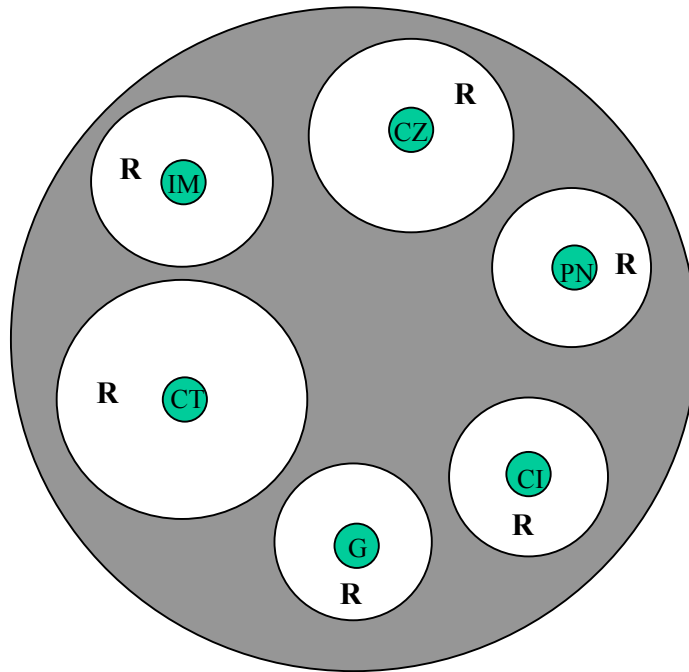
### 7.3 Use of templates for interpreting zone diameters

A template may be used for interpreting zone diameters (see Figure 2). A program for preparing templates is available from the BSAC (<http://www.bsac.org.uk>).

The test plate is placed over the template and the zones of inhibition are examined in relationship to the template zones. If the zone of inhibition of the test strain is within the area marked with an 'R', the organism is resistant. If the zone of inhibition is equal to or larger than the marked area, the organism is susceptible.



Figure 2: Template for interpreting zone diameters



## 8. Methicillin/oxacillin/cefoxitin testing of staphylococci

Methicillin susceptibility testing is difficult with some strains. Expression of resistance is affected by test conditions and resistance is often heterogeneous, with only a proportion of cells showing resistance. Adding NaCl or lowering incubation temperatures increases the proportion of cells showing resistance. Methicillin susceptibility testing of coagulase-negative staphylococci is further complicated as some strains do not grow well on media containing NaCl and are often slower-growing than *Staphylococcus aureus*. Detection of methicillin resistance in coagulase-negative staphylococci may require incubation for 48 h.

### 8.1 Method for detection of methicillin/oxacillin resistance in *S. aureus* and coagulase-negative staphylococci

#### 8.1.1 Medium

Prepare Columbia (See list of suppliers) or Mueller-Hinton agar (See list of suppliers) following the manufacturer's instructions and add 2% NaCl. After autoclaving, mix well to distribute the sodium chloride. Pour plates to give a depth of 4 mm ( $\pm$  0.5 mm) in a 90 mm sterile Petri dish (25 ml). Dry and store plates as previously described (section 1).

#### 8.1.2 Inoculum

Prepare inoculum as previously described (section 3).

#### 8.1.3 Control

Susceptible control strains (*Staphylococcus aureus* ATCC 25923 or NCTC 6571) test the reliability of disc content.

*Staphylococcus aureus* NCTC 12493 is a methicillin resistant strain and is used to check that the test will detect resistant organisms (although no strain can be representative of all the MRSA types in terms of their response to changes in test conditions).

#### 8.1.4 Discs

Place a methicillin 5 µg or an oxacillin 1 µg disc on to the surface of inoculated agar. Discs should be stored and handled as previously described (section 5).

#### 8.1.5 Incubation

Incubate plates for 24 h at 30°C.

#### 8.1.6 Zone measurement

Measure zone diameters (mm) as previously described (section 7).

Examine zones carefully in good light to detect colonies, which may be minute, in zones. If there is suspicion that the colonies growing within zones are contaminants they should be identified and the isolate re-tested for resistance to methicillin/oxacillin if necessary.

#### 8.1.7 Interpretation

For both methicillin and oxacillin interpretation is as follows:

Susceptible =  $\geq 15$  mm diameter, resistant =  $\leq 14$  mm diameter.

**NB. Hyper-production of  $\beta$ -lactamase does not confer clinical resistance to penicillinase-resistant penicillins and such isolates should be reported susceptible to methicillin/oxacillin.** Some hyper-producers of  $\beta$ -lactamase give zones within the range of 7-14 mm and, if possible, such isolates should be checked by a PCR method for *mecA* or by a latex agglutination test for PBP2a. Increase in methicillin/oxacillin zone size in the presence of clavulanic acid is not a reliable test for hyper-producers of  $\beta$ -lactamase as zones of inhibition with some MRSA also increase in the presence of clavulanic acid. Rarely, hyper-producers of  $\beta$ -lactamase give no zone in this test and would therefore not be distinguished from MRSA.

### 8.2 Detection of methicillin/oxacillin/cefoxitin resistance in *Staphylococcus aureus* by use of cefoxitin as the test agent

#### 8.2.1 Medium

Prepare Iso-Sensitest agar as previously described (section 1).

#### 8.2.2 Inoculum

Prepare inoculum as previously described (section 3).

#### 8.2.3 Control

Use control strains as previously described (section 8.1.3).

#### 8.2.4 Discs

Place a 10 µg cefoxitin disc on the surface of inoculated agar.

Discs should be stored and handled as previously described (section 5).

#### 8.2.5 Incubation

Incubate plates at 35°C for 18-20 h.

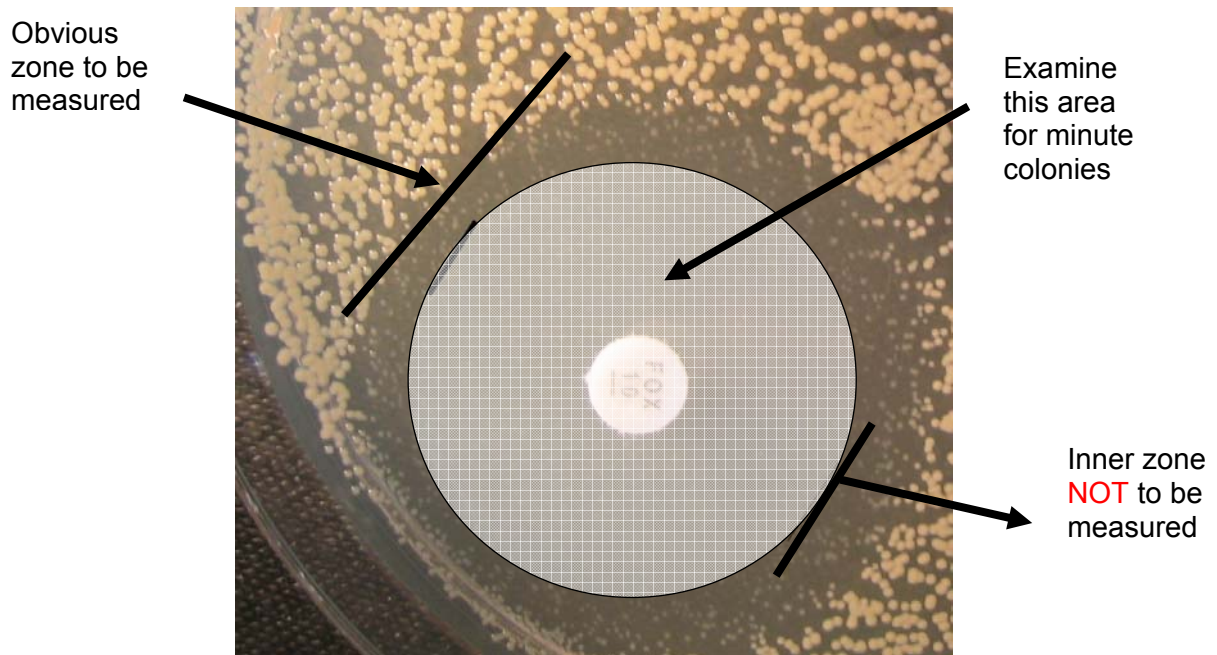
**NB.** It is important that the temperature does not exceed 36°C, as tests incubated at higher temperatures are less reliable.

### 8.2.6 Zone measurement

Measure zone diameters as previously described (section 7), reading the obvious zone edge (see Figure 3).

Examine zones carefully in good light to detect colonies, which may be minute, in zones. If there is suspicion that the colonies growing within zones are contaminants they should be identified and the isolate re-tested for resistance to cefoxitin if necessary.

Figure 3: Reading cefoxitin zones of inhibition with *Staphylococcus aureus*



### 8.2.7 Interpretation

Susceptible =  $\geq 22$  mm diameter, resistant =  $\leq 21$  mm diameter.

**NB. Hyper-production of  $\beta$ -lactamase does not confer clinical resistance to penicillinase-resistant penicillins and such isolates should be reported susceptible to cefoxitin.** Hyper-producers of  $\beta$ -lactamase give zones within the ranges of the susceptible population.

Table 6: MIC and zone breakpoints for Enterobacteriaceae (including *Salmonella* and *Shigella* spp.).

Antibiotic	MIC breakpoint (mg/L)			Disc content (µg)	Interpretation of zone diameters (mm)		
	R >	I	S ≤		R ≤	I	S ≥
Amikacin <sup>1</sup>	16	16	8	30	15	16-18	19
Amoxicillin <sup>2</sup>	16	16	8	10	11	12-14	15
Ampicillin <sup>2</sup>	16	16	8	10	11	12-14	15
Azithromycin <sup>3</sup>	-	-	-	-	-	-	-
Aztreonam <sup>4</sup>	8	2-8	1	30	22	23-27	28
Cefaclor	1	-	1	30	34	-	35
Cefamandole <sup>5,6</sup>	8	-	8	30	19	-	20
Cefepime	8	2-8	1	30	26	27-31	32
Cefixime	1	-	1	5	19	-	20
Cefoperazone <sup>5</sup>	4	-	4	30	24	-	25
Cefotaxime <sup>7</sup>	2	2	1	30	29	-	30
Cefotetan <sup>5</sup>	4	-	4	30	23	-	24
Cefoxitin <sup>6</sup>	8	-	8	30	19	-	20
Cefpirome	1	-	1	20	24	-	25
Cefpodoxime <sup>8,9</sup>	1	-	1	10	19	-	20
Ceftazidime	8	2-8	1	30	17	18-29	30
Ceftibuten	1	-	1	10	27	-	28
Ceftizoxime	1	-	1	30	29	-	30
Ceftriaxone	2	2	1	30	23	24-27	28
Cefuroxime (axetil) <sup>1</sup>	1	-	1	30	24	-	25
Cefuroxime (parenteral) <sup>1,10</sup>	8	-	8	30	19	-	20
Cefalothin <sup>6</sup>	8	-	8	30	26	-	27
Cefradine <sup>6</sup>	8	-	8	30	11	-	12
Chloramphenicol	8	-	8	30	20	-	21
Ciprofloxacin <sup>11,12</sup>	1	1	0.5	1	16	17-19	20
Co-amoxiclav	16	16	8	20/10	11	12-14	15
Colistin <sup>13</sup>	4	-	4	25	14	-	15
Co-trimoxazole <sup>14,15</sup>	2	-	2	1.25/23.75	15	-	16
Doxycycline	1	-	1	30	28	-	29
Ertapenem	1	1	0.5	10	15	16-27	28
Gatifloxacin	1	-	1	2	19	-	20
Gemifloxacin	0.25	-	0.25	1	19	-	20
Gentamicin <sup>1,16</sup>	4	4	2	10	16	17-19	20
Imipenem <sup>17</sup>	8	4-8	2	10	16	17-20	21
Levofloxacin	2	2	1	1	13	14-16	17
Meropenem	8	4-8	2	10	19	20-26	27
Mezlocillin	16	-	16	75	21	-	22
Moxifloxacin	1	1	0.5	1	16	17-19	20
Ofloxacin	1	1	0.5	5	25	26-28	29
Piperacillin /Tazobactam	16	-	16	75/10	21	-	22
Piperacillin	16	-	16	75	23	-	24
Streptomycin <sup>5</sup>	8	-	8	10	12	-	13
Sulfamethoxazole	32	-	32	100	13	-	14
Temocillin <sup>18</sup>	8	-	8	30	19	-	20
Tigecycline <sup>19</sup>	2	2	1	15	19	20-23	24
Ticarcillin/clavulanate	16	-	16	85	20	-	21

Antibiotic	MIC breakpoint (mg/L)				Interpretation of zone diameters (mm)		
	R >	I	S ≤	Disc content (µg)	R ≤	I	S ≥
Tobramycin <sup>1,16</sup>	4	4	2	10	17	18-20	21
Trimethoprim	2	1-2	0.5	2.5	14	15-19	20

Some problems with testing *Serratia* spp. have been related to difficulties in achieving the correct inoculum. Once a clinically significant isolate of *Serratia* sp. has been identified, it might be prudent to determine the susceptibility by an MIC method, or the disc diffusion test must be repeated if the inoculum density is outside the acceptable range.

The identification of Enterobacteriaceae to species level is essential for the application of expert rules for the interpretation of susceptibility. Species that typically have inducible AmpC enzymes (*Enterobacter* spp., *Citrobacter* spp., *Serratia* spp., *Morganella morganii* and *Providencia* spp.) readily mutate to stably derepressed AmpC production during treatment (in 20% cases with *Enterobacter* spp), conferring resistance to all first, second and third generation cephalosporins.

- 1 *Salmonella* spp. should be reported resistant to these agents, irrespective of susceptibility testing result, as they are inactive *in-vivo*.
- 2 These interpretative standards apply only to *Escherichia coli* and *Proteus mirabilis*
- 3 Azithromycin has been used in the treatment of infections with *S. typhi* (MIC ≤16 mg/L for wild type isolates) and some enteric infections.
- 4 The MIC breakpoint for aztreonam has been set to ensure that ESBL producers with aztreonam MIC values of 4 mg/L are not interpreted as susceptible to this agent.
- 5 Zone diameter breakpoints are valid only for *Escherichia coli*, *Klebsiella* spp. and *Proteus mirabilis*.
- 6 The MIC breakpoints have been adjusted to take account of the MIC distribution for the population lacking a mechanism of resistance.
- 7 The zone diameters relate to an MIC BP of 1 mg/L as no data for the intermediate category are currently available.
- 8 All Enterobacteriaceae isolates should be tested with cefpodoxime or both cefotaxime (or ceftriaxone) and ceftazidime. Enterobacteriaceae with resistance to cefpodoxime, ceftriaxone, cefotaxime or ceftazidime should be tested for the presence of ESBLs. Organisms inferred to have ESBLs should be reported resistant to all penicillins (except temocillin) and cephalosporins, including the fourth-generation cephalosporins cefepime and ceftipime. For serious infections, carbapenems (imipenem, meropenem and ertapenem) are the treatment of choice.
- 9 Organisms with cefpodoxime zone diameters of < 20 mm have a substantive mechanism of resistance. Organisms with zone diameters of 21-25 mm are uncommonly ESBL-producers and may require further investigation.
- 10 The breakpoint pertains to a dosage of 1.5 g three times a day and to *E. coli*, *Klebsiella* spp. and *P. mirabilis* only.
- 11 Isolates of *Escherichia coli* and *Klebsiella* spp. with ciprofloxacin MICs of 0.25 and 0.5 mg/L may be reported as resistant. These MICs are higher than those for the 'wild susceptible' populations for the species and may indicate a mechanism of resistance with clinical significance.
- 12 For ciprofloxacin, there is clinical evidence to indicate a poor response in systemic infections caused by *Salmonella* spp. with reduced susceptibility to fluoroquinolones (ciprofloxacin MICs 0.125-1 mg/L). It is recommended that a ciprofloxacin MIC should be determined for all invasive Salmonellae infections.
- 13 Some strains of Enterobacteriaceae (particularly *Serratia*, *Providencia*, *Citrobacter* and *Enterobacter* spp.) produce clear zones of inhibition with small colonies around the colistin disc. These isolates are resistant as the MICs typically exceed 128 mg/L.

- <sup>14</sup> The MIC breakpoint is based on the trimethoprim concentration in a 1:19 combination with sulphamethoxazole.
- <sup>15</sup> For advice on testing susceptibility to co-trimoxazole, see Appendix 1.
- <sup>16</sup> Individual aminoglycoside agents must be tested; susceptibility to other aminoglycosides cannot be inferred from the gentamicin result and *vice versa*.
- <sup>17</sup> *Proteus* spp. and *Morganella morganii* are considered poor targets for imipenem.
- <sup>18</sup> The distribution for ESBL and AmpC producers straddles the zone diameter breakpoint. Organisms that appear resistant by disc testing should have resistance confirmed by MIC.
- <sup>19</sup> *Morganella morganii*, *Providencia* spp. and *Proteus* spp. are considered inherently non-susceptible to tigecycline.

Table 7: MIC and zone breakpoints for *Acinetobacter* species

Antibiotic	MIC breakpoint (mg/L)			Disc content ( $\mu\text{g}$ )	Interpretation of zone diameters (mm)		
	R >	I	S $\leq$		R $\leq$	I	S $\geq$
Ciprofloxacin	1	-	1	1	20	-	21
Gentamicin	4	-	4	10	19	-	20
Imipenem	8	4-8	2	10	13	14-24	25
Meropenem	8	4-8	2	10	12	13-19	20
Piperacillin/tazobactam	16	-	16	75/10	21	-	22
Tigecycline	2	2	1	15	19	20-23	24

Table 8: MIC and zone diameter breakpoints for *Pseudomonas* spp.

Antibiotic	MIC breakpoint (mg/L)				Interpretation of zone diameters (mm)		
	R >	I	S ≤	Disc content (µg)	R ≤	I	S ≥
Amikacin	16	16	8	30	15	16-18	19
Aztreonam <sup>1</sup>	8	-	8	30	22	-	23
Carbenicillin	128	-	128	100	12	-	13
Cefotaxime	1	-	1	30	26	-	27
Cefpirome	1	-	1	20	19	20-24	25
Ceftazidime	8	-	8	30	23	-	24
Ceftriaxone	1	-	1	30	29	-	30
Ciprofloxacin	1	1	0.5	1	12	13-22	23
Ciprofloxacin	1	1	0.5	5	19	20-29	30
Colistin	4	-	4	25	13	-	14
Gatifloxacin	1	-	1	2	19	-	20
Gemifloxacin	0.25	-	0.25	5	19	-	20
Gentamicin	4	-	4	10	17	-	18
Imipenem <sup>2</sup>	8	8	4	10	16	17-22	23
Levofloxacin	2	2	1	5	16	17-21	22
Meropenem <sup>2</sup>	8	4-8	2	10	21	22-26	27
Moxifloxacin	4	2-4	1	5	17	18-24	25
Netilmicin	4	-	4	10	13	-	14
Piperacillin	16	-	16	75	23	-	24
Piperacillin /tazobactam	16	-	16	75/10	21	-	22
Ticarcillin	64	32-64	16	75	19	-	20
Timentin	64	32-64	16	85	19	-	20
Tobramycin	4	-	4	10	19	-	20

<sup>1</sup> Relates only to patients with cystic fibrosis given high dosage therapy to treat *P. aeruginosa* infection

<sup>2</sup> The detection of resistance mediated by carbapenemase is difficult, particularly if resistance is not fully expressed. Consideration should be given to testing ceftazidime and carbapenem resistant isolates for the presence of carbapenemases.



Table 9: MIC and zone diameter breakpoints for *Stenotrophomonas maltophilia*<sup>1</sup>.

Antibiotic	MIC breakpoint (mg/L)				Interpretation of zone diameters (mm)		
	R >	I	S ≤	Disc content (µg)	R ≤	I	S ≥
Co-trimoxazole <sup>2</sup>	2	-	2	25	19	-	20

<sup>1</sup> For *Stenotrophomonas maltophilia*, susceptibility testing is not recommended except for co-trimoxazole (see [www.bsac.org.uk](http://www.bsac.org.uk) BSAC Standardized Susceptibility Testing Method, Additional Methodology, *Stenotrophomonas maltophilia*).

<sup>2</sup> The MIC breakpoint is based on the trimethoprim concentration in a 1:19 combination with sulphamethoxazole.

Table 10: MIC and zone diameter breakpoints for staphylococci.

Antibiotic	MIC breakpoint (mg/L)				Interpretation of zone diameters (mm)		
	R >	I	S ≤	Disc content (µg unless stated)	R ≤	I	S ≥
Amikacin <i>Staphylococcus aureus</i>	16	16	8	30	15	16-18	19
Amikacin coagulase-negative staphylococci	16	16	8	30	21	22-24	25
Azithromycin	1	-	1	15	19	-	20
Cefoxitin <sup>1</sup> <i>Staphylococcus aureus</i>	4	-	4	10	21	-	22
Cefoxitin <sup>1,2</sup> Coagulase negative staphylococci	<b>4</b>	-	<b>4</b>	<b>10</b>	<b>21</b>	-	<b>27</b>
Chloramphenicol	8	-	8	10	14	-	15
Ciprofloxacin <sup>3</sup>	1	-	1	1	<b>13</b>	-	<b>14</b>
Clarithromycin	0.5	-	0.5	2	19	-	20
Clindamycin <sup>4</sup>	0.5	-	0.5	2	25	-	26
Co-amoxiclav <sup>1</sup>	1	-	1	3	17	-	18
Co-trimoxazole <sup>5,6</sup>	2	-	2	1.25/23.75	16	-	17
Daptomycin <sup>7,8</sup>	<b>1</b>	-	<b>1</b>	-	-	-	-
Doxycycline	1	-	1	30	30	-	31
Erythromycin	0.5	-	0.5	5	19	-	20
Fusidic acid	1	-	1	10	29	-	30
Gatifloxacin	1	-	1	2	19	-	20
Gemifloxacin	0.25	-	0.25	1	19	-	20
Gentamicin	1	-	1	10	19	-	20
Linezolid <sup>9</sup>	4	-	4	10	19	-	20
Methicillin <sup>1,10,11</sup>	4	-	4	5	14	-	15
Minocycline	0.5	-	0.5	30	27	-	28
Moxifloxacin	1	1	0.5	1	15	16-19	20
Mupirocin <sup>12,13</sup>	4	-	4	5	21	-	22
Mupirocin <sup>13</sup>	256	8-256	4	20	6	7-26	27
Neomycin <sup>14</sup>	-	-	-	10	16	-	17
Ofloxacin	1	-	1	5	27	-	28
Oxacillin <sup>1,10,11,15</sup>	2	-	2	1	14	-	15
Penicillin <sup>1,16</sup>	0.12	-	0.12	1 unit	24	-	25
Quinupristin/ Dalfopristin <sup>17</sup>	2	-	2	15	19	-	20
Rifampicin	0.06	-	0.06	2	29	-	30
Teicoplanin <sup>18,19</sup>	8	8	4	30	14	-	15
Telithromycin	0.5	-	0.5	15	26	-	27
Tetracycline	1	-	1	10	19	-	20
Tigecycline	0.5	-	0.5	15	25	-	26
Tobramycin for <i>Staphylococcus aureus</i>	1	-	1	10	20	-	21
Tobramycin for coagulase – negative staphylococci	1	-	1	10	29	-	30
Trimethoprim <sup>20</sup>	1	-	1	5	19	-	20
Vancomycin <sup>19</sup>	8	8	4	5	11	-	12

The information in bold is tentative. Breakpoints will remain tentative for one year from when first published.

- 1 Staphylococci exhibiting resistance to methicillin/oxacillin/cefoxitin should be regarded  
as resistant to other penicillins, cephalosporins, carbapenems and combinations of  $\beta$ -  
lactam and  $\beta$ -lactamase inhibitors.
- 2 For zone diameters 22-26 mm PCR for *mecA* is needed to determine susceptibility. In  
the absence of this, treatment of a deep seated infection due to coagulase-negative  
staphylococci with any  $\beta$ -lactam is not advised.
- 3 MIC breakpoints relate to high-dose therapy (750 mg).
- 4 Organisms that appear resistant to erythromycin, but susceptible to clindamycin  
should be checked for the presence of inducible resistance (see  
[www.bsac.org.uk/Susceptibility](http://www.bsac.org.uk/Susceptibility) Testing/BSAC Standardized Disc Susceptibility  
Method/Additional Methods). Clindamycin should be used with caution (if at all) for  
organisms with inducible MLS<sub>B</sub> resistance.
- 5 For advice on testing susceptibility to co-trimoxazole see Appendix 1.
- 6 The MIC breakpoint is based on the trimethoprim concentration in a 1:19 combination  
with sulphamethoxazole.
- 7 Strains with MIC values above the susceptible breakpoint are very rare or not yet  
reported. The identification and antimicrobial susceptibility tests on any such isolate  
must be repeated and if the result is confirmed the isolate sent to a reference  
laboratory. Until there is evidence regarding the clinical response for confirmed  
isolates with MIC above the current resistant breakpoint they should be reported  
resistant.
- 8 Susceptibility testing by disc diffusion is not recommended.
- 9 Information on clinical response in patients with serious staphylococcal infections is  
not yet available. In such patients an MIC determination might be appropriate.
- 10 Recommendations for tests on Mueller-Hinton or Columbia agars with 2% NaCl.
- 11 Some hyper-producers of  $\beta$ -lactamase give zones within the range of 7-14 mm and if  
possible, should be checked by a PCR method for *mecA* or a latex agglutination test  
for PBP2a. Increase in methicillin/oxacillin zone size in the presence of clavulanic  
acid is not a reliable test for hyper-producers of  $\beta$ -lactamase as zones of inhibition  
with some MRSA also increase in the presence of clavulanic acid. Rarely, hyper-  
producers of  $\beta$ -lactamase give no zone in this test and would therefore not be  
distinguished from MRSA.
- 12 An Etest or other MIC method should be performed on any strain designated  
mupirocin resistant when tested with a 5  $\mu$ g disc. The MIC will indicate whether the  
strain has low-level (MIC 8 – 256 mg/L) or high-level (MIC  $\geq$ 512 mg/L) resistance.
- 13 Isolates with low-level resistance to mupirocin (MICs 8-256 mg/L) may be eradicated  
more slowly than susceptible isolates.
- 14 For topical use only. The zone diameter breakpoint distinguishes isolates outside the  
“wild type” population.
- 15 MIC breakpoint for coagulase-negative staphylococci is currently under review.
- 16 Penicillin; check for heaped zone edge (= resistant)
- 17 The presence of blood has a marked effect on the activity of quinupristin/dalfopristin.  
On the rare occasions when blood needs to be added to enhance the growth of  
staphylococci, susceptible =  $\geq$ 15 mm, resistant  $\leq$ 14 mm.
- 18 Teicoplanin disc testing is not recommended for coagulase-negative staphylococci.  
An MIC method should be used to determine susceptibility.
- 19 Glycopeptide intermediate *Staphylococcus aureus* (GISA) cannot be detected by this  
method or any other disc diffusion method. The Etest “macro-method” may be used  
to screen for GISA and GISA with heterogenous resistance to vancomycin (hetero-  
GISA) but positive results require confirmation. Population analysis is the most  
reliable method for confirming resistance and for distinguishing susceptible, hetero-  
GISA and GISA isolates. If, on clinical grounds, resistance to vancomycin is  
suspected, it is recommended that the organism be sent to a specialist laboratory,  
such as Southmead Hospital in Bristol or the Antibiotic Resistance Monitoring and  
Reference Laboratory at Colindale for further investigation.

- <sup>20</sup> Amended zone diameter breakpoints are microbiological breakpoints based on the MIC distribution for the wild type population. However, there is no clear evidence correlating these breakpoints with clinical efficacy.

Table 11: MIC and zone diameter breakpoints for *Streptococcus pneumoniae*.

Antibiotic	MIC breakpoint (mg/L)			Disc content (µg)	Interpretation of zone diameters (mm)		
	R>	I	S ≤		R ≤	I	S ≥
Azithromycin	1	-	1	15	19	-	20
Cefaclor <sup>1</sup>	1	-	1	30	24	-	25
Cefixime <sup>1</sup>	1	-	1	5	19	-	20
Cefotaxime <sup>1</sup>	2	1-2	0.5	5	20	21-24	25
Cefpodoxime <sup>1</sup>	1	-	1	1	21	-	22
Ceftibuten <sup>1</sup>	1	-	1	10	27	-	28
Ceftizoxime <sup>1</sup>	1	-	1	30	29	-	30
Ceftriaxone <sup>1</sup>	2	1-2	0.5	30	23	24-27	28
Cefuroxime <sup>1,2</sup>	1	1	0.5	5	24	-	25
Cefadroxil <sup>1</sup>	1	-	1	30	24	-	25
Cefalexin <sup>1</sup>	2	-	2	30	24	-	25
Chloramphenicol	8	-	8	10	17	-	18
Ciprofloxacin <sup>3</sup>	2	0.25-2	0.12	1	9	10-24	25
Clarithromycin	0.5	-	0.5	2	19	-	20
Co-trimoxazole <sup>4,5</sup>	2	-	2	1.25/23.75	16	-	17
Ertapenem <sup>1</sup>	0.5	-	0.5	10	32	-	33
Erythromycin	0.5	-	0.5	5	19	-	20
Gatifloxacin	1	-	1	2	19	-	20
Gemifloxacin	0.25	-	0.25	1	19	-	20
Imipenem <sup>1</sup>	4	-	4	10	24	-	25
Levofloxacin	2	-	2	1	9	-	10
Linezolid	4	4	2	10	19	-	20
Meropenem <sup>1</sup>	4	-	4	10	27	-	28
Moxifloxacin	0.5	-	0.5	1	17	-	18
Ofloxacin <sup>3</sup>	4	0.25-4	0.12	5	15	16-27	28
Penicillin <sup>1,6</sup>	1	0.12-1	0.06	Oxacillin 1	19	-	20
Quinupristin/ Dalfopristin	2	-	2	15	19	-	20
Rifampicin	1	-	1	5	21	-	22
Telithromycin	0.5	-	0.5	15	28	-	29
Tetracycline	1	-	1	10	19	-	20
Vancomycin	4	-	4	5	12	-	13

The information in bold is tentative. Breakpoints will remain tentative for one year from when first published.

- <sup>1</sup> Organisms with reduced susceptibility to penicillin: confirm resistance with a test for penicillin MIC. Organisms with an MIC ≤ 1 mg/L are considered susceptible to β-lactam agents except in infections of the central nervous system. In addition, cefotaxime or ceftriaxone MIC determination is advised for strains isolated from meningitis or other invasive infections.
- <sup>2</sup> The zone diameters relate to an MIC BP of 0.5 mg/L as no data for the intermediate category are currently available.
- <sup>3</sup> Isolates with ciprofloxacin or ofloxacin MICs of ≤2 mg/L are considered as having intermediate susceptibility.
- <sup>4</sup> For advice on testing susceptibility to co-trimoxazole see Appendix 1.
- <sup>5</sup> The MIC breakpoint is based on the trimethoprim concentration in a 1:19 combination with sulphamethoxazole.
- <sup>6</sup> Reduced susceptibility to in *Streptococcus pneumoniae* is detected with an oxacillin 1 µg disc.

Table 12: MIC and zone diameter breakpoints for enterococci.

Antibiotic	MIC breakpoint (mg/L)				Interpretation of zone diameters (mm)		
	R >	I	S ≤	Disc content (µg)	R ≤	I	S ≥
Ampicillin	8	-	8	10	19	-	20
Azithromycin	1	-	1	15	29	-	30
Gentamicin <sup>1</sup>	128	-	128	200	14	-	15
Imipenem <sup>2</sup>	8	8	4	10	16	17-18	19
Linezolid	4	-	4	10	19	-	20
Meropenem	4	-	4	10	19	-	20
Quinupristin/ dalfopristin <sup>3</sup>	2	-	2	15	19	-	20
Teicoplanin <sup>4,5</sup>	8	8	4	30	19	-	20
Tetracycline	1	-	1	10	25	-	26
Tigecycline <sup>6</sup>	0.5	0.5	0.25	15	20	-	21
Vancomycin <sup>4,5</sup>	8	8	4	5	12	-	13

The information in bold is tentative. Breakpoints will remain tentative for one year from when first published.

- <sup>1</sup> High-level gentamicin-resistant enterococci usually give no zone or only a trace of inhibition around gentamicin 200 µg discs. Occasionally, however, the plasmid carrying the resistance gene may be unstable and the resistance is seen as a zone of inhibition with a few small colonies within the zone. Retesting of resistant colonies results in growth to the disc or increased numbers of colonies within the zone. Zones should be carefully examined to avoid missing such resistant organisms. If in doubt, isolates may be sent to the reference laboratory for confirmation.
- <sup>2</sup> Recommendations for *E. faecalis* only.
- <sup>3</sup> The presence of blood has a marked effect on the activity of quinupristin/dalfopristin. On the rare occasions when blood needs to be added to enhance the growth of enterococci, susceptible = ≥15 mm, resistant = ≤14 mm.
- <sup>4</sup> To ensure that microcolonies with reduced susceptibility to the glycopeptides are detected, it is essential that plates be incubated for at least 24 h before reporting a strain as susceptible to vancomycin or teicoplanin.
- <sup>5</sup> Zone diameter breakpoints relate to the MIC breakpoint of 4 mg/L as no data for the intermediate category are currently available.
- <sup>6</sup> No intermediate category for disc diffusion, as non-susceptible isolates are rare and were not available for testing.

**NB.** For isolates from endocarditis the MIC should be determined and interpreted according to national endocarditis guidelines (Elliott TS et al. Guidelines for the antibiotic treatment of endocarditis in adults: report of the Working Party of the British Society for Antimicrobial Chemotherapy. J Antimicrob Chemother. 2004; **54**: 971-81).

Table 13: MIC and zone diameter breakpoints for  $\alpha$ -haemolytic streptococci

Antibiotic	MIC breakpoint (mg/L)				Interpretation of zone diameters (mm)		
	R >	I	S ≤	Disc content (µg unless stated)	R ≤	I	S ≥
Amoxicillin	1	-	1	2	19	-	20
Cefotaxime	1	-	1	5	20	-	21
Clindamycin <sup>1</sup>	0.5	-	0.5	2	19	-	20
Erythromycin	0.5	-	0.5	5	19	-	20
Linezolid	2	-	2	10	19	-	20
Penicillin	0.12	-	0.12	1 unit	21	-	22
Teicoplanin	4	-	4	30	15	-	16
Tetracycline	1	-	1	10	23	-	24
Tigecycline	0.5	0.5	0.25	15	19	20-24	25
Vancomycin	4	-	4	5	13	-	14

<sup>1</sup> Organisms that appear resistant to erythromycin, but susceptible to clindamycin should be checked for the presence of inducible resistance (see [www.bsac.org.uk/Susceptibility](http://www.bsac.org.uk/Susceptibility) Testing/BSAC Standardized Disc Susceptibility Method/Additional Methods). Clindamycin should be used with caution (if at all) for organisms with inducible MLS<sub>B</sub> resistance.

**NB.** For isolates from endocarditis the MIC should be determined and interpreted according to national endocarditis guidelines (Elliott TS et al. Guidelines for the antibiotic treatment of endocarditis in adults: report of the Working Party of the British Society for Antimicrobial Chemotherapy. J Antimicrob Chemother. 2004; **54**: 971-81).

Table 14: MIC and zone diameter breakpoints for  $\beta$ -haemolytic streptococci

Antibiotic	MIC breakpoint (mg/L)			Disc content ( $\mu$ g unless stated)	Interpretation of zone diameters (mm)		
	R >	I	S $\leq$		R	I	S $\geq$
Azithromycin	1	-	1	15	19	-	20
Cefadroxil	1	-	1	30	24	-	25
Cefixime	1	-	1	5	19	-	20
Cefotaxime	0.5	-	0.5	5	23	-	24
Cefalexin	2	-	2	30	24	-	25
Cefalothin	1	-	1	30	28	-	29
Clarithromycin	0.5	-	0.5	2	19	-	20
Clindamycin <sup>1</sup>	0.5	-	0.5	2	16	-	17
Co-trimoxazole <sup>2,3</sup>	2	-	2	1.25/23.75	16	-	17
Daptomycin <sup>4,5</sup>	<b>1</b>	-	<b>1</b>	-	-	-	-
Ertapenem	0.5	-	0.5	10	34	-	35
Erythromycin	0.5	-	0.5	5	19	-	20
Linezolid <sup>6</sup>	4	4	2	10	19	-	20
Penicillin	0.12	-	0.12	1 unit	19	-	20
Telithromycin	0.5	-	0.5	15	25	-	26
Tetracycline	1	-	1	10	19	-	20
Tigecycline	0.5	0.5	0.25	15	19	20-24	25

The information in bold is tentative. Breakpoints will remain tentative for one year from when first published.

- <sup>1</sup> Organisms that appear resistant to erythromycin, but susceptible to clindamycin should be checked for the presence of inducible resistance (see [www.bsac.org.uk/Susceptibility](http://www.bsac.org.uk/Susceptibility) Testing/BSAC Standardized Disc Susceptibility Method/Additional Methods). Clindamycin should be used with caution (if at all) for organisms with inducible MLS<sub>B</sub> resistance.
- <sup>2</sup> For advice on testing susceptibility to co-trimoxazole see Appendix 1.
- <sup>3</sup> The MIC breakpoint is based on the trimethoprim concentration in a 1:19 combination with sulphamethoxazole.
- <sup>4</sup> Strains with MIC values above the susceptible breakpoint are very rare or not yet reported. The identification and antimicrobial susceptibility tests on any such isolate must be repeated and if the result is confirmed the isolate sent to a reference laboratory. Until there is evidence regarding the clinical response for confirmed isolates with MIC above the current resistant breakpoint they should be reported resistant.
- <sup>5</sup> Disc susceptibility testing is not recommended.
- <sup>6</sup> Zone diameter breakpoints relate to the MIC breakpoint of 2 mg/L as no data for the intermediate category are currently available.



Table 15: MIC and zone diameter breakpoints for *Moraxella catarrhalis*

Antibiotic	MIC breakpoint (mg/L)			Disc content (µg)	Interpretation of zone diameters (mm)		
	R >	I	S ≤		R ≤	I	S ≥
Ampicillin <sup>1</sup>	1	-	1	2	29	-	30
Cefaclor	1	-	1	30	22	-	23
Cefuroxime <sup>2</sup>	2	2	1	5	19	-	20
Chloramphenicol	2	-	2	10	22	-	23
Ciprofloxacin <sup>3</sup>	0.5	-	0.5	1	17	-	18
Clarithromycin	0.5	-	0.5	2	19	-	20
Co-amoxiclav	1	-	1	2/1	18	-	19
Co-trimoxazole <sup>4,5</sup>	2	-	2	1.25/23.75	11	-	12
Ertapenem	0.5	-	0.5	10	34	-	35
Erythromycin	0.5	-	0.5	5	27	-	28
Gatifloxacin <sup>3</sup>	1	-	1	2	19	-	20
Gemifloxacin <sup>3</sup>	0.25	-	0.25	1	19	-	20
Levofloxacin	1	-	1	1	19	-	20
Linezolid	4	-	4	10	19	-	20
Moxifloxacin <sup>3</sup>	0.5	-	0.5	1	17	-	18
Nalidixic acid <sup>6</sup>	-	-	-	30	-	-	-
Ofloxacin <sup>3</sup>	0.5	-	0.5	5	34	-	35
Telithromycin	0.5	-	0.5	15	29	-	30
Tetracycline	1	-	1	10	21	-	22

- <sup>1</sup> Test for β-lactamase. β-Lactamase positive isolates of *Moraxella catarrhalis* are often slow to become positive and tests for β-lactamase production must be examined after the longest recommended time for the test before being interpreted as negative.
- <sup>2</sup> Zone diameter breakpoints relate to the MIC breakpoint of 1 mg//L as no data for the intermediate category are currently available.
- <sup>3</sup> Quinolone resistance is most reliably detected with nalidixic acid discs. Isolates with reduced susceptibility to fluoroquinolones show no zone of inhibition with nalidixic acid.
- <sup>4</sup> For advice on testing susceptibility to co-trimoxazole, see Appendix 1.
- <sup>5</sup> The MIC breakpoint is based on the trimethoprim concentration in a 1:19 combination with sulphamethoxazole.
- <sup>6</sup> Quinolone resistance is most reliably detected with nalidixic acid. Strains with reduced susceptibility to fluoroquinolones give no zone of inhibition with a 30 µg nalidixic acid disc.

Table 16: MIC and zone diameter breakpoints for *Neisseria gonorrhoeae*

Antibiotic	MIC breakpoint (mg/L)			Disc content (µg unless stated)	Interpretation of zone diameters (mm)		
	R >	I	S ≤		R ≤	I	S ≥
Azithromycin	1	-	1	15	27	-	28
Cefixime <sup>1</sup>	1	-	1	5	29	-	30
Cefotaxime <sup>1</sup>	0.12	-	0.12	5	29	-	30
Ceftriaxone <sup>1</sup>	0.12	-	0.12	5	34	-	35
Cefuroxime <sup>1</sup>	1	-	1	5	19	-	20
Ciprofloxacin <sup>2</sup>	0.06	0.06	0.03	1	28	-	29
Erythromycin <sup>3</sup>	0.5	-	0.5	5	11	-	12
Nalidixic acid <sup>4</sup>	-	-	-	30	9	10-31	32
Penicillin <sup>5</sup>	1	0.12-1	0.06	1 unit	17	18-25	26
Rifampicin	1	-	1	2	20	-	21
Spectinomycin	64	-	64	25	13	-	14
Tetracycline <sup>6</sup>	1	-	1	10	26	-	27

- <sup>1</sup> Resistance to ceftriaxone, cefotaxime and cefixime has not been described. Isolates with chromosomally encoded reduced susceptibility to penicillin have slightly reduced zones of inhibition with these agents but they remain susceptible. Results for isolates with reduced zones around ceftriaxone, cefotaxime and cefixime discs should be confirmed by MIC determinations. Although cefuroxime is not recommended for clinical use, it can be used as an indicator antibiotic to detect reductions in susceptibility to other oxyimino cephalosporin.
- <sup>2</sup> Zone diameter breakpoints relate to the MIC breakpoint of 0.03mg/L as no data for the intermediate category are currently available.
- <sup>3</sup> Erythromycin is no longer used for therapy, but may be tested for epidemiological purposes.
- <sup>4</sup> Quinolone resistance is generally reliably detected with nalidixic acid, however there have been a few isolates that are resistant to ciprofloxacin yet susceptible to nalidixic acid in disc diffusion tests. The mechanism of resistance and the prevalence of these isolates in the UK is still under investigation. Isolates with reduced susceptibility to fluoroquinolones normally have no zone of inhibition with a 30 µg nalidixic acid disc. For organisms with nalidixic acid zone diameters 10-31 mm a ciprofloxacin MIC should be determined if the patient is to be treated with this agent.
- <sup>5</sup> Test for β-lactamase.
- <sup>6</sup> Use the tetracycline result to infer susceptibility to doxycycline.

Table 17: MIC and zone diameter breakpoints for *Neisseria meningitidis*.

Antibiotic	MIC breakpoint (mg/L)			Disc content (µg unless stated)	Interpretation of zone diameters (mm)		
	R >	I	S ≤		R ≤	I	S ≥
Ampicillin <sup>1</sup>	-	-	-	2	31	-	32
Amoxicillin <sup>1</sup>	-	-	-	2	29	-	30
Cefotaxime	0.12	-	0.12	5	39	-	40
Ceftriaxone	0.12	-	0.12	5	39	-	40
Chloramphenicol	2	-	2	10	19	-	20
Ciprofloxacin <sup>2,3</sup>	0.06	0.06	0.03	1	31	-	32
Erythromycin	0.5	-	0.5	5	26	-	27
Penicillin	0.06	-	0.06	1 unit	30	-	31
Rifampicin	1	-	1	2	29	-	30
Tetracycline	1	-	1	10	21	-	22

MIC determinations should be undertaken on all organisms with reduced susceptibility by disc testing.

NB. *Neisseria meningitidis* is a category 2 pathogen, but has derogation to 3 when heavy suspensions are used (DoH Hazard 29 January 1993). Consequently suspension and dilution of organisms and inoculation of plates for susceptibility tests must be carried out in a class 1 safety cabinet.

- <sup>1</sup> Ampicillin and amoxicillin are used as indicator antibiotics to detect reduced susceptibility to penicillin. The recommendations given are for this purpose only; ampicillin and amoxicillin should not be tested therapeutically.
- <sup>2</sup> Quinolone resistance is most reliably detected with nalidixic acid. Isolates with reduced susceptibility to fluoroquinolones have no zone of inhibition with nalidixic acid discs.
- <sup>3</sup> Zone diameter breakpoints relate to the MIC breakpoint of 0.03 mg/L as no data for the intermediate category are currently available.

Table 18: MIC and zone diameter breakpoints for *Haemophilus influenzae*.

Antibiotic	MIC breakpoint (mg/L)			Disc content ( $\mu\text{g}$ unless stated)	Interpretation of zone diameters (mm)		
	R >	I	S $\leq$		R $\leq$	I	S $\geq$
Amoxicillin <sup>1</sup>	1	-	1	2	16	-	17
Ampicillin <sup>1</sup>	1	-	1	2	17	-	18
Azithromycin <sup>2</sup>	4	0.5-4	0.25	15	19	20-34	35
Cefaclor <sup>3</sup>	1	-	1	30	36	-	37
Cefotaxime	0.12	-	0.12	5	24	-	25
Ceftazidime	2	-	2	30	29	-	30
Ceftriaxone	0.12	-	0.12	30	24	-	25
Cefuroxime <sup>4</sup>	2	2	1	5	16	-	17
Chloramphenicol	2	-	2	10	24	-	25
Ciprofloxacin <sup>5</sup>	0.5	-	0.5	1	27	-	28
Clarithromycin	16	1-16	0.5	5	9	10-24	25
Co-amoxiclav	1	-	1	2/1	16	-	17
Co-trimoxazole <sup>6,7</sup>	2	-	2	25	21	-	22
Ertapenem	0.5	-	0.5	10	32	-	33
Erythromycin	8	1-8	0.5	5	14	15-27	28
Gatifloxacin <sup>5</sup>	1	-	1	2	19	-	20
Gemifloxacin <sup>5</sup>	0.25	-	0.25	1	19	-	20
Imipenem	2	-	2	10	22	-	23
Levofloxacin <sup>5</sup>	1	-	1	1	19	-	20
Meropenem	2	-	2	10	22	-	23
Moxifloxacin <sup>5</sup>	0.5	-	0.5	1	17	-	18
Nalidixic acid <sup>5</sup>	-	-	-	30	-	-	-
Ofloxacin <sup>5</sup>	0.5	-	0.5	5	36	-	37
Telithromycin <sup>8</sup>	2	1-2	0.5	15	15	16-19	20
Tetracycline	1	-	1	10	21	-	22
Trimethoprim	0.5	-	0.5	2.5	20	-	21

<sup>1</sup> Test for  $\beta$ -lactamase.

<sup>2</sup> No resistant strains yet described.

<sup>3</sup> See Appendix 2.

<sup>4</sup> Zone diameter breakpoints relate to the MIC breakpoint of 1 mg/L as no data for the intermediate category are currently available.

<sup>5</sup> Quinolone resistance is most reliably detected with nalidixic acid. Strains with reduced susceptibility to fluoroquinolones give no zone of inhibition with a 30 $\mu\text{g}$  nalidixic acid disc.

<sup>6</sup> For advice on testing susceptibility to co-trimoxazole see Appendix 1.

<sup>7</sup> The MIC breakpoint is based on the trimethoprim concentration in a 1:19 combination with sulphamethoxazole.

<sup>8</sup> The mode telithromycin MIC for these organisms is 1 mg/L; therefore the majority of isolates will be interpreted as having intermediate susceptibility.

Table 19: MIC and zone diameter breakpoints for *Pasteurella multocida*.

Antibiotic	MIC breakpoint (mg/L)			Disc content (µg unless stated)	Interpretation of zone diameters (mm)		
	R >	I	S ≤		R ≤	I	S ≥
Ampicillin	1	-	1	10	29	-	30
Cefotaxime	1	-	1	5	33	-	34
Ciprofloxacin <sup>1</sup>	1	-	1	1	28	-	29
Nalidixic acid <sup>1</sup>	-	-	-	30	27	-	28
Penicillin	0.12	-	0.12	1 unit	21	-	22
Tetracycline	1	-	1	10	25	-	26

<sup>1</sup> Quinolone resistance is most reliably detected with nalidixic acid discs.

Table 20: MIC and zone diameter breakpoints for *Campylobacter* spp.

Antibiotic	MIC breakpoint (mg/L)			Disc content (µg unless stated)	Interpretation of zone diameters (mm)		
	R >	I	S ≤		R ≤	I	S ≥
Erythromycin	0.5	-	0.5	5	19	-	20
Ciprofloxacin <sup>1,2</sup>	1	1	0.5	1	17	-	18
Nalidixic acid <sup>1</sup>	-	-	-	30	-	-	-

<sup>1</sup> Quinolone resistance is most reliably detected with nalidixic acid discs. Strains with reduced susceptibility to fluoroquinolones give no zone of inhibition with a 30µg nalidixic acid disc.

<sup>2</sup> The zone diameters relate to an MIC breakpoint of 0.5 mg/L as no data for the intermediate category are currently available.

Table 21: MIC and zone diameter breakpoints for Coryneform organisms.

Antibiotic	MIC breakpoint (mg/L)				Interpretation of zone diameters (mm)		
	R >	I	S ≤	Disc content (µg unless stated)	R ≤	I	S ≥
Ciprofloxacin <sup>1</sup>	1	1	0.5	1	11	12-16	17
Penicillin	0.12	-	0.12	1 unit	19	-	20
Vancomycin <sup>2</sup>	8	8	4	5	19	-	20

<sup>1</sup> The zone diameters relate to an MIC breakpoint of 0.5 mg/L as no data for the intermediate category are currently available.

<sup>2</sup> The zone diameters relate to an MIC breakpoint of 4 mg/L as no data for the intermediate category are currently available.

Table 22: MIC and zone diameter breakpoints for *Bacteroides fragilis*

Antibiotic	MIC breakpoint (mg/L)			Disc content (µg unless stated)	Interpretation of zone diameters (mm)		
	R >	I	S ≤		R ≤	I	S ≥
Clindamycin <sup>1</sup>	4	-	4	2	9	-	10
Co-amoxiclav <sup>1</sup>	8	-	8	30	27	-	28
Meropenem <sup>1</sup>	8	4-8	2	10	18	19-25	26
Metronidazole	8	-	8	5	17	-	18
Piperacillin/tazobactam <sup>1</sup>	16	-	16	75/10	26	-	27

**NB.** *B. fragilis* is inherently resistant to penicillin.

- <sup>1</sup> The recommendations have been established based on the distribution for the 'wild susceptible' population as there is little published clinical data. Organisms that appear resistant by disc testing should have resistance confirmed by an MIC test and resistant isolates should be sent to the Anaerobe Reference Laboratory in Cardiff.



Table 23: MIC and zone diameter breakpoints for *Bacteroides thetaiotaomicron*

Antibiotic	MIC breakpoint (mg/L)				Interpretation of zone diameters (mm)		
	R >	I	S ≤	Disc content (µg unless stated)	R ≤	I	S ≥
Clindamycin <sup>1</sup>	4	-	4	2	9	-	10
Meropenem <sup>1</sup>	8	4-8	2	10	18	19-25	26
Metronidazole	8	-	8	5	17	-	18

**NB.** *B. thetaiotaomicron* is inherently resistant to penicillin.

There is a poor relationship between MIC and zone of inhibition for inhibitor combinations and therefore recommendations are not given for co-amoxiclav or piperacillin/tazobactam. If the recommendations for *B. fragilis* are used for *B. thetaiotaomicron* interpretation may be erroneous.

- <sup>1</sup> The recommendations have been established based on the distribution for the 'wild susceptible' population as there is little published clinical data. Organisms that appear resistant by disc testing should have resistance confirmed by an MIC test and resistant isolates should be sent to the Anaerobe Reference Laboratory in Cardiff.

Table 24: MIC and zone diameter breakpoints for *Clostridium perfringens*.

Antibiotic	MIC breakpoint (mg/L)			Disc content (µg unless stated)	Interpretation of zone diameters (mm)		
	R >	I	S ≤		R ≤	I	S ≥
Clindamycin <sup>1</sup>	4	-	4	2	9	-	10
Co-amoxiclav <sup>1</sup>	8	-	8	30	27	-	28
Meropenem <sup>1</sup>	8	4-8	2	10	18	19-25	26
Metronidazole	8	-	8	5	17	-	18
Penicillin <sup>1</sup>	0.12	-	0.12	1 unit	19	-	20
Piperacillin/tazobactam <sup>1</sup>	16	-	16	75/10	26	-	27

- <sup>1</sup> The recommendations have been established based on the distribution for the 'wild susceptible' population as there is little published clinical data. Organisms that appear resistant by disc testing should have resistance confirmed by an MIC test and resistant isolates should be sent to the Anaerobe Reference Laboratory in Cardiff.

Table 25: MIC and zone diameter breakpoints for Gram-negative rods isolated from urinary tract infections<sup>1-4</sup>.

Antibiotic	MIC breakpoint (mg/L)			Disc content (µg)	Coliforms <sup>5</sup>			Interpretation of zone diameters (mm)								
	R >	I	S ≤		R ≤	I	S ≥	<i>Escherichia coli</i>			<i>Klebsiella</i> spp.			<i>Proteus mirabilis</i>		
Amoxicillin <sup>6</sup>	32	-	32	25	11	-	12	11	-	12	-	-	-	11	-	12
Ampicillin <sup>6</sup>	32	-	32	25	11	-	12	11	-	12	-	-	-	11	-	12
Cefalexin <sup>7</sup>	32	-	32	30	-	-	-	15	-	16	15	-	16	11	-	12
Ciprofloxacin	4	-	4	1	19	-	20	19	-	20	19	-	20	19	-	20
Co-amoxiclav	32	-	32	20/10	11	-	12	11	-	12	11	-	12	11	-	12
Fosfomycin <sup>8,9</sup>	128	-	128	200/50	-	-	-	19	-	20	-	-	-	33	-	34
Mecillinam <sup>10</sup>	8	-	8	10	-	-	-	13	-	14	13	-	14	13	-	14
Nalidixic acid	16	-	16	30	17	-	18	17	-	18	17	-	18	17	-	18
Nitrofurantoin	32	-	32	200	-	-	-	19	-	20	-	-	-	-	-	-
Norfloxacin	4	-	4	2	15	-	16	15	-	16	15	-	16	15	-	16
Temocillin	32	-	32	30	11	-	12	11	-	12	11	-	12	11	-	12
Trimethoprim	2	-	2	2.5	16	-	17	16	-	17	16	-	17	16	-	17

NB. These recommendations are for organisms associated with uncomplicated urinary tract infections. For complicated infections systemic recommendations should be used.

- <sup>1</sup> If an organism is isolated from multiple sites, for example from blood and urine, interpretation of susceptibility should be made with regard to the systemic site (e.g., if the blood isolate is resistant and the urine isolate susceptible, both should be reported resistant irrespective of the results obtained using interpretative criteria for urine isolates).
- <sup>2</sup> For agents not listed criteria given for systemic isolates may be used for urinary tract isolates (see Tables 1 and 2).
- <sup>3</sup> Direct susceptibility tests on urine samples may be performed as long as the inoculum gives semi-confluent growth.
- <sup>4</sup> In the absence of definitive organism identification, use the recommendations most appropriate for the presumptive identification, accepting that on some occasions the interpretation may be incorrect. A more cautious approach is to use the systemic recommendations.
- <sup>5</sup> On-line Medical Dictionary March 2000: "A common name for *E. coli* that is used as an indicator of faecal contamination of water, measured in terms of Coliform count. Occasionally used to refer to all lactose fermenting bacteria."
- <sup>6</sup> These interpretative standards apply only to *Escherichia coli* and *Proteus mirabilis* and not to species that have chromosomal penicillinases (*Klebsiella* spp.) or those that typically have inducible AmpC enzymes (e.g. *Enterobacter* spp., *Citrobacter* spp. and *Serratia* spp.). The identification of Enterobacteriaceae to species level is essential before applying expert rules for the interpretation of susceptibility.
- <sup>7</sup> Cefalexin results may be used to report susceptibility to cefadroxil.
- <sup>8</sup> Fosfomycin/glucose-6-phosphate
- <sup>9</sup> Fosfomycin – the susceptibility of *Proteus* spp. that swarm up to the disc can be difficult to interpret.

- <sup>10</sup> Isolates of *Escherichia coli* and *Klebsiella* spp. that produce ESBLs often appear susceptible to mecillinam *in vitro* but clinical efficacy against these organisms is unproven.

Table 26: MIC and zone diameter breakpoints for Gram-positive cocci isolated from urinary tract infections<sup>1,2</sup>.

Antibiotic	MIC breakpoint (mg/L)				Interpretation of zone diameters (mm)								
	R >	I	S ≤	Disc content (µg)	Enterococci			Staphylococcus saprophyticus			Group B streptococci		
	R >	I	S ≤	Disc content (µg)	R ≤	I	S ≥	R ≤	I	S ≥	R ≤	I	S ≥
Ampicillin	32	-	32	25	19	-	20	25	-	26	25	-	26
Cefalexin <sup>3</sup>	32	-	32	30	-	-	-	-	-	-	23	-	24
Ciprofloxacin	4	-	4	1	11	-	12	17	-	18	12	-	13
Ciprofloxacin	4	-	4	5	15	-	16	-	-	-	18	-	19
Co-amoxiclav	32	-	32	20/10	20	-	21	27	-	28	27	-	28
Fosfomycin <sup>4</sup>	128	-	128	200/50	19	-	20	19	-	20	-	-	-
Mecillinam	64	-	64	50	-	-	-	9	-	10	-	-	-
Nalidixic acid	16	-	16	30	17	-	18	-	-	-	-	-	-
Nitrofurantoin	32	-	32	200	14	-	15	19	-	20	19	-	20
Norfloxacin	4	-	4	2	15	-	16	-	-	-	-	-	-
Trimethoprim <sup>5</sup>	2	-	2	2.5	21	-	22	14	-	15	15	-	16

NB. These recommendations are for organisms associated with uncomplicated urinary tract infections. For complicated infections and infections caused by *Staphylococcus aureus* and *Staphylococcus epidermidis*, which are associated with more serious infections, systemic recommendations should be used.

<sup>1</sup> If an organism is isolated from multiple sites, for example from blood and urine, interpretation of susceptibility should be made with regard to the systemic site (e.g., if the blood isolate is resistant and the urine isolate susceptible, both should be reported resistant irrespective of the results obtained using interpretative criteria for urine isolates).

<sup>2</sup> Direct susceptibility tests on urine samples may be performed as long as the inoculum gives semi-confluent growth.

<sup>3</sup> Cefalexin results may be used to report susceptibility to cefadroxil.

<sup>4</sup> Fosfomycin/glucose-6-phosphate.

<sup>5</sup> There is some doubt about the clinical relevance of testing the susceptibility of enterococci to trimethoprim

## Appendix 1: Testing antimicrobial susceptibility to co-trimoxazole

Breakpoints for testing susceptibility to co-trimoxazole are provided. However, the following recommendations from the UK Committee on the Safety of Medicines (CSM) should be noted.

”Co-trimoxazole should be limited to the role of drug of choice in *Pneumocystis carinii* pneumonia, it is also indicated for toxoplasmosis and nocardiosis. It should now only be considered for use in acute exacerbations of chronic bronchitis and infections of the urinary tract when there is good bacteriological evidence of sensitivity to co-trimoxazole and good reason to prefer this combination to a single antibiotic; similarly it should only be used in acute otitis media in children when there is good reason to prefer it. Review of the safety of co-trimoxazole using spontaneous adverse drug reaction data has indicated that the profile of reported adverse reactions with trimethoprim is similar to that with co-trimoxazole; blood and generalised skin disorders are the most serious reactions with both drugs and predominantly have been reported to occur in elderly patients. A recent large post-marketing study has demonstrated that such reactions are very rare with co-trimoxazole; the study did not distinguish between co-trimoxazole and trimethoprim with respect to serious hepatic, renal, blood or skin disorders.”

## **Appendix 2: Efficacy of cefaclor in the treatment of respiratory infections caused by *Haemophilus influenzae***

Concerns have been expressed, particularly by laboratories moving from Stokes' method to the BSAC disc diffusion method, about the interpretation of susceptibility of *Haemophilus influenzae* to cefaclor. When using Stokes' method the majority of isolates appeared susceptible; but with the BSAC disc diffusion method most isolates are now reported resistant. The following comments explain the BSAC rationale for interpretation of cefaclor susceptibility.

### *Cefaclor pharmacokinetics*

Cefaclor is dosed at 250-500 mg TDS po: 250 mg TDS is probably the most common dose but data is absent to confirm this. The expected  $C_{max}$  for 250 mg is 5-10 mg/L and 10-20 mg/l for 500 mg; the half life is 1 h; drug concentration in blood is <1 mg/L at 4 h and the protein binding is 25-50%. Tissue penetration is similar to other  $\beta$ -lactams.

### *Cefaclor potency against Haemophilus influenzae*

Data from the BSAC surveillance programme 2003-2004 (n= 899) indicates that the cefaclor MIC range is 0.12-128 mg/L; MIC<sub>50</sub> 2 mg/L; MIC<sub>90</sub> 8 mg/L.

### *Pharmacodynamics*

An average patient with an *Haemophilus influenzae* infection will have a free drug Time>MIC of 25% with 250 mg dosing and 37% with 500 mg dosing. A conservative Time>MIC target for cephalosporins in community practice is 40-50%, but this is not achieved with cefaclor. Therefore, it is likely that cefaclor will have at best borderline activity against *Haemophilus influenzae*.

### *Conclusion*

The pharmacodynamic data indicate that cefaclor has borderline activity against *Haemophilus influenzae*, even for community use. The outcome of infection will be difficult to predict and susceptibility testing is likely to be of limited value.

## Acknowledgment

The BSAC acknowledges the assistance of the Swedish Reference Group for Antibiotics (SRGA) in supplying some breakpoint data for inclusion in this document.

## References

1. Moosdeen, F., Williams, J.D. & Secker, A. (1988). Standardization of inoculum size for disc susceptibility testing: a preliminary report of a spectrophotometric method. *J. Antimicrob Chemother* **21**, 439-43.



## Additional information

### 1. Susceptibility testing of *Helicobacter pylori*

Disc diffusion methods are not suitable for testing *Helicobacter pylori* as this species is slow growing and results may not be accurate. The recommended method of susceptibility testing is Etest (follow technical guide instructions).

Suspend colonies from a 2-3 day culture on a blood agar plate in sterile distilled water and adjust the density to equal a McFarland 3 standard.

Use a swab dipped in the suspension to inoculate evenly the entire surface of the plate. The medium of choice is Mueller-Hinton agar or Wilkins-Chalgren agar with 5-10% horse blood.

Allow the plate to dry and apply Etest strip.

Incubate at 35°C in microaerophilic conditions for 3-5 days. Read the MIC at the point of complete inhibition of all growth, including hazes and isolated colonies. Tentative interpretative criteria for MICs are given in Table 1.

Table 1: Tentative MIC breakpoints for *Helicobacter pylori*

Antimicrobial agent	MIC breakpoint (mg/L)	
	R >	S ≤
Amoxicillin	1	1
Clarithromycin	1	1
Tetracycline	2	2
Metronidazole	4	4

### 2. Susceptibility testing of *Brucella* species

*Brucella* spp. are Hazard Group 3 pathogens and all work must be done in containment level 3 accommodation. The antimicrobial agents most commonly used for treatment are doxycycline, rifampicin, ciprofloxacin, tetracycline and streptomycin and, from the limited information available, there is little or no resistance to these drugs. *Brucella* spp. are uncommon isolates and interpretative standards are not available. Since *Brucella* spp. are highly infectious, susceptibility testing in routine laboratories is not recommended.

### 3. Susceptibility testing of *Legionella* species

*Legionella* spp. are slow growing and have particular growth requirements. Disc diffusion methods for susceptibility testing are unsuitable. Susceptibility should be determined by agar dilution MICs on buffered yeast extract agar with 5% water-lysed horse blood. The antimicrobial agents commonly used for treatment are macrolides, rifampicin and fluoroquinolones. Validated MIC breakpoints are not established for *Legionella* spp. If results for test isolates are within range of the normal wild type distribution, given in table 2, clinical susceptibility may be assumed.

Table 2: MIC ranges for wild type *Legionella* spp.

Antimicrobial agent	MIC range for wild-type <i>Legionella</i> spp. (mg/L)
Erythromycin	0.06-0.5
Clarithromycin	0.004-0.06
Rifampicin	0.004-0.06
Ciprofloxacin	0.016-0.06

#### 4. Susceptibility testing of topical antibiotics

MIC breakpoints specifically for topical antibiotics are not given because there are no pharmacological, pharmacodynamic or clinical response data on which to base recommendations. [Relevant data would be gratefully received].

#### 5. Development of MIC and zone diameter breakpoints

All breakpoints are subject to review in the light of additional data and any data relating to breakpoints, control zone ranges or any other aspect of antimicrobial susceptibility testing would be welcome (contact the Working Party secretary or any member listed at the front of this document).

The BSAC is part of the European Committee on Antimicrobial Susceptibility Testing (EUCAST) and is actively involved in the process of harmonization of MIC breakpoints in Europe. This process will undoubtedly lead to some small breakpoint adjustments, and these will be incorporated into the BSAC method as European breakpoints are agreed.

The BSAC has a mechanism to modify and publish changes to breakpoints on an annual basis via the BSAC www site ([www.bsac.org.uk](http://www.bsac.org.uk)). Any changes will be dated.

*Ad hoc* modifications to breakpoints by users are not acceptable.

## Control of Antimicrobial Susceptibility Testing

### 1. Control strains

Control strains include susceptible strains to monitor test performance (not for the interpretation of susceptibility), and resistant strains to confirm that the method will detect particular mechanisms of resistance, for example, *Haemophilus influenzae* ATCC 49247 is a  $\beta$ -lactamase negative, ampicillin resistant strain (see table 2 of Disc Diffusion Method). Tables 2-6 provide zone diameters for recommended control organisms under a range of test conditions.

Control strains can be purchased from the National Collection of Type Cultures (NCTC; HPA Centre for Infections, 61 Colindale Avenue, London NW9 5HT). Alternatively, some may be obtained commercially (see section on suppliers)

### 2. Maintenance of control strains

Store control strains by a method that minimises the risk of mutations, for example, at  $-70^{\circ}\text{C}$ , on beads in glycerol broth. Ideally, two vials of each control strain should be stored, one as an "in-use" supply, the other for archiving. Every week a bead from the "in-use" vial should be subcultured on to appropriate non-selective media and checked for purity. From this pure culture, prepare one subculture for each of the following 7 days. Alternatively, for fastidious organisms that will not survive on plates for 7 days, subculture the strain daily for no more than 6 days.

### 3. Calculation of control ranges for disc diffusion tests

The acceptable ranges for the control strains have been calculated by combining zone diameter data from 'field studies' and from multiple centres supplying their daily control data, from which cumulative distributions of zones of inhibition have been prepared. From these distributions, the 2.5 and 97.5 percentiles were read to provide a range that would contain 95% of observations. If distributions are normal, these ranges correspond to the mean  $\pm$  1.96 SD. The percentile ranges obtained by this method are, however, still valid even if the data do not show a normal distribution.

### 4. Frequency of routine testing with control strains

When the method is first introduced, daily testing is required until there are acceptable readings from 20 consecutive days (this also applies when new agents are introduced or when any test component changes). This provides sufficient data to support once weekly testing.

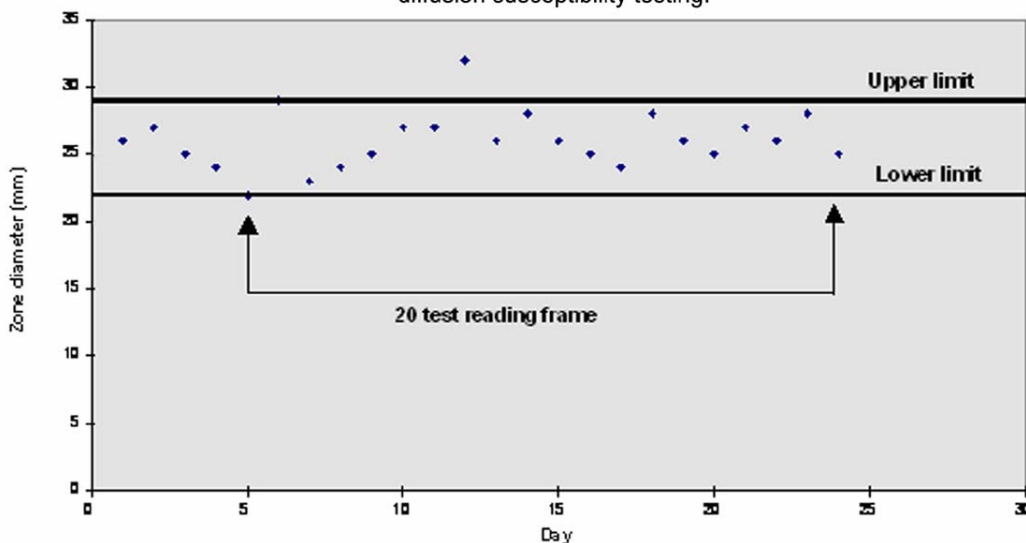
### 5. Use of control data to monitor the performance of disc diffusion tests

Use a reading frame of 20 consecutive results (remove the oldest result when adding a new one to make a total of 20) as illustrated in Figure 1. Testing is acceptable if no more than 1 in every 20 results is outside the limits of acceptability. If 2 or more results fall out of the acceptable range this requires immediate investigation.

Look for trends within the limits of acceptability e.g. tendency for zones to be at the limits of acceptability; tendency for zones to be consistently above or below the mean;

gradual drift in zone diameters. Quality Assurance will often pick up trends before the controls go out of range.

Figure 1. Use of control strain to monitor performance of disc diffusion susceptibility testing.



A free, supported QC programme is available from the following website:  
<http://www.thehealthcarenet.com/shareware.htm>

## 6. Recognition of atypical results for clinical isolates

Atypical results with clinical isolates may indicate problems in testing that may or may not be reflected in zone diameters with control strains.

An organism with inherent resistance appears susceptible e.g. *Proteus* spp. susceptible to colistin or nitrofurantoin.

Resistance is seen in an organism when resistance has previously not been observed, e.g. penicillin resistance in Group A streptococci.

Resistance is seen in an organism when resistance is rare or has not been seen locally, e.g. vancomycin resistance in *Staphylococcus aureus*.

Incompatible susceptibilities are reported, e.g. a methicillin resistant staphylococcus reported susceptible to a  $\beta$ -lactam antibiotic.

In order to apply such rules related to atypical results it is useful to install an 'expert' system for laboratory reporting to avoid erroneous interpretation.

## 7. Investigation of possible sources of error

If the control values are found to be outside acceptable limits on more than one occasion during a reading frame of twenty tests, investigation into the possible source of error is required. Possible problem areas are indicated in table 1.

Table 1: Potential sources of error in disc diffusion antimicrobial susceptibility testing.

Possible source of error	Detail to check
Test conditions	Excessive pre-incubation before discs applied Excessive pre-diffusion before plates incubated Incorrect incubation temperature Incorrect incubation atmosphere Incorrect incubation time Inadequate illumination of plates when reading Incorrect reading of zone edges
Medium	Required susceptibility testing agar not used Not prepared as required by the manufacturer's instructions Batch to batch variation Antagonists present (e.g. with sulphonamides and trimethoprim) Incorrect pH Incorrect divalent cation concentration Incorrect depth of agar plates Agar plates not level Expiry date exceeded
Antimicrobial discs	Wrong agent or content used Labile agent possibly deteriorated Light sensitive agent left in light Incorrect storage leading to deterioration Disc containers opened before reaching room temperature Incorrect labelling of disc dispensers Expiry date exceeded
Control strains	Contamination Mutation Incorrect inoculum density Uneven inoculation Old culture used

## 8. Reporting susceptibility results when controls indicate problems

Microbiologists must use a pragmatic approach, as results from repeat testing are not available on the same day. If results with control strains are out of range the implications for test results need to be assessed.

### *Control results out of range*

If control zones are below range but test results are susceptible, or control zones are above range but test results are resistant, investigate possible sources of error but report the test results. Otherwise it may be necessary to suppress reports on affected agents, investigate and retest.

### *Atypical results*

If results are atypical with clinical isolates, the purity of the isolate and identification should be confirmed and the susceptibility repeated. Suppress the results for individual agents and retest.

Table 2: Acceptable zone diameter (mm) ranges for control strains on Iso-Sensitest agar, plates incubated at 35-37 °C in air for 18-20 h.

Antimicrobial agent	Disc content (µg unless stated)	<i>Escherichia coli</i>			<i>Pseudomonas aeruginosa</i>		<i>Staphylococcus aureus</i>		<i>Enterococcus faecalis</i>
		NCTC 10418	ATCC 25922	NCTC 11560 <sup>1</sup>	NCTC 10662	ATCC 27853	NCTC 6571	ATCC 25923	ATCC 29212
Amikacin	30	24-27	23-27	-	21-30	26-32	-	-	-
Ampicillin	10	21-26	16-22	-	-	-	-	-	26-35
Ampicillin	25	24-30	21-28	-	-	-	-	-	-
Aztreonam	30	39-44	36-40	-	27-30	26-30	-	-	-
Azithromycin	15	-	-	-	-	-	-	-	15-21
Cefixime	5	32-36	27-30	-	-	-	-	-	-
Cefoxitin	30	28-33	26-30	-	-	-	-	-	-
Cefotaxime	30	36-45	34-44	-	20-29	20-24	-	-	-
Ceftazidime	30	32-40	31-39	-	29-37	27-35	-	-	-
Cefuroxime	30	25-32	24-29	-	-	-	-	-	-
Cefalexin	30	21-28	16-21	-	-	-	-	-	-
Cefradine	30	19-25	16-22	-	-	-	-	-	-
Chloramphenicol	10	21-27	20-29	-	-	-	20-26	19-27	-
Ciprofloxacin	1	31-40	31-37	-	21-28	24-30	25-32	17-22	14-19
Ciprofloxacin	5	-	-	-	29-37	31-37	-	-	21-27
Clindamycin	2	-	-	-	-	-	30-35	26-33	No zone
Co-amoxiclav	3	-	-	-	-	-	-	27-32	-
Co-amoxiclav	30	18-31	20-26	12-18	-	-	-	-	-
Colistin	25	15-19	16-20	-	17-20	16-20	-	-	-
Doxycycline	30	-	-	-	-	-	35-40	33-37	-
Ertapenem	10	35-41	35-39	-	-	-	-	-	-
Erythromycin	5	-	-	-	-	-	22-31	22-29	-
Fusidic acid	10	-	-	-	-	-	32-40	30-37	-
Gentamicin	10	21-27	21-27	-	20-26	22-28	24-30	22-29	-
Gentamicin	200	-	-	-	-	-	-	-	22-27
Imipenem	10	32-37	33-37	-	20-27	23-28	-	-	28-32
Levofloxacin	1	30-33	28-34	-	-	-	-	-	-

Antimicrobial agent	Disc content (µg unless stated)	<i>Escherichia coli</i>			<i>Pseudomonas aeruginosa</i>		<i>Staphylococcus aureus</i>		<i>Enterococcus faecalis</i>
		NCTC 10418	ATCC 25922	NCTC 11560 <sup>1</sup>	NCTC 10662	ATCC 27853	NCTC 6571	ATCC 25923	ATCC 29212
Levofloxacin	5	-	-	-	22-29	23-29	-	-	-
Linezolid	10	-	-	-	-	-	26-33	26-30	24-29
Meropenem	10	38-42	27-39	-	26-33	32-39	-	-	22-28
Minocycline	30	-	-	-	-	-	34-39	33-36	-
Mupirocin	5	-	-	-	-	-	26-35	24-34	-
Mupirocin	20	-	-	-	-	-	30-38	27-35	-
Nalidixic acid	30	28-36	26-32	-	-	-	-	-	-
Neomycin	10	-	-	-	-	-	-	21-27	-
Netilmicin	10	22-27	22-26	-	17-20	20-24	-	22-28	-
Nitrofurantoin	200	25-30	23-27	-	-	-	21-25	20-26	-
Norfloxacin	2	34-37	32-36	-	-	-	-	-	-
Ofloxacin	5	31-37	31-38	-	18-26	18-25	-	-	-
Penicillin	1 unit	-	-	-	-	-	32-40	28-36	-
Piperacillin	75	30-35	27-32	-	27-35	27-34	-	-	-
Pip/tazobactam	85	30-35	26-31	-	28-35	28-35	-	-	26-32
Quinupristin/ Dalfopristin	15	-	-	-	-	-	27-31	-	12-19
Rifampicin	2	-	-	-	-	-	27-39	29-36	-
Streptomycin	10	18-24	17-22	-	-	-	-	-	-
Teicoplanin	30	-	-	-	-	-	17-23	16-20	19-25
Tetracycline	10	23-29	22-28	-	-	-	31-40	26-35	-
Ticarcillin	75	32-35	27-30	-	24-28	23-27	-	-	-
Ticarcillin/ clavulanic acid	85	33-37	27-31	-	25-29	24-27	-	-	-
Tigecycline	15	29-32	28-32	-	-	-	29-34	27-30	26-31
Tobramycin	10	24-27	-	-	23-30	26-32	-	29-35	-
Trimethoprim	2.5	30-37	25-31	-	-	-	25-30	20-28	28-35
"	5	-	-	-	-	-	24-34	-	-
Vancomycin	5	-	-	-	-	-	14-20	13-17	13-19

26 β-Lactamase producing strain

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Table 3: Acceptable zone diameter (mm) ranges for control strains on Iso-Sensitest agar supplemented with 5% defibrinated horse blood, with or without the addition of NAD, plates incubated at 35-37°C in air for 18-20 h.

Antimicrobial agent	Disc content (µg unless stated)	<i>Staphylococcus aureus</i>		Group A streptococci	
		NCTC 6571	ATCC 25923	NCTC 8198	ATCC 19615
Clindamycin	2	-	-	25-28	29-35
Erythromycin	5	22-29	23-29	-	-
Penicillin	1 unit	30-41	27-35	-	-
Tetracycline	10	30-38	28-36	-	-

Table 4: Acceptable zone diameter ranges for control strains for detection of methicillin/oxacillin/cefoxitin resistance in staphylococci (methicillin/oxacillin incubated at 30°C; cefoxitin incubated at 35°C).

Antimicrobial agent	Medium	Disc content (µg)	<i>Staphylococcus aureus</i>		
			NCTC 6571	ATCC 25923	NCTC 12493 <sup>a</sup>
Methicillin	Columbia/Mueller Hinton agar + 2% NaCl	5	18-30	18-28	No zone
Oxacillin	Columbia/Mueller Hinton agar + 2% NaCl	1	19-30	19-29	No zone
Cefoxitin	ISA	10	26-31	24-29	10-20

<sup>a</sup> Methicillin/oxacillin/cefoxitin- resistant strain.



Table 5: Acceptable zone diameter (mm) ranges for control strains on Iso-Sensitest agar supplemented with 5% defibrinated horse blood and NAD, plates incubated at 35-37°C in 10% CO<sub>2</sub>/10% H<sub>2</sub>/80% N<sub>2</sub> for 18-20 h.

Antimicrobial agent	Disc content (µg unless stated)	<i>Bacteroides fragilis</i> NCTC 9343	<i>Bacteroides</i> <i>thetaiotaomicron</i> ATCC 29741	<i>Clostridium perfringens</i> NCTC 8359
Clindamycin	2	13-27	11-25	23-28
Co-amoxiclav	30	43-49	-	40-45
Meropenem	10	42-50	36-43	39-45
Metronidazole	5	34-43	26-40	11-23
Penicillin	1 unit	6	6	26-30
Piperacillin/tazobactam	75/10	41-48	-	37-43

Table 6: Acceptable zone diameter (mm) ranges for control strains on Iso-Sensitest agar supplemented with 5% defibrinated horse blood with or without the addition of NAD, plates incubated at 35-37°C in 4-6% CO<sub>2</sub> for 18-20 h.

Antimicrobial agent	Disc content ( µg unless stated)	<i>Pasteurella</i>	<i>Neisseria</i>	<i>Staphylococcus</i>		<i>Haemophilus</i>		<i>Streptococcus</i>
		<i>multocida</i>	<i>gonorrhoeae</i> (with NAD)	<i>aureus</i>	<i>aureus</i>	<i>influenzae</i> (with NAD)	<i>influenzae</i> (with NAD)	<i>pneumoniae</i>
		NCTC 8489	NCTC 12700	NCTC 6571	ATCC 25923	NCTC 11931	ATCC 49247 <sup>a</sup>	ATCC 49619
Amoxicillin	2	-	-	29-34	-	-	-	-
Ampicillin	2	-	-	-	-	22-30	6-13	-
Ampicillin	10	32-37	-	-	-	-	-	-
Azithromycin	15	-	30-40	-	-	24-36	20-30	-
Cefixime	5	-	33-44	-	-	-	-	-
Cefotaxime	5	35-41	32-44	26-32	-	33-45	27-38	-
Ceftriaxone	5	-	33-47	-	-	-	-	-
Cefuroxime	5	-	23-32	22-29	24-29	22-28	6-16	-
Chloramphenicol	10	-	-	21-26	-	30-40	30-38	21-29
Ciprofloxacin	1	31-37	40-50	22-29	18-23	32-40	33-44	14-21
Clindamycin	2	-	-	21-25	-	-	-	-
Co-amoxiclav	3	-	-	-	-	20-27	10-20	-
Ertapenem	10	-	-	-	-	30-38	25-34	35-40
Erythromycin	5	-	20-29	25-29	-	12-23	9-16	23-36
Linezolid	10	-	-	22-26	-	-	-	-
Nalidixic acid	30	-	32-40	9-17	9-17	33-38	-	-
Oxacillin	1	-	-	-	-	-	-	8-16
Penicillin	1 unit	24-28	12-20	37-44	29-36	-	-	-
Quinupristin/ Dalfopristin	15	-	-	-	-	-	-	21-29
Rifampicin	2	-	26-34	32-37	-	-	-	-
Rifampicin	5	-	-	-	-	-	-	28-35
Spectinomycin	25	-	17-23	-	-	-	-	-
Teicoplanin	30	-	-	14-19	-	-	-	-
Tetracycline	10	29-34	27-35	33-40	27-34	27-35	9-14	26-36
Tigecycline	15	-	-	27-30	24-28	-	-	26-30
Trimethoprim	2.5	-	-	-	-	30-40	28-36	-
Vancomycin	5	-	-	12-16	-	-	-	-

<sup>a</sup>  $\beta$ -Lactamase-negative, ampicillin-resistant strain

## 9. Control of MIC determination

Tables 7-10 provide target MIC (mg/L) values for recommended control strains by BSAC methodology.<sup>1,2</sup> MICs should be within one two-fold dilution of the target values.

Table 7: Target MICs (mg/L) for *Haemophilus influenzae*, *Enterococcus faecalis*, *Streptococcus pneumoniae*, *Bacteroides fragilis* and *Neisseria gonorrhoeae* control strains by BSAC methods

Antimicrobial agent	<i>Haemophilus influenzae</i>		<i>Enterococcus faecalis</i>	<i>Streptococcus pneumoniae</i>	<i>Bacteroides fragilis</i>	<i>Neisseria gonorrhoeae</i>
	NCTC	ATCC	ATCC	ATCC	NCTC	ATCC
	11931	49247	29212	49619	9343	49226
Amikacin	-	-	128	-	-	-
Amoxicillin	0.5	4	0.5	0.06	32	0.5
Ampicillin	-	-	1	0.06	32	-
Azithromycin	2	2	-	0.12	-	-
Azlocillin	-	-	-	-	4	-
Aztreonam	-	-	>128	-	2	-
Cefaclor	-	128	>32	2	>128	-
Cefamandole	-	-	-	-	8	-
Cefixime	0.03	0.25	-	1	64	-
Cefotaxime	-	0.25	32	0.06	4	-
Cefoxitin	-	-	-	-	4	-
Cefpirome	0.06	0.5	16	-	16	-
Cefpodoxime	0.12	0.5	>32	0.12	32	-
Ceftazidime	0.12	-	>32	-	8	-
Ceftriaxone	-	-	>32	0.06	4	-
Cefuroxime	2	16	>32	0.25	32	-
Cephadroxil	-	-	>32	-	32	-
Cephalexin	-	-	>32	-	64	-
Cephalothin	-	-	16	-	-	-
Chloramphenicol	-	-	4	4	4	-
Ciprofloxacin	0.008	0.008	1	1	2	0.004
Clarithromycin	8	4	-	0.03	0.25	0.5
Clindamycin	-	-	8	0.12	0.5	-
Co-amoxiclav	0.5	8	0.5	0.06	0.5	0.5
Cotrimoxazole	-	1	2	4	-	-
Dalfopristin/ quinupristin	-	-	1	0.5	16	-
Enoxacin	-	-	-	-	1	-
Ertapenem	0.12	0.5	-	0.12	0.25	-
Erythromycin	8	8	4	0.12	1	0.5
Faropenem	-	-	-	0.06	1	-
Fleroxacin	-	-	-	-	4	-
Flucloxacillin	-	-	-	-	16	-
Fucidic acid	-	-	2	-	-	-
Gatifloxacin	0.008	-	0.25	0.25	0.5	0.004
Gemifloxacin	0.12	-	0.03	0.03	0.25	0.002
Gentamicin	-	-	8	-	128	-
Grepafloxacin	-	0.004	-	0.25	-	-
Imipenem	-	-	0.5	-	0.06	-
Levofloxacin	0.008	0.015	1	0.5	0.5	0.008
Linezolid	-	-	-	2	4	-
Loracarbef	-	128	>32	2	>128	-
Mecillinam	-	-	>128	-	>128	-
Meropenem	-	-	2	-	0.06	-

Antimicrobial agent	<i>Haemophilus influenzae</i>		<i>Enterococcus faecalis</i>	<i>Streptococcus pneumoniae</i>	<i>Bacteroides fragilis</i>	<i>Neisseria gonorrhoeae</i>
	NCTC	ATCC	ATCC	ATCC	NCTC	ATCC
	11931	49247	29212	49619	9343	49226
Metronidazole	-	-	-	-	0.5	-
Moxalactam	-	-	-	-	0.25	-
Moxifloxacin	0.03	0.03	0.25	0.5	-	0.004
Naladixic acid	-	1	-	>128	64	-
Nitrofurantoin	-	-	8	-	-	-
Norfloxacin	-	-	2	-	16	-
Ofloxacin	-	-	2	-	1	-
Oxacillin	-	-	-	1	-	-
Pefloxacin	-	-	-	-	1	-
Penicillin	-	4	2	0.5	16	-
Piperacillin	-	-	2	-	2	-
Rifampicin	-	-	2	0.03	-	-
Roxithromycin	16	16	-	0.12	2	-
Rufloxacin	-	-	-	-	16	-
Sparfloxacin	-	0.002	-	0.25	1	-
Teicoplanin	-	-	0.25	-	-	-
Telithromycin	1	2	0.008	0.008	-	0.03
Tetracycline	-	16	16	0.12	0.5	-
Ticarcillin	-	-	-	-	4	-
Tigecycline	-	-	0.12	0.06	-	-
Tobramycin	-	-	16	-	-	-
Trimethoprim	-	-	0.25	4	16	-
Trovaflaxacin	0.008	0.002	0.06	0.12	0.12	-
Vancomycin	-	-	2	0.25	16	-

Table 8: Target MICs (mg/L) for *Escherichia coli*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* control strains by BSAC methods

Antimicrobial agent	<i>Escherichia coli</i>		<i>Pseudomonas aeruginosa</i>		<i>Staphylococcus aureus</i>		
	NCTC 10418	ATCC 25922	NCTC 10662	ATCC 27853	NCTC 6571	ATCC 25923	ATCC 29213
Amikacin	0.5	1	2	2	1	-	2
Amoxicillin	2	4	>128	>128	0.12	0.25	0.5
Ampicillin	2	4	>128	>128	0.06	-	-
Azithromycin	-	-	-	-	0.12	0.12	0.12
Azlocillin	4	-	4	-	0.25	-	-
Aztreonam	0.03	0.25	4	2	>128	-	>128
Carbenicillin	2	-	32	-	0.5	-	-
Cefaclor	1	2	>128	>128	1	-	1
Cefamandole	0.25	-	>128	>128	0.25	-	-
Cefixime	0.06	0.25	16	-	8	8	16
Cefotaxime	0.03	0.06	8	8	0.5	-	1
Cefotetan	0.06	-	>128	>128	4	-	-
Cefoxitin	4	-	>128	>128	2	-	-
Cefpirome	0.03	0.03	4	1	0.25	-	0.5
Cefpodoxime	0.25	0.25	128	>128	1	4	2
Ceftazidime	0.06	0.25	1	1	4	-	8
Ceftizoxime	0.008	-	-	-	2	-	-
Ceftriaxone	0.03	0.06	8	8	1	-	2
Cefuroxime	2	4	>128	>128	0.5	1	1
Cephadroxil	8	8	>128	>128	1	-	2
Cephalexin	4	8	>128	>128	1	-	4
Cephaloridine	-	-	>128	>128	0.06	-	-
Cephalothin	4	8	>128	>128	0.5	-	0.25
Cephradine	-	-	>128	>128	2	-	-
Chloramphenicol	2	4	128	-	2	-	2
Ciprofloxacin	0.015	0.015	0.25	0.25	0.12	0.5	0.5
Clarithromycin	-	-	-	-	0.12	0.12	0.12
Clindamycin	-	-	-	-	0.06	0.12	0.06
Co-amoxiclav	2	4	>128	128	0.12	0.12	0.25
Colistin	0.5	-	2	-	128	-	-
Cotrimoxazole	0.25	0.25	-	-	-	-	2
Dalfopristin/ Quinupristin	-	-	-	-	0.12	0.25	0.25
Dirythromycin	-	-	-	-	1	-	1
Doxycycline	-	-	-	-	0.06	0.12	-
Enoxacin	0.25	-	1	-	0.5	-	-
Ertapenem	0.008	0.015	-	-	-	-	-
Erythromycin	-	-	-	-	0.12	0.5	0.25
Farapenem	0.25	-	>128	>128	0.12	-	-
Fleroxacin	0.06	0.12	1	-	0.5	-	-
Flucloxacillin	-	-	>128	>128	0.06	-	-
Flumequine	2	-	>128	>128	-	-	-
Fosfomycin	4	-	>128	>128	8	-	-
Fusidic acid	>128	-	-	-	0.06	0.12	0.06
Gatifloxacin	0.015	0.015	1	1	0.03	0.12	0.12
Gemifloxacin	0.008	0.008	0.25	0.25	0.015	0.03	0.03
Gentamicin	0.25	0.5	1	1	0.12	0.25	0.25
Grepafloxacin	0.03	0.03	0.5	-	0.03	-	-
Imipenem	0.06	0.12	2	1	0.015	-	0.015
Kanamycin	1	-	1	-	2	-	-
Levofloxacin	0.03	0.03	0.5	0.5	0.12	0.25	0.25

Antimicrobial agent	<i>Escherichia coli</i>		<i>Pseudomonas aeruginosa</i>		<i>Staphylococcus aureus</i>		
	NCTC 10418	ATCC 25922	NCTC 10662	ATCC 27853	NCTC 6571	ATCC 25923	ATCC 29213
Linezolid	-	-	-	-	0.5	1	-
Lomefloxacin	-	-	-	-	0.5	-	-
Loracarbef	0.5	1	>128	>128	0.5	-	1
Mecillinam	0.12	0.12	8	-	8	-	64
Meropenem	0.015	0.008	2	0.25	0.03	-	0.06
Methicillin	-	-	>128	>128	1	2	2
Mezlocillin	2	-	8	-	0.5	-	-
Minocycline	-	-	-	-	0.06	0.06	-
Moxalactam	0.03	-	8	-	8	-	-
Moxifloxacin	0.03	0.03	2	2	0.06	0.06	0.06
Mupirocin	-	-	-	-	0.25	0.25	0.12
Nalidixic acid	2	4	>128	>128	>128	128	128
Neomycin	-	-	32	-	0.12	-	-
Netilmicin	-	-	1	0.5	-	-	-
Nitrofurantoin	4	8	-	-	8	-	16
Norfloxacin	0.06	0.06	1	1	0.25	-	1
Ofloxacin	0.06	0.03	1	1	0.25	-	0.5
Oxacillin	-	-	>128	>128	0.25	0.25	0.5
Pefloxacin	0.06	-	0.5	-	0.25	-	-
Penicillin	-	-	>128	>128	0.03	0.03	0.12
Piperacillin	0.5	2	4	2	0.25	-	1
Rifampicin	16	-	-	-	0.004	0.015	0.004
Roxithromycin	-	-	-	-	0.25	0.5	0.5
Rufloxacin	0.5	-	8	-	1	-	-
Sparfloxacin	0.015	0.015	0.5	0.5	0.03	-	-
Sulphonamide	16	-	>128	>128	64	-	-
Teicoplanin	-	-	-	-	0.25	1	1
Telithromycin	-	-	-	-	0.03	0.06	0.06
Temocillin	2	-	>128	-	128	-	-
Tetracycline	1	2	-	32	0.06	-	0.5
Ticarcillin	1	-	16	-	0.5	-	-
Ticarcillin/ 4mg/L clavulanate	-	-	32	16	-	-	-
Tigecycline	0.12	0.12	-	-	0.12	-	-
Tobramycin	0.25	0.5	0.5	0.5	0.12	-	0.5
Trimethoprim	0.12	0.25	32	-	0.25	-	0.5
Trovafoxacin	0.015	0.015	0.5	0.5	0.015	0.03	0.03
Vancomycin	-	-	-	-	0.5	0.5	1

Table 9: Target MICs (mg/L) for *Pasteurella multocida* control strain by BSAC methods

Antimicrobial agents	<i>Pasteurella multocida</i>	
	NCTC 8489	
Ampicillin	0.12	
Cefotaxime	0.004	
Ciprofloxacin	0.008	
Penicillin	0.12	
Tetracycline	0.25	

Table 10: Target MICs (mg/L) for anaerobic control strains by BSAC methods on Iso-Sensitest agar supplemented with 5% defibrinated horse blood and 20 mg/L NAD

Antimicrobial agent	<i>Bacteroides fragilis</i>	<i>Bacteroides thetaiotaomicron</i>	<i>Clostridium perfringens</i>
	NCTC 9343	ATCC 29741	NCTC 8359
Clindamycin	0.5	2	0.06
Co-amoxiclav (2:1 ratio)	0.5	0.5	≤ 0.06
Meropenem	0.06	0.12	≤ 0.015
Metronidazole	0.5	4	8
Penicillin	16	16	0.06
Piperacillin/tazobactam (fixed 4 mg/L tazobactam)	≤ 0.12	8	0.5

Table 11: Target MICs (mg/L) for Group A streptococci control strains by BSAC methods

Antimicrobial agent	Group A streptococci	
	NCTC 8198	ATCC 19615
Clindamycin	0.03	0.06



**References**

1. Andrews, J.M. Determination of minimum inhibitory concentrations. *Journal of Antimicrobial Chemotherapy*, Suppl S1 to Volume 48 July 2001.
2. Andrews, J. M., Jevons, G., Brenwald, N. and Fraise, A. for the BSAC Working Party on Sensitivity Testing. Susceptibility testing *Pasteurella multocida* by BSAC standardized methodology. *Journal of Antimicrobial Chemotherapy*.

**Suppliers**

<b>Reagent</b>	<b>Suppliers (others may be available)</b>
ISA	CM471, Oxoid, Basingstoke, UK
Columbia agar	CM331, Oxoid, Basingstoke, UK
Mueller Hinton agar	CM337, Oxoid, Basingstoke, UK
NAD	Mast Group, Merseyside, UK
McFarland turbidity standards	bioMérieux, Basingstoke, UK
Control strains	NCTC, Colindale, London Oxoid, Basingstoke, UK Mast Laboratories, Merseyside, UK Becton Dickinson, Oxford, UK TCS Biosciences Ltd. Buckingham, UK

**Useful web sites**

BSAC	British Society for Antimicrobial Chemotherapy	<a href="http://www.bsac.org.uk">http://www.bsac.org.uk</a>
SRGA	The Swedish Reference Group for Antibiotics	<a href="http://www.srga.org">http://www.srga.org</a>
CDC	Centre for Disease Control (Atlanta, USA)	<a href="http://www.cdc.gov">http://www.cdc.gov</a>
WHO	World Health Organisation (Geneva, Switzerland)	<a href="http://www.who.int">http://www.who.int</a>
CLSI	Clinical and Laboratory Standards Institute	<a href="http://www.clsi.org">http://www.clsi.org</a>
NEQAS	National External Quality Assessment Scheme	<a href="http://www.ukneqas.org.uk">http://www.ukneqas.org.uk</a>
NCTC	National Collection of Type Cultures	<a href="http://www.ukncc.co.uk">http://www.ukncc.co.uk</a>
JAC	The Journal of Antimicrobial Chemotherapy	<a href="http://www.jac.oupjournals.org">http://www.jac.oupjournals.org</a>
EUCAST	European Committee on Antimicrobial Susceptibility Testing	<a href="http://www.eucast.org">http://www.eucast.org</a>