Healthy animals, safe food – but to what extent is antimicrobial use in pig production a cause for concern?

# Problems of antibiotic resistance in pigs in the UK

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THE fact that large quantities of antimicrobials are used in pig production in the UK has led to the assumption that antimicrobial resistance must be posing major problems. This, in turn, raises a number of pertinent questions. For example, do veterinary practitioners feel that resistance is compromising the successful treatment of their patients? Are antimicrobials overused in pigs or are they not used prudently? Finally, does antimicrobial use in pigs have an adverse effect on humans, either directly from the transmission of resistant zoonotic pathogens or indirectly through the transmission of antimicrobial resistance via commensal organisms? This article reviews recent data on antimicrobial usage and resistance problems in pigs, with a view to shedding light on these questions and related issues.

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USE OF ANTIMICROBIALS IN VETERINARY MEDICINE AND IN PIGS

The Veterinary Medicines Directorate (VMD) recently published data on the use of antimicrobials in veterinary medicine in the UK, covering the period 1998 to 2002 (VMD 2003). The overall use of therapeutic products over these five years was relatively static, ranging from 445 to 462 tonnes, with 457 tonnes being used in 2002. This is in spite of a fall in the numbers of pigs slaughtered of about 37 per cent during this period. However, during this time several antimicrobial growth promoters were withdrawn from the market, some of which had disease-preventing effects. Furthermore, a major new immunosuppressive infection – postweaning multisystemic wasting syndrome (PMWS), associated with porcine circovirus type 2 – swept the UK, resulting in the increased use of therapeutic antimicrobials.

THERAPEUTIC ANTIMICROBIALS

The graph, above right, shows the major groups of antimicrobial products used for therapeutic purposes in the veterinary field. As can be seen, tetracyclines account for the greatest quantity of active substance used (217 tonnes [47 per cent] in 2002), and this is primarily due to the use of chlortetracycline feed premixes, which are common treatments for respiratory infections in both pigs and poultry. In pigs, they are primarily given for *Mycoplasma hyopneumoniae* (enzootic pneumonia), *Pasteurella multocida* and *Actinobacillus pleuropneumoniae* infections. Trimethoprim/sulphonamide combi-

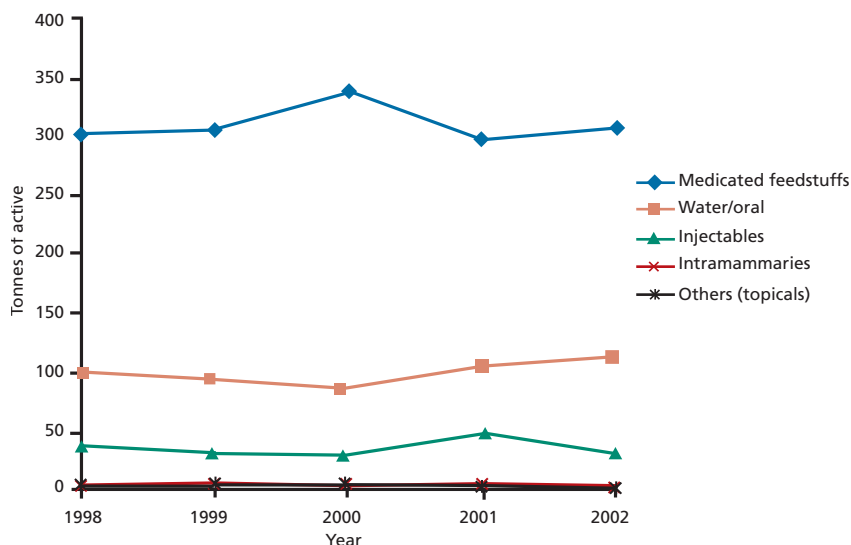**Major therapeutic antimicrobial groups used in veterinary medicine.** From VMD (2003)
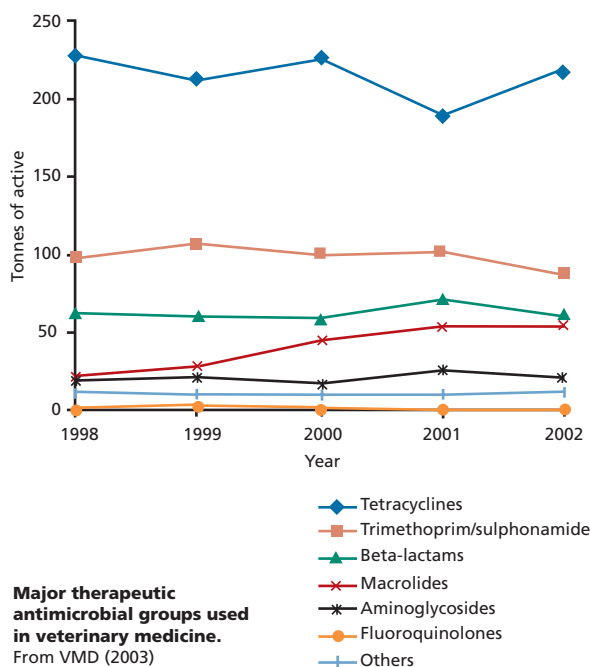
nations are the second mostly commonly used products (at 88 tonnes [19 per cent] in 2002). They are used for the treatment of both respiratory and enteric bacterial disease, especially *Escherichia coli* and *Salmonella* species infections in weaner and growing pigs, which have increased in PMWS-affected herds. These products are available in water-soluble, piglet doser and injectable forms, as well as feed premixes. The use of beta-lactams,

Antimicrobial use in animals, by route of administration.
From VMD (2003)

Route of administration

In its report, the VMD also reviews the use of therapeutic antimicrobial products by route of administration, but unfortunately the data is not broken down according to individual species, although efforts are being made to apportion the results in the future. In 2002, the medicated feedingstuffs route accounted for 307 tonnes (67 per cent), the oral and water route 110 tonnes (24 per cent), injectables 34 tonnes (7 per cent), intramammaries 4 tonnes (1 per cent), and 'others' (mainly topicals) 2 tonnes (<1 per cent) (see graph on the left).

In-feed medication is the preferred route of administration for preventing and treating infections in pigs because it requires very little labour on the farmer's part; injections, on the other hand, are very laborious. In general, the cost of in-feed products is relatively low in comparison with water solubles and injectables; for example, the cost of chlortetracycline in feed is 1·5p and in water is 27·5p per gram of active substance, whereas injectable oxytetracycline costs 65p per gram. This may not be entirely representative of all antimicrobial product ranges, but it demonstrates the value in cost/benefit terms of in-feed medication and explains why in-feed chlortetracycline is the principal product used.

Use in pigs

Precise usage figures for different species are difficult to calculate, as many of the products are used in more than one, but estimates would suggest that 40 to 45 per cent of therapeutic antimicrobials are used in pigs.

which include penicillins and synthetic penicillins, such as ampicillin and amoxycillin, has been relatively stable, at around 60 tonnes (13 per cent). The penicillins are popular as feed premixes (eg, penicillin V and amoxycillin), but also as soluble forms for poultry in particular. Macrolides, mainly in the form of tylosin premix, have seen a marked increase in use in recent years. Since the ban on the use of tylosin as a growth promoter was introduced in 1999, its therapeutic use under prescription for porcine proliferative enteropathy ('ileitis') and enzootic pneumonia has increased steadily, reaching 56 tonnes (12 per cent) in 2002. Aminoglycosides have fluctuated in volume, but in 2002 accounted for 22 tonnes (5 per cent). The main premixes are neomycin and apramycin, which also come in soluble and oral doser forms for piglets and are commonly used for *E coli* and *Salmonella* species infections. Fluoroquinolones are not widely used in the UK in tonnage terms. There are no feed premix formulations, but there are water-soluble preparations for poultry (in particular, turkeys) and calves, and also injectables and piglet dosers.

The 'others' group (see graph on page 37) includes the pleuromutilins, tiamulin and valnemulin, and the lincosamides, which are primarily used for swine dysentery, colitis and ileitis caused by *Brachyspira hyodysenteriae*, *Brachyspira pilosicoli* and *Lawsonia intracellularis,* respectively, as well as *M hyopneumoniae* infections. They have shown very little fluctuation in recent years, with 13 tonnes (3 per cent) used in 2002.

OTHER ANTIMICROBIALS
Growth promoters

Growth promoters accounted for an additional 27 tonnes of antimicrobial usage in 2002. The major ones in the UK of 'resistance concern', because they are related to antimicrobials used in man, are avoparcin (a glycopeptide – related to vancomycin in man), virginiamycin (a streptogramin – related to dalfopristin-quinupristin), tylosin (a macrolide – related to erythromycin), and zinc bacitracin. All of these are no longer in use, having been withdrawn in mid-1999 or before under the 'precautionary principle'. The remaining ones, which will be withdrawn on December 31, 2005, are avilamycin, flavophospholipol, salinomycin in pigs, and monensin in cattle; these growth promoters are not currently associated with resistance transfer issues, as neither they, nor any related compounds, are used in humans.

(right) Disc diffusion test, showing large zones of inhibition around the antibiotic-impregnated discs. (far right) The Etest (Bio-Stat) is an antimicrobial gradient technique based on disc diffusion; the MIC can be read off the antimicrobial gradient in the strip where the zone of inhibition disappears.
Pictures, Professor D. Taylor, University of Glasgow
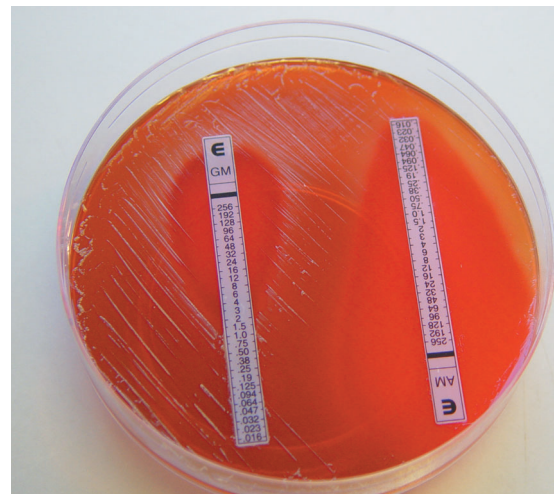
Coccidiostats

The amount of antimicrobials used for the control of coccidiosis in pigs is relatively small compared to that used in poultry (250 tonnes in 2002). Resistance to products such as toltrazuril in piglets does not appear to be a problem.

EFFECT OF ANTIMICROBIAL USE ON THE DEVELOPMENT OF RESISTANCE IN PIGS

A report on antimicrobial sensitivity of isolates in 2002 has recently been published by the Veterinary Laboratories Agency (VLA 2004). *E coli* is a useful marker bacterium, across all species of animal, for showing (albeit not in absolute terms) where antimicrobial resistance lies. It is an organism that readily gains resistance to many antimicrobials, so is also a reasonable indicator of antimicrobial use.

The antimicrobial disc diffusion test (as illustrated on page 38) is the main technique used for determining sensitivity. It involves growing organisms on Isosensitest agar plates (Oxoid), with media supplementation for fastidious organisms. The uniform cut-off point for resistance and sensitivity is a 13 mm diameter zone of inhibition around the disc. This method has been standardised across all of the VLA's regional veterinary laboratories. Many of the organisms may have come from animals that have been treated with antimicrobials and will therefore have been under selective pressure. The test is relatively simple, so may either over- or underestimate the sensitivity of an organism to a certain antimicrobial. The minimal inhibitory concentration (MIC) test, coupled with the pharmacokinetic data of the antimicrobial, is a more accurate way of assessing sensitivity; nevertheless, for monitoring purposes, disc diffusion remains a very useful method.

From the figures shown in the table, above right, it can be seen that there is a high level of resistance in porcine *E coli* to tetracycline and trimethoprim/sulphonamide combinations. Avian isolates also show high resistance to these antimicrobials. Of interest is the level of fluoroquinolone (enrofloxacin) resistance in pigs, which has been quite low in the past but has recently increased.

E coli infections usually affect young suckling pigs (neonatal scours) and, in particular, the weaned pig at around 28 days of age, and are often associated with strains expressing the K88 antigen (now reclassified as the fimbrial antigen F4). Thereafter, they tend to subside, with occasional cases of bowel oedema being seen in growing pigs. In adults, *E coli* particularly affects the sow at the time of farrowing, causing the so-called mastitis-metritis-agalactia (MMA) syndrome, and may be associated with vulval discharges and infertility later on.

As can be seen from the table on the right, levels of resistance tend to be higher in younger suckling pigs, where more sophisticated antimicrobials are administered individually, especially by piglet dosers or injection. The category of pigs over six months of age (presumably periparturient sows) shows a surprisingly high level of resistance, but there are relatively few isolates (15) and the report notes that two of the three enrofloxacin isolates came from the same farm, causing this wide fluctuation (VLA 2004).

Overall, the apparent trend over the period 1998 to 2002 has been for increased *E coli* resistance in pigs to tetracycline, trimethoprim/sulphonamide and the fluoroquinolones; little net change in resistance to the aminoglycosides (apramycin and neomycin); and decreased resistance to ampicillin (see graph below).

This has been an interesting period for pig production, as 1998 not only saw the start of the collapse of production in the UK, but also the emergence of the first cases of PMWS, which subsequently spread across the UK. Initially, this disease, which is associated with destruction of the lymphoid immune system, caused up to 30 per cent mortality, but gradually mortality fell to about 5 per cent, and it still tends to grumble on at around this level. PMWS-affected herds experience an increase in diarrhoea (53 per cent of cases) due to mixed infections, respiratory disease (68 per cent of cases), and systemic infections caused by *Streptococcus suis* and *Haemophilus parasuis* in particular. As mentioned earlier, the need to control these secondary bacterial infections would account for the higher usage in feed of chlortetracycline and trimethoprim/sulphonamides, in spite of the fall in pig numbers. It is surprising that aminoglycoside resistance has remained relatively static; however, there is still a substantial use of zinc oxide in weaner feeds to prevent *E coli* diarrhoeas and this has a major benefit of reducing the use of, and resistance development pressure on, the aminoglycosides.

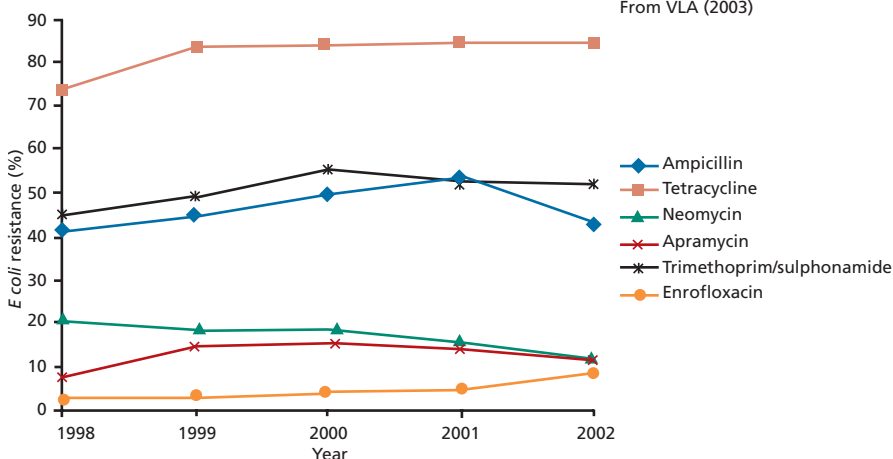| COMPARISON OF ANTIMICROBIAL RESISTANCE (%) IN *ESCHERICHIA COLI* FROM DIFFERENT ANIMAL SPECIES OF ALL AGES (DATA FOR 2002)				
Antimicrobial/disc strength	*Pigs*	*Cattle*	*Sheep*	*Avian*
Number of isolates	*365*	*4193*	*299*	*141*
Ampicillin 10 µg	43	44	22	48
Amoxycillin/clavulanate 20/10 iu	–	14	3	–
Tetracycline 10 µg	85	48	36	62
Neomycin 10 µg	11	26	14	12
Apramycin 15 µg	12	3	2	4
Trimethoprim/sulphonamide 25 µg	52	23	13	33
Enrofloxacin 5 µg	8	0·1	0	3
From VLA (2004)				

Resistance of *Escherichia coli* isolates to various antimicrobials in pigs. From VLA (2003)

COMPARISON OF ANTIMICROBIAL RESISTANCE (%) IN *ESCHERICHIA COLI* FROM PIGS OF DIFFERENT AGE GROUPS AND FROM ONES EXPRESSING THE K88 (F4) ANTIGEN (DATA FOR 2002)					
Antimicrobial	*<1 month*	*1-6 months*	*>6 months*	*All ages*	*K88*
Number of isolates	*114*	*195*	*15*	*365*	*52*
Ampicillin 10 µg	44	44	40	43	54
Tetracycline 10 µg	85	90	60	85	94
Neomycin 10 µg	11	10	7	11	8
Apramycin 15 µg	16	11	0	12	23
Trimethoprim/sulphonamide 25 µg	58	49	67	52	65
Enrofloxacin 5 µg	11	4	20	8	13
From VLA (2004)					

than one month old, whereas resistance was still relatively low in finishing pigs of slaughter age (one to six months). The majority of isolates had the K88 antigen.

In its report, the VLA also covered a number of other important pathogens in the pig, including *Arcanobacterium pyogenes* which causes abscesses, often following tail biting (see table on the left). There has been very little change in the development of antimicrobial resistance by these organisms in recent years. Over 90 per cent of *P multocida* isolates are still sensitive to the tetracyclines, in spite of their widespread use; *A pleuropneumoniae* is less sensitive, albeit 78 per cent is still a high proportion. Unfortunately, there are no vaccines for *A pleuropneumoniae* commercially available in the UK. *S suis* is largely resistant to the tetracyclines, but remains completely sensitive to the penicillins, synthetic penicillins and cephalosporins, as does *A pyogenes*.

A pleuropneumoniae can be a difficult organism to treat but, fortunately, remains generally susceptible to trimethoprim/sulphonamide and ampicillin. It shows some resistance to enrofloxacin, which is administered by injection. This may be due to an increase in the use of fluoroquinolones in PMWS cases, where, due to the destruction of the immune system, better efficacy is achieved with bactericidal antimicrobials that kill the organism directly rather than bacteriostatic products that require the assistance of the immune system to clear up the infection. It is for similar reasons that aminoglycosides and fluoroquinolones have become so important in human medicine, where they are used to treat patients who are immunocompromised following radiotherapy, chemotherapy for cancer or transplantation, or are infected with human immunodeficiency virus (HIV).

So far, although there have been some high levels of tetracycline and trimethoprim/sulphonamide resistance reported in *E coli* in pigs, the same does not appear to be true for the bacteria associated with respiratory disease, such as *P multocida*, *A pleuropneumoniae* and (although not included in the VLA report) *H parasuis* and *M hyopneumoniae*. *S suis*, the cause of meningitis and arthritis, is still highly sensitive to the penicillins. Thus, it can be seen that the development of resistance is both antimicrobial and organism specific.

With regard to enteric bacteria other than *E coli*, there are a number of infections seen in the grower pig such as swine dysentery, colitis and ileitis caused by *B hyodysenteriae*, *B pilosicoli* and *L intracellularis*. The first two organisms are difficult to culture and sensitivity testing is not routinely carried out, but MICs can be determined. The third is only cultured in cell cultures and antimicrobial sensitivities are likewise difficult to carry out; however, an intracellular MIC has been established for a few isolates.

MICs provide very useful information as they give the activity of the antimicrobial for a particular isolate or, in the case of the MIC50 or MIC90, for 50 per cent or 90 per cent of the isolates, respectively (see table above left). This can be related to the maximum concentration of the antimicrobial found in the gut and an effective level, or 'breakpoint', can be estimated. So, although the MICs for valnemulin against the *Brachyspira* species look low, the concentration achieved in the colon is also quite low; conversely, for lincomycin the concentration is quite high but the MICs are high and at the top of the

The development of resistance to fluoroquinolones in animals is of great concern in relation to the possible transmission of resistant organisms to humans, where these medicines are considered essential for the treatment of potentially terminal cases. Pressure is being applied to bring about the withdrawal of these products for oral use in food animal medicine, particularly in the USA where a court case is ongoing to stop their use in poultry. Fluoroquinolones are not permitted for use in pigs in the USA and they are not used in food animals in Australia.

As can be seen from the graph below, enrofloxacin resistance in *E coli* isolates from pigs of all ages doubled between 2000 and 2002, which is a potential concern. However, the majority of isolates were from piglets less

Development of fluoroquinolone (enrofloxacin) resistance in *Escherichia coli* from pigs. From VLA (2004)
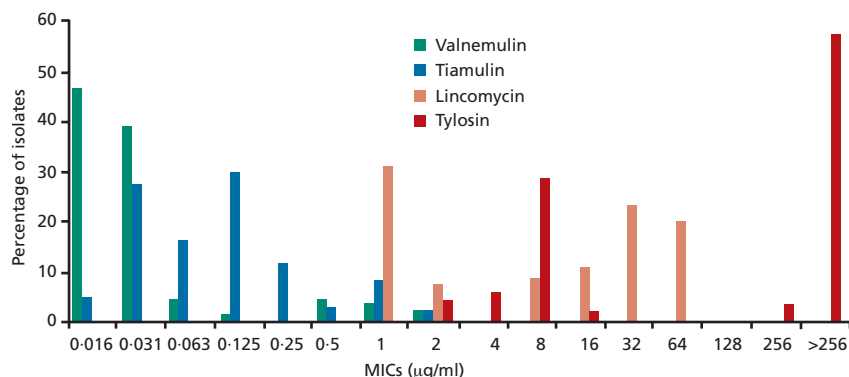
range there is definite resistance. For tylosin, there is resistance even at the MIC50, suggesting that this antibacterial is of limited value for these conditions. Whether this is because the product was used as a growth promoter is debatable. Organisms tend to develop resistance to tylosin quite quickly, whereas resistance to the pleuromutilins and lincomycin develops in a much slower, 'stepwise' fashion. Karlsson and others (2002) demonstrated an interesting pattern of susceptibility by *B hyodysenteriae* (see graph on the right).

All of these products, except valnemulin, have been available for over 20 years, so the pattern of resistance has become established by the mode of action of the antibiotic rather than just its use. The wave-like patterns may indicate where mutations have occurred and frank resistance has developed (eg, tylosin). There was concern that there was resistance developing to tiamulin in the UK in the late 1990s, but this has in general subsided with the introduction of valnemulin and the culling of less efficient infected herds. However, in Germany there is resistance to the pleuromutilins, which may have been exacerbated by the EU ban on the quinoxaline derivatives, carbadox and olaquindox, for the prevention of swine dysentery, and also the nitroimidazoles, dimetridazole and ronidazole, on safety grounds. Widespread resistance to the pleuromutilins would pose a major problem in the UK, as currently there are no other suitable alternatives. Culling of infected herds would have to be considered.

Pattern of susceptibility shown by *Brachyspira hyodysenteriae* to various antimicrobials. From Karlsson and others (2002)

TRANSMISSION OF RESISTANCE TO MAN

ZOONOTIC PATHOGENS

The major potential zoonotic pathogens of concern are *Salmonella* and *Campylobacter* species, and *S suis*. The last is transmitted relatively infrequently (approximately two reported cases per year), but has been found mainly in pig farm workers, slaughtermen and butchers (ie, those in close contact with pigs and meat; Barlow and others 2003). Antimicrobial resistance is not a practical problem, as *S suis* is still highly susceptible to the penicillins; however, immunocompromised people are advised not to work with pigs, as there is an increased risk of infection.

Of the campylobacters, *Campylobacter coli* is the dominant strain in pigs (>90 per cent of isolates), whereas *Campylobacter jejuni* is the major cause of food poisoning in humans (>90 per cent of cases) globally. A study using erythromycin resistance as a marker (Burch 2002), and another involving genetic profiling of *C coli* (Guevremont and others 2004), have demonstrated that pig meat presents either a very low or no risk of transmission of campylobacters to humans. These are relatively fragile organisms and chilling of the carcase also helps to destroy them (Guertler and others 2004). However, in some countries, such as Germany and Denmark, raw minced pig meat (eg, steak tartar) is consumed and this may increase the risk of transmission, although this is unproven as yet. Thus, if the risk of transmission is very small, or even zero, so is the risk of transfer of antimicrobial resistance.

With regard to the transmission of salmonellae from pigs to man, there is a definite reported link to *Salmonella enterica* serovar Typhimurium, as certain definitive types found in human *S* Typhimurium cases are associated with specific porcine isolates DT 193 (13·6 per cent of pig isolates and 6·9 per cent of human isolates) and U310 (4·8 per cent pigs and 3·2 per cent humans) (VLA 2003). However, *S* Typhimurium only

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Current impact on clinical practice

From the pig practitioner's point of view, antimicrobial resistance is not currently perceived as being a major clinical problem in the UK. There are usually suitable, effective, alternative antimicrobials available and, fortunately, a number of new molecules (albeit often related to, or derivatives of, older compounds) continue to be introduced, such as florfenicol (chloramphenicol), tulathromycin and acetylisovaleryl tylosin (macrolides); a number of others are still under development.

Antimicrobials do appear to be widely used in the national pig herd, especially in comparison with, say, Denmark, where there has been a higher focus on herd health and disease eradication than in the UK. For example, in 2002, approximately 17 tonnes of active substance were used in the UK per million pigs slaughtered, compared with 3 tonnes per million pigs slaughtered in Denmark (Danmap 2003). The UK industry finds itself in a poor competitive situation and has been in severe decline in recent years. Contributing factors have been the introduction of the ban on sow stalls and tethers, banning of the used of meat and bonemeal in feed, the strength of sterling against the euro, and PMWS (which did not appear in Denmark until 2002). Within a declining industry, underinvestment and shortcuts are bound to occur, especially in the areas of hygiene and pen cleaning, which can lead to increased enteric disease and, as a result, greater reliance on antimicrobials.

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COMPARISON OF ANTIMICROBIAL RESISTANCE (%) IN ALL *SALMONELLA* ISOLATES BY ANIMAL SPECIES				
Antimicrobial	*Pigs*	*Cattle*	*Sheep*	*Poultry*
Number of isolates	*309*	*862*	*192*	*1580*
Ampicillin 10 μg	61	11	5	10
Tetracycline 10 μg	84	13	6	16
Neomycin 10 μg	7	0	0	7
Apramycin 15 μg	5	0	0	0
Trimethoprim/sulphonamide 25 μg	63	4	2	24
Nalidixic acid 30 μg	6	1	1	2
Ciprofloxacin MIC >2 μg/ml	0	0	0	0
Ceftazidime 30 μg	0	0	0	0
Amikacin 30 μg	0	0	0	0
From VLA (2003)				
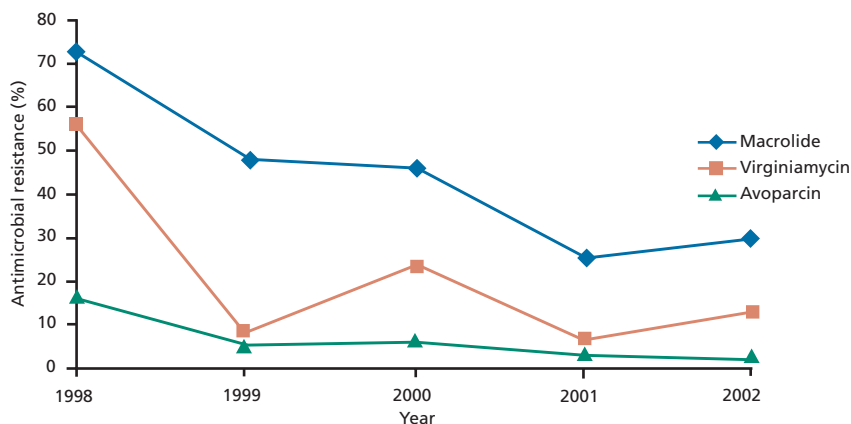
Fall in resistance to various antimicrobial growth promoters by porcine *Enterococcus faecium*, following their withdrawal from use. From Danmap (2003)

accounts for 13·1 per cent of total salmonella cases in man, whereas *S* Enteritidis still predominates at 64·5 per cent of cases and is mainly associated with chickens and eggs. According to the VLA report, *S* Derby, which was found in 7·7 per cent of incidents in pigs in 2002, was not recorded in humans that year and is presumably well below the 1 per cent level. *S* Typhimurium is the dominant species isolated in pigs and can be invasive and found in meat tissues; sausages are reported to have a contamination rate of about 8 per cent.

As can be seen from the table on page 41, in terms of salmonellae, pigs do carry a relatively high resistance rate in comparison with other species, because of the dominance of *S* Typhimurium (71 per cent of isolates) in pigs. The resistance patterns are similar to those displayed by *E coli,* with high resistance being seen to tetracycline, trimethoprim/sulphonamide and ampicillin. However, there is no resistance reported to ceftazidime (cephalosporin) and amikacin (aminoglycoside), which are two very important antimicrobials in human medicine. There is a 6 per cent incidence of nalidixic acid resistance, which is an indicator of the first step in the development of resistance to the fluoroquinolones. However, there is no reported ciprofloxacin (fluoroquinolone) resistance above the 2 μg/ml MIC breakpoint commonly used; furthermore, only four out of 2943 reported food animal isolates above the 1 μg/ml level showed resistance and 5/2943 at the more sensitive 0·5 μg/ml level (0·3 per cent in total) (VLA 2004). Consequently, although salmonellae may be transmitted to humans, the level of transfer of resistance to antimicrobials that are critical in human medicine is minimal.

COMMENSAL BACTERIA

Pigs are not usually associated with *E coli* O157:H7 verocytotoxic strains, which are directly pathogenic in humans, and predominate in cattle. However, there is a potential risk of resistance transfer through the ingestion of organisms, particularly by pig farm and slaughterhouse workers, and subsequently, to a lesser extent, by meat handlers along the food chain (where it becomes a food processing, preparation and hygiene issue).

With regard to the enterococci, *Enterococcus faecium* and *Enterococcus faecalis*, direct links have been demonstrated to pig farm workers, slaughterhouse workers and the community in general in Europe of vancomycin-resistant enterococci (VRE). However, a recent assessment of risk concerning a treatment failure in humans associated with macrolide-resistant *E faecium* from pigs estimated the risk to be very small, with a probability of less than 1 in 21 billion (Doores and others 2003).

In Denmark, a marked fall in resistance in *E faecium* from pigs has been recorded since the removal of the antimicrobial growth promoters tylosin, virginiamycin and avoparcin (see graph on the left). Unfortunately, there is no comparative data in the UK. However, a similar picture is anticipated, as the levels of *E faecium* identified in a 1999/2000 slaughterhouse survey (Teale 2002) showed resistance to tylosin at a level of 90 per cent and to quinupristin/dalfopristin at 47 per cent; however, resistance to vancomycin was low, at 1 per cent. The main concern has been with regard to immunocompromised patients coming into contact with meat contaminated with vancomycin-resistant *E faecium,* but it looks as if this potential route is almost eliminated. Nevertheless, there remains the important route of hospital-acquired VRE infections in immunocompromised patients which are often epidemic and have been shown to be genetically distinct from porcine isolates (Homan and others 2002).

WHAT IS THE STATE OF PLAY?

There is resistance in bacteria in pigs, but generally it does not appear to cause major clinical problems to the veterinary surgeon, as effective alternatives are currently available. There is no room for complacency, however, and these products should be used prudently. Vaccination and close attention to hygiene, management, feeding and biosecurity are necessary to maintain or, better still, improve the situation by helping to reduce dependency on antimicrobials.

On the question of resistance transfer to humans, the closer humans are to the pig in the production chain, the greater the risk of contamination. Clearly, pig farm and slaughterhouse workers are the most exposed. Further down the production chain, pig meat represents a potential risk; certainly, for *S* Typhimurium, there is a risk of infection but apparently a low risk of transmission of resistance to the major antimicrobials used to control the infection in man. The new Zoonoses Action Plan, which was launched on behalf of the pig industry by the British Pig Executive in December 2000, and which classifies farms according to the incidence of positives to a meat juice ELISA for salmonella, and implements a clean-up programme for the worst affected, will also help to reduce the level of contamination of carcases. With regard to the campylobacters, there is a comparatively lower risk of transfer via pig meat. Similarly, there is a low risk with *E faecium* and the situation regarding VREs in the community is likely to have improved further following the removal of growth promoters.

Overall, the antimicrobial resistance situation in porcine veterinary medicine is fairly static and under control, although it is important to remain vigilant, especially given the forthcoming withdrawal of the remaining growth promoters. The transmission of salmonellae to humans does pose an ongoing problem, but the risk of spread of resistance to humans, which might impair salmonella treatment, is low. *C coli* resistance to macrolides is high, but the risk of transmission is low. The risks of transmission of VRE to humans are expected to fall following the removal of the glycopeptide growth promoter, avoparcin, but it will be interesting to see whether this actually reduces the incidence of infection in hospitals.

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