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Antibiotic Resistance Epidemiology: Links between Antibiotic Use in Food Animals and Resistance in Human Bacteria*

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Introduction

Approximately 50% of all antibacterial agents used yearly in the European Union (EU) are given to animals (1). These antibiotics are not only used (on veterinary indication) for therapy and the prevention of bacterial infections, but they are also added continuously to animal feeds to promote growth, to increase feed efficacy, and to decrease waste production. The antibiotics used for this purpose are commonly called feed savers, performance enhancers, or antimicrobial growth promoters (AMGP). In Europe, approximately 30% of all antibiotics used in animals are used as AMPG, but large differences between the EU member states exist. Since the recommendations of the Swann report (1) in 1969 have been followed by most EU member states, molecules that are used for therapy in humans and/or animals are not allowed to be used as AMPG. However, many of the AMPG that are used today in the EU are analogues of, and show cross-resistance with, therapeutic antibiotics. AMPG are mainly active against Gram-positive bacteria (2–3) (table I) (4), with the exception of carbadox and olaquindox, which are mainly active against Gram-negatives (5). Approximately 90% of all antibiotics used for veterinary purposes are given orally to food animals like poultry, pigs and calves. In these cases, the antibiotics are mostly mixed in the feed, but sometimes they are poured over the feed or dissolved in the drinking water or milk. In the Netherlands, AMGP are included in nearly all feeds for pigs, broilers, and veal calves. The amount of antibiotics used as AMGP is of the same size order as for veterinary purposes; 250 vs. 300 tons of active drug (2). In other countries, like the UK for example, the veterinary use is more than three times as high as the use for growth promotion.

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Table 1
Normal susceptibility ranges of clostridia and enterococci for some AMGP compared to permitted levels in feed for performance enhancement (modified from (2) and (3)

Antibacterial substance	*Range of Minimum Inhibitory Concentrations (MIC in mg/l)*		*Dosage used for growth enhancement (mg/Kg feed)*
	Clostridia	*Enterococci*	
Avilamycin (evernimomycin)	< 0.25–0.5	Not available	2.5–40
Avoparcin (glycopeptide)	0.5–2	1–2	5–40
Bacitracin (polypeptides)	1–4	0.5–16	5–100
Flavophospholipol (bambermycins)	< 1–8	0.25–4	1–25
Monensin (polyether)	0.5–4	1–2	10–40
Spiramycin (macrolide)	0.25–8	0.5–4	5–80
Tylosin (macrolide)	< 1	1–4	4–40
Virginiamycin (pristinamycin)	0.25–1	0.25–8	5–80

Resistance

Many retrospective and prospective studies have been performed concerning the emergence and selection of resistance in bacteria by the use of antibiotics. Despite large differences in methodology, most results show after the introduction of antibiotic into veterinary practise, resistance in pathogenic bacteria and/or in faecal flora increases, like in human medicine. Some bacteria, however, like most *Enterobacteriaceae,* staphylococci and *Pasteurella* spp., become more readily resistant to certain antibiotics than others do, such as *Clostridium* spp. and streptococci, which are still fully susceptible to penicillin-G.

The literature on resistance against AMGP is very limited as most of these molecules are not used for therapy and therefore susceptibility testing is not regularly performed. *Linton et al.* (6) found a significant increase in the prevalence of resistance against tylosin and bacitracin in faecal enterococci of pigs and poultry that had been fed these substances. Virginiamycin usage, however, did not result in an increase in resistance in this study. After the introduction of olaquindox in 1982 on farms using olaquindox as an AMGP, the prevalence of resistance in faecal *Escherichia coli* in pigs increased in three years from 0.004 to 6 %, whereas on farms not using olaquindox the prevalence of resistance increased as well, but to a significantly lesser degree, suggesting dissemination of resistant clones (7).

Ohmae et al. (8–9) noticed an increase of resistance against carbadox in faecal *E. coli* isolates of pigs after its introduction as an AMGP. All resistant isolates from six farms that fed carbadox continuously to pigs either as AMGP or for the prevention of swine dysentery, carried the same transferable plasmid conferring carbadox resistance. Carbadox is not used in poultry and no carbadox resistance was found in *E. coli* isolates from poultry in the same region. *Mills and Kelly* (10) also reported, after the introduction of carbadox, an increase in resistance in *E. coli* isolates from 37 to 61 %. Carbadox, however, was not only used as an AMGP, but also for the prevention of swine dysentery and as therapy for salmonellosis.

Interest in the selection of resistance by AMPG increased after the emergence of vancomycin resistance enterococci (VRE) in human infections. It was soon recognised that avoparcin, like vancomycin, a glycopeptide and until recently commonly used as AMGP in most EU member states, selects for VRE in the intestinal flora of animals (11). In countries where avoparcin was used as an AMGP, VRE were not only found in food animals fed avoparcin, but also in the faecal flora of healthy humans and in pet animals (5, 12–15) (table II). Furthermore, resistance against MLS antibiotics like erythromycin and pristiniamycins (quinupristin-dalfopristin) is quite common in enterococci from animals fed related antibiotics as AMGP, like tylosin (a macrolide) or virginiamycin (a pristiniamycin) (15). Similar figures have been found in other European countries such as Denmark (16), where in 1995 a prevalence of resistance was found in enterococci from pigs and poultry against vancomycin (21 % and 56 %), erythromycin (91 % and 59 %, and quinupristin-dalfopristin (53 % and 37 %). In Finland, however, where tylosin is not used as an

Table 2
Prevalence of vancomycin, erythromycin, and pristiniamycin resistant enterococci in the faecal flora of healthy animals and humans in the Netherlands

Population	*n*	*Prevalence of resistance*		
		Vancomycin/ VanA	*Erythromycin*	*Quinupristin-dalfopristin**
Veal calves	539	92	–	–
Broilers	51	80	94	98
Turkeys	47	50	–	–
Pigs	282	34	84	75
Dogs and cats	23	17	–	–
Hospital patients	3	3	–	–
Urban residents	117	12	50	30
Extramural patients	168	8	–	–

* only *Enterococcus faecium*

AMGP and only in limited quantities for veterinary purposes, the prevalence of erythromycin resistance in enterococci was significantly lower, 18% and 9% respectively (17). Since 1986, Sweden has banned the use of AMGP in animal feeds. The prevalence of resistance against AMGP or related compounds in faecal samples of Swedish pigs was in 1997 significantly lower than in Dutch pigs, as shown in table III (18).

In Sweden and the USA, where avoparcin has never been used, no high level VRE (*VanA* resistance) has been found in faecal samples of food animals or in healthy humans outside hospitals (18–20). Mevius (submitted for publication) observed in Dutch veal calves from farms using avoparcin as an AMGP a significantly higher percentage VRE per gram faeces (10–100%) than in faecal samples of calves fed bacitracin as an AMGP (1–10%). The prevalence of VRE in turkey flocks fed avoparcin was 60%, in contrast to 8% in flocks not exposed to avoparcin (21). The relative odds ratio was 7.5. In Denmark, *Bager et al.* (19) found a high correlation between the usage of avoparcin on a farm and the prevalence of VRE in the intestinal flora of animals. The change of VRE isolation from the faecal samples of these animals (pigs and poultry) was three times higher in animals fed with avoparcin than from other animals. The relative odds ratio for the usage of avoparcin on the presence of VRE in the faecal flora of these animals was 2.9 (1.4–5.9) for poultry and 3.3 (0.9–12.3) for pigs. It can be concluded that the use of AMGP, like veterinary antibiotic usage, selects for resistance among susceptible microorganisms, not only in pathogens but also in bacteria belonging to the normal flora of animals like enterococci and *E. coli*. This has been shown for avoparcin, bacitracin, tylosin, virginiamycin, carbadox and olaquindox.

Table 3
Prevalence (%) of antibiotic resistant *Escherichia coli* and percentage of samples with a high degree of resistance in Swedish and Dutch faecal samples of pigs

Antibiotic	*Concentration In agar (mg/l)*	*Sweden*			*The Netherlands*		
		n	*Prevalence*	*High degree*	*n*	*Prevalence*	*High degree*
Amoxycillin	25	100	51	3	1321	85*	14**
Oxytetracycline	25	100	69	6	3121	93*	40*
Chloramphenicol	25	100	3	0	1022	63*	3
Florfenicol	25	100	0	0	1321	0	0
Nitrofurantoin	50	100	0	0	1321	3	0
Trimethoprim	8	100	46	1	1321	85*	21*
Neomycin	32	100	17	3	1321	56*	0
Gentamicin	16	100	0	0	1321	2	0
Flumequin	16	100	1	0	1321	3	0
Ciprofloxacin	4	100	0	0	1321	1	0

* Significantly higher, $P < 0.001$
** Significantly higher, $P = 0.005$

Transfer of resistant bacteria from animals to humans

Zoonotic bacteria

Most investigations on the transfer of resistant bacteria from animals to humans concern food infections caused by Gram-negative bacteria such as *Salmonella* spp., *Campylobacter* spp., and *Yersinia* spp. Transfer of resistant salmonellae from animals to humans has been described by several authors (22–25). Since the resistance of *Salmonella*-isolates from humans and animals has been monitored for many years, the emergence and dissemination of resistance in this species is very well documented. Before the introduction of antibiotics (Murray collection), isolates were fully susceptible to most antibiotics (26). Humans become infected with salmonellae from animals by direct contact with infected animals or animal faeces, but the most important source of human infection are food products of animal origin. Asymptomatic salmonella infections and carriers are common in food animals in intensive animal husbandry. Salmonellae from the intestinal tract of these animals contaminate during slaughtering carcasses, meat, and meat products and via these meat(products), eggs etc., humans can become infected.

Also humans do not always become ill after a salmonella infection. *Deleener and Haebaert* (27) showed that the frequency and variation of the different isolated *Salmonella* serotypes from asymptomatic carriers in a meat packing plant corresponded with the serotypes isolated from the supplied meat and from the produced meat products. Despite the fact that since the introduction of antibiotics in clinical medicine, resistance in human and animal isolates increased in general (28), the majority of clinical isolates are still susceptible to most antibiotics. In the Netherlands, the prevalence of tetracycline resistance in human and animal *Salmonella*-isolates increased clearly until the ban in 1969 on tetracycline use as AMGP (29), when it started to decline gradually (30–33). Also in Great Britain after this ban tetracycline resistant *S. typhimurium* isolates from calves fell from 60 % in 1970 to 8 % in 1977 (34). However, the spontaneous ending of epidemics by virulent tetracycline resistant *S. typhimurium* clones might have contributed to this decrease as well (35). In most EU member states, *S. enteritidis* is at this moment the most commonly isolated serotype from human infections, as a result of its extensive dissemination among poultry since 1980 (36). Because this serotype does not, in most cases, cause clinical symptoms in affected flocks, the animals are not treated with antibiotics. Therefore, the selection pressure is low and most isolates are still susceptible to most antibiotics.

Sporadically, however, epidemics of salmonella-clones with an enhanced virulence and pathogenicity for animals occur, such as *S. typhimurium* phage type 29 from 1963 till 1969, definitive type (DT) 204 in 1977, and DT 204 and DT 193 in 1980 (34). The primary reservoir of *S. typhimurium* are calves, but sheep, goats, pigs, poultry and horses can also become infected. During all these epidemics the same phage type with identical resistance profiles was isolated from animal and

human infections. Since these strains cause serious disease in affected animals, these animals were treated with antibiotics, and as a result of the selection pressure these strains tended to become (multi)resistant. Since 1994, *S. typhimurium* DT 104 has been responsible for an epidemic. This strain was from the start resistant to most of the antibiotics normally used to treat enteric infections in animals, but it has acquired in addition, resistance against trimethoprim and fluoroquinolones (28), most likely because affected groups of animals could only be treated with these antibiotics. The most important reservoir for human *Campylobacter* infections is poultry. *Endtz et al.* (13) observed that the emergence of fluoroquinolone resistant *Campylobacter jejuni* infections in humans in the Netherlands coincided with the introduction of enrofloxacin, a fluoroquinolone for poultry therapy in the spring of 1987. Enrofloxacin and ciprofloxacin, introduced in October 1988 for human therapy in the Netherlands, are fully cross-resistant. In 1989, 14 % of poultry and 11 % of human isolates of *C. jejuni* were resistant against ciprofloxacin. Experimentally it was shown that in flocks only colonised with ciprofloxacin susceptible *C. jejuni* after a therapy with enrofloxacin, ciprofloxacin resistant mutants emerged (37). In Great Britain, enrofloxacin was registered for veterinary use in 1993, and in that year 14 % *of C. jejuni* isolates from poultry carcasses imported from the Netherlands were fluoroquinolone resistant, but nearly none of the United Kingdom isolates were (38). In 1997, however, the percentage of fluoroquinolone resistant *C. jejuni* from English broilers had approached the continental level of more than 10 %. Transfer of chloramphenicol resistant *Yersinia enterocolitcia* strains from animals to humans has been described by Perez-Trallero et al (39).

Disturbance of colonisation resistance

Another aspect of the usage of antibiotics is the disturbance of the colonisation resistance (CR) of the intestinal flora of animals exposed to certain antibiotics (39, 40). In the case of reduced colonisation resistance, not only the minimal infection or colonisation dose of pathogenic or resistant bacteria is considerable lower, but animals excrete these bacteria in higher numbers and over a longer period of time compared to animals with an intact colonisation resistance. This enhances not only dissemination of *Salmonellae* or resistant bacteria within a group of animals, but it also increases the contamination of carcasses with these bacteria during slaughter. This effect has been clearly demonstrated for most broad-spectrum antibiotics (41) and for certain AMGP: avoparcin (42–44) and to a lesser extent, virginiamycin and tylosin (45–46). Avilamycin and bacitracin seem not to disturb the CR in the dosages used for growth promotion (47–51). Flavophospholipol has been shown to provide a certain protection against Salmonella infection (52).

Indicator bacteria

As a result of exposure to antibiotics, the level of resistance against antibiotics among bacteria belonging to the normal intestinal flora of humans and animals has

increased. These bacteria constitute an enormous reservoir of resistance genes for (potentially) pathogenic bacteria, but also the level of resistance in the endogenous flora is considered a good indicator for the selection pressure exerted by antibiotic use in that population (53), and for resistance problems to be expected in pathogens (54). Resistant bacteria from the intestinal flora of food animals contaminate, like zoonotic bacteria, the carcasses of slaughtered animals and reach the intestinal tract of humans via the food chain. Investigation of the prevalence of resistance of certain indicator bacteria like *E. coli* and enterococci in the intestinal tract of different populations of animals and humans makes it feasible to compare the prevalence of resistance in different populations, and to detect a possible transfer of resistant bacteria from animals to humans and vice versa. Because of the inevitable high usage of antibiotics in hospitals, selection and dissemination of resistant clones and resistance genes are high in hospitals, but emergence of new resistance due to the acquirement of new genes or gene clusters like the *VanA* gene cluster are not likely to occur in hospitals, but must once have been introduced into hospitals. Healthy individuals in the community outside hospitals are considered to be a suitable population to study the possibility of transfer of resistant bacteria or resistance genes from animals to humans and vice versa. *Corpet* (55) showed that the prevalence and degree of resistance in the faecal *E. coli* flora of humans who used only sterilised food decreased significantly. *Nijsten* (56–57) found in the faecal flora of pig farmers significantly more resistant *E. coli* than in faecal samples from pig slaughterers and (sub)urban residents. Because the personal antibiotic usage of the farmers was much higher than that of urban residents, it was difficult to draw a conclusion. However, comparison of the prevalence of ciprofloxacin resistant *E. coli* in faecal samples of turkeys and turkey farmers with pig and pig farmers strongly indicated the transfer of ciprofloxacin resistant *E. coli* strains from turkeys to turkey farmers (table IV). (18). In the Netherlands, enrofloxacin is commonly used in turkeys but not in pigs because no oral formulation for pigs was available at the time of study. Tetracyclines are used extensively in both animal species. The prevalence of ciprofloxacin resistant *E. coli* was not only significantly higher in turkey farmers and turkeys than in pig farmers and pigs, but also *E. coli* strains were isolated from farmers and turkeys which were completely identical in pulsed-field gel electrophoresis (PFGE) after

Table 4
Prevalence (%) of resistant faecal *E. coli* in different populations

Population	*n*	*Ciprofloxacin*	*Tetracycline*	*Furazolidone*
Turkey farmers	47	29	82	2
Turkey slaughterers	47	2	58	0
Pigs	291	2	100	17
Pig farmers	290	1	79	8
Pig slaughterers	317	0	47	4
Urban residents	117	0	31	0

*Xba*I digestion. None of the turkey farmers and suburban residents in this study had used antibiotics in the three months prior to the study. For the turkey slaughterers, the infection risk seemed much lower, despite the fact that ciprofloxacin resistant *E. coli* strains had been isolated from the turkey carcasses after slaughtering (14). In contrast, there was no difference between the prevalence of furazolidone resistant *E. coli* between the two animal populations and between the two groups of farmers, which was to be expected as furazolidon has been used extensively in both animal species. The use of furazolidone, also an antibiotic for which transferable resistance is not important, was banned for animal use in the Netherlands in 1994 and for human usage before 1980, which might explain the relatively low prevalence of resistance. These results also suggest the transfer of resistant strains from animals to humans. The extent of transfer seems to be correlated with the prevalence of resistance in the animal population, which is positively correlated with the amounts of antibiotics to which the animal population is exposed. In the same study, VRE was also isolated from a turkey farmer and from his turkeys, which were not only identical by PFGE after *Sma*I digestion, but also had a *VanA* gene with a unique mutation (58). This again strongly indicated the transfer of resistant strains from animals to humans. Moreover, in Sweden, where in 1986 all antibiotic use as AMGP has been banned, were not only none VRE detectable in the faecal flora of healthy humans and animals, it was also not detected in the stool samples of healthy volunteers after taking a course of vancomycin orally (58). In Belgium in a similar experiment, however, all volunteers, in whom no VRE was found in their stool samples before the study, became positive after taking vancomycin orally (59–60). This is in concordance with the results of *Quednau et al.* (58), who were able to isolate VRE from Danish, but not from Swedish meat(products) (61). In Swedish hospitals no *VanA*-resistance has been found in clinical enterococcal isolates (62–63). The only VRE isolated from a hospital patient contained the *VanB* gene cluster and was acquired abroad. Avoparcin does not select for the *VanB* type of resistance against glycopeptides, probably because it does not induce *vanB* resistance. Unfortunately no data on prevalence of VRE in Sweden are available from before 1986, but as until that time avoparcin was used in Sweden in a similar way as in other European countries, it is most likely that at that time VRE were common in the endogenous flora of food animals and of the general population. After the ban in Denmark the prevalence of vancomycin resistant *Enterococcus faecium* in faecal samples of broilers decreased from more than 80 % in 1995 to less than 5 % in 1998 (64). In contrast the prevalence in pigs (±20 %) did not change during this time span. In Germany two years after the ban of avoparcin a decrease in the prevalence of VRE was detected in frozen and fresh poultry meats from 100 % till 26 % (65). In the same study a decline in the prevalence of VRE was also observed in faecal samples of healthy persons from 12 % to 3 %. In Italy the prevalence of VRE in poultry meats decreased within 18 months after the ban from 15 % to 8 % ($p = 0.01$) (66). Also in the Netherlands the prevalence of VRE in the faecal flora decreased within two years after the

ban of avoparcin significantly in broilers from 80 % to 31 %, in pigs from 34 % to 17 % and in healthy humans from 12 % to 6 % (67). These results point not only to avoparcin use in animals as a cause of resistance in human enterococci, but also strongly suggest that removal of the selective pressure i.e. the usage of avoparcin as AMGP, can remove VRE from a population in due time.

Transfer of resistance genes from the animal bacterial flora to pathogenic bacteria and human intestinal flora

In 1976 *Levy et al.* observed in a prospective study, that chickens fed tetracycline transfer tetracycline resistance genes between chicken *E. coli* strains, from chicken to chicken and from chicken to humans (68). A wide dissemination of a tetracycline resistance gene, *tetQ*, was observed by *Nikolich et al.* (69) and *Shoemaker et al.* (70). They found identical *tetQ* genes in host-specific intestinal flora bacteria: *Bacteriodes* spp. and *Prevotella intermedius* from humans, and *Prevotella ruminicola* from bovines (49–50). The relation between the usage of an antibiotic and the dissemination of bacterial resistance from animals to humans has been described in detail by *Hummel et al.* (71). In 1982 in the former German Democratic Republic (DDR) nourseotricin, a streptotricin antibiotic was introduced as an AMGP for pigs. Streptotricin antibiotics have never been used in human or veterinary medicine and do not show cross-resistance with other antibiotics. Resistance to nourseotricin did not occur in faecal *E. coli* from pigs before the use of nourseotricin, but was within one year after its introduction, commonly found in pigs fed this antibiotic. The resistance genes were located on a transposon Tn*1825*, and within two years this transposon was found not only in faecal isolates from pig farmers and their family members, but also in urban residents and in *E. coli* isolated from urinary tract infections in humans. A few years later it was also found in pathogenic bacteria, not only in zoonotic bacteria like *Salmonella* spp. but also in *Shigella* spp., which only affect humans and do not have an animal reservoir. Outside the DDR nourseotricin resistance had never been found. Other examples of the dissemination of resistance genes from animals to humans are the dissemination of the *aacC4* gene (apramycin resistance) and *hphB* gene (hygromycin resistance) which are linked together, from animals to human bacteria. Despite the fact that apramycin is only used in animals (and hygromycin has never been used in humans or animals), these genes have not only been found in animal isolates or zoonotic bacteria isolated from humans, but also from *Enterobacteriaceae* in the environment, the intestinal flora of farmers, and hospital isolates (72–76).

Conclusion

In animals as in humans, the use of antibiotics causes not only an increase of resistance in pathogenic bacteria, but also in the endogenous flora of these animals. Resistant bacteria from animals (zoonotic bacteria or intestinal flora) can infect or reach the human population not only by direct contact, but also via food products

of animal origin. These resistant bacteria can either colonise humans and/or transfer their resistance genes to other bacteria belonging to the endogenous flora of man. Moreover, the greater the number of resistant bacteria in the intestinal flora, the greater the likelihood that genes encoding resistance will be transferred to (potentially) pathogenic bacteria and dissemination into the environment and from animals to food of animal origin. In this respect one might consider the resistance observed in zoonotic and nosocomial pathogens to be just the tip of the resistance iceberg. As bacteria from the human flora cannot only cause infections in immunocompromised hosts but are also considered an important reservoir of resistance genes for (potentially) pathogens, it has been proposed that a low level of carriage of resistant strains by humans should be a public health goal in much the same way as normal blood pressure and low serum cholesterol level (54). Despite the fact that it is not clear yet to what extend the use of antibiotics in animals contributes to the resistance problems in human medicine, it cannot be disputed that it is a certain factor. Since we are now encountering in human medicine some microorganisms that are so multiresistant that it is difficult, and may soon be impossible, to fight these with the clinically available antibiotics, every source of resistance must be controlled as much as feasible. Therefore, a low level of resistance in the intestinal flora of food animals should be thought of as a safety and distinguishing benchmark for food animals (15, 77). Moreover, this will not only protect public health, but also safeguard the future efficacy of antibiotics in veterinary medicine. This goal can only be achieved by reducing the amounts of antibiotics used in animals. The requirement for antibiotics in veterinary therapy and bacterial infection prevention in animals should be minimised by improving methods of animal husbandry, disease eradication, optimal usage of existing vaccines, and the development of new vaccines. If antibiotics have to be used, the usage of small spectrum molecules should be preferred and it should be done according to a sensible veterinary antibiotic policy (78). Discontinuing the practice of routinely adding AMGP to animal feeds would reduce the amounts of antibiotics used for animals in the EU by a minimal 30 % and in some countries even by 50 %. In this case the public health risks should be weighed against the economical profits and/or alternatives to AMGP, such as pre- and probiotics, which should be developed. The Swedish have shown that modern and profitable animal husbandry without AMPG is feasible (79).

Summary

An inevitable side effect of the use of antibiotics is the emergence and dissemination of resistant bacteria not only in pathogenic bacteria but also in the endogenous flora of man ad animals. Resistant commensal bacteria of food animals might contaminate, like zoonotic bacteria, meat(products) and so reach the intestinal tract of humans. Resistance genes against antibiotics that are or have only been used in animals were soon after their introduction not only found in animal bacteria, but also in the commensal flora of humans, in zoonotic pathogens like *Salmonellae*, but

also in strictly human pathogens, like *Shigellae.* This makes it clear that not only clonal spread of resistant strains occurs, but also transfer of resistance genes between human and animal bacteria. Moreover, since the EU ban of avoparcin, in several European countries a significant decrease in the prevalence of vancomycin resistant enterococci in meat(products), in faecal samples of food animals and of healthy humans has been observed, which underlines the role of antimicrobial usage in food animals in the selection of bacterial resistance and the transport of these resistances via the food chain to humans.

To safeguard public health the therapeutic use of antibiotics in animals should be reduced and the use of antibiotics as growth promoters stopped.

Zusammenfassung

Ein unvermeidbarer Nachteil in der Anwendung von Antibiotika ist das Entstehen und die Ausbreitung von resistenten Bakterien, nicht nur bei pathogenen Bakterien, sondern auch in der endogenen Flora bei Mensch und Tier. Resistente kommensale Bakterien von Schlachttieren können, wie auch die tiereigenen Bakterien, Fleischprodukte und somit dann den Intestinaltrakt des Menschen kontaminieren. Resistenzgene gegen Antibiotika, die lediglich in Tieren angewandt wurden, wurden bald nach ihrer Einführung nicht nur bei Tieren gefunden, sondern in der kommensalen Flora beim Menschen, in tierischen Pathogenen wie *Salmonella,* aber auch in rein menschlichen Pathogenen, wie *Shigella*-Stämmen. Dies zeigt, dass nicht allein eine klonale Verbreitung von resistenten Stämmen auftritt, sondern auch ein Transfer von resistenten Genen zwischen menschlichen und tierischen Bakterien stattfindet. Mehr noch, seit dem EU-Verbot von Avoparcin ist in mehreren europäischen Ländern eine bedeutende Verringerung der sonst vorherrschenden vancomycinresistenten Enterokokken in Fleischprodukten, in Fäkalproben von Tieren für die Lebensmittelindustrie und von gesunden Menschen beobachtet worden. Das unterstreicht doch die Rolle der antimikrobiellen Anwendung bei Tieren in ihrer Selektion von bakterieller Resistenz und dem Transport dieser Resistenzen via Lebensmittelkette zu den Menschen.

Um die Volksgesundheit zu gewährleisten, ist die therapeutische Anwendung von Antibiotika bei Tieren zu reduzieren und der Gebrauch von Antibiotika als Wachstumsförderer zu stoppen.

Résumé

Une conséquence inévitable de l'utilisation des antibiotiques dans l'alimentation animale a été l'émergence et la dissémination de souches des bactéries résistantes. Il peut s'agir de bactéries pathogènes mais également de souches provenant de la flore endogène de l'homme et de l'animal. Les bactéries commensales des animaux à viande auraient la capacité, à l'instar des bactéries zoonotiques, de contaminer les produits carnés et d'atteindre ainsi le tractus gastro-intestinal humain. On a pu constater, chez des bactéries animales mais aussi chez des bactéries commensales de

l'humain, chez des pathogènes comme *Salmonellae* et même chez des pathogènes strictement humains tels que *Shigellae,* des gènes de résistance à des antibiotiques qui n'ont été utilisés que chez l'animal. Cela apporte clairement la preuve d'un transfert de gènes de résistance entre les bactéries humains et animales. De surcroît, depuis l'interdiction de l'avoparcine en Europe, on a pu constater une diminution significative de la prévalence d'entérocoques résistants à la vancomycine dans les produits carnés aussi bien que dans les selles des animaux à viande et également dans les selles des humains sains. Ceci met en évidence le rôle que les antibiotiques utilisés dans l'alimentation animale jouent dans la sélection de résistances bactériennes et dans le transport de ces résistances jusqu'à l'humain par le biais de la chaîne alimentaire.

Dans l'entérêt de la santé publique, il serait judicieux de réduire l'utilisation thérapeutique d'antibiotiques chez l'animal et de stopper leur utilisation comme facteur de croissance.

Key words

Resistance, Antibiotic, Animal, Feed, Human, Food

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