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Prescription patterns of antimicrobials in veterinary practices in Switzerland

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***Objectives*: The objective of this study was to analyse antimicrobial prescriptions by veterinarians and to evaluate the appropriateness of use compared with prudent use guidelines.**

***Practices and methods*: Computerized records of prescriptions and treatments from eight mixed veterinary practices were analysed over a period of 2 years. A total of 61 212 antimicrobial treatments were recorded. Treatments were classified according to animal species treated, indication for treatment, route of administration and antimicrobial class used. For each treatment and antimicrobial substance, the prescribed dose was calculated. Dosage, antimicrobial classes and combinations of different classes used for different indications were compared with published recommendations.**

***Results*: From the total amount of 1590 kg of active antimicrobial substance, sulphonamides (594 kg), tetracyclines (335 kg), and penicillins and cephalosporins (290 kg) were the classes of which the largest quantity was prescribed. Penicillins and cephalosporins were most frequently prescribed (37% of treatments), followed by aminoglycosides (18%), tetracyclines (14%) and sulphonamides (11%). Sixty-one per cent of the amount of antimicrobials prescribed was used for the treatment of groups of animals via feed or water. Antimicrobial classes classified as highest priority for human medicine by an international group of experts were used in 9% of the prescriptions. The dosage corresponded to the manufacturer's recommendation in 45% of the analysed prescriptions.**

***Conclusions*: Most prescriptions corresponded well to guidelines on prudent use of antimicrobials. Nevertheless, the large variation of prescriptions among different veterinarians indicates that the usage of critical antimicrobial substances and the amount of antimicrobials used for group medication without a specific indication could be further reduced.**

Keywords: antimicrobial use, veterinary medicine, usage statistics

Introduction

Animal use of antimicrobials can contribute to antimicrobial resistance in bacteria of relevance for human and animal health. For this reason, guidelines to limit the spread of resistant bacteria have been issued by international organizations.[1,2] Suggested measures include stringent requirements for approval and marketing of antimicrobials for veterinary use, restrictions on the use of classes of antimicrobials that are important for human medicine and education of veterinarians and farmers towards prudent use of antimicrobials. Guidelines for prudent use of antimicrobials have been issued by different veterinary organizations.[3–5] However, these guidelines are not binding, and the success of voluntary measures for limiting the spread of resistant bacteria greatly depends on acceptance by veterinarians in practice. For determining the compliance of veterinarians with prudent use of antimicrobials, it is therefore important to document whether actual prescriptions correspond to recommendations. Monitoring antimicrobial usage is also a prerequisite for risk assessments of the impact of animal antimicrobial use on resistance in bacteria relevant to humans, and for evaluating the effect of interventions such as restriction of use of critical antimicrobial classes.[6]

Antimicrobial use can be monitored via national data on import or sales of antimicrobials, via pharmacies, veterinarians or farm records. National sales data are used most often,

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because they are relatively easy to obtain.[7,8] Nevertheless, these data do not include information on the indication for treatment, the animal species and age group treated, or the dosage applied. This information is critical for determining whether antimicrobials are used responsibly. Summary data on a national basis can only be expressed as amount in kilograms of active substance, which is not sufficient to evaluate treatment intensity for different animal species and the risk of development of antimicrobial resistance. Pharmacies can be used as data sources in countries such as Denmark and Sweden where most veterinary drugs are marketed through this channel.[9,10] In countries such as Switzerland, where most veterinary practices purchase antimicrobials directly from distributors, records of veterinarians or farmers are the only valid source of usage data that allows conclusions on the animals treated and the indication for treatment.

In 2006, 1582 practicing veterinarians were registered with the Swiss Veterinary organization (Gesellschaft Schweizerischer Tierärzte, GST) and ~960 veterinary practices existed in Switzerland (Patrick von Gunten, Provet AG, personal communication). Approximately 100 were large animal practices, 400 mixed practices, 20 specialized horse practices and 450 specialized small animal practices. Although the majority of veterinarians in Switzerland keep computerized records on the disease history of animals and antimicrobial prescriptions, the documented information is not standardized and is therefore difficult to analyse. Our goal was to describe the information on antimicrobial usage and prescription patterns available from veterinarians' records documented in a standard practice software. Specific objectives of this study were to analyse the amount of substance from different antimicrobial classes prescribed by veterinarians, to evaluate the appropriateness of use compared with prudent use guidelines and to describe the variation in prescription patterns among different veterinary practices.

Materials and methods

Eight mixed veterinary practices were recruited for participation in the study via an advertisement. Only practices with at least one-third of large animal clientele and electronic recording of disease history and prescriptions were included in the study. Treatment records for the years 2004 and 2005 were exported into a Microsoft Access® database. The data were made anonymous by deleting all information on animal owners, and drug names and dosage were related to information on active compounds from a national compendium for animal drugs.[11] One treatment was defined as one entry in the database, which corresponded to the administration, dispensing or prescription of one or several drugs for one animal or a group of animals on the same day for the same indication. For each treatment, the following information was obtained from the records: animal species treated (cattle, pig, unspecified farm animal, horse, small ruminant, pet, not specified); age group (adult, young, not specified); indication for treatment (prophylactic treatment, respiratory disease, gastrointestinal disease, udder or teat disease, fertility or birth disorder, problem of claw or limb, other indication, not specified); and route of administration (oral, parenteral, intramammary, intrauterine, topical, not specified).

The data available allowed us to evaluate the following criteria from published guidelines on prudent use:[3] (i) antimicrobial class used for the treatment (an appropriate narrow-spectrum agent should be selected in preference to a broad-spectrum agent; preference should be given to antimicrobial classes with minor relevance to human medicine); (ii) usage of combinations of substances (the indiscriminate use of antibiotic combinations should be avoided because of the potential for increased toxicity, pharmacological antagonism and the selection of resistant organisms); and (iii) dosage applied in the treatment (dosage should be in accordance with the recommended dosage regimen to avoid administration of sub-therapeutic doses, which can lead to a lack of efficacy and, in some cases, may increase the risk of resistance).

For each antimicrobial substance administered, dispensed or prescribed in a treatment, the dose per treatment was calculated by multiplying the amount of drug prescribed with the amount of antimicrobial substance contained in a standard dose (e.g. 1 mL). Active substances were grouped according to antimicrobial class to obtain summary data on kilograms of active substance. The number of treatments with different combinations of antimicrobial classes was calculated by adding combinations contained within the same drug and combinations of several drugs on the same day for the same indication. The amount of antimicrobial used from different antimicrobial classes was compared with the FAO, WHO and OIE list of critical antimicrobials for human medicine.[12]

For parenteral and intrauterine treatments, dosages of antimicrobial substances were compared with the manufacturers' recommendations. A dosage within ±10% of the recommended dose was classified as correct according to recommendations. For recommendations given per kilogram of body weight, the minimum and maximum recommended dosages were obtained by multiplying the recommended dose with a standard body weight of 400–500 kg for cattle, 80–100 kg for calves, 80–100 kg for fattening pigs, 120–150 kg for sows, 40–50 kg for sheep and goats, 5–30 kg for dogs and 3–10 kg for cats, respectively. Only antimicrobials with at least 50 recorded treatments for the respective animal category were included in the analysis. Because of missing information on animal species or age group treated, 1579 records had to be excluded from this analysis. For oral and intramammary application of treatment, the dose for an individual animal could not be compared with recommendations because the number of animals and quarters that were treated could not be determined from the records. Descriptive statistics were derived directly from Microsoft Access® via queries. Box plots were created in the software NCSS 2004© (Kaysville, UT, USA) to represent variation in the percentiles of usage of different antimicrobial classes among the eight practices.

Results

Practices were located in different geographic areas of Switzerland and covered a population of 1800–3700 cattle and 0–9400 pigs (as estimated by the practice owner). Small animals contributed to 50% and 30% of the practice income in two practices each, and <30% in the remaining four practices. One practice employed four veterinarians, one practice employed three veterinarians, two practices employed two veterinarians and four practices employed one veterinarian. The eight participating practices represented 1.5% of all large and mixed animal practices and 1% of all practicing veterinarians of Switzerland. The different practices contributed between 4098 and 11 229 records on antimicrobial treatments. A total of 61 212 antimicrobial treatments were analysed, and 1590 kg of active antimicrobial substance was prescribed in these practices over 2 years. This corresponded to 1.2% of the total of 129141 kg antimicrobial sales in Switzerland in 2004 and 2005.[13] The participating practices prescribed 1.0% of all sulphonamides sold in

Switzerland during this time period, 1.2% of all penicillins and cephalosporins and 1.6% of all tetracyclines.

A median amount of 78 kg per year and practice was prescribed, with amounts per practice and year ranging from 26 to 317 kg. Each veterinarian prescribed a median amount of 44.4 kg per year, with values per veterinarian ranging from 8.7 to 165.3 kg. A median of 17.9 g of active substance was used for one treatment, with values per practice ranging from 6.0 to 56.4 g per treatment. Forty-five per cent of the amount of antimicrobial substance was prescribed for cattle, 39% for pigs and 14% for any of the two categories (only 'large farm animals' specified in the records). Each of the animal categories small ruminants (goats and sheep), horses and pets (cats and dogs) accounted for 0.7% of the use of antimicrobial substance by weight, respectively. For cattle, 16.4 g of active substance was prescribed per treatment. For pigs and 'large farm animals', the amount per prescription was 104.3 and 118.0 g, respectively. In small ruminants, an average of 6.7 g was prescribed, compared with 19.3 g in horses and 1.4 g in pets. Table 1 shows the distribution of substances in different antimicrobial classes. In Table 2, the relative importance of the different antimicrobial classes is given for the different animal species. While sulphonamides and tetracyclines were the antimicrobials of which the greatest quantity was prescribed, penicillins and cephalosporins were the most frequently prescribed antimicrobials. The antimicrobial classes classified as the highest priority antimicrobials critical for human medicine by FAO, WHO and OIE experts (fluoroquinolones, macrolides and third- and fourth-generation cephalosporins) were used in small quantities. Nevertheless, these potent antimicrobials represent a considerably higher share of the total prescriptions. Fluoroquinolones were used in 7.8% of the prescriptions, macrolides in 3.5% and third- and fourth-generation cephalosporins in 3.1%, respectively, when prescriptions of combinations of antimicrobials were counted as a single prescription rather than one separate prescription for each component ingredient. These critical antimicrobials were mostly prescribed as one single antimicrobial substance, whereas prescriptions of combinations of substances from several classes within the same pharmaceutical product were common for other antimicrobials. The proportion of amount of antimicrobial substance and number of prescriptions of antimicrobials (combinations of antimicrobials counted as one separate prescription

Table 1. Distribution of antimicrobial prescriptions in the most important antimicrobial classes in eight veterinary practices over 2 years

	Active substance (kg)	Percentage	Number of prescriptions[a]	Percentage
Sulphonamides	594.4	37.4	10409	11.4
Trimethoprim	60.5	3.8	4159	4.5
Tetracyclines	335.4	21.1	12778	13.9
Penicillins and cephalosporins	290.0	18.2	33634	36.7
Aminoglycosides	148.8	9.4	16136	17.6
Polymyxins	103.7	6.5	4526	4.9
Macrolides	46.3	2.9	2169	2.4
Quinolones	9.6	0.6	4762	5.2
Clavulanic acid	0.9	0.1	2208	2.4
Other[b]	0.9	0.1	881	1.0

[a]Prescriptions of combinations of antimicrobials from different classes are counted as one prescription for each component ingredient, respectively.
[b]Other antimicrobial substances include amphenicols, nitrofurans, ionophores, imidazoles, rifamycin and fusidic acid.

Table 2. Relative importance of the most important antimicrobial classes in different animal species; percentage of total amount of antimicrobial substance used for each species

	Cattle	Pigs	Horses	Goats/sheep	Dogs	Cats
Sulphonamides	31.7	37.9	70.9	32.6	9.4	6.7
Trimethoprim	1.6	6.1	11.9	1.6	0.4	0.0
Tetracyclines	24.5	17.4	1.7	25.6	1.6	14.4
Penicillins and cephalosporins	27.3	11.1	8.3	22.2	68.2	69.4
Aminoglycosides	12.2	7.1	7.1	15.7	1.5	0.8
Polymyxins	0.2	15.6	0.0	0.2	0.2	0.2
Macrolides	2.1	4.1	0.0	1.0	1.5	0.1
Quinolones	0.4	0.7	0.0	1.1	1.6	3.2
Clavulanic acid	0.0	0.0	0.0	0.0	5.8	0.9
Other[a]	0.0	0.0	0.1	0.0	9.9	4.2

[a]Other antimicrobial substances include amphenicols, nitrofurans, ionophores, imidazoles, rifamycin and fusidic acid.

for each component ingredient) classified as critically important, highly important and important is shown in Figure 1.

Of the total of 1590 kg of active substance prescribed by the participating practices, 976 kg (61%) were sales of antimicrobial premixes for application in feed or water. Because prescriptions of premixes require a specific official paper-based form, no indication for treatment was noted in the electronic veterinary records for 87% of the amount prescribed. For the remaining premix prescriptions, respiratory disease was the most frequent indication (8% of antimicrobial amount in premix), followed by gastrointestinal disease (2%). Premixes had the greatest share of treatments without a specific recorded indication, which accounted for 65% of the total antimicrobial use. Eight per cent of the antimicrobial amount was prescribed for diseases of udder and teats. Treatment of infections related to fertility and birth, gastrointestinal and respiratory diseases were responsible for 7%, 6% and 6% of the prescribed antimicrobial amount, respectively. Sixty-eight per cent of the antimicrobials were administered orally, 90% of which were given as antimicrobial premixes. Parenteral application was used for 17% of the amount of antimicrobials, 9% were intramammary, 5% were intrauterine and 0.3% were topical applications, respectively.

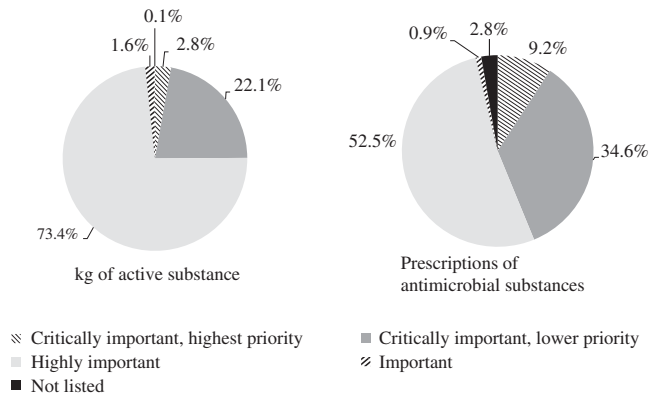

Figure 1. Classification of the antimicrobials used by eight veterinary practices according to FAO, WHO and OIE criteria for critically important antimicrobials for human medicine. Percentages of amount of active substance and percentages of prescriptions in each category are shown. Prescriptions of combinations of antimicrobials from different classes are counted as one prescription for each component ingredient, respectively.

Of a total of 61212 recorded antimicrobial treatments, 25780 corresponded to an antimicrobial drug that was prescribed at least 50 times in the same animal type for parenteral or intrauterine treatment, and had complete information on animal species and age class. Table 3 shows the comparison of the recorded with the recommended dosage for different animal species. Forty-five per cent of the analysed dosage regimens corresponded to the recommended dosage. In 8% of the records, a dosage below the recommended range was used, whereas 31% of records showed a dosage that was above the indicated range, but within two times the maximum recommended dosage. A dosage above twice the recommended dosage, which could indicate treatment of more than one animal without recording of the number treated, was observed in 16% of the records. In Table 4, the comparison of applied and recommended dosages is shown for different antimicrobial classes. Dosage below the recommended dose was mainly observed for aminoglycosides, fluoroquinolones and sulphonamides. Tetracyclines and penicillins/cephalosporins were often prescribed in dosages above the recommended dose.

The 61212 recorded antimicrobial treatments correspond to 91662 applications of antimicrobial substances. In 56% of the treatments, only one single antimicrobial substance was applied. A combination of two antimicrobial substances was used in 39% of the treatments and three substances were used in 5% of the treatments. Of the 27060 treatments with more than one antimicrobial substance, 4797 treatments (corresponding to 406 kg of active substance) were combinations of sulphonamides or sulphonamide and trimethoprim. A combination of amoxicillin and clavulanic acid was applied in 2187 treatments (4.5 kg). Combinations of different penicillins were used in 1413 treatments (18 kg). Treatments with a penicillin and an aminoglycoside, a penicillin and colistin, and an aminoglycoside and a macrolide or lincosamide were used in 13725 (237 kg), 2522 (8.5 kg) and 645 (26 kg) treatments, respectively. In 506 treatments (356 kg), a triple combination of tetracycline, sulphonamide and a macrolide was prescribed. Other combinations accounted for 1265 antimicrobial treatments and 63 kg of active substance.

The antimicrobial classes described for different indications were relatively uniform among the eight participating practices for mastitis in cows, but varied greatly for other indications. The

Table 3. Comparison of recorded dosage with the dosage recommended by the manufacturer of the respective antimicrobial for different animal species; number of treatments and percentage within each dosage category; a total of 25780 parenteral and intrauterine treatments were included in the analysis

	Dosage within recommended range (%)	Dosage below minimum (%)	Dosage above maximum (%)	Dosage above two times the maximum (%)[a]
Adult cattle	7871 (45.0)	1431 (8.2)	5859 (33.5)	2344 (13.4)
Calves	2105 (42.4)	544 (11.0)	1099 (22.1)	1216 (24.5)
Adult pigs	6 (3.7)	7 (4.3)	96 (58.5)	55 (33.5)
Fattening pigs	55 (45.1)	0 (0)	14 (11.5)	53 (43.4)
Goats/sheep	99 (17.1)	16 (2.8)	73 (12.6)	391 (67.5)
Dogs	356 (42.9)	13 (1.6)	413 (49.8)	48 (5.8)
Cats	1076 (66.6)	134 (8.3)	359 (22.2)	47 (2.9)

[a]Dosages above two times the recommended maximum dosage are reported separately because they may reflect treatment of more than one animal.

Table 4. Comparison of recorded dosage with the dosage recommended by the manufacturer of the respective antimicrobial for different antimicrobial classes; number of prescriptions of component ingredients and percentage of all prescribed component ingredients of the same antimicrobial class; a total of 25780 parenteral and intrauterine treatments with 38986 component ingredients were included in the analysis

	Dosage within recommended range (%)	Dosage below minimum (%)	Dosage above maximum (%)	Dosage above two times the maximum (%)[a]
Sulphonamides	605 (63.6)	228 (24.0)	112 (11.8)	6 (0.6)
Trimethoprim/sulphonamide	1973 (78.0)	66 (2.6)	354 (14.0)	136 (5.4)
Tetracyclines	8409 (49.0)	229 (1.3)	7655 (44.6)	862 (5.0)
Penicillins	2416 (41.8)	338 (5.8)	1905 (33.0)	1120 (19.4)
Cephalosporins	269 (17.2)	111 (7.1)	618 (39.6)	562 (36.0)
Aminoglycosides	1000 (16.6)	2193 (36.4)	1467 (24.4)	1358 (22.6)
Macrolides	299 (53.7)	37 (6.6)	55 (9.9)	166 (29.8)
Quinolones	1396 (32.7)	1079 (25.3)	1054 (24.7)	738 (17.3)
Gentamicin	62 (36.5)	8 (4.7)	4 (2.4)	96 (56.5)

[a]Dosages above two times the recommended maximum dosage are reported separately because they may reflect treatment of more than one animal.

variation of usage of different antimicrobial classes for four different indications among the eight practices is shown in Figure 2.

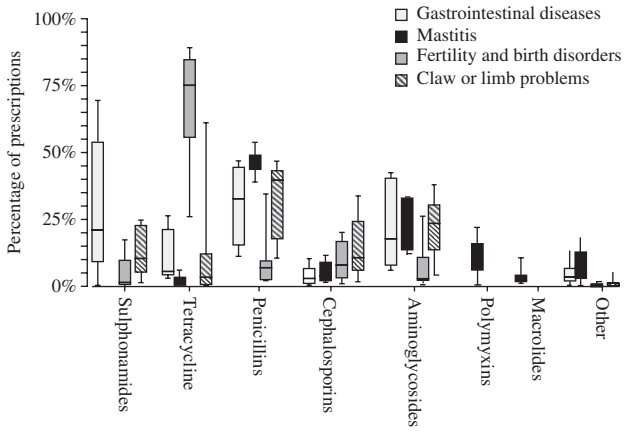

Figure 2. Variation among eight different veterinary practices in the antimicrobial classes prescribed for different indications in dairy cows. Percentages of prescriptions of each antimicrobial class for each indication are shown. Prescriptions of combinations of antimicrobials from different classes are counted as one prescription for each component ingredient, respectively.

Discussion

Participation in the study was voluntary and depended on the use of an electronic recording system, which may have favoured participation of well-informed practices that keep good records and are aware of the principles of prudent use of antimicrobials. This bias was inevitable because we needed the support of the veterinarians for obtaining adequate data quality. Even though the eight participating veterinary practices were not representative, the amount of their antimicrobial prescriptions and the distribution of antimicrobial classes were in good agreement with national sales data.[13] The large variation among individual practices in the amount of antimicrobials prescribed could partially be explained by differences in the number of veterinarians in the practice, the structure of the animal population and the geographic location of the practice. Practices with a large number of cattle and pigs in their clientele prescribed larger amounts of antimicrobials than practices with a greater number of pets. Practices in mountain regions tended to prescribe smaller amounts, because these practices generally had smaller farms in their clientele. Nevertheless, some differences remain that may be due to more restrictive use of antimicrobials in some practices. The differences among practices regarding the amount of antimicrobial substance prescribed per treatment mainly reflected differences in the animal species treated. Because prescriptions for pigs and the category 'large animals' were often group treatments, a much greater amount of antimicrobial substance was used for each treatment in these animal categories compared with cattle, horses and pets, where individual treatments are common.

Many of the criteria stated in recommendations for prudent usage of antimicrobials could not be evaluated with the data available in this study. For example, it was not possible to determine whether an accurate diagnosis or susceptibility testing was performed prior to antimicrobial treatment. This study could therefore only analyse the adherence of veterinarians to selected aspects of prudent use.

Even though only 25% of the amount of active substance prescribed belonged to antimicrobial classes classified as critically important for treatment of humans by FAO, WHO and OIE experts,[12] 44% of the prescriptions involved antimicrobials classified as critically important. This discrepancy was observed because newer classes of antimicrobials often have a higher potency and are prescribed in lower dosages. Moreover, these newer substances with high potency are often prescribed for pets, where the amount of substance needed is much smaller than in farm animals. The treatment intensity is therefore more relevant than the amount of active substance for the risk of selecting bacteria with antimicrobial resistance.[14] In interpreting antimicrobial usage data, a careful choice of the measurement unit is necessary, because different units greatly influence the

interpretation of the data.[15] For comparing the treatment intensity among different animal species, a measurement that refers to the number of treated animals and their body weights would be preferable. However, this could not be obtained from veterinary prescription data because of missing information on the number and weight of the animals treated. For the same reason, a comparison with human consumption data, which is described as defined daily doses per 1000 inhabitants, is difficult. Compared with other European countries, human consumption of antimicrobials in Switzerland is relatively low.[16]

Fluoroquinolones, third- and fourth-generation cephalosporins and macrolides were used in <10% of the prescriptions, indicating that veterinarians use the antimicrobials of highest importance for the treatment of humans carefully, as recommended by prudent use guidelines.[3] An important prerequisite for prudent use of antimicrobials is an accurate diagnosis prior to treatment. The large number of prescriptions without a record of the indication for treatment might indicate a low compliance with prudent use guidelines. Nevertheless, it is more likely to reflect a lack of information in veterinarians' records. For example, 8% of the antimicrobial amount was used for treatments for udder and teat diseases, whereas the route of administration was recorded to be intramammary for 9% of the antimicrobial amount. Indications for oral group medication were recorded in the mandatory official form instead of the electronic records; therefore, information on the indication was often missing in the electronic records of these treatments. Despite a ban on antimicrobial growth promoters in Switzerland since 1999,[17] prophylactic use of prescription-only antimicrobials in medicated feed remains a major part of antimicrobial use. Prescriptions for medicated feed need thus to be analysed in addition to veterinary records to obtain valid information on these treatments. Since the ban on antimicrobial growth promoters, sales statistics have indicated a decrease in the total amount of antimicrobials marketed in Switzerland. In addition, a detailed analysis of medicated feed in pigs concluded that the ban on antimicrobial growth promoters did not increase therapeutic use in medicated feed.[17]

Most prescriptions contained either one single antimicrobial substance or a combination of two antimicrobials that complement each other, such as sulphonamide and trimethoprim, amoxicillin and clavulanic acid, and penicillin and an aminoglycoside. However, more than 500 prescriptions of a triple combination of sulphonamide, tetracycline and a macrolide were observed, which is likely to select for multidrug-resistant bacteria.[18,19] Various authorized premixes contain this fixed combination, since Swiss regulations prohibit the addition of more than one premix at a time in the feed (Arzneimittel-Bewilligungsverordnung, Art. 2). Like all antimicrobials in Switzerland, premixes are prescription-only products that are authorized by the same procedure as other antimicrobials. A premix may be added to the feed either in a commercial mill or directly on site. It may also be applied directly into the trough ('top dressing') or, if so authorized, in water. For the on site application, Swiss regulations require a contract with a specifically trained 'qualified person' responsible for checking the adequacy of the installation (including meeting hygiene requirements) and for enforcing the correct documentation of use. Sales data for the year 2006 show that almost two-thirds of the total tonnage of antimicrobials sold in this year were premixes, representing 45.9 tons of active substance.[13] This may indicate that the amount of prescriptions of premixes was slightly underestimated in our study. The breakdown of the sales of premixes according to antimicrobial classes shows 44% for the fixed triple combination sulphonamide/tetracycline/macrolide, 24% for the sulphonamide/trimethoprim combination, 6% for other combinations of two antimicrobials without sulphonamide and 26% for premixes containing only one antimicrobial (mostly an aminopenicillin or a tetracycline) (Swissmedic, unpublished data).

The interpretation of the antimicrobial use data recorded by veterinarians is inherently limited by the quality of the data available in the electronic records. Analysis of antimicrobial usage at the level of the individual farm could supplement the data from this study to obtain a more comprehensive picture of animal antimicrobial use. No standardized measures such as prescribed daily dose[14] could be calculated, because the animal population treated by each practice could only roughly be estimated and the duration of the treatment was not recorded. Many records were incomplete, because the animal species, indication or number of animals treated was missing, and had therefore to be excluded from analyses on good prescription practice. We conclude that veterinarians' records need to be interpreted with caution when determining the correctness of dosage of antimicrobials. The large number of treatments with a dosage above two times the recommended maximum dose in sheep and goats, where group treatment is common, is an indication that the percentage of records with overdosing may be overestimated. Nevertheless, overdosing was also found to be common in dogs and cats. The finding of our study that many prescriptions differ substantially from the dosage recommended by the manufacturer is also consistent with the results of a study on antimicrobial usage in pigs in Belgium[20] and a study on antimicrobials prescribed in pig feed in Germany,[21] even though the latter classified a dosage of 30% above or below the recommended dose as accurate. This is of concern in view of the risk of selecting resistant bacteria. A dosage below the effective concentration may only select bacteria harbouring low-level resistance without eliminating the infection and thus further the development of resistant strains. This has been demonstrated for tylosin in broilers[22] and tetracycline in pigs.[23]

The large variation in antimicrobial classes prescribed for the same indication and animal species in the eight different practices is most likely due to different prescription practices. Some practices extensively used newer broad-spectrum antimicrobials, while others used them restrictively. This may indicate a potential for improvement by raising veterinarians' awareness for a more targeted prescription of antimicrobials.

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Transparency declarations

None to declare.

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