

**STANDARD ARTICLE**

Effect of antimicrobial stewardship on antimicrobial prescriptions for selected diseases of dogs in Switzerland

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Abstract

Background: Antimicrobial stewardship programs (ASPs) are important tools to foster prudent antimicrobial use.

Objective: To evaluate antimicrobial prescriptions by Swiss veterinarians before and after introduction of the online ASP AntibioticScout.ch in December 2016.

Animals: Dogs presented to 2 university hospitals and 14 private practices in 2016 or 2018 for acute diarrhea (AD; n = 779), urinary tract infection (UTI; n = 505), respiratory tract infection (RTI; n = 580), or wound infection (WI; n = 341).

Methods: Retrospective study. Prescriptions of antimicrobials in 2016 and 2018 were compared and their appropriateness assessed by a justification score.

Results: The proportion of dogs prescribed antimicrobials decreased significantly between 2016 and 2018 (74% vs 59%; $P < .001$). The proportion of prescriptions in complete agreement with guidelines increased significantly (48% vs 60%; $P < .001$) and those in complete disagreement significantly decreased (38% vs 24%; $P < .001$) during this time. Antimicrobial prescriptions for dogs with AD were significantly correlated with the presence of hemorrhagic diarrhea in both years, but a significantly lower proportion of dogs with hemorrhagic diarrhea were unnecessarily prescribed antimicrobials in 2018 (65% vs 36%; $P < .001$). In private practices, in 2018 a bacterial etiology of UTI was confirmed in 16% of dogs. Prescriptions for fluoroquinolones significantly decreased (29% vs 14%; $P = .002$). Prescriptions for antimicrobials decreased significantly in private practices for RTI (54% vs 31%; $P < .001$).

Abbreviations: AD, acute diarrhea; ASP, antimicrobial stewardship program; BAL, bronchoalveolar lavage; HPCIA, highest priority critically important antimicrobial; ISCAID, international society for companion animal infectious diseases; JS, justification score; RTI, respiratory tract infection; UTI, urinary tract infection; WI, wound infection.

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Conclusion: Antimicrobials were used more prudently for the examined indications in 2018 compared to 2016. The study highlights the continued need for ASPs in veterinary medicine.

KEYWORDS

antibiotic, antimicrobial resistance, dog, guidelines, prescribing habits

1 | INTRODUCTION

Antimicrobial stewardship refers to interventions designed to foster the prudent use of antimicrobial agents with the aim of optimizing clinical outcomes while minimizing unintended consequences of antimicrobial use, such as adverse effects and the emergence of resistance.¹ Antimicrobial stewardship programs (ASPs) are often multifaceted and include guidelines, surveillance, education, preauthorization, and audit of practice.² In human medicine, individual or bundled ASP measures are effective in reducing antimicrobial prescriptions without increase in mortality.³⁻⁹ Antimicrobial stewardship provided via national and local guidelines positively influences antimicrobial prescribing habits in human and veterinary medicine leading to both a decreased and more appropriate use as well as a reduction in resistance.³⁻¹³

In 2015, the Swiss National Strategy on Antibiotic Resistance (StAR) was passed by the federal council. As part of its implementation, an online tool (AntibioticScout.ch) assisting veterinarians in the selection of prudent empirical antimicrobial treatment based on international guidelines was created.^{14,15} The tool allows users to retrieve short and specific recommendations for antimicrobial treatment online after selection of species, organ system, and suspected or confirmed diagnosis. The result of a search may also recommend to refrain from antimicrobial treatment in the absence of specific indications. This tool became available to veterinarians in December 2016 as an extension of a well-established and highly frequented drug information web site (CliniPharm.ch). AntibioticScout.ch was promoted to Swiss veterinarians in various ways, including publications,^{14,15} newsletters of the Swiss Veterinary Society, flyers, and continuing education events for practitioners. The prescribing habits of veterinarians for selected diseases in cats and dogs in Switzerland before introduction of AntibioticScout.ch have been reported.^{16,17}

The aim of this study was to evaluate whether there is a change in antimicrobial prescriptions by Swiss veterinarians after the introduction of the online ASP tool AntibioticScout.ch. Four conditions in dogs that are often inappropriately treated with antimicrobials, including acute diarrhea (AD), urinary tract infection (UTI), respiratory tract infection (RTI), and wound infections (WI) were assessed.

2 | MATERIALS AND METHODS

2.1 | Study design

This retrospective multi-center study is based on clinical and antimicrobial prescription data from 2 university hospitals with caseloads of

6000 and 12 000 cases/year and 14 private practices across Switzerland ranging from 1-vet mixed practices to middle-sized small animal clinics. It also included 1 large private clinic with over 80 000 cases per year. The clinics and practices enrolled in the study on a voluntary basis after being introduced to the online tool AntibioticScout.ch. The exact number of veterinarians prescribing antimicrobials in these clinics and practices as well as their individual awareness and use of AntibioticScout.ch were not examined. However, at the time of the study, the web site was accessed 300 to 600 times per day. Data from 2016, before introduction of AntibioticScout.ch, were compared to data from 2018.

2.2 | Data collection

Suitable dogs were identified by full text searches of electronic medical records by predefined search terms (Table 1). Inclusion criteria for dogs with AD, proven or suspected UTI, proven or suspected RTI, or WI are shown in Table 1.

Private practices by the OblonData (Amacker & Partner Informatik AG, Switzerland) or Diana SUISSE (Diana Software AG, Switzerland) practice management software were enrolled on a voluntary basis. For private practices, the necessary sample size was calculated to estimate the prevalence of antimicrobial treatment according to guidelines with a precision of $\pm 8\%$, assuming a prevalence of 50%, a confidence level of 95% and a population size of 550.000 registered dogs in Switzerland.¹⁸ The sample size of 151 cases per indication and year, which was determined with the Epitools online calculator (<https://epitools.ausvet.io/site/samplesize>), was rounded up to a target sample size of 160. To avoid overrepresentation of large practices, the number of cases per practice was limited to 16 (10% of the target sample size), which were randomly selected via the sampling function in EXCEL. As the number of participating practices exceeded the expected number of 10, the number of samples per indication and year for private practices exceeded the target sample size of 160. For university clinics, all available cases were included, in order to get close to the target sample size of 160 cases per indication.

As dogs with uncomplicated abscesses and bite wounds are rarely presented to university hospitals, these cases were only assessed in private practices.

Antimicrobial prescription data (class, dosage, frequency of application, duration of treatment) were recorded for each case together with signalment, vaccination status, clinical history, physical examination findings, diagnostic work-up and comorbidities (acute or chronic

TABLE 1 Inclusion and exclusion criteria and search terms for the surveyed indications

Indication	Included	Excluded	Search terms
Acute diarrhea	<ul style="list-style-type: none"> • Diarrhea <3 wk • Acute hemorrhagic diarrhea syndrome (AHDS) • Parasitic diarrhea • Nonspecific diarrhea 	<ul style="list-style-type: none"> • Diarrhea >3 wk or relapsing • Diarrhea related to drug administration or another extradigestive disease • Diarrhea that started during hospitalization • Parvovirus 	Diarrhea, colitis, duodenitis, enteritis, ileitis, gastritis, AHDS, hemorrhagic gastro-enteritis, Giardia, watery feces
Urinary tract infection	<ul style="list-style-type: none"> • Suspicion or diagnosis of bacterial cystitis • Suspicion or diagnosis of pyelonephritis 	<ul style="list-style-type: none"> • Glomerulonephritis • Leptospirosis • Urolithiasis without signs of bacteriuria 	Urinary tract infection, dysuria, difficult urination, stranguria, hematuria, bloody urine, blood in urine, polyuria, pollakiuria, pyelonephritis, inflammation of the bladder, cystitis, bladder, urinalysis
Respiratory tract infection	<ul style="list-style-type: none"> • Aspiration pneumonia • Pneumonia (bacterial, viral, unknown) • Bronchitis • Kennel cough 	<ul style="list-style-type: none"> • Nasal infections • Fungal infections • Neoplasia of the respiratory tract • Lung worms 	Respiratory tract infection, respiratory tract disease, cough, tracheitis, tracheobronchitis, pneumonia, inflammation of the lungs, bronchitis, bronchopneumonia, kennel cough, distemper, influenza, adenovirus, dyspnea, tachypnea
Wound infection	<ul style="list-style-type: none"> • Bite wound • Abscess 	<ul style="list-style-type: none"> • Anal gland abscess • Dental abscess • Abscess because of a foreign body • Hot-spot 	Wound infection, abscess, purulent wound, bite

diseases present at the same time as the primary complaint). If antimicrobials could unequivocally be assigned to the treatment of coinfection of a different organ system, they were not taken into account.

2.3 | Definitions

Sepsis was defined as the presence of lethargy plus at least 1 of the following: body temperature >39.4°C, heart rate >140/min, WBC <4 or >25 × 10⁹/L, banded neutrophils >1.5 × 10⁹/L.¹⁹ Bacteriuria was defined as the presence of bacteria in microscopic sediment analysis or bacterial culture of a urine sample, which was collected aseptically by cystocentesis.

In accordance with previous guidelines, UTIs were classified as complicated in cases of infection in the presence of anatomical or functional changes or disorders of the immune system, recurrent UTI (three or more times per year) and UTI in noncastrated male dogs.²⁰ In the meantime, UTI have been reclassified as either sporadic, recurrent, or persistent,²¹ and recommendations on AntibioticScout.ch have been revised accordingly in 2019. The correct treatment according to culture and sensitivity profile was defined as follows: (a) Susceptibility of the cultured bacteria to chosen antimicrobial, (b) sufficient antimicrobial penetration into site of infection, and (c) preference given to those that are not considered highest priority critically important antimicrobials (HPCIA) whenever possible.

As suggested by the World Health Organization, third or fourth generation cephalosporins, fluoroquinolones, macrolides, ketolides, glycopeptides, and polymyxins were considered HPCIA.²² Treatment with 2 or more antimicrobial classes at the same time was defined as combination treatment.

2.4 | Justification score (JS)

The appropriateness of antimicrobial treatments was assessed by comparing them to the recommendations outlined in Table 2. These recommendations were compiled by a panel of clinical specialists and pharmacologists based on existing national and international consensus guidelines, which were available in 2016.^{20,23-25} In all cases for which sufficient clinical information was recorded, the appropriateness of antimicrobial prescription was assessed by a previously published justification score with modifications (JS-1 to JS-4; Table 3).²⁶ Diversions of ±1 day from the recommended treatment duration and of ±20% of the recommended dosage were accepted. Every case was recorded only once and only initial treatments were assessed. In order to determine the robustness of the score, 60 cases (30 cases from 2016 and 2018 each) were assessed independently by 2 evaluators with an observed Cohen's kappa of 0.975 (SE of 0.025; 95% CI of 0.926-1.000).²⁷

2.5 | Statistical analysis

Data were analyzed by the commercial SPSS software (SPSS Inc, Chicago, Illinois). Descriptive statistics were applied for demographic and clinical data, antimicrobial prescriptions, and JS. Demographic and clinical data, differences in diagnostic work-up, antibiotic classes, the use of HPCIA or combination treatment, duration of treatment, and JS were compared between dogs presented in 2016 and 2018 by chi squared test for categorical and Mann-Whitney *U* test for continuous variables. The Bonferroni method was applied to correct the significance levels for multiple comparisons.

Risk factors for JS-4 (treatment in complete disagreement with guidelines) were determined by univariate logistic regression analysis.

TABLE 2 Criteria used to judge appropriate use of antimicrobials based on national and international recommendations^{20,23-25}

Indication	Comment	Antimicrobial	Dosage (mg/kg)	Application frequency	Treatment duration (days)
Acute diarrhea	Antimicrobial treatment NOT indicated unless suspicion of sepsis based on clinical and clinicopathologic data ^a	Ampicillin ^b	20	q12h/q8h	5-7
		Amoxicillin	11-15	q12h/q8h	5-7
		Amoxicillin/Clavulanic acid	12.5-20	q12h/q8h	5-7
		Ampicillin/Sulbactam ^c	30	q12h/q8h	5-7
	If suspicion of sepsis ^a and no improvement with initial treatment after 2 to 3 d, antimicrobial spectrum may be extended by adding	Enrofloxacin OR	10-20	q24h	5-7
		Marbofloxacin AND/OR Metronidazole	2 15	q24h q24h	5-7 5-7
Urinary tract infections	Antimicrobial treatment only indicated if bacteriuria was confirmed by sediment or culture of urine collected via cystocentesis.	<i>Sporadic (uncomplicated) UTI</i>	11-15	q12h/q8h	5-7
		Amoxicillin	20	q12h/q8h	5-7
		Ampicillin ^b			
	In previous guidelines, complicated UTI were defined as infections that occur in the presence of an anatomic or functional abnormality or a comorbidity that predisposes the patient to persistent infection, recurrent infection, or treatment failure. ²⁰	<i>Complicated UTI</i>	11-15	q12h/q8h	5-28
		Amoxicillin	12.5-20	q12h/q8h	5-28
		Amoxicillin/Clavulanic acid	20	q12h/q8h	5-28
		Ampicillin ^b	30	q12h/q8h	5-28
		Ampicillin/Sulbactam ^c	15	q12h	5-28
		Trimethoprim/Sulfadiazin	15	q12h	5-28
		Trimethoprim/Sulfamethoxazole			
		<i>Noncastrated male dogs^d</i>	10-20	q24h	5-42
		Enrofloxacin	2	q24h	5-42
		Marbofloxacin			
		<i>Pyelonephritis</i>	12.5-20	q12h/q8h	5-42
Amoxicillin/Clavulanic acid	30	q12h/q8h	5-42		
Ampicillin/Sulbactam ^c	10-20	q24h	5-42		
Enrofloxacin	2	q24h	5-42		
Marbofloxacin					
Respiratory tract infections	Aspiration pneumonia or bacterial bronchopneumonia	<i>Mild to moderate disease</i>	10	q24h	Treatment 1 week beyond resolution of clinical/radiographic signs
		Doxycycline	12.5-20	q12h/q8h	
		Amoxicillin/Clavulanic acid	30	q12h/q8h	
		Ampicillin/Sulbactam ^c			
		<i>Severe cases^e</i>	12.5-20	q12h/q8h	
		Amoxicillin/Clavulanic acid OR	30	q12h/q8h	
		Ampicillin/Sulbactam ^c	10-20	q24h	
		AND	2	q24h	
	Enrofloxacin OR				
	Marbofloxacin				
Kennel cough: antimicrobial treatment only indicated if: poor general condition, rectal T >39.4°C or signs of lower airway involvement	Doxycycline	10 or 5	q24h or q12h	5-14	
Wound infections	<i>Bite wounds</i> : antimicrobial treatment always indicated, except damage limited to epidermis	Amoxicillin/Clavulanic acid	12.5-20	q12h	Abscesses or superficial ^f bite wounds: 5-7 Deep ^g or penetrating bite wounds: 7-10
		Cefalexin	20-35	q12h/q8h	
		Clindamycin	10-15	q12h	
	<i>Abscesses</i> : antimicrobial treatment only indicated if fever, reduced general demeanor, very contaminated wound, or proximity to fragile tissues (ie, joints)				

Abbreviation: UTI, urinary tract infection.

^aSepsis criteria: lethargy plus at least 1 of the following: body temperature >39.4°C, heart rate >140/min, WBC <4 or >25 × 10⁹/L, banded neutrophils >1.5 × 10⁹/L.

^bIV or SC.

^cIV.

^dTreatment as listed for complicated UTI also judged appropriate.

^eSevere clinical, laboratory or radiographic signs.

^fOnly skin damaged.

^gSkin and deeper structures damaged.

TABLE 3 Modified justification score used to judge the accordance of antimicrobial prescriptions in dogs

Justification score	Criteria
JS-1	Empirical prescription in accordance with international recommendations, that is, correct indication, antimicrobial class, dosage and treatment duration OR correct prescription according to culture and sensitivity profile OR no antibiotic indicated, and none prescribed
JS-2	Dosage and/or duration of prescription not in accordance with guidelines
JS-3	Antimicrobial class not in accordance with guidelines
JS-4	Decision to treat in complete disagreement with guidelines, that is, antibiotic prescription when not indicated or no antibiotic prescription although indicated

Abbreviation: JS, justification score.

Multivariable logistic regression analysis was attempted but, due to the low number of dogs in each category for which detailed clinical information was available, no relevant associations could be identified.

3 | RESULTS

3.1 | Case characteristics

Case characteristics for each indication examined in the years 2016 and 2018 are shown in Table 4. In total, 2205 dogs were included in the study, of which 761 were presented to university hospitals and 1444 to private practices. There were no significant differences with regards to the proportion of cases enrolled for each indication, age, sex, neuter status, and proportion of pure-bred dogs between 2016 and 2018 (Table 4).

3.2 | Antimicrobial prescriptions overall

The proportion of dogs prescribed antimicrobials decreased significantly from 74% (786/1056 dogs) in 2016 to 59% (669/1140 dogs) in 2018 ($P < .001$). The most commonly prescribed antimicrobial classes in 2016 and 2018 are shown in Figure 1. The prescription of potentiated aminopenicillins increased significantly from 2016 to 2018, whereas the prescription of nitroimidazoles decreased significantly. Overall, the proportion of dogs prescribed HPClAs did not differ significantly between the 2 years.

The distribution of justification scores for the 2 years is shown in Figure 2. In 2018, there was a significantly higher proportion of cases in which the appropriateness of treatment could not be assessed ($P < .001$). When excluding these cases, there was a significantly higher proportion of cases in 2018 for which prescribed treatment was in complete accordance with guidelines (JS-1; 2016: 48%; 2018:

60%; $P < .001$) and a significantly lower proportion of cases for which prescribed treatment was in complete disagreement with guidelines (JS-4; 2016:38%; 2018:24%; $P < .001$). The proportions of cases where antimicrobials were prescribed at an incorrect dosage, an incorrect treatment duration, or both (JS-2) or where the antimicrobial class was not in accordance with guidelines (JS-3) were small in both years and did not change significantly.

3.3 | Antimicrobial prescriptions for acute diarrhea (AD)

Antimicrobial prescriptions, minimal diagnostic work-up, use of HPClAs, combination treatment, duration of treatment in 2016 and 2018 in university hospitals and private practices are shown in Table 5. The proportion of dogs, which had minimal diagnostic work-up performed consisting of a CBC, increased significantly from 2016 to 2018 in university hospitals but not in private practices. Both in university hospitals and in private practices, the proportion of dogs with AD prescribed antimicrobials decreased significantly from 2016 to 2018.

In university hospitals, the proportion of dogs prescribed nitroimidazoles in 2018 decreased significantly, while a significantly higher proportion of dogs was prescribed potentiated aminopenicillins, fluoroquinolones, or both antimicrobial classes. There was also a significantly higher proportion of dogs prescribed combination treatment in 2018 than in 2016.

In private practices, there were no significant changes between 2016 and 2018 regarding the antimicrobial classes prescribed.

The proportions of cases in 2016 and 2018 for which a JS could be assessed (JS-1-4) and those where missing clinical information precluded attribution of a JS are shown in Table 5. When excluding cases where judgment of antimicrobial treatment was impossible the proportion of cases of AD with a JS-1 (complete adherence to guidelines) increased significantly from 34% to 62% ($P < .001$) in university hospitals and from 37% to 55% ($P = .001$) in private practices. At the same time, the proportion of cases with a JS-4 (complete disagreement with guidelines) decreased significantly from 54% to 29% ($P < .001$) in university hospitals and from 61% to 43% ($P = .001$) in private practices. The proportion of dogs prescribed antimicrobials although not indicated (subpopulation of JS-4) decreased significantly from 52% (86/164 dogs) in 2016 to 26% (50/195 dogs) in 2018 ($P < .001$) in university hospitals and from 61% (101/167 dogs) to 43% (62/145; $P = .002$) in private practices. In cases with a JS-3 (antimicrobial class not in agreement with guidelines), dogs were prescribed a fluoroquinolone or metronidazole in 11/17 cases each in 2018, either as mono- or as combination treatment. In 2016, these had been 1/18 dogs prescribed a fluoroquinolone and 17/18 dogs metronidazole.

The median duration of prescribed antimicrobial treatment was significantly shorter in 2018 than in 2016 in university hospitals, while this did not change significantly in private practices (Table 5).

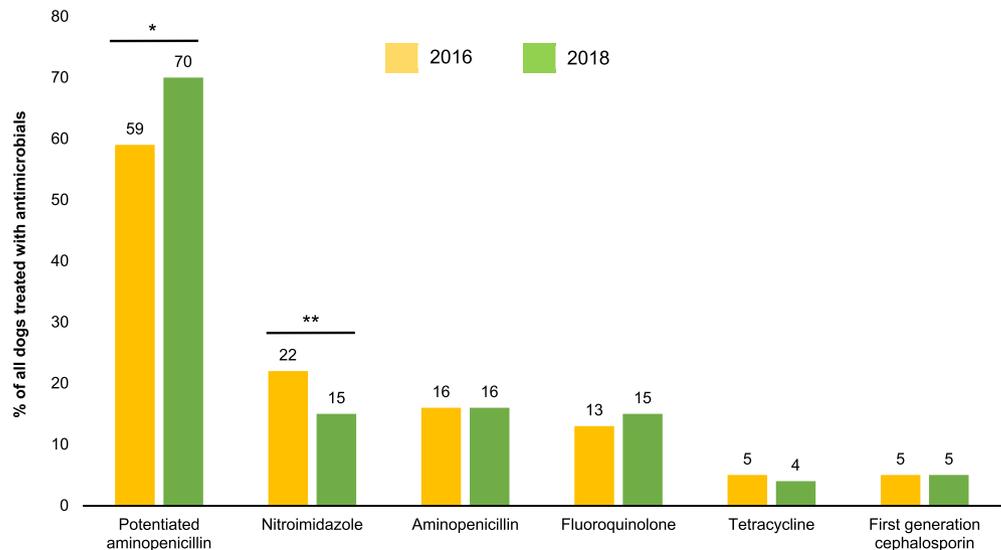
Looking at all cases for which sufficient clinical information was available, the prescription of combination treatment with 2 or more

TABLE 4 Characteristics of dogs presented with the indicated diseases in 2016 or 2018

Parameter	Acute diarrhea			Urinary tract infections			Respiratory tract infections			Bite wounds/abscesses		
	2016	2018	P-value	2016	2018	P-value	2016	2018	P-value	2016	2018	P-value
Total	371	408	.64	245	260	.91	274	306	.55	175	166	.23
Sex			.19			.67			.78			.05
Female	173	178		151	160		129	134		91	71	
Male	193	223		92	99		143	169		81	86	
Unknown	5	7		2	1		2	3		3	9	
Age (years) Median (IQR ^a)	5 (1-9)	5 (2-9)	.69	9 (5-11)	9 (4-12)	.16	6 (2-11)	7 (2-11)	.60	6 (3-9)	7 (3-10)	.14
Breed			.20			.84			.36			.22
Purebred	305	317		194	200		226	248		133	121	
Mixed breed	60	86		47	56		42	55		40	38	
Unknown	6	5		4	4		6	3		2	7	

^aInterquartile range.

FIGURE 1 Most commonly used antimicrobial classes in 2016 and 2018. * $P < .001$; ** $P = .001$; other antimicrobial classes were each used in less than 2% of all cases and are therefore not shown



antimicrobial classes was significantly associated with the presence of lethargy and at least 1 sepsis criterion (body temperature $>39.4^{\circ}\text{C}$, heart rate $>140/\text{min}$, WBC <4 or $>25 \times 10^9/\text{L}$, banded neutrophils $>1.5 \times 10^9/\text{L}$; $P < .001$)¹⁹ in both years. Unlike in 2016, the prescription of HPClAs was significantly associated with the presence of sepsis criteria ($P < .001$) in 2018.

In both years, the prescription of antimicrobials was associated with the presence of hemorrhagic diarrhea ($P < .001$). However, the proportion of dogs presented with hemorrhagic diarrhea that were unnecessarily prescribed antimicrobials decreased significantly from 65% (100/153 dogs) in 2016 to 36% (54/150 dogs) in 2018 ($P < .001$). Univariate logistic regression analysis revealed that in 2018, dogs with hemorrhagic diarrhea were 1.67 times more likely to be prescribed antimicrobials in disagreement to guidelines (JS-4) than dogs with nonhemorrhagic diarrhea ($P = .027$), while in 2016 they had been 2.26 times more likely ($P < .001$).

3.4 | Antimicrobial prescriptions for urinary tract infections (UTI)

Antimicrobial prescriptions, diagnostic work-up, and justification scores for UTI in 2016 and 2018 in university hospitals and private practices are shown in Table 6. The frequency of urine culture or microscopic sediment analysis performed in dogs with suspected UTI did not change significantly between 2016 and 2018 regardless of whether they were presented at university hospitals or private practices. At university hospitals, no significant changes in antimicrobial prescribing patterns for UTI could be detected between 2016 and 2018.

At private practices, however, fluoroquinolones were prescribed significantly less frequently in 2018 while the proportion of uncastrated males did not change between the 2 years. Unlike in 2016, the prescription of fluoroquinolones was significantly correlated with a noncastrated male status in 2018 ($P < .001$).

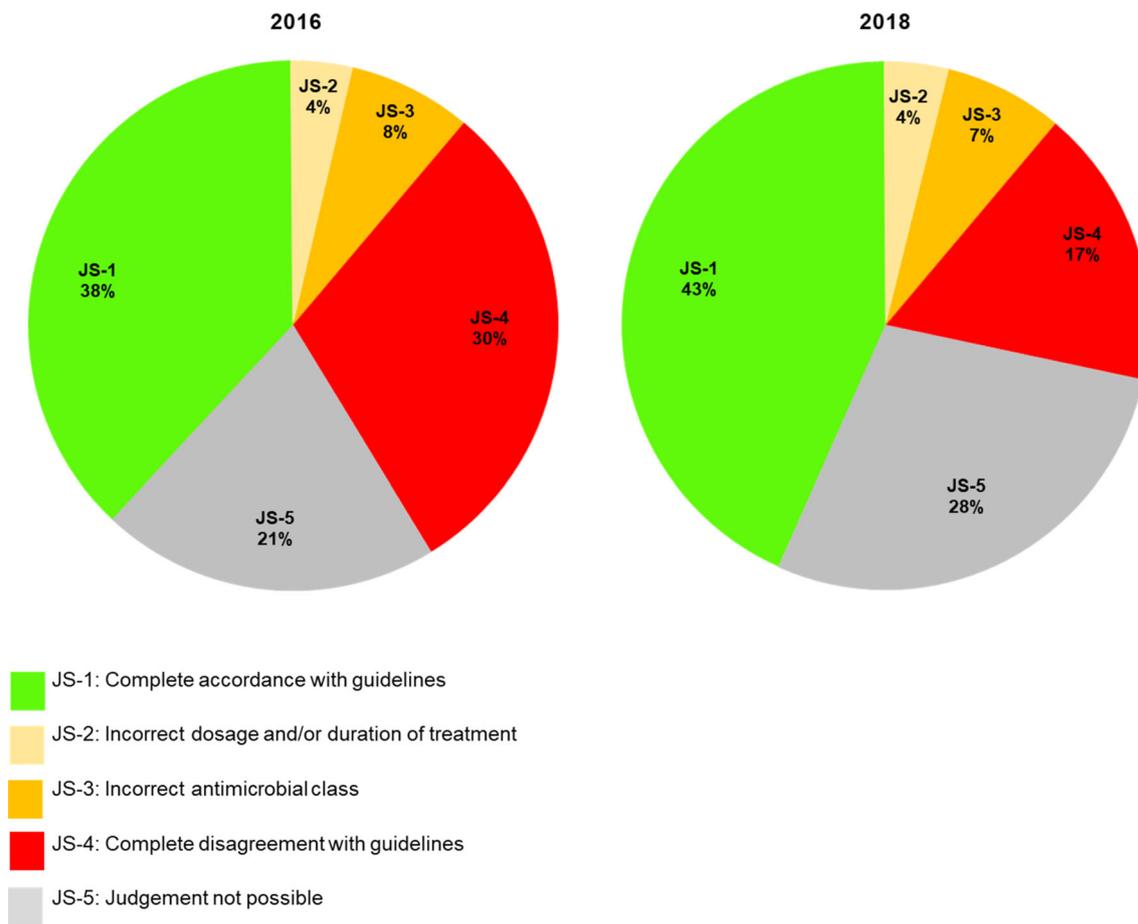


FIGURE 2 Proportions of justification scores in 2016 and 2018

When looking at diagnoses and taking both years together, a significantly higher proportion of dogs was diagnosed with a complicated UTI at university hospitals (109/166 dogs, 66%) than at private practices (104/339 dogs, 31%; $P < .001$). There was also a significantly higher proportion of dogs diagnosed with pyelonephritis at university hospitals (17/166 dogs, 10%) than at private practices (2/339 dogs, 1%; $P < .001$).

As in 2016, the appropriateness of antimicrobial treatment could not be determined in over 2 thirds of the cases presented to private practices in 2018 due to a lack of information in the medical records or lacking diagnostic work-up.

The proportions of dogs with prescribed treatments in complete agreement, partial agreement, or disagreement with guidelines did not significantly change between 2016 and 2018. For cases of uncomplicated UTI, the reason for a JS-3 (wrong antimicrobial class) was in the majority of cases the prescription of potentiated aminopenicillins instead of the recommended nonpotentiated aminopenicillins (2016:13/21 cases, 62%; 2018:19/21 cases, 90%).

3.5 | Antimicrobial prescriptions for respiratory tract infections (RTI)

Antimicrobial prescriptions, diagnostic work-up and justification scores in 2016 and 2018 in university hospitals and private practices

are listed in Table 7. The proportion of dogs with RTI that were treated with antimicrobials decreased from 2016 to 2018 both in university hospitals and in private practices, but this reduction was only statistically significant in private practices. The antimicrobial classes prescribed were not significantly different in 2018 compared to 2016, with potentiated aminopenicillins and fluoroquinolones being the most commonly prescribed classes at university hospitals and potentiated and nonpotentiated aminopenicillins as well as tetracyclines the most commonly prescribed classes at private practices.

A diagnosis of RTI was based only on clinical signs in over 80% of cases presented to private practices both in 2016 and in 2018. At university hospitals, diagnostic work-up was performed more frequently, and the proportion of cases with at least minimal work-up (thoracic radiographs and CBC) increased significantly from 2016 to 2018. The proportion of dogs in which bronchoalveolar lavage (BAL) was performed remained generally low in 2018.

Looking at cases from 2016 and 2018 together, the most common diagnosis in university hospitals was aspiration pneumonia (93/233 dogs, 40%), which was rarely diagnosed in private practices (6/347 dogs, 2%; $P < .001$). Bacterial pneumonia was only diagnosed in 2 dogs (1%) at university hospitals and none in private practices. Veterinarians suspected Canine Infectious Respiratory Disease Complex in 29 dogs (12%) at university hospitals and in 20 dogs (6%) at private practices ($P = .005$, not significant after Bonferroni correction).

TABLE 5 Antimicrobial prescriptions and justification scores for acute diarrhea in 2016 and 2018 in university hospitals and private practices

	University hospitals			Private practices		
	2016	2018	P-value	2016	2018	P-value
Total number of cases	165	197		206	211	
Dogs prescribed antimicrobials	116 (70%)	80 (41%)	<.001	127 (62%)	90 (43%)	<.001
Antimicrobial classes prescribed	74 (64%)	22 (28%)	<.001	100 (79%)	74 (82%)	.53
Nitroimidazole	55 (47%)	70 (88%)	<.001	13 (10%)	10 (11%)	.84
Potentiated aminopenicillin	3 (3%)	18 (23%)	<.001	15 (12%)	6 (7%)	.21
Fluoroquinolone	0 (0%)	1 (1%)	.23	—	—	—
First generation cephalosporin	—	—	—	9 (7%)	8 (9%)	.63
Aminopenicillin	—	—	—	3 (2%)	0 (0%)	.14
Third generation cephalosporin	—	—	—	3 (2%)	0 (0%)	.14
Tetracycline	—	—	—	0 (0%)	4 (4%)	.02
Potentiated sulfonamide	—	—	—	—	—	—
At least 1 HPCIA prescribed	3 (3%)	18 (23%)	<.001	18 (14%)	6 (7%)	.08
Combination treatment	11 (10%)	24 (30%)	<.001	6 (5%)	6 (7%)	.54
Duration (d) Median (IQR)	9 (7-11.5)	6 (5-10)	.001	7 (5-9)	6 (5-9)	.76
At least minimal work-up ^a performed	131 (79%)	178 (90%)	.003	16 (8%)	18 (9%)	.78
JS	56 (34%)	120 (61%)	<.001	62 (30%)	80 (38%)	.09
1	5 (3%)	5 (3%)	.78	0 (0%)	0 (0%)	—
2	15 (9%)	14 (7%)	.49	3 (2%)	3 (1%)	.98
3	88 (53%)	56 (28%)	<.001	102 (50%)	62 (29%)	<.001
4	1 (.6%)	2 (1%)	.67	39 (19%)	66 (31%)	.004
Judgment not possible	—	—	—	—	—	—

Note: Bonferroni corrected P-value for significance $\leq .003$.

Abbreviations: HPCIA, highest priority critically important antimicrobial; JS, justification score.

^aCBC.

The proportion of cases without a confirmed diagnosis was significantly lower in university hospitals (73/233 dogs, 31%) than in private practices (312/347 dogs, 90%; $P < .001$).

In university hospitals as well as in private practices, the proportion of cases where accordance to guidelines could not be judged was significantly higher in 2018 (Table 7). When excluding these cases, the proportion of JS-1 (complete adherence to guidelines) increased mildly but not significantly from 2016 to 2018 in university hospitals (2016:66%; 2018:72%; $P = .34$), and significantly in private practices (2016:52%; 2018:75%; $P = .001$). The proportion of cases with JS-4 (complete disagreement with guidelines) decreased significantly both in university hospitals (2016:18%; 2018:8%; $P = .022$) and private practices (2016:37%; 2018:15%; $P < .001$). For all cases in which judgment was possible, the proportion of dogs prescribed antimicrobials although not indicated decreased significantly from 18% (19/103 dogs) in 2016 to 0% (0/104 dogs) in 2018 ($P < .001$) in university hospitals and from 35% (43/123 dogs) to 13% (13/102 dogs; $P < .001$) in private practices.

3.6 | Antimicrobial prescriptions for abscesses and bite wounds (WI)

Antimicrobial prescriptions and justification scores for abscesses and bite wounds in private practices in 2016 and 2018 are shown in

Table 8. No significant changes between the 2 years were found regarding antimicrobial prescriptions. As in 2016, the majority of dogs were prescribed antimicrobials in 2018, the most commonly used classes being potentiated and nonpotentiated aminopenicillins and first generation cephalosporins.

Of all dogs presented for abscesses and prescribed antimicrobials, the proportion of dogs not showing any indications for antimicrobial use listed in the guidelines (fever, lethargy, severely contaminated wound, or proximity to fragile tissues) decreased mildly but not significantly from 2016 to 2018 (2016:36%; 2018:26%; $P = .30$).

The proportion of dogs receiving local wound treatment, which is considered an important part of the treatment of abscesses and bite wounds^{28,29} increased between 2016 and 2018, while the proportion of dogs in which drains were placed did not increase (Table 8).

The proportion of cases where no JS could be applied was significantly higher in 2018 compared to 2016. When excluding these cases, there were no significant differences in the proportion of cases with JS-1 (2016: 64%; 2018: 60%; $P = .52$) and JS-4 (complete disagreement with guidelines; 2016: 17%; 2018: 15%; $P = .71$).

4 | DISCUSSION

ASPs are efficient measures to foster prudent antimicrobial use in human and veterinary medicine.³⁻¹³ This study evaluates the effects

TABLE 6 Antimicrobial prescriptions, diagnostic work-up and justification scores for urinary tract infections in 2016 and 2018 in university hospitals and private practices

	University hospitals			Private practices		
	2016	2018	P-value	2016	2018	P-value
Total number of cases	70	96		175	164	
Dogs prescribed antimicrobials	68 (97%)	88 (91%)	.14	147 (84%)	125 (76%)	.07
Antimicrobial classes prescribed	53 (78%)	64 (73%)	.46	97 (66%)	100 (80%)	.01
Potentiated aminopenicillin	12 (18%)	23 (26%)	.21	43 (29%)	17 (14%)	.002
Fluoroquinolone	5 (7%)	4 (5%)	.46	22 (15%)	31 (25%)	.04
Aminopenicillin	2 (3%)	1 (1%)	.42	11 (8%)	5 (4%)	.22
First generation cephalosporin	2 (3%)	0 (0%)	.11	—	—	—
Lincosamide	1 (2%)	2 (2%)	.72	—	—	—
Potentiated sulfonamide	1 (2%)	0 (0%)	.25	—	—	—
Amphenicol	0 (0%)	2 (2%)	.21	—	—	—
Aminoglycoside	0 (0%)	1 (1%)	.38	0 (0%)	1 (.8%)	.28
Tetracycline	—	—	—	3 (2%)	1 (.8%)	.40
Third generation cephalosporin	—	—	—	—	—	—
At least 1 HPCIA prescribed	12 (18%)	25 (28%)	.12	46 (31%)	18 (14%)	.001
Combination treatment	5 (7%)	3 (3%)	.27	0 (0%)	4 (3%)	.03
Duration (d) Median (IQR)	21 (10-27.5)	15 (10-28)	.43	10 (8-14)	10 (7-14)	.40
Culture performed	67 (96%)	91 (95%)	.78	43 (25%)	31 (19%)	.21
Microscopic sediment analysis performed	59 (84%)	77 (80%)	.50	73 (42%)	75 (46%)	.77
Bacterial etiology confirmed	62 (89%)	85 (89%)	1	27 (15%)	26 (16%)	.91
JS	38 (54%)	49 (51%)	.68	11 (6%)	15 (9%)	.32
1	4 (6%)	8 (8%)	.52	1 (.6%)	2 (1%)	.52
2	13 (19%)	22 (23%)	.50	17 (10%)	10 (6%)	.22
3	14 (20%)	14 (15%)	.36	25 (14%)	21 (13%)	.69
4	1 (1%)	3 (3%)	.48	121 (69%)	116 (71%)	.75
Judgment not possible	—	—	—	—	—	—

Note: Bonferroni corrected P-value for significance $\leq .002$.

Abbreviations: HPCIA, highest priority critically important antimicrobial; JS, justification score.

of an online ASP tool in small animal medicine and applies a detailed justification score to accurately evaluate changes of antimicrobial prescriptions.

The ASP of this study (AntibioticScout.ch) is an online tool that allows veterinarians to quickly retrieve recommendations for prudent antimicrobial use for specific indications online. The tool was introduced at the end of December 2016 along with a bundle of educational measures including conference talks, workshops, and press releases promoting an attitude of prudent antimicrobial use as part of the National Strategy on Antimicrobial Resistance (StAR). At the time of writing, AntibioticScout.ch is accessed more than 400 times per day.

A retrospective analysis of 2205 case files demonstrated that the proportion of dogs treated with antimicrobials significantly decreased between 2016 and 2018. At the same time, the proportion of therapies in complete accordance with guidelines (JS-1) increased and the proportion of treatments in complete disagreement (JS-4) decreased. These findings suggest that the introduction of AntibioticScout.ch, in the context of other implemented educational measures, led to a more prudent use of antimicrobials in the participating practices and hospitals.

The most common deviations from prudent use in both years were prescription of antimicrobials where none were needed for AD,

unconfirmed UTI, and wounds or abscesses that could have been managed with local wound treatment only.

Substantial changes in prescribing were seen in dogs presented for AD (Table 5). For this subgroup, the prescription of antimicrobials decreased significantly, and a significantly higher proportion of dogs was prescribed in accordance with guidelines, which recommend the use of antimicrobials only in cases with suspected sepsis.^{24,25} Unlike in 2016, the prescription of HPCIA was significantly correlated with the presence of sepsis criteria in 2018, which implies a more prudent use of HPCIA. Nevertheless, over 3/4 of the cases where fluoroquinolones were prescribed in 2018 were judged with JS-3 (wrong antimicrobial class) or JS-4 (complete disagreement with guidelines), suggesting that a large proportion of the prescribed fluoroquinolones was still unnecessary. This should be monitored closely in the future to ensure the sustainable use of these important drugs.

As in dogs with nonhemorrhagic diarrhea, the use of antimicrobials in dogs with hemorrhagic diarrhea without signs of sepsis has been considered unnecessary for many years now, as it does not change the outcome.^{18,30,31} In 2018, the proportion of dogs with hemorrhagic diarrhea that were prescribed antimicrobials although not indicated decreased significantly. This finding suggests that a

TABLE 7 Antimicrobial prescriptions, diagnostic work-up and justification scores for respiratory tract infections in 2016 and 2018 in university hospitals and private practices

	University hospitals			Private practices		
	2016	2018	P-value	2016	2018	P-value
Total number of cases	108	125		166	181	
Dogs prescribed antimicrobials	82 (76%)	83 (66%)	.11	89 (54%)	56 (31%)	<.001
Antimicrobial classes prescribed	59 (72%)	71 (86%)	.03	58 (65%)	34 (61%)	.59
Potentiated aminopenicillin	23 (28%)	27 (33%)	.53	4 (5%)	4 (7%)	.50
Fluoroquinolone	12 (15%)	12 (15%)	.97	26 (29%)	15 (27%)	.75
Tetracycline	4 (5%)	1 (1%)	.17	0 (0%)	1 (2%)	.21
First generation cephalosporin	2 (2%)	0 (0%)	.15	33 (37%)	16 (29%)	.29
Aminopenicillin	1 (1%)	5 (6%)	.10	—	—	—
Nitroimidazole	1 (1%)	0 (0%)	.31	—	—	—
Macrolide	1(1%)	0 (0%)	.31	3 (3%)	1 (2%)	.57
Third generation cephalosporin	—	—	—	0 (0%)	1 (2%)	.21
Penicillin	—	—	—	0 (0%)	1 (2%)	.21
Amphenicol						
At least 1 HPCIA prescribed	25 (31%)	27 (33%)	.78	7 (8%)	5 (9%)	.82
Combination treatment	18 (22%)	23 (28%)	.39	4 (5%)	1 (2%)	.38
Duration (d) Median (IQR)	14 (10-21)	15 (8-28)	.32	9 (6.5-11)	8 (7-10)	.44
Clinical exam only	6 (6%)	3 (2%)	.21	145 (87%)	155 (86%)	.64
At least minimal work-up ^a performed	75 (69%)	101 (81%)	.04	1 (.6%)	3 (2%)	.36
BAL and culture performed	8 (7%)	4 (3%)	.15	2 (1%)	0 (0%)	.14
JS	68 (63%)	75 (60%)	.64	64 (39%)	76 (42%)	.58
1	1 (.9%)	7 (6%)	.05	3 (2%)	1 (.6%)	.27
2	15 (14%)	14 (11%)	.54	11 (7%)	10 (6%)	.67
3	19 (18%)	8 (6%)	.008	45 (27%)	15 (8%)	<.001
4	5 (5%)	21 (17%)	.003	43 (26%)	79 (44%)	.001
Judgment not possible						

Note: Bonferroni corrected *p*-value for significance $\leq .002$.

Abbreviations: BAL, bronchoalveolar lavage; HPCIA, highest priority critically important antimicrobial; JS, justification score.

^aThoracic radiographs and CBC.

growing proportion of veterinarians in Switzerland is aware of the recommendations for treatment of diarrhea and prescribes antimicrobials accordingly. Since the use of antimicrobials in dogs with hemorrhagic diarrhea has long been endorsed irrespective of signs of sepsis,³² it is comprehensible that it will take more time and continuous education until the majority of veterinarians adapt their treatment habits for this condition.

For the treatment of proven or suspected UTI, no significant changes were found regarding antimicrobial classes prescribed in university hospitals (Table 6). In private practices, the proportion of dogs prescribed aminopenicillins (potentiated and nonpotentiated) increased significantly from 2016 to 2018, while that prescribed fluoroquinolones decreased significantly. Although fluoroquinolones are not first-line drugs for UTI, their prescription has been recommended for the treatment of uncastrated male dogs with UTI until recently.³³ This was due to the belief that the prostate is usually infected in uncastrated male dogs with UTI, thereby requiring treatment with an antibiotic with good penetration into the prostate.³⁴⁻³⁶ In the new guidelines by the International Society for Companion Animal Infectious Diseases (ISCAID) the use of fluoroquinolones in

uncastrated males is only recommended if there is evidence of prostatic involvement.²¹ The proportion of uncastrated males presented to private practices did not differ significantly between 2016 and 2018 and the prescription of fluoroquinolones was associated with an uncastrated male status only in 2018. These findings show that fluoroquinolones were mostly prescribed to uncastrated male dogs in 2018, which, together with the significantly lower proportion of dogs treated with fluoroquinolones, suggests a more prudent use of fluoroquinolones for UTI in private practices in 2018.

However, this survey could not show a significant increase in the proportion of UTI cases in accordance with guidelines, which could be due at least partly to the high proportion of instances where no judgment was possible. The fact that in more than two thirds of cases in private practices a judgment of the appropriateness of antimicrobial treatment was not possible highlights that adequate diagnostic steps are still undertaken only in a minority of dogs presented with signs of UTI. This finding is consistent with results of previous reports.³⁷⁻³⁹ In a study from Denmark, even when looking only at the subgroup of guideline-users (a group of veterinarians expected to be interested in prudent antimicrobial use), only 39% stated to frequently perform

TABLE 8 Antimicrobial prescriptions and justifications scores for abscesses and bite wounds in 2016 and 2018 in private practices

	2016	2018	P-value
Total number of cases	175	166	
Dogs prescribed antimicrobials	157 (90%)	147 (89%)	.73
Antimicrobial classes prescribed	132 (84%)	117 (80%)	.31
Potentiated aminopenicillin	54 (34%)	45 (31%)	.48
Aminopenicillin	18 (12%)	23 (16%)	.29
First generation cephalosporin	5 (3%)	4 (3%)	.81
Fluoroquinolone	2 (1%)	1 (.7%)	.60
Third generation cephalosporin	1 (.6%)	4 (3%)	.15
Lincosamide	0 (0%)	1 (.7%)	.30
Nitroimidazole			
At least 1 HPCIA prescribed	7 (5%)	5 (3%)	.64
Combination therapy	3 (2%)	6 (4%)	.26
Duration (d) Median (IQR)	7 (6-10)	8 (7-11)	.13
Local wound treatment	113 (65%)	124 (75%)	.04
Drain placement	14 (8%)	27 (16%)	.02
JS	105 (60%)	78 (47%)	.02
1	26 (15%)	22 (13%)	.67
2	6 (3%)	10 (6%)	.26
3	28 (16%)	20 (12%)	.29
4	10 (6%)	36 (22%)	<.001
Judgment not possible			

Note: Bonferroni corrected P-value for significance $\leq .003$.

Abbreviations: HPCIA, highest priority critically important antimicrobial; JS, justification score.

culture and sensitivity testing before treating a UTI.¹¹ The same study found the main barriers for veterinarians to perform culture and sensitivity testing to be good experiences with empiric treatments and owners' financial concerns.

Another reason for the lack of complete adherence to guidelines is the still frequent use of potentiated aminopenicillins in cases of uncomplicated/sporadic UTI instead of the recommended non-potentiated aminopenicillins.

Both in university hospitals and private practices, the duration of antimicrobial treatment for UTI did not change significantly (Table 6). At university hospitals, long treatment durations were common. This can be explained by the significantly higher proportions of dogs with complicated UTI and pyelonephritis treated at university hospitals compared to private practices, as earlier guidelines suggested treating complicated UTI with antimicrobials for 4 weeks and pyelonephritis for 4 to 6 weeks.²⁰ However, the new ISCAID guidelines recommend a much shorter treatment of 3-14 days, depending on the specific situation.²¹ For sporadic UTI, the recommended treatment duration has been decreased from 7-14 days to 3-5 days.^{20,21} The recommendations on AntibioticScout.ch have been revised accordingly.

For dogs presented with signs of RTI, there was a higher proportion of prescriptions in complete accordance with guidelines and a lower proportion of treatments in complete disagreement with guidelines in 2018. In private practices, the prescription of antimicrobials decreased significantly, while it decreased only mildly in university hospitals (Table 7). A possible explanation for this finding is the significantly higher proportion of dogs with aspiration pneumonia

presented at university hospitals, a condition for which the use of antimicrobials is commonly deemed necessary. In private practices, a high proportion of dogs is presented because of acute coughing without signs of systemic disease—cases in which antimicrobials are not indicated.²³

The differences in the cases presented also likely explain the much more common use of further diagnostics at university hospitals (Table 7). The proportion of dogs in which diagnosis was based on clinical signs and clinical examination findings alone was high in private practices in both years. However, this is understandable considering the high proportion of dogs with mild and uncomplicated coughing presented to private practices. In these cases, further diagnostic tests are often not recommended in the absence of signs of pneumonia.²³

For dogs presented with abscesses and bite wounds, there were no significant differences between 2016 and 2018 regarding the proportion of dogs prescribed antimicrobials and the adherence to guidelines (Table 8). While for bite wounds, antimicrobial treatment is recommended for the majority of cases (unless only the epidermis is damaged), it is rarely indicated to treat abscesses unless there are signs of a generalized infection (lethargy, fever), severely contaminated lesions, or lesions close to fragile tissues.^{33,40} The proportion of dogs presented for abscesses and treated with antimicrobials in the absence of a clinical sign listed in the guidelines decreased from 36% to 26%. Although this finding was not statistically significant, it might still indicate a slightly more prudent antimicrobial use for treatment of abscesses in 2018. A similar result was found for bite wound

abscesses in cats in Switzerland, where 96% were treated with antimicrobials while only 30% showed at least 1 clinical sign that would justify antimicrobial treatment.¹⁶

As in 2016, potentiated aminopenicillins were used to treat the majority of abscesses and bite wounds in 2018, which is in accordance with current recommendations. In contrast, in 2016, 1 quarter of cats in Switzerland presented for abscesses were treated with a third generation cephalosporin, a subclass classified as HPCIA, which should be reserved for infections with bacteria that are resistant to first line antimicrobials.¹⁶ A possible explanation for this difference is that it is easier to administer oral medication in dogs than cats, and the only injectable antimicrobial with a long duration of action registered for cats in Switzerland is cefovecin.

Local treatment is a very important part of the treatment of wounds, and can be sufficient without the addition of systemic antimicrobial treatment, especially for abscesses.^{28,29} The finding that the proportion of dogs receiving local wound treatment increased suggests that a growing proportion of veterinarians in Switzerland is aware of its importance. However, in most cases, antimicrobials are still added as a preventive measure.

Although this study found a significantly more prudent prescription of antimicrobials in 2018 compared to 2016, there are still some aspects that require improvement. Previous reports on the impact of ASPs revealed similar findings.^{11,12} Several studies have investigated the barriers of prudent antimicrobial use in veterinary medicine. According to their results, the main barriers seem to be old prescribing habits, unavailability of recommended drugs on the national market, client expectations, the fact that diagnostic tests are cost- and time-consuming, fear of negative consequences for animals or for the veterinarians themselves due to nonprescription of antimicrobials, and the convenience of administration of some drugs.^{11,41,42} Furthermore, veterinary medicine faces the problem of discordant opinions concerning the treatment of some conditions, as well as various knowledge-gaps (ie, adequate treatment duration for UTI).^{21,42} On the other hand, factors leading to a more prudent use of antimicrobials were found to be awareness of antimicrobial resistance, prevention of infections, professional learning, and regulatory measures by the government or other institutions.⁴¹

Further efforts should be made addressing and counteracting the identified barriers while fostering the drivers of prudent antimicrobial use. Since October 2019, veterinarians in Switzerland are obliged to report signalment, indication, product, dosage, and duration of treatment for every antimicrobial prescription via direct data transfer to the competent authority (Information System on Antibiotics in Veterinary Medicine; IS-ABV). The goals of this new requirement are to more closely monitor antimicrobial prescriptions in small animals, to evaluate the effects of established actions, and to compare antimicrobial use on a regional, national, and international level.⁴³ In the future, veterinarians will receive a feedback regarding their reported antimicrobial prescriptions in comparison to national benchmarks. Further possible actions could include the distribution of nonprescription leaflets, handed out to owners of animals that do not require antimicrobial treatments.⁴⁴

The limitations of this study are partly due to its retrospective design. Insufficient documentation of clinical and laboratory findings precluded judgment of antimicrobial prescriptions in a substantial proportion of cases. Moreover, as private practices participated on a voluntary basis, a certain selection bias cannot be excluded. The practices taking part in the study might be more aware of the importance of prudent antimicrobial use and might therefore not accurately represent the situation in all practices across Switzerland. Furthermore, data were collected and evaluated manually, leaving some room for interpretation and confirmation bias. To allow comparison between 2016 and 2018, criteria used to judge the appropriateness of prescriptions were based on guidelines that were available in 2016. For some conditions, recommendations regarding antimicrobial treatment have changed since then. Thus, some of the included cases might have been judged differently according to newer guidelines.

The justification score was developed for this study based on published literature.²⁶ For reasons of simplicity, the categories “inappropriate dosage” and “inappropriate duration of treatment” were grouped into 1 category (JS-2). In future studies, separate scoring of these 2 categories should be considered in order to refine the assessment.

The exact impact of AntibioticScout.ch is hard to evaluate, as it was implemented in the context of other national measures aiming for a more prudent use of antimicrobials. Moreover, the worldwide awareness of antimicrobial resistance and the need to preserve the effectiveness of antimicrobials is rising. It is likely that this fact also had an influence on the changes in prescribing patterns found in this study. However, a user-friendly decision support tool like AntibioticScout.ch providing specific recommendations likely supports veterinary practitioners in correctly adopting prudent use principles.

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CONFLICT OF INTEREST DECLARATION

Authors declare no conflict of interest.

OFF-LABEL ANTIMICROBIAL DECLARATION

Authors declare no off-label use of antimicrobials.

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) OR OTHER APPROVAL DECLARATION

Authors declare no IACUC or other approval was needed.

HUMAN ETHICS APPROVAL DECLARATION

Authors declare human ethics approval was not needed for this study.

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