

Diagnosis-Associated Antimicrobial Prescribing Patterns in a Resource-Limited Veterinary District Setting: Evidence from Mongar, Bhutan (2023–2026)

Narayan Pokhrel

vetpokhrel@gmail.com

District Veterinary Hospital, Royal Government of Bhutan

Cheda Cheda

District Veterinary Hospital, Royal Government of Bhutan

Research Article

Keywords: antimicrobial use, diagnosis-associated prescribing, veterinary stewardship, AWaRe classification, resource-limited setting, Bhutan, One Health

Posted Date: September 11th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10790194/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Routine veterinary records in resource-limited settings often provide limited information on antimicrobial prescribing at the individual-animal level. Bhutan's National Action Plan on Antimicrobial Resistance has identified this as an important data gap. To our knowledge, only a handful of studies from Bhutan have linked the diagnosis and choice of antimicrobial agent and documented client counselling in routine veterinary records.

Methods

We reviewed retrospective clinical records from the district veterinary service in Mongar, eastern Bhutan, including DVH and its 16 Renewable Natural Resources Extension, which covers 8881 clinical visits and 17482 medicine-dispensing records. Of these, 1063 antimicrobial prescriptions were recorded between January 2023 and June 2026. We explored whether antimicrobial prescribing was associated with diagnosis, whether prescribing patterns matched conditions where a bacterial infection was a reasonable concern, and whether documented counselling on course completion differed by the World Health Organization (WHO) AWaRe risk tier. To test these associations, we used chi-square tests, Monte Carlo simulations, and logistic regressions.

Results

Of the 8881 visits, 1022 (11.51%, 95% CI: 10.9–12.2%) resulted in at least one antimicrobial prescription. The diagnosis system was significantly associated with the antimicrobial class ($\chi^2 = 470.53$, $df = 77$, $p < 0.001$; Cramer's $V = 0.26$): tetracyclines dominated in cattle, and penicillins dominated in dogs and cats. Prescribing rates vary widely by diagnosis, ranging from 0% to 80% (highest for urinary tract infection, pneumonia, and fracture; 0% for allergy and sarcoptic range). Documented course-completion counselling was recorded for 55.7% of access-tier line items but only 23.7% of watch-tier line items ($\chi^2 = 82.7$, $df = 1$, $p < 0.001$; unadjusted OR = 0.25). This gap was substantially explained by the route of administration: after adjustment, the AWaRe effect was greatly attenuated and no longer significant (adjusted OR = 0.71, 95% CI: 0.47–1.06), which was robust to further adjustment and sensitivity analyses for nonindependence. A secondary finding was that Watch-tier use was greater in food-producing species (29.8%) than in companion animals (23.2%) and was highly sensitive to the classification of a single antimicrobial, oxytetracycline, reversing the direction under an alternative classification.

Conclusions

Antimicrobial choice across all Mongar district veterinary services is diagnosis-associated and consistent with expected bacterial involvement. Documented client counselling was strongly associated with the route of administration, with substantially lower documentation for injectable prescriptions than for oral prescriptions; this association explains most of the crude difference by the AWaRe tier, which becomes a secondary, descriptive factor once the route is accounted for, representing a specific, actionable stewardship target.

Introduction

Antimicrobial resistance is widely acknowledged as a serious global threat. In resource-limited settings, a key issue in tackling antimicrobial resistance is the lack of records on how antibiotics are prescribed to individual animals. Instead, it focuses only on consolidated usage and is rarely analysed [1, 2]. The present study addresses this gap by analyzing a Mongar district veterinary hospital dataset that links diagnosis, drug choice, and client counselling. Tackling antimicrobial resistance is increasingly framed as a One Health issue involving people, animals, and the environment [3].

Livestock antimicrobial use in Bhutan is approximately 120 times less common than the published South Asian average [8]. The nationwide use of the same standard treatment guidelines for veterinary services under the Department of Livestock could be attributed to unique trends. [7]. Prescribing patterns at the district hospital and RNR-EC networks likely reflect this coherent national system rather than purely local approaches. Bhutan acknowledged the data gap in the use of an action plan for AMR [4] and reviews of livestock antibiotic resistance [9]. The same issues are mirrored across the region, where countries such as Bhutan, Nepal, Pakistan, Timor-Leste and Papua New Guinea have strong national AMR action plans on paper, but their animal health programmes do not keep pace with plans[12].

A national-level prescribing benchmark, but different from the consumption and volume studies above, already exists for Bhutan. A 2021 study of 2266 handwritten consultation records from 23 premises identified 31% of consultations as an antibiotic prescription (95% CI: 29–33%), with diarrhoea and wounds dominating the treatments and access-tier antimicrobials accounting for 45–70% of prescriptions [10]. This analysis provides initial insight, but it was limited to a single year (2017) of paper-based, broad-category records. Moreover, it failed to investigate whether communication around a prescription varied with the antimicrobial's risk profile.

Internationally, diagnosis-linked study designs have demonstrated what this level of detail can add. A 2024 study reported from district veterinary clinics in Ethiopia, a system similar to Bhutan's system, associated routine diagnosis with prescribed drug classes and identified a substantial proportion of cases [13, 14]. A similar pattern was reported in Indian dairy cattle [15]. Higher-resource companion-animal hospital settings in the United States, United Kingdom, Italy, and Switzerland, with analogous designs, identified the conditions that drive antibiotic use and major prescribing-guidance gaps. [21, 22, 23, 24, 25, 26, 27].

A second, less obvious gap appears in this literature: nearly all diagnosis-linked prescribing studies, including those cited above, stop at the point of drug dispensing. To our knowledge, no studies have examined whether the ways prescriptions are communicated vary in ways that matter for stewardship—for

example, whether owners are consistently advised to complete the full course of a high-risk antimicrobial compared with a low-risk antimicrobial. Stewardship guidance considers client counselling as an important pillar of conscientious use, not a secondary matter to drug choice [28, 30]. This is rarely measured alongside prescribing patterns, as suitable data are usually not available.

The dataset provides an opportunity to examine diagnosis-linked antimicrobial prescribing alongside documentation of client counselling. We therefore assessed whether antimicrobial prescribing varied according to clinical diagnosis and whether course-completion counselling differed according to the antimicrobial prescribed.

This study aimed to answer three questions. First, is the antimicrobial class across the Mongar district veterinary services substantially associated with clinical diagnosis? Second, do prescribing rates vary in accordance with conditions of bacterial infection, and are there conditions where use appears disproportionately high or low? Third, does documented course-completion counselling vary by the WHO AWaRe risk tier of the antimicrobial prescribed, and if so, in which direction? In essence, these findings provide a detailed description of diagnosis-linked antimicrobial prescribing and documented stewardship counselling within a district veterinary service in Bhutan. Furthermore, it will enhance the existing national benchmark with concise diagnostic resolution, a more recent period, and a novel look at the communication side of stewardship.

Methods

Study design and setting

This retrospective observational study analysed the routinely collected clinical records maintained at the district veterinary services in Mongar, comprising the District Veterinary Hospital (DVH) and networks of Renewable Natural Resources Extension Centres (RNR-ECs). Although the data cover a 3.5-year period (January 2023–June 2026), each clinical visit was treated as the unit of analysis for visit-level outcomes; the study design is therefore best described as a retrospective analysis of routinely collected clinical records instead of a longitudinal cohort design. The DVH and RNR-ECs provide veterinary clinical services across all 17 gewogs (subdistricts) of the Mongar District. This service network functions under the Department of Livestock, Ministry of Agriculture and Livestock, Royal Government of Bhutan. This study is reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guideline for cross-sectional studies (Additional file 1).

Study site

Mongar District is located approximately 460 km east of the capital, Thimphu, along the country's east–west national highway (Fig. 1). It has an approximate geographical area of 1940 km² with an elevational gradient ranging from 400 to 4000 masl, spanning both subtropical and temperate agroecological zones within a single administrative unit [6]. The district has 17 gewogs (subdistricts) with a human population of 36,383 (2022 projection; 17498 male, 18886 female), of which 10084 live in urban areas and 26299 live in rural areas [6]. According to the livestock census (2021), there are 24881 cattle, 55257 poultry, 4214 cats, 1864 dogs, 381 equines, 120 pigs, 29 goats, and 1 sheep in the district [5]. This composition is broadly consistent with the species distribution of the clinical caseload analysed here. Veterinary service delivery across the district is catered jointly by the DVH located in Mongar town, and 16 RNR-ECs are distributed across the district's other gewogs. The clinical data used for analysis in this study were extracted from both DVH and RNR-ECs. “Resource-limited” in this paper refers specifically to this veterinary infrastructure setting: no bacterial culture or antimicrobial susceptibility testing facility is available at DVH or any RNR-EC, no diagnostic imaging or laboratory support is locally accessible, the staffing of technical staff is limited relative to caseload, the drug formulary is narrow, and geographical setbacks in rural places across the district make travel to and between clinical sites difficult. These specific constraints truly define the practical environment described here.

Data source and eligibility

All clinical case records entered into the shared veterinary information system (VIS) between 1 January 2023 and 30 June 2026, which included both DVH Mongar and the district's 16 RNR-ECs, were eligible for inclusion. No exclusions were given by species, age, or diagnosis. The dataset comprised 17,482 medicine-dispensing line items across 8,881 clinical visits, of which 619 antimicrobial line items originated at DVH and 444 at the RNR-ECs collectively. Antimicrobial-class records were available for DVH and 15 of the 16 RNR-ECs; Thang-Rong RNR-EC recorded no antimicrobial dispensing during the study period, although it did record other clinical activities.

No formal sample-size calculation was performed, as this was a complete enumeration of routinely collected records over the study period rather than a sampled survey. The VIS was not newly introduced at the start of the study. A 2017 Joint External Evaluation of Bhutan's International Health Regulations (IHR) core capacities documented an operational, web-based veterinary information system already in use nationally for animal health event reporting [33]. This indicates that the platform had approximately six years of prior operational history before the January 2023 start date. Electronic entry into the VIS was mandatory across the DVH and the RNR-ECs throughout the study period. The authors were not aware of major changes in data-entry procedures during this time, although no formal published audit of VIS data-entry completeness was conducted either during the study period or for years prior to 2023, so unmeasured variation in completeness cannot be ruled out.

Case definition and unit of analysis

A single clinical visit could generate more than one medicine line item. For this reason, the visit was used as the unit of analysis for visit-level outcomes, namely, the overall antimicrobial prescribing rate (Table 1) and the diagnosis-specific prescribing rate (Table 4, Fig. 2). A visit was defined as a unique

combination of patient identifier and treatment date. The final diagnoses were recorded at two hierarchical levels in the VIS: a broad diagnosis system (for example, the Digestive System) and a specific diagnosis condition (for example, enteritis) nested within it. The diagnosis was consistent within a visit in 98.3% of the patients. Where more than one diagnosis condition was recorded, the modal—or most frequently repeated—diagnosis was retained as the visit-level diagnosis. Antimicrobial exposure at the visit level was defined as the dispensing of at least one medicine classified under ‘Antimicrobials’ in the VIS medicine class.

Table 1

Descriptive characteristics of clinical visits recorded across the district veterinary service in Mongar, Bhutan, comprising DVH and its 16 RNR-ECs (January 2023–June 2026, n = 8881 visits).

Characteristic	n	%
Species (n = 8881 visits)		
Bovine	6647	74.8
Canine	1111	12.5
Feline	1070	12.0
Equine	14	0.2
Swine	14	0.2
Poultry	13	0.1
Caprine	7	0.1
Wildlife	5	0.1
Diagnosis system (n = 8881 visits)		
Integumentary System	2815	31.7
Digestive System	2395	27.0
Reproductive System	685	7.7
Notifiable Disease	536	6.0
Respiratory System	491	5.5
General Systemic Conditions	464	5.2
Musculoskeletal System	369	4.2
General Clinical Examination	279	3.1
Uro-genital System	232	2.6
Metabolic Diseases	149	1.7
Eye and Ear	146	1.6
Vitamin and Mineral Deficiency	138	1.6
Poisonings	124	1.4
Infectious Diseases	38	0.4
Cardiovascular System	10	0.1
Management Practice	7	0.1
Nervous System	3	< 0.1
Antimicrobial exposure		
Visits with ≥ 1 antimicrobial dispensed	1022	11.5
Visits with no antimicrobial dispensed	7859	88.5
Visits excluded (placeholder diagnosis)	290	3.3
Percentages are calculated against the total of 8881 visits. Species and diagnosis-system percentages may not sum exactly to 100% because of rounding. The diagnosis-system breakdown includes all 8881 visits: all 290 condition 1 placeholder visits carry a genuine, nonplaceholder value at the broader diagnosis-system level (general systemic conditions), even though their more specific diagnosis-condition field defaults to the placeholder. Diagnosis-condition-specific analyses elsewhere in this paper (Tables 2 and 4) accordingly use the smaller denominator of 8591 genuine-diagnosis-condition visits.		

Table 4

Antimicrobial prescribing rate by diagnosis condition, restricted to conditions with ≥ 20 recorded visits ($n = 37$ conditions), with 95% Wilson confidence intervals. Overall rate among visits with an identifiable diagnosis: 11.3% (95% CI: 10.6–12.0%). The predominant species column shows which species accounted for the largest share of visits for that condition and what percentage of visits for that condition it represented.

Diagnosis condition	Visits (n)	AM-treated (n)	AM rate (%)	95% CI	Predominant species	% of that species
Urinary Tract Infection (UTI)	25	20	80.0	60.9–91.1	Bovine	64
Pneumonia	30	20	66.7	48.8–80.8	Bovine	96.7
Fracture	37	20	54.1	38.4–69.0	Bovine	75.7
Dystocia	52	25	48.1	35.1–61.3	Bovine	88.5
Lameness	109	35	32.1	24.1–41.4	Bovine	91.7
Canine Transmissible Venereal Tumour (CTVT)	20	6	30.0	14.5–51.9	Canine	100
Animal Bite Wound (other than dogs)	32	9	28.1	15.6–45.4	Bovine	50
Wound (accidents)	78	21	26.9	18.3–37.7	Bovine	82.1
Constipation	55	11	20.0	11.6–32.4	Bovine	90.9
Fever	56	11	19.6	11.3–31.8	Bovine	92.9
Mastitis	247	47	19.0	14.6–24.4	Bovine	97.6
Enteritis (Diarrhoea)	881	152	17.3	14.9–19.9	Bovine	90.4
Oak Poisoning in Cattle	29	4	13.8	5.5–30.6	Bovine	100
Pain	76	10	13.2	7.3–22.6	Bovine	44.7
Retention of Placenta (ROP)	323	40	12.4	9.2–16.4	Bovine	99.7
Wound	1266	149	11.8	10.1–13.7	Bovine	71.9
Cough	443	50	11.3	8.7–14.6	Bovine	94.1
Poisoning	70	7	10.0	4.9–19.2	Bovine	84.3
Repeat Breeder	22	2	9.1	2.5–27.8	Bovine	100
General Clinical Examination	278	25	9.0	6.2–12.9	Bovine	91.4
Milk Fever (Parturient Paresis/Hypocalcemia)	118	10	8.5	4.7–14.9	Bovine	100
Lumpy Skin Disease	537	43	8.0	6.0–10.6	Bovine	99.8
Myiasis	443	30	6.8	4.8–9.5	Bovine	85.6
Simple Indigestion/Inappetence	1071	69	6.4	5.1–8.1	Bovine	83.2
Pruritus	168	10	6.0	3.3–10.6	Canine	59.5
Weakness	64	3	4.7	1.6–12.9	Bovine	95.3
Vomiting	95	4	4.2	1.6–10.3	Feline	71.9
BEH (Bovine Enzootic Haematuria)	25	1	4.0	0.7–19.5	Bovine	100
Dermatitis	786	29	3.7	2.6–5.2	Feline	51.4
Demodectic Mange	28	1	3.6	0.6–17.7	Feline	60.7
Lactacidosis (Carbohydrate engorgement)	31	1	3.2	0.6–16.2	Bovine	100
Bloat	207	5	2.4	1.0–5.5	Bovine	100
Haematuria	181	4	2.2	0.9–5.5	Bovine	98.9
Conjunctivitis (Red eye)	111	1	0.9	0.2–4.9	Bovine	45.9
Vitamin & Mineral Deficiency	140	1	0.7	0.1–3.9	Bovine	90.8
Allergy	38	0	0.0	0–9.2	Bovine	73.7
Sarcoptic Mange	32	0	0.0	0–10.7	Feline	71.9

Conditions are ordered according to the descending antimicrobial prescribing rate. The confidence intervals for conditions with small sample sizes (e.g., urinary tract infection, $n = 25$) are wide and should be interpreted with caution.

In contrast, analyses of the pharmacological class and WHO AWaRe tier (Table 2, Table 3, Fig. 3) were conducted at the level of the individual antimicrobial line item, not the visit. This distinction matters because 38 of the 1,022 antimicrobial-treated visits (3.7%) involved more than one antimicrobial line item, and 13 visits (1.3% of all antimicrobial-treated visits) included antimicrobials from more than one AWaRe tier. Rather than collapsing such visits to a single tier by an arbitrary rule—for example, assigning the highest-risk tier present—each antimicrobial line item was retained and analysed individually. A visit with one access-tier and one watch-tier antimicrobial therefore contributes one line item to each tier in Table 2, Table 3, and Fig. 3. Given that only 13 visits were affected, this approach is not expected to materially influence the reported associations. Because the VIS advice field is entered once per visit rather than once per drug, antimicrobial line items originating from the same multidrug visit necessarily share an identical counselling outcome; this is a form of pseudoreplication that could inflate the apparent precision of the counselling analyses. The visit-restricted sensitivity analysis described below (one antimicrobial per visit, the first-listed line item) directly addresses this concern, since it removes any possibility of a single documented counselling outcome being counted more than once.

Table 2

Antimicrobial pharmacological class by diagnosis system among antimicrobial line items with a valid diagnosis (n = 1008 line items). Of the 1063 antimicrobials recorded overall, 55 were associated with the “condition 1” placeholder diagnosis and were excluded from this and all other diagnosis-specific analyses ($\chi^2 = 470.0001$).

Diagnosis system	Tetracyclines	Penicillins	Sulf+Trim	Sulfonamides	Fluoroquin.	Ceph (3rd)	Ceph (1st)	Aminogly.	Aminogly + Pen	Nitroimid.	Sulf (comb)
Digestive System	89	97	49	0	10	0	2	0	1	13	1
Integumentary System	41	153	1	1	20	8	2	4	2	0	0
Reproductive System	87	27	3	0	3	2	1	9	7	0	0
Musculo-skeletal System	65	30	4	0	10	0	0	0	0	0	0
Respiratory System	24	15	29	0	7	2	0	8	0	0	0
Notifiable Disease	34	2	1	0	3	0	0	1	3	0	0
Uro-genital system	17	9	6	0	3	0	3	0	0	0	0
General clinical exam	13	9	0	0	1	0	0	2	0	0	1
General Systemic Cond.	10	8	4	0	1	0	0	0	0	0	0
Metabolic Diseases	10	1	0	0	0	0	0	0	0	1	0
Poisonings	6	1	2	0	1	0	0	0	0	2	0
Eye and Ear	0	6	0	0	4	1	0	0	0	0	0
Infectious Diseases	1	2	1	0	3	2	0	0	0	0	0
Cardiovascular System	4	0	0	0	1	0	0	0	0	0	0
Vit. & Mineral Defic.	0	0	1	0	0	0	0	0	0	0	0
Total	401	360	101	1	67	15	8	24	13	16	2

Abbreviations: Sulf+Trim = sulfonamides+trimethoprim; Fluoroquin. = fluoroquinolones; Ceph (3rd)/(1st) = cephalosporins (3rd/1st generation); Aminogly. = aminoglycosides; Aminogly + Pen = aminoglycoside+penicillin combination; Nitroimid. = nitroimidazoles; Sulf (comb) = Sulfamonomethoxine-diaveridine-menadione combination (not classified). The table total (n = 1008) is lower than the overall antimicrobial line-item count (n = 1063) because 55 antimicrobial line items belong to visits carrying “condition1” placeholder diagnosis and were excluded, which is consistent with Table 3.

Table 3
WHO AWaRe tier distribution of antimicrobial prescribing by diagnosis system.

Diagnosis system	Access (n)	Watch (n)	Not classified (n)	Total (n)	Access (%)	Watch (%)
Digestive System	225	36	1	262	85.9	13.7
Integumentary System	172	60	0	232	74.1	25.9
Reproductive System	81	58	0	139	58.3	41.7
Musculoskeletal System	65	44	0	109	59.6	40.4
Respiratory System	74	11	0	85	87.1	12.9
Notifiable Disease	21	23	0	44	47.7	52.3
Uro-genital System	23	15	0	38	60.5	39.5
General Clinical Examination	22	3	1	26	84.6	11.5
General Systemic Conditions	13	10	0	23	56.5	43.5
Metabolic Diseases	4	8	0	12	33.3	66.7
Poisonings	9	3	0	12	75	25
Eye and Ear	6	5	0	11	54.5	45.5
Infectious Diseases	4	5	0	9	44.4	55.6
Cardiovascular System	3	2	0	5	60	40
Vitamin and Mineral Deficiency	1	0	0	1	100	0
<i>Watch-tier counts and percentages are shown in bold to highlight the higher-risk stewardship category. Access (%) and Watch (%) are calculated among AWaRe-classified line items only. One antimicrobial (sulfaquinoxaline–diaveridine–menadione combination) is not classified under the WHO AWaRe system and is excluded from these percentage calculations.</i>						

Data cleaning and missing data

The Medicine class and medicine name fields were missing in 0.2% of the line items and were excluded listwise from drug-specific analyses. A small subset of visits (n = 290, 3.3% of all visits) carried the diagnosis value 'condition1,' a system-generated placeholder rather than a genuine clinician-entered diagnosis. These visits were retained in overall denominators, such as total visit count and overall antimicrobial prescribing rate, but excluded from diagnosis-specific analyses. The visit itself, its species, and antimicrobial exposure were genuine and correctly recorded; only the diagnosis label was a data entry error.

Two overall antimicrobial prescribing rates are reported in this paper, and we make the numerator and denominator explicit to avoid ambiguity. Across the full sample of 8,881 visits, 1,022 involved at least one antimicrobial (11.51%). Among the 8,591 visits with a genuine diagnosis, 968 involved at least one antimicrobial (11.3%). The remaining 54 antimicrobial-treated visits fall within the 290 condition 1 cases and are therefore excluded from diagnosis-specific analyses. Condition 1 visits were concentrated in bovine (88.8%) and feline (10.5%) cases. These patients also had a higher antimicrobial rate (54/290, 18.6%) than did those with genuine-diagnosis visits (968/8,591, 11.3%). Whether this reflects a real clinical pattern or a data entry artifact linked to more complex or urgent cases cannot be determined, and we note this as a limitation. Because condition 1 visits carry no genuine diagnosis label, they cannot be incorporated into any diagnosis-specific analysis regardless of how they are handled; the overall antimicrobial-prescribing-rate estimate is, however, essentially unaffected by their inclusion or exclusion (11.51% across all 8,881 visits versus 11.3% restricted to the 8,591 visits with a genuine diagnosis), indicating that this 3.3% subset does not materially distort the headline prescribing-rate finding, even though its exclusion from diagnosis-specific analyses remains a source of potential selection bias for those specific comparisons.

Because several denominators are used across the paper, the full analytical flow is set out here. Among the 8,881 clinical visits, 1,022 were antimicrobial-treated. These generated 1,063 antimicrobial line items, since a visit could involve more than one drug. Of these, 55 line items were linked to the condition 1 placeholder and excluded from the diagnosis-specific analyses, leaving 1,008 valid line items. This 1,008 figure is the denominator for Tables 2 and 4 and the diagnosis–drug class analysis. Of these 1,008, two line items corresponded to a sulfaquinoxaline–diaveridine–menadione combination product with no WHO AWaRe equivalent. These were excluded from AWaRe-specific analyses, leaving 1,006 line items. This 1,006 figure is the denominator for Table 3, Fig. 4, and the counselling analyses.

Free-text diagnosis entries also produced a few near-duplicate condition labels differing only in capitalisation or spacing (for example, 'Sarcoptic mange' versus 'Sarcoptic Mange'). These were retained exactly as recorded in the source system and not consolidated, which is consistent with our general approach of avoiding post-hoc reclassification of free-text fields. The affected conditions are rare, so this does not materially alter the diagnosis-level findings. No imputation was performed for any missing fields.

Antimicrobial classification

Each of the 21 distinct antimicrobial formulations recorded was assigned to a pharmacological class, such as tetracyclines, penicillins, or fluoroquinolones (Supplementary Table S1). The formulations were also mapped to a WHO AWaRe tier (Access, Watch, or Reserve), where a corresponding classification was

available. One product, a sulfaquinoxaline–diaveridine–menadione combination, has no direct WHO AWaRe equivalent. It was retained in pharmacological class analyses but excluded from AWaRe-specific analyses (Table 3, Fig. 4, and the counselling analyses). AWaRe assignment followed the WHO 2023 AWaRe classification [16], the 2024 WHO list of medically important antimicrobials [17], and the WHO’s first- and second-choice antibiotic recommendations [18]. The WHO 2023 AWaRe framework was prespecified as the primary reference, in preference to the World Organisation for Animal Health (WOAH) or European Medicines Agency (EMA) antimicrobial classification systems [19], because this study assesses antimicrobial use from a human-health stewardship perspective, for which the WHO framework is the most widely used comparator. In particular, oxytetracycline is classified here as a watch tier under the WHO. This is a deliberate choice, since oxytetracycline is classified as accessible under some agricultural or WOAH-oriented frameworks. Oxytetracycline accounts for a substantial share of the use in this dataset (201 of 1008 line items, 19.9%). This single classification decision materially affects Watch-tier estimates in food-producing species: reclassifying oxytetracycline as accessible would reduce the Watch-tier share in food-producing species from 29.8% to approximately 2.9%. This sensitivity is discussed further below.

Course-completion counselling

The VIS ‘Advice’ free-text field was entered by the attending clinician at the point of treatment. We screened it for course completion counselling via a keyword match (complete, course, finish, full dose). The most common phrasings were manually reviewed first to confirm that the keywords captured the intended clinical meaning. This produced a binary indicator of documented course completion advice for each antimicrobial-treated visit.

To check the accuracy of this keyword-based indicator, we carry out a manual validation exercise. A random sample of 150 advice entries (drawn from antimicrobial-treated visits, excluding blanks) was independently classified by two raters, a veterinarian and a veterinary paraprofessional, as either describing course completion counselling or not, who were blinded to the algorithm’s classification. Compared with the other two methods, the algorithm had a sensitivity of 91.4% and specificity of 97.0–98.5% (overall accuracy 93.9–94.6%). The two raters agreed with each other on 100% of the 146 entries where neither recorded genuine uncertainty (Cohen’s $\kappa = 1.00$).

The small number of disagreements between the algorithm and the human raters were concentrated in general care advice not specific to antimicrobial course completion (for example, wound-care or follow-up instructions), which the raters sometimes interpreted more broadly than the algorithm’s narrower construct. This validation indicates that the keyword-based indicator performs well against independent human judgement of the construct it was designed to measure, although by design, it cannot capture verbal counselling that was never recorded in the Advice field.

Statistical analysis

We assessed the association between the diagnosis system and antimicrobial pharmacological class using Pearson’s chi-square test at the line-item level ($n = 1008$). To avoid unstable results from sparse categories, diagnosis systems and pharmacological classes with fewer than 10 line items were excluded from this test, leaving a working table of 96 cells (12 diagnosis systems by 8 pharmacological classes). This collapsing applied only to the significance test; the descriptive counts in Table 2 retain all categories. Even so, 66 of the 96 cells (68.8%) had expected counts less than 5, so we also computed a Monte Carlo simulated p-value (10,000 replicates), which does not rely on asymptotic approximation, and reported Cramer’s V as an effect size. Because some visits contributed more than one antimicrobial line item, potentially complicating the chi-square independence assumption, we repeated the test restricted to one antimicrobial per visit (the first-listed line item, a prespecified rule) as a sensitivity check. Since the dataset spans both DVH and the district’s RNR-ECs, which differ in caseload composition, we also repeated the diagnosis–drug class test separately within each facility type and compared the AWaRe tier distribution and counselling rates between DVH and RNR-ECs via the chi-square test. As visits were defined by patient identifier and treatment date, the same animal could contribute more than one visit, introducing possible within-animal clustering. We therefore quantified repeat visits per animal and, for the adjusted logistic regression below, refitted the model with cluster-robust standard errors clustered on the animal identifier.

This study reports numerous statistical comparisons, including diagnosis–drug class associations, species- and facility-stratified analyses, AWaRe-tier and route-of-administration comparisons, temporal trend analysis, and logistic regression models. These were primarily prespecified, hypothesis-driven, or descriptive comparisons rather than exploratory searches across many independent outcomes, and no formal correction for multiple testing was applied. Emphasis throughout is placed on effect sizes and confidence intervals rather than isolated p-values, and readers should weigh the totality of sensitivity analyses rather than any single test in isolation when interpreting the associations.

The associations between the AWaRe tier and course-completion counselling were assessed via Pearson’s chi-square test with Yates’ continuity correction and via logistic regression with documented counselling as the outcome. An unadjusted model included the AWaRe tier only. A second model was additionally adjusted for route of administration (oral versus injectable/other), given the descriptive association between route and both the AWaRe tier and counselling documentation. Because species and facility type were also plausible confounders, a third model was additionally adjusted for species group (bovine, companion, other) and facility (DVH versus RNR-EC). The diagnosis system was not included as a covariate because several of its 15 categories had fewer than 15 line items, which would risk unstable estimates; the diagnosis–drug class association is instead addressed separately via the chi-square analyses described above. Odds ratios with 95% confidence intervals are reported for all the models. Course-completion counselling was also cross-tabulated descriptively against the route of administration and the diagnostic system.

Visit-level antimicrobial prescribing rates were calculated as the proportion of visits with a given diagnosis that resulted in antimicrobial dispensing, restricted to conditions with at least 20 recorded visits to ensure stable estimates. For all reported proportions, 95% Wilson confidence intervals were calculated. Statistical significance was set at $p < 0.05$. Data management and analysis were carried out in R (version 4.3.3; R Core Team) via the readxl, dplyr, binom, vcd, and writexl packages.

Ethical considerations

This study used retrospective, deidentified clinical records, with no direct animal or human experimental intervention. The full details are provided in the Declarations section.

Use of AI tools

AI-based tools were used to assist with the literature search and to improve English-language clarity and readability during manuscript preparation. All analytical decisions, interpretations, and content were reviewed and approved by the authors, who take full responsibility for the manuscript.

Results

Study population

A total of 17482 medicine-dispensing entries across 8881 separate clinical visits were recorded in the VIS between January 2023 and June 2026 across the Mongar district veterinary service (DVH and its 16 RNR-ECs). A small proportion of these 290 visits (3.3%) were entered as “condition 1” as the recorded diagnosis. This was identified as a data-entry error rather than an actual clinical diagnosis, so these visits were not included in the diagnosis-specific analyses, resulting in 8591 visits with a genuine diagnosis recorded. Cattle made the majority of the caseload (6647 visits, 74.8%), followed by dogs (1111, 12.5%) and cats (1070, 12.0%). The remaining species, equine, caprine, swine, poultry, and wildlife, together made up less than 1% of all visits (Table 1).

Frequency of antimicrobial use

Among the 8881 visits, 1022 resulted in the prescription of at least one antimicrobial. This gives an overall prescribing rate of 11.51% (95% CI: 10.9–12.2%). In total, these visits generated 1063 antimicrobial line items across 21 different formulations and eight pharmacological classes (Supplementary Table S1). Among the 8591 visits with a genuine diagnosis, 968 involved at least one antimicrobial (11.3%, 95% CI: 10.6–12.0%). The remaining 54 visits resulting in antimicrobial prescriptions fell among the 290 condition 1 placeholder-diagnosis visits, which had a numerically higher antimicrobial rate (18.6%) than did the actual diagnosis visits; this is further discussed under limitations.

The annual rate of antimicrobial prescribing has remained stable across the study period: 10.6% in 2023 ($n = 3068$ visits), 11.7% in 2024 ($n = 2195$), 12.2% in 2025 ($n = 2395$), and 12.1% in the first half of 2026 ($n = 1223$). No significant association between calendar year and antimicrobial prescribing was found by a chi-square test ($\chi^2 = 4.23$, $df = 3$, $p = 0.237$), showing no evidence of a temporal trend over the 3.5-year study period.

Associations between diagnosis and drug class and species-specific differences

There was a significant association between the pharmacological class of antimicrobial prescribed and the diagnosis system ($\chi^2 = 470.53$, $df = 77$, $p < 0.001$; Table 2). Sixty-six of the 96 cells (68.8%) in this table had an expected count of less than 5. Therefore, we confirmed this result with a Monte Carlo simulated p value (10000 replicates), which does not depend on the large-sample approximation underlying the standard chi-square test. The result remained significant (Monte Carlo $p < 0.001$). The effect size, Cramer's $V = 0.262$, points to a small-to-moderate association. Some visits contributed more than one antimicrobial prescription. We therefore repeated this analysis restricted to one antimicrobial per visit ($n = 967$ visits, using the first-listed line item per visit as a prespecified rule). The association remained significant and of similar magnitude ($\chi^2 = 432.04$, $df = 70$, $p < 0.001$; Monte Carlo $p < 0.001$), showing that the result is not an artifact of nonindependent observations within visits.

This association differed by species. In cattle, tetracyclines are the main choice, especially for digestive, reproductive, and musculoskeletal cases. In dogs and cats, penicillins dominate instead and are used primarily in skin and wounds. When penicillins are not prescribed, fluoroquinolones are the second best choice for both species. Smaller numbers of cephalosporins and aminoglycosides, specifically in cats, resulted in a companion-animal drug profile that leaned more towards Watch-tier classes than towards the tetracycline-dominated pattern in cattle. Since the diagnosis system is itself associated with species, the diagnosis-drug class test was repeated separately within each of the three main species groups. Given the small cell counts in each stratum, we used Monte Carlo-simulated p values. The association remained significant within bovine ($n = 721$, Monte Carlo $p < 0.001$), canine ($n = 154$, $p = 0.004$), and feline ($n = 117$, $p = 0.005$) cases, indicating that the diagnosis–drug association is not solely attributable to species composition.

Diagnosis conditions associated with antimicrobial use

Antimicrobial prescriptions were not evenly distributed across the 129 diagnostic conditions recorded in the dataset. Rather, it was concentrated among a small number of common cases (Fig. 2). Enteritis and wounds together made up nearly one-third of all antimicrobial-treated visits (15.4% and 15.0%, respectively), followed by simple indigestion/inappetence, cough, and mastitis. The complete list of 129 diagnostic conditions is provided in Supplementary Table S2.

Antimicrobial prescribing rate by diagnosis condition

Among conditions with sufficient visit volume for a stable rate estimate ($n \geq 20$ visits), the antimicrobial prescribing rate ranged from 0% to 80%. This range was set against a baseline of 11.3% (95% CI: 10.6–12.0%) among visits with an identifiable diagnosis (Fig. 3; Table 4). The highest rates were observed for urinary tract infection (80.0%, 95% CI: 60.9–91.1%), pneumonia (66.7%, 95% CI: 48.8–80.8%), fracture (54.1%, 95% CI: 38.4–69.0%), dystocia (48.1%, 95% CI: 35.1–61.3%), and lameness (32.1%, 95% CI: 24.1–41.4%). Bacterial involvement was reasonably suspected for each of these conditions. The confidence intervals for the highest-ranked conditions were wide, reflecting the relatively small sample sizes involved ($n = 25$ –37 visits). These top-ranked percentages, particularly for UTIs, should be read as broad indicators of clinical intent rather than as precise point estimates. In contrast, allergies (0%, 95% CI: 0–9.2%, $n = 38$) and sarcoptic mange (0%, 95% CI: 0–10.7%, $n = 32$) had no antimicrobial-treated visits, which is consistent with the fact that neither condition has a bacterial basis.

WHO AWaRe tier distribution by diagnosis system

Access-tier antimicrobials make up the majority of antimicrobials used across most diagnosis systems, although the proportion varies considerably (Table 3). Respiratory (87.1% Access) and Digestive (85.9% Access) cases remained largely within the lower-risk tier. Metabolic diseases, infectious diseases, and notifiable disease cases exhibited the opposite pattern, with watch-tier drugs accounting for more than half of antimicrobial use. The notifiable disease category is dominated by lumpy skin disease and was first reported in Bhutan in 2020 [32]. LSD is a viral disease, so antimicrobial use recorded against this disease most likely reflects treatment of secondary bacterial complications and wound management from skin lesions rather than treatment of the viral disease itself. The dataset does not allow these possibilities to be distinguished. Musculoskeletal cases are of particular note: they combine a high overall prescribing rate, largely attributable to lameness, with a high proportion of watch-tier use (40.4%).

Antimicrobial use in poultry, goats, and pigs

There were too few antimicrobial line items for poultry, caprine, and swine species for statistical comparison ($n = 6, 4$, and 4 , respectively), but their pharmacological patterns are worth describing descriptively. Goats and pigs were treated with tetracyclines and penicillins, the same classes that dominate cattle prescribing, which is consistent with their similar production-animal context. Poultry prescribing followed a more distinct pattern: along with tetracyclines, a combination of sulfaquinoxaline, diaveridine, and menadione was used, an antibacterial–anticoccidial formulation not used in any other species in this dataset, reflecting the particular relevance of coccidiosis-related disease management in poultry.

Watch-tier use in food-producing versus companion animal species

Approximately 3 of the 10 antimicrobial prescriptions for food-producing species (cattle, goats, pigs, poultry) involved a Watch-tier drug (29.8%). Compared with approximately 1 in 4 in dogs and cats (23.2%). This comparison, however, is primarily due to a single classification decision. Oxytetracycline accounted for 19.9% of all antimicrobial line items (201 of 1008). If we put it in the access tier, as some agricultural or WOA frameworks do, then the food-producing watch-tier share becomes 2.9%, and the companion-animal share becomes 22.5% (Supplementary Table S3). This reverses which group shows the higher proportion. This change flips which group has a higher proportion. We report both methods because the result depends on which classification rule is used. This sensitivity is explained further below.

Facility-level comparison: DVH versus the RNR extension centres

Since the dataset covers both DVH and its 16 RNR-ECs, we assessed whether the three primary outcomes of this study, diagnosis–drug class association, AWARe tier distribution, and course-completion counselling, differed by facility type. The species caseload differed notably between the two groups: the antimicrobial-treated visits to DVH were mostly companion-animal caseloads (22.5% canine, 15.0% feline, and 60.9% bovine), whereas the RNR-ECs treated almost all bovine caseloads (88.4% bovine, with canine and feline cases together accounting for only 10.1%). Even with this difference in caseload structure, the diagnosis–drug class associations reported above held independently and significantly at both DVH ($n = 619$, Monte Carlo $p < 0.001$) and RNR–EC ($n = 389$, Monte Carlo $p < 0.001$), indicating that the associations are not artifacts of pooling facility types with different caseloads.

The AWARe tier distribution also differed significantly across facilities: Watch-tier antimicrobials accounted for 24.1% of the line items classified at DVH, whereas they accounted for 34.6% of those classified at RNR-ECs ($\chi^2 = 12.23$, $df = 1$, $p < 0.001$). This difference is well explained by oxytetracycline, which accounts for 26.7% of RNR-EC antimicrobial use compared with 15.7% at DVH. The long-acting formulation of oxytetracycline reduces the need for repeat visits, which may be especially practical in remote rural centres compared with central hospitals. However, this explanation was not directly tested. On the other hand, no significant difference was observed in course-completion counselling by facility (45.6% at DVH versus 48.8% at the RNR-ECs; $\chi^2 = 0.91$, $df = 1$, $p = 0.341$), indicating that the counselling gap reported above is not confounded by facility type.

Course-completion counselling by AWARe tier

Overall, course-completion counselling was recorded for just under half of the antimicrobial-treated visits (46.8%). By AWARe tier, a noticeable difference was observed, with nonoverlapping confidence intervals: 55.7% (95% CI: 52.1–59.3%) for access-tier cases, compared with 23.7% (95% CI: 19.1–29.0%) for watch-tier cases ($\chi^2 = 82.7$, $df = 1$, $p < 0.001$; Fig. 4). This association remained statistically significant even with the relatively large sample of antimicrobial line items underlying it.

Course-completion counselling by the diagnosis system

Course-completion counselling was most consistently recorded for general clinical examination cases (88.5%) and respiratory cases (71.8%). It was lower for metabolic diseases (16.7%) and integumentary system cases (25.0%). The latter is driven largely by wounds, one of the two conditions responsible for nearly one-third of all antimicrobial use in this dataset. The most common reason for antimicrobial prescription across the Mongar district veterinary service is also among the least likely to be accompanied by recorded advice to complete the course.

Course-completion counselling by administration route

Since Watch-tier antimicrobials in this dataset are largely administered by injection, we also assessed counselling rates by route of administration. The difference was profound. Course-completion advice was recorded for 77.6% of the antimicrobial line items administered orally ($n = 527$). Compared with 12.7% of antimicrobial line items administered intramuscularly ($n = 448$), 18.2% of intravenous line items ($n = 11$), 20.0% of intramammary line items ($n = 10$), and 33.3% of topical line items ($n = 6$) were used. The route and AWARe tiers were closely related: 78.5% of the watch-tier line items were administered intramuscularly, whereas 33.2% of the access-tier line items were predominantly oral (66.8%). The route therefore represents a primary candidate confounder for the AWARe-tier counselling gap reported above, formally tested in the next section.

Adjusted analysis: is the AWARe-counselling association independent of route?

We fitted logistic regression models to test whether the AWaRe-tier association with documented counselling persisted after accounting for the route of administration. In the unadjusted model, the Watch tier had substantially lower odds of counselling than the Access tier did (OR = 0.25, 95% CI: 0.18–0.33, $p < 0.001$), matching the chi-square result reported above. Adjusting for route of administration (oral versus injectable/other) sharply attenuated this effect, and it was no longer significant (adjusted OR = 0.71, 95% CI: 0.47–1.06, $p = 0.091$); route itself remained strongly associated with counselling (OR = 0.05, 95% CI: 0.03–0.07). A route-only model fit almost as well as the combined route-plus-AWaRe model (AIC 937.0 versus 936.2). This attenuation suggests that the route of administration accounts for much of the crude AWaRe-tier difference in documented advice rather than the drug risk tier operating as an independent driver.

Species and facility type were also plausible confounders, so we extended the model to include both. This fuller model fit significantly better than the route-only version (likelihood ratio test, $p = 0.031$), largely because of a species effect: companion animals showed somewhat higher, although nonsignificant, odds of counselling than cattle did (OR = 1.45, 95% CI: 0.94–2.23). Facility type was not independently associated with counselling by route or species (OR = 0.95, 95% CI: 0.67–1.35, RNR-EC versus DVH). Critically, the AWaRe-tier and route estimates barely moved (AWaRe tier adjusted OR = 0.73, 95% CI: 0.48–1.12; route OR = 0.04, 95% CI: 0.03–0.06), so the route-driven explanation for the counselling gap does not depend on leaving the species and facility out of the model.

Two checks addressed possible nonindependence in the data. Because some visits included more than one antimicrobial line item, we reran the analysis using only one antimicrobial per visit ($n = 965$, the first-listed line item — a prespecified rule used purely as a robustness check). The result held (unadjusted OR = 0.19, $\chi^2 = 75.2$, $df = 1$, $p < 0.001$; adjusted OR = 0.74, 95% CI: 0.49–1.13), closely tracking the line-item-level estimate. We also considered that, since a visit was defined by patient identifier and treatment date, a single animal could contribute multiple visits: across all 8881 visits, 6868 unique animals were represented, and 17.4% of the animals accounted for more than one visit (36.2% of all visits). Among the 1006 AWaRe-classified line items used in the adjusted model specifically, 864 unique animals were rare, with only 6.8% contributing more than one such visit. Refitting the model with cluster-robust standard errors, clustered by animal identifier, left the estimates essentially unchanged (adjusted OR = 0.71 for AWaRe tier, OR = 0.05 for route; 95% CI: 0.46–1.09 and 0.03–0.08, respectively), with the same pattern of statistical significance. Clustering — whether from multiple line items within a visit or multiple visits by the same animal — does not meaningfully affect this result.

Discussion

Summary of key findings

This study assessed whether the type of antimicrobial prescribed depends on the clinical diagnosis. The results show that the choice of antimicrobial class clearly varied by diagnosis system, both overall and within each species analysed separately.

The antimicrobial class varies by diagnosis, including across species. However, these records cannot be used to determine whether individual prescriptions were clinically appropriate because clinical indications, drug availability, cost, and clinician preference were not consistently captured. What we describe here is an association, not a judgement of appropriateness, as no culture or susceptibility data were available.

The association between the AWaRe tier and documented course-completion counselling was substantially reduced after adjustment for the route of administration. This suggests that the lower counselling rate observed for Watch-tier antimicrobials was largely related to their greater use by injection rather than to the AWaRe tier itself. To our knowledge, very few studies have reported these findings: the Ethiopian, Indian, Italian, Swiss, and US diagnosis-linked studies discussed above all report which antimicrobial agents are prescribed for which diagnosis, but no study has reported whether counselling is documented or varies by drug risk tier [13, 14, 15, 21, 22, 23, 24, 25, 26, 27]. The free-text advice field in the VIS also provided a practical way to assess whether course-completion counselling had been documented. Whether the counselling gap is a general feature of veterinary practice or specific to settings such as Mongar remains an open question.

Interpretation of the diagnosis–drug relationship

The common use of tetracyclines in cattle likely reflects their broad-spectrum activity, affordability, and established use in livestock care, a pattern also reported in Ethiopian and Indian settings [13, 14, 15]. As drug cost, stock availability, and clinician preference were not directly measured in this study, their influence remains a possibility rather than something we can confirm. A similar pattern has been reported in companion animal studies from the United States, Italy, Switzerland, and the United Kingdom [21, 22, 23, 24, 25, 26, 27], even though there are major differences in healthcare settings and resources. Wound and skin conditions therefore appear to be common reasons for antimicrobial treatment in companion animals in several settings, although our data cannot explain why this pattern occurs.

Prescribing was also more common than the district-wide baseline for UTI, pneumonia, fracture, dystocia, and lameness, conditions in which bacterial infection may reasonably be considered. This finding is consistent with published clinical guidance that recognises bacterial urinary tract infection as a condition requiring antimicrobial therapy [29]. For some of these conditions, particularly pneumonia and lameness, bacterial involvement is plausible but not the only possible cause; this distinction is discussed further below.

The high prescribing rate for fractures (54.1%) raises a specific question: are these largely open, wound-associated fractures, where antimicrobial use is justified for infection risk, or are they largely prophylactically prescribed? The VIS does not classify fractures as open or closed as a structured field, but the free-text notes provide some clues. Among the 37 fracture visits, 6 (16.2%) explicitly mentioned a wound in the free-text history, and 1 (2.7%) was noted as closed; the remaining 30 (81.1%) did not specify. This highlights that at least some fracture cases are truly wound associated, in keeping with an infection risk rationale. For the majority, however, it is not clear whether prescribing reflects documented wound involvement or a more general precautionary practice. This should therefore be treated as an open question, not a documented fact. The conditions without a bacterial basis, such as allergies and sarcoptic

mange, received no antimicrobial treatment in the combined 70 patients. This pattern points to selective rather than indiscriminate prescribing, although it does not by itself establish overall prescribing appropriateness.

A note on the sensitivity of the food-producing species finding

As shown in the Results and Supplementary Table S3, the comparisons between food-producing and companion animals were reversed entirely on the basis of how oxytetracycline is classified, whether as Watch (WHO 2023 AWaRe, which we use throughout) or as Access (as in some agricultural or WOA-based frameworks). We report figures using the WHO 2023 AWaRe classification because it was the prespecified classification framework for this analysis. However, it is important to note that this comparison depends substantially, not marginally, on that single classification choice. The broader AWaRe-tier-by-diagnosis-system pattern in Table 3, which draws on a wider range of drug classes, is comparatively more robust to this sensitivity.

Facility-level differences: DVH and the RNR extension centres

Oxytetracycline also drives the facility-level AWaRe difference reported in the Results, since it makes up a larger share of prescriptions at RNR-EC than at DVH. A likely explanation, although untested, is practical, not clinical: long-acting oxytetracycline reduces the number of follow-up visits needed to finish a course, a property commonly relied upon in resource-limited veterinary settings [34]; it is even more relevant at remote centres, where a comparable Ethiopian study revealed accessible crop–livestock keepers averaged over three times as many annual service–provider visits as remote pastoralists (11.1 versus 3.3 per year) [35]. Notably, the paper’s central stewardship finding, the counselling gap by AWaRe tier, did not differ significantly between DVH and the RNR-ECs. This suggests that the gap reflects district-wide practice rather than being tied to one facility type.

Possible explanations for the counselling gap

The adjusted analyses help explain why Watch-tier prescriptions were receiving less counselling: this is largely due to route of administration, although not entirely. Watch-tier antimicrobials are mostly injectable, and injectable items receive course-completion advice much less often than oral items do, regardless of the AWaRe tier. The adjusted analysis therefore indicates that the route of administration, rather than the AWaRe tier itself, accounts for most of the observed difference in documented counselling. One possible explanation is that oral treatments require owners to administer subsequent doses at home, making counselling about completing the course more likely to be documented. Injectable treatments, particularly single-dose treatments administered at the clinic, may be less likely to generate such documentation. We caution against treating this as a complete justification. Even when a drug is given as a single dose or in a long-acting injectable form, some client advice is still justified. Stewardship guidance is clear: injections are not exempt from the expectation of counselling [28, 30]. Watch-tier drugs were also used predominantly in acute, high-severity cases such as pneumonia, fractures, and UTIs—where staff attention may have centred on stabilisation rather than client education under caseload pressure. This pattern echoes survey findings that Bhutanese veterinary staff report gaps in structured stewardship training, even though their underlying knowledge is sound [11]. A further possibility, discussed under limitations, is that some counselling was given but was not documented. Whatever the mix of mechanisms, the finding is actionable: injectable prescriptions are where counselling messages are least often delivered—or at least rarely recorded.

Implications for food-producing species and wider stewardship

Watch-tier antimicrobial use in food-producing species remains elevated even when oxytetracycline sensitivity is set aside because fluoroquinolones and third-generation cephalosporins, both of which are classified by the WHO as critically important for human medicine [17, 20], are unaffected by that particular sensitivity. This gap also matters outside veterinary practice. However, on its own, it does not prove a human health impact—that would require residue or resistance surveillance data, which we do not have here. Previous systematic reviews have linked restricted antibiotic use in food-producing animals to reduced resistance in both animals and humans [31]. This makes it a reasonable, quantified starting point for food-chain risk assessment—an area Bhutan’s own NAP-AMR highlights as a gap in the animal-health sector [4].

Policy implications

These findings point to a simple, low-cost way to strengthen stewardship monitoring in Bhutan’s animal health sector. Client communication is central to responsible antimicrobial use [28, 30], and Bhutan’s NAP-AMR already calls for better use of routine clinical data [4]. Monitoring could therefore include whether counselling is documented, broken down by the AWaRe tier or route. One practical step—since the VIS already has a free-text advice field—would be to add a structured or checkbox option, which is mandatory for injectable Watch-tier prescriptions. This could be piloted at DVH and, if effective, rolled out through the Standard Treatment Guidelines [7]. More broadly, Bhutan’s VIS could serve as a model for other resource-limited countries that want to build stewardship monitoring capacity without major new investment.

Limitations

There are several limitations in this study. First, this study relies on retrospective clinical diagnosis rather than laboratory-confirmed etiology, and no culture or susceptibility testing was performed for the bacterial-involvement framework used throughout. This approach is the standard for routine records studies of this type [10, 13, 14], but it restricts any causal claim about prescribing appropriateness. Furthermore, the VIS diagnosis categories were not detailed enough to distinguish therapeutic from prophylactic antimicrobial use. This applies not only to the fractures discussed above but also potentially to dystocia, lameness, and wounds.

Second, our counselling indicator came from keyword matching in a free-text field that staff filled unevenly over time. Manual validation (Methods) revealed strong agreement with two independent raters (sensitivity 91.4%, specificity 97.0–98.5%, accuracy 93.9–94.6% across 150 blinded entries), which reassures

us that the measure captures the intended construct. Nevertheless, it cannot reflect advice given verbally but never noted down or phrased outside the keyword list. In practice, this means that the measure reflects documented advice rather than the full frequency of counselling, which is especially relevant to the route-of-administration analysis. Here, the outcome should be read as documentation of advice in the clinical record, not direct observation of clinician–client communication. A further structural issue is that each line item represents one prescribing decision, not a full client interaction. For example, some Watch-tier injectables (such as cefotaxime and enrofloxacin) were logged as single-line items despite 3–5-day courses, so advice given at later visits was not captured.

Third, the higher Watch-tier use in food-producing animals relies on whether oxytetracycline is classified as Watch or Access, as noted above. Fourth, species representation was heavily skewed towards cattle, dogs, and cats; the other five species together made up less than 1% of visits. Findings should not be inferred for poultry, swine, or small ruminants without dedicated study. Fifth, small sample sizes limit precision for several high-ranked conditions, especially urinary tract infection (n = 25) and pneumonia (n = 30). The confidence intervals in Table 4 should therefore be read alongside the point estimates. Sixth, although the dataset spans the whole district service—DVH and 16 RNR-ECs—it is still confined to one district and may not be generalizable to areas with different caseloads, staffing, or drug access. Finally, 3.3% of visits carried a placeholder diagnosis that was excluded from diagnosis-specific analyses, and free-text entry sometimes produced near-duplicate condition labels differing only in capitalisation. Both are VIS data quality issues worth addressing in future data collection.

Generalizability

With these limitations in mind, the primary findings of this study may still provide insight beyond Mongar District, although they do not claim national representativeness. This dataset covers both the district’s central hospital and 16 RNR-ECs instead of a single site, so the results are likely to reflect prescribing practices across Mongar, which spans urban and rural centres. Three patterns emerge: diagnosis-linked drug selection, prescribing that tracks conditions where bacterial infection is plausible, and a counselling gap in injectable, higher-risk prescriptions. These patterns may be relevant to other district-level veterinary services working under similar resource constraints and Fleming Fund-supported treatment guidelines in Bhutan [7] and may have comparable settings elsewhere in South Asia [15]. The specific percentages reported here, however, are properties of this district’s dataset and, in some cases, depend on classification choices. They should be treated as a baseline for future comparisons, not as a regional norm.

Declarations

Ethics approval and consent to participate

The Livestock Research Technical Committee (LRTC) of the National Livestock Research Centre, Bumthang, Bhutan (LRED Form 1A), reviewed this proposal, ‘Retrospective Analysis of Veterinary Information System (VIS) and Laboratory Information Management System (LIMS) Data in Mongar District’, and endorsed it on both scientific and administrative grounds. Under institutional practice, no separate ethics committee review was required for this type of study, and no letter was issued. The decision reflects the retrospective, non-interventional nature of the work: it involved secondary analysis of routine clinical records, with no animals or human participants directly involved, no experimental intervention, and no prospective sampling. The dataset was accessed only by the study authors. Before analysis, all owner-identifying fields (name, mobile number, CID, and microchip number) were removed, and no identifiable information appeared in the results. Consent to participate was not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contribution

NP conceived and designed the study, extracted and cleaned the VIS data, conducted the statistical analysis, and drafted the manuscript. CC contributed to the literature review, reviewed the analysis, and revised the manuscript. Both authors read and approved the final manuscript.

Acknowledgement

The authors would like to thank the staff of DVH Mongar and the 16 RNR-extension centres in Mongar District for their role in routine clinical data collection and entry of data in the VIS, which made this analysis possible.

Data Availability

The original clinical dataset is not publicly available because it contains potentially identifiable owner and animal information. The dataset(s) supporting the conclusions of this article is (are) included within the article and its additional files: a deidentified analytical dataset, from which all owner-identifying fields (owner name, mobile number, CID, and animal microchip number) have been removed, is provided in Additional file 2. A complete, tested R script that reproduces every table, figure, and statistic reported in this manuscript from this deidentified dataset is provided in Additional file 3 (R_script_Analysis.R).

References

1. GBD 2021 Antimicrobial Resistance Collaborators. Global burden of bacterial antimicrobial resistance 1990–2021: a systematic analysis with forecasts to 2050. *Lancet*. 2024;404(10459):1199–226.
2. O'Neill J. Tackling drug-resistant infections globally: final report and recommendations. London: Review on Antimicrobial Resistance; 2016.
3. Food and Agriculture Organization of the United Nations. World Organisation for Animal Health, World Health Organization. Taking a multisectoral, One Health approach: a tripartite guide to addressing zoonotic diseases in countries. Geneva: WHO; 2019.
4. Royal Government of Bhutan. National action plan on antimicrobial resistance 2018–2022. Ministry of Agriculture and Forests/Ministry of Health; 2018.
5. National Statistics Bureau. Livestock census of Bhutan 2021. Thimphu: Royal Government of Bhutan; 2022.
6. Dzongkhag, Administration. Mongar. About Dzongkhag. Royal Government of Bhutan; 2023. <https://mongar.gov.bt/about-us/about-dzongkhag/>. Accessed 7 Aug 2026.
7. Department of Livestock. Standard treatment guidelines, 2nd edition. Thimphu: Ministry of Agriculture and Livestock, Royal Government of Bhutan; 2025.
8. Gurung RB, Zangmo KP, Gilkerson JR, Browning GF, Ferdinand AS, Coppo MJC. Antimicrobial consumption in the livestock sector in Bhutan: volumes, values, rates, and trends for the period 2017–2021. *Antibiot (Basel)*. 2023;12(2):411.
9. Thapa NK, Sharma PM, Dahal N, Chamling SB, Raika V, Dorjee J, et al. Antimicrobial resistance (AMR) in Bhutanese livestock: a review. *Bhutan J Anim Sci*. 2018;2(1):123–6.
10. Villanueva-Cabezas JP, Rinzin K, Dorjee S, Tshewang P, Namgyel U, Sharma PM, Stevenson MA, McVernon J. Antibiotic prescription in veterinary consultations in Bhutan: a retrospective cross-sectional study. *Front Vet Sci*. 2021;8:641488.
11. Wangmo K, Dorji T, Pokhrel N, Dorji T, Dorji J, Tenzin T. Knowledge, attitude, and practice on antibiotic use and antibiotic resistance among the veterinarians and para-veterinarians in Bhutan. *PLoS ONE*. 2021;16(5):e0251327.
12. Gunasekara YD, Bailey KE, Scarborough RO, Sri AE, Coppo MJC, Gilkerson JR, Browning GF, Hardefeldt LY. National action plan on antimicrobial resistance in selected Asia-Pacific low- and middle-income countries: perspectives of One Health stakeholders. *One Health*. 2025;21:101259.
13. Tufa TB, Amenu K, Fasil N, Regassa F, Beyene TJ, Revie CW, Hogeveen H, Stegeman JA. Prudent use and antimicrobial prescription practices in Ethiopian veterinary clinics located in different agroecological areas. *BMC Vet Res*. 2024;20:538.
14. Etefa M, Beyi AF, Ayana D, Beyene TJ, Tufa TB. Veterinary drug prescribing practices at selected district veterinary clinics of rift valley areas of Ethiopia. *Vet Med Int*. 2021;2021:6669036.
15. Vijay D, Bedi JS, Dhaka P, Singh R, Singh J, Arora AK, Gill JPS. Monitoring of antimicrobial usage among adult bovines in dairy herds of Punjab, India: a quantitative analysis of pattern and frequency. *Front Vet Sci*. 2023;10:1089307.
16. World Health Organization. 2023 AWaRe classification of antibiotics for evaluation and monitoring of use (WHO-MHP-HPS-EML-2023.04). Geneva: WHO; 2023.
17. World Health Organization. WHO list of medically important antimicrobials for human use, 6th revision. Geneva: WHO; 2024.
18. Moja L, Zanichelli V, Mertz D, Gandra S, Cappello B, Cooke GS, et al. WHO's essential medicines and AWaRe: recommendations on first- and second-choice antibiotics for empiric treatment of clinical infections. *Clin Microbiol Infect*. 2024;30:S1–51.
19. Gehring R, Mochel JP, Schmerold I. Understanding the background and clinical significance of the WHO, WOA, and EMA classifications of antimicrobials to mitigate antimicrobial resistance. *Front Vet Sci*. 2023;10:1153048.
20. World Organisation for Animal Health. Annual report on antimicrobial agents intended for use in animals, 9th report. Paris: WOA; 2025.
21. Goggs R, Menard JM, Altier C, Cummings KJ, Jacob ME, Lalonde-Paul DF, Papich MG, Norman KN, Fajt VR, Scott HM, Lawhon SD. Patterns of antimicrobial drug use in veterinary primary care and specialty practice: a 6-year multi-institution study. *J Vet Intern Med*. 2021;35(3):1496–508.
22. De Marchi L, Vernaccini M, Meucci V, Briganti A, Lippi I, Marchetti V, Intorre L. Six-year prescription pattern of antimicrobial use in cats at the Veterinary Teaching Hospital of the University of Pisa. *Anim (Basel)*. 2024;14(3):521.
23. Vernaccini M, De Marchi L, Briganti A, Lippi I, Marchetti V, Meucci V, Intorre L. Antimicrobial use in cats in a university veterinary hospital in central Italy: a retrospective study. *Antibiot (Basel)*. 2024;13(10):927.
24. Fidanzio F, Rega M, Bertini S, Carrillo Heredero AM, Corsini A, Corti F, Crosara S, Quintavalla C. Overview on antimicrobial prescription habits in cats at different clinical services of the Veterinary Teaching Hospital of Parma. *BMC Vet Res*. 2025;21:106.
25. Schmitt K, Lehner C, Schuller S, Schüpbach-Regula G, Mevissen M, Peter R, Müntener CR, Naegeli H, Willi B. Antimicrobial use for selected diseases in cats in Switzerland. *BMC Vet Res*. 2019;15:94.
26. Hubbuch A, Schmitt K, Lehner C, Hartnack S, Schuller S, Schüpbach-Regula G, Mevissen M, Peter R, Müntener C, Naegeli H, Willi B. Antimicrobial prescriptions in cats in Switzerland before and after the introduction of an online antimicrobial stewardship tool. *BMC Vet Res*. 2020;16:229.

27. Summers JF, Hendricks A, Brodbelt DC. Prescribing practices of primary-care veterinary practitioners in dogs diagnosed with bacterial pyoderma. *BMC Vet Res.* 2014;10:240.
28. Allerton F, Prior C, Bagcigil AF, Broens E, Callens B, Damborg P, et al. Overview and evaluation of existing guidelines for rational antimicrobial use in small-animal veterinary practice in Europe. *Antibiot (Basel).* 2021;10(4):409.
29. Weese JS, Blondeau J, Boothe D, Guardabassi LG, Gumley N, Papich M, Jessen LR, Lappin M, Rankin S, Westropp JL, Sykes J. International Society for Companion Animal Infectious Diseases (ISCAID) guidelines for the diagnosis and management of bacterial urinary tract infections in dogs and cats. *Vet J.* 2019;247:8–25. 10.1016/j.tvjl.2019.02.008.
30. Weese JS, Giguere S, Guardabassi L, Morley PS, Papich M, Ricciuto DR, Sykes JE. ACVIM consensus statement on therapeutic antimicrobial use in animals and antimicrobial resistance. *J Vet Intern Med.* 2015;29(2):487–98.
31. Tang KL, Caffrey NP, Nobrega DB, Cork SC, Ronksley PE, Barkema HW, et al. Restricting the use of antibiotics in food-producing animals and its associations with antibiotic resistance in food-producing animals and human beings: a systematic review and meta-analysis. *Lancet Planet Health.* 2017;1(8):e316–27.
32. Rinchen S, Wangchuk P, Namgyel U, Peldon S, Thapa NK, Jamtsho S, Mahat H, Sharma P, Lhamo K, Wangmo D, Wangdi K, Gurung RB. Descriptive epidemiology of the first lumpy skin disease outbreak in Bhutan. *Bhutan J Anim Sci.* 2022;6(1):46–51.
33. World Health Organization. Joint external evaluation of IHR core capacities of the Kingdom of Bhutan, 11–15 December 2017 (WHO/OHE/2016.4). Geneva: WHO; 2018.
34. Lei Z, Liu Q, Yang B, Ahmed S, Xiong J, Song T, Chen P, Cao J, He Q. Evaluation of bioequivalence of two long-acting 20% oxytetracycline formulations in pigs. *Front Vet Sci.* 2017;4:61.
35. Gizaw S, Woldehanna M, Anteneh H, Ayaleo G, Awol F, Gebreyohannes G, Gebremedhin B, Wieland B. Animal health service delivery in crop-livestock and pastoral systems in Ethiopia. *Front Vet Sci.* 2021;8:601878.

Figures

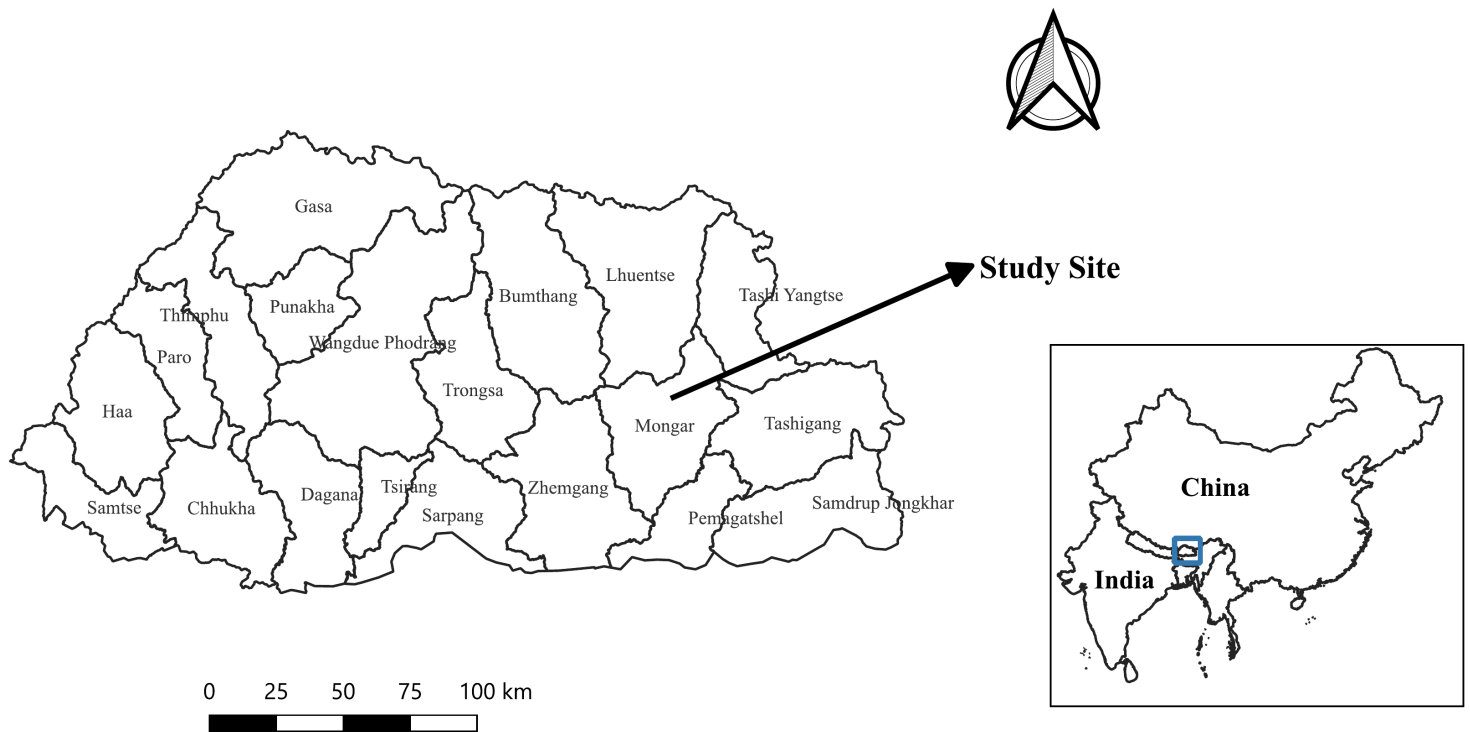


Figure 1

Map of Bhutan showing the 20 districts, with Mongar district, the study site, indicated by the arrow. Inset: location of Bhutan between India and China. Map created in QGIS.

Top 10 diagnosis conditions driving antimicrobial prescribing

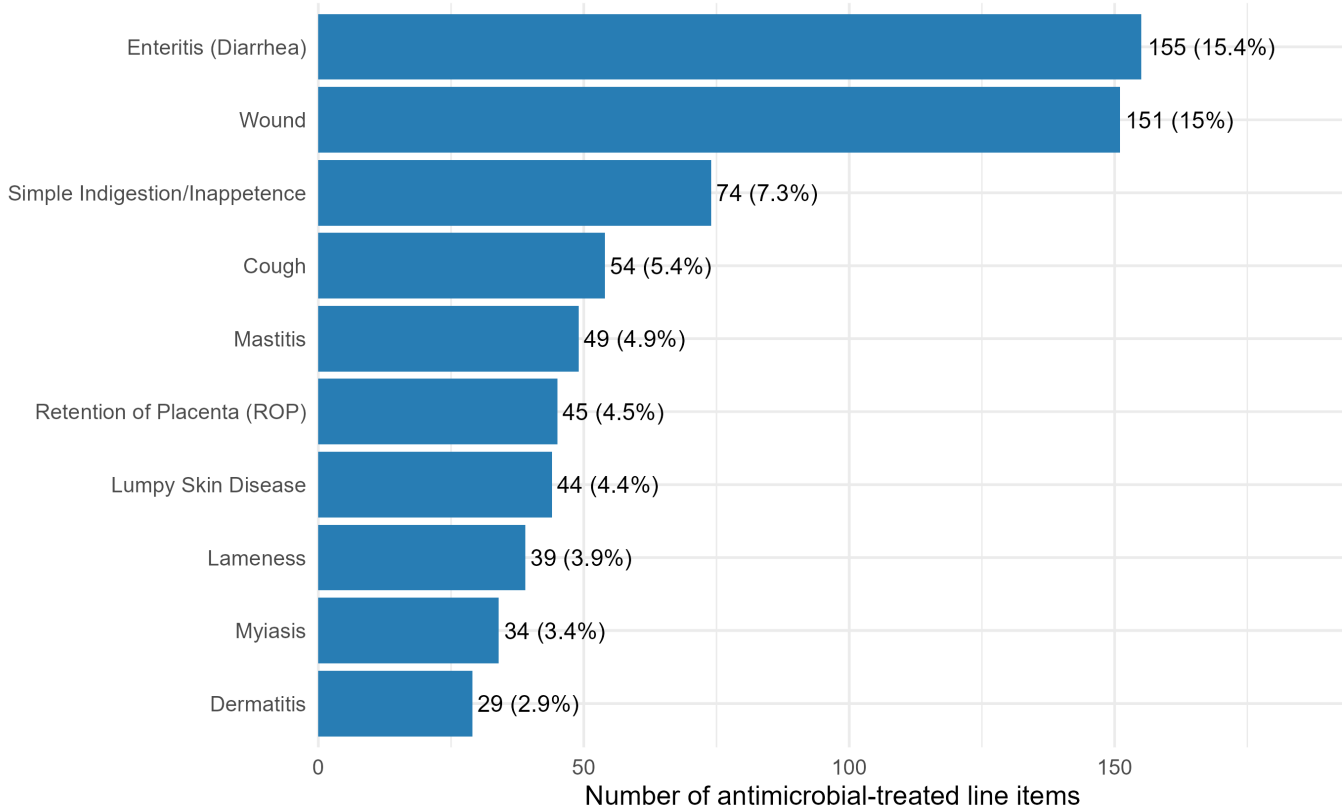


Figure 2

Top 10 diagnostic conditions driving antimicrobial prescribing among antimicrobial-treated line items (n = 1008 line items, excluding those linked to the "condition 1" placeholder diagnosis). The bars show the number of antimicrobial line items attributed to each diagnosis condition, with the percentage of total antimicrobial line items shown alongside each bar.

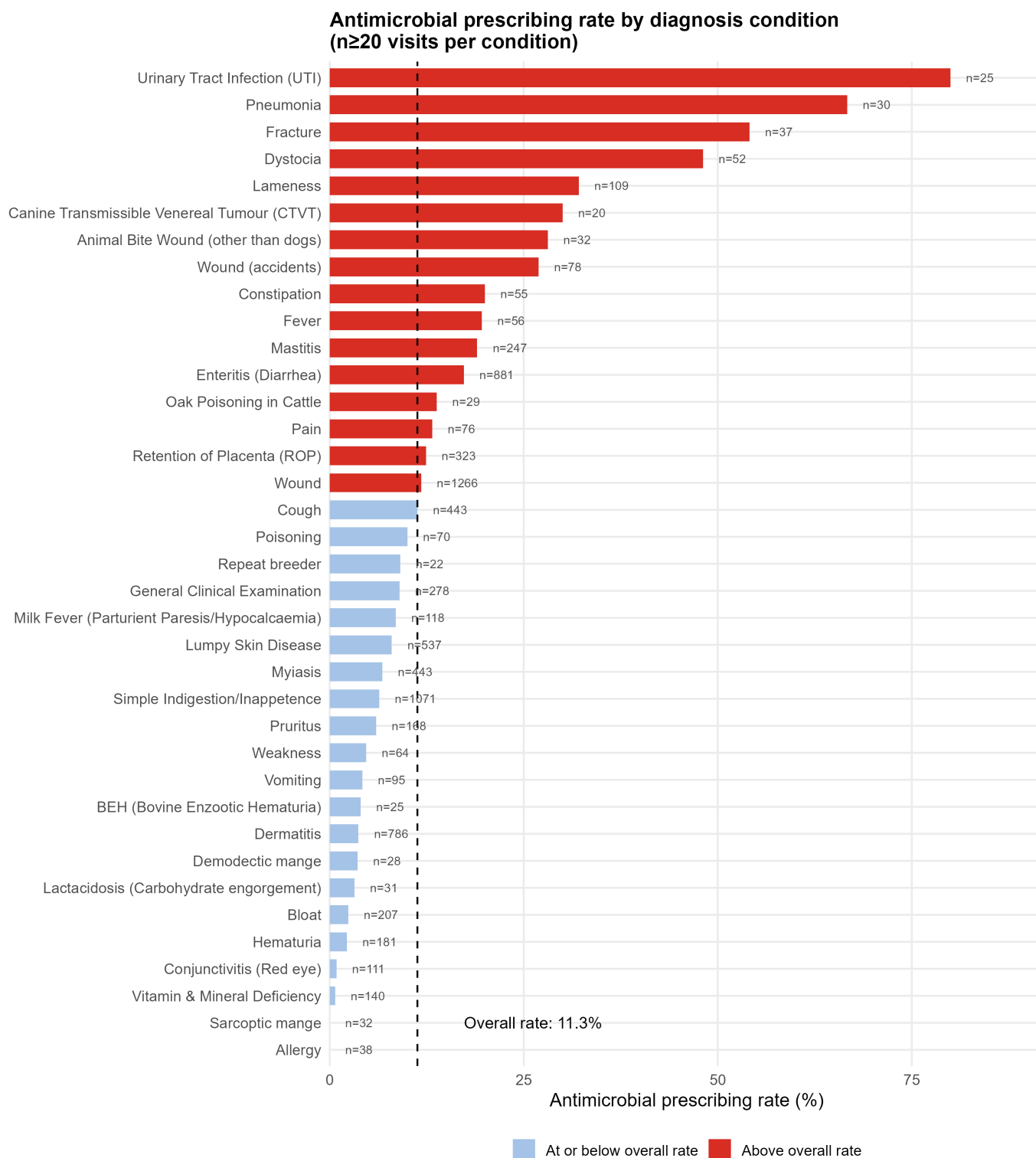


Figure 3

Antimicrobial prescribing rate by diagnosis condition, restricted to conditions with ≥20 recorded visits (n = 37 conditions). Rates are calculated at the visit level (visits with ≥1 antimicrobial dispensed/total visits with that diagnosis). The error bars show 95% Wilson confidence intervals; several high-ranking conditions with small samples, notably, urinary tract infection (n = 25) and canine transmissible venous tumour (n = 20), show correspondingly wide intervals and should be interpreted with this uncertainty in mind. The dashed line indicates the overall visit-level antimicrobial prescribing rate among visits with an identifiable diagnosis (11.3%). The bars are coloured to indicate whether the condition-specific rate falls above or below this overall rate.

Course-completion counseling by AWaRe tier

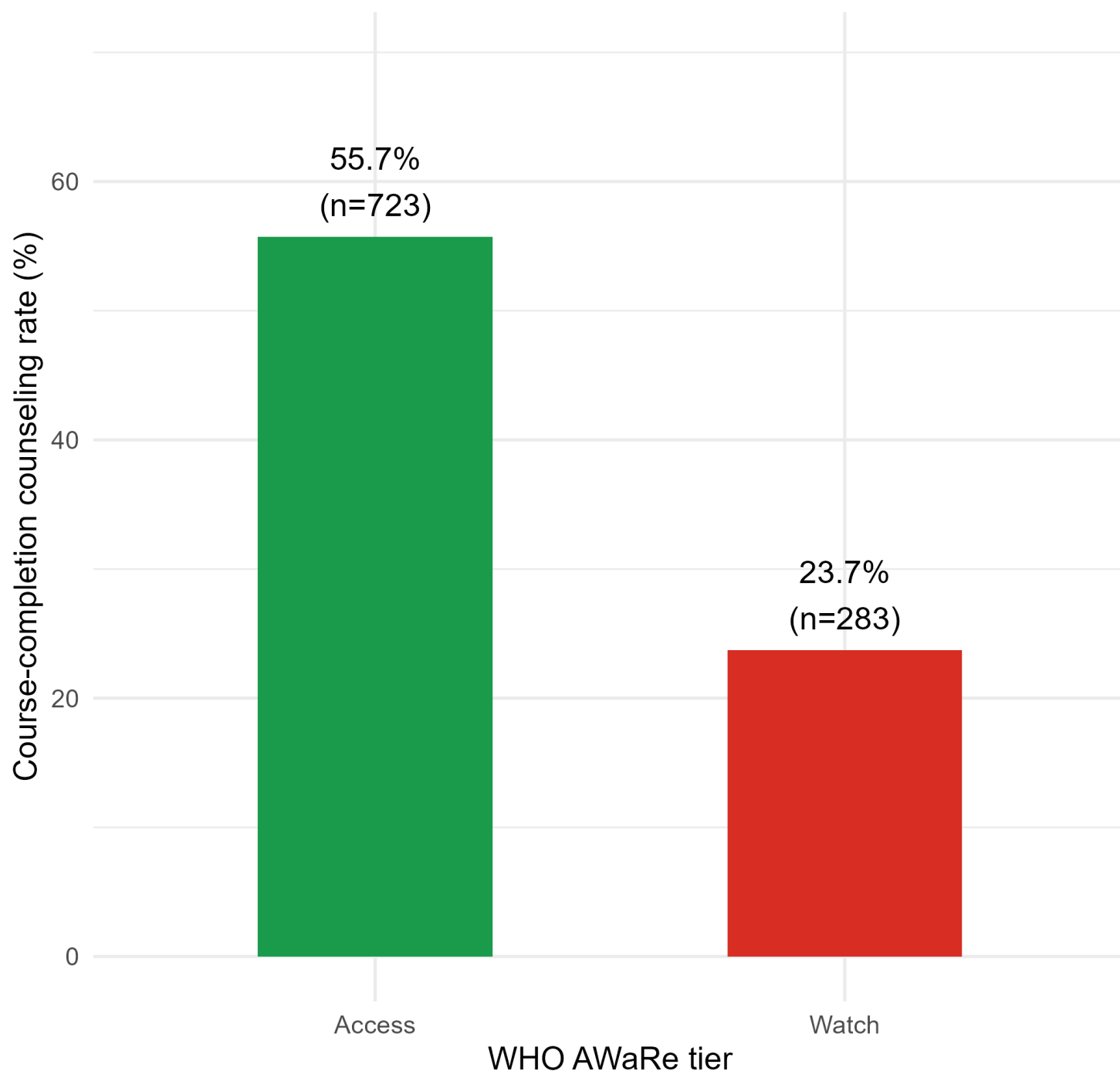


Figure 4

Course-completion counselling rate by WHO AWaRe tier among antimicrobial line items. The bars show the percentages of access-tier (n = 723) and watch-tier (n = 283) antimicrobial line items with documented course-completion advice in the clinician's notes ($\chi^2 = 82.7$, $df = 1$, $p < 0.001$; unadjusted OR = 0.25, 95% CI: 0.18–0.33 for watch versus access).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Additionalfile1STROBEChecklist.docx](#)
- [SupplementaryTableS2.docx](#)
- [SupplementaryTableS3.docx](#)

- [SupplementaryTableS1.docx](#)
- [Additionalfile3RscriptAnalysis.r](#)
- [Additionalfile2deidentifiedanalyticaldataset.xlsx](#)