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Antimicrobials used for surgical prophylaxis by equine veterinary practitioners in Australia

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Summary

Background: Antimicrobials are widely used in Australian veterinary practices, but no investigation into the classes of antimicrobials used or the appropriateness of use in horses has been conducted.

Objectives: The aim of the study was to describe antimicrobial use for surgical prophylaxis in equine practice in Australia.

Study design: Cross-sectional questionnaire survey.

Methods: An online questionnaire was used to document antimicrobial usage patterns. Information solicited in the questionnaire included: demographic details of the respondents, the frequency with which antibiotics were used for specific surgical conditions (including the dose, timing and duration of therapy) and practice antimicrobial use policies and sources of information about antimicrobials and their uses.

Results: In total, 337 members of the Australian veterinary profession completed the survey. Generally, the choice of antimicrobial was appropriate for the specified equine surgical condition, but the dose and duration of therapy varied greatly. While there was poor optimal compliance with British Equine Veterinary Association guidelines in all scenarios (range 1 - 15%) except removal of a non-ulcerated dermal mass (42%), suboptimal compliance (compliant antimicrobial drug selection but inappropriate timing, dose or duration of therapy) was moderate for all scenarios (range 48 – 68%) except for an uninfected contaminated wound over the thorax, where both optimal and suboptimal compliance was very poor (1%). Veterinarians practicing at a university hospital had higher odds of compliance than general practice veterinarians (Odds ratio 3.2, 95%CI, 1.1 to 8.9, P = 0.03).

Main limitations: Many survey responses were collected at conferences which may introduce selection bias, as veterinarians attending conferences may be more likely to have been exposed to contemporary antimicrobial prescribing recommendations.

Conclusions: Antimicrobial use guidelines need to be developed and promoted to improve the responsible use of antimicrobials in equine practice in Australia. An emphasis should be placed on antimicrobial therapy for wounds and appropriate dosing for procaine penicillin.

Introduction

Antimicrobial use in humans and animals generates selective pressure that selects for increased levels of antimicrobial resistance in bacterial populations [1-3]. With the growing threat of antimicrobial resistant bacteria in medical hospitals, the community, and in animals, there is an increasing focus on veterinary antimicrobial usage [4]. Companion animals, including horses, and their owners share skin and gut microbiota through direct contact, with exchange of antimicrobial resistant bacteria possible [5-10]. Data on the amounts of antimicrobial use in animals in Australia is limited to periodic reports provided by the Australian Pesticides and Veterinary Medicines Authority, which records the amounts of antimicrobial drugs imported for use in the veterinary and agricultural sectors [11]. While these data provide a useful starting point for improved antimicrobial stewardship, the quantities reported cannot be stratified by species or production type, except for specific formulations, such as intramammary therapies, where use is largely limited to the treatment of clinical and subclinical mastitis in dairy cows. Recent studies from Canada [12; 13] and the United Kingdom [14] have concluded that inappropriate use of antimicrobials is common in horses. However, the classes of antimicrobials, the appropriateness of drug doses and the duration of therapy used by equine practitioners in surgical prophylaxis have not been comprehensively examined.

The Australian Strategic and Technical Advisory Group on Antimicrobial Resistance (ASTAG) issued importance ratings of antibacterials used in human health in Australia in 2015 [15]. Of the antimicrobials licenced for use in horses, 3rd generation cephalosporins are listed as high importance by ASTAG and therefore it is recommended that they should only be used where culture and susceptibility testing, or other compelling clinical evidence, provide justification for their use.

In Australia, there are no guidelines for antimicrobial use in equines. The British Equine Veterinary Association (BEVA) has released antimicrobial use guidelines, including guidance for antimicrobial use in surgical prophylaxis [16]. These guidelines recommend administration of penicillin pre- and post-operatively for 24 hours for clean surgeries, penicillin and gentamicin pre- and post-operatively for five days for contaminated surgeries and penicillin and gentamicin pre- and post-operatively for ten days for high risk surgeries. For uncomplicated contaminated wounds, antimicrobial therapy is not recommended. While these guidelines provide a necessary first step towards the implementation of veterinary antimicrobial stewardship, audit and feedback are necessary to improve prescribing practices. Antimicrobial use for surgical prophylaxis has been an area in human medicine where application of guidelines and monitoring has led to more appropriate antimicrobial therapy [17].

The aim of this study was to investigate self-reported antimicrobial use in a range of surgical conditions in equine practice in Australia and to assess compliance with BEVA's PROTECT-ME guidelines.

Materials and methods

Details of the source, eligible and study group for this study are described elsewhere [18]. Briefly, the eligible population comprised those registered veterinarians who were working in equine practice in Australia at the time of completion of the questionnaire (estimated to be 2960 veterinarians [19] in 2015).

Sample size calculations

Sample size calculations were carried out to determine the number of respondents required to make appropriate inferences from the survey. To be 95% certain that our estimate of the population prevalence of veterinarians using a given class of antimicrobials was within 6% of a true population prevalence of 50%, a total of 245 completed surveys were required. Sample size calculations were carried out assuming a 50% population prevalence because this provided the largest sample size estimate for a constant margin of error.

Study data were collected and managed using REDCap electronic data capture tools [20]. The survey details are described elsewhere [18]. The equine surgical scenarios included in the survey were castration, a clean wound that is sutured, removal of a non-ulcerated dermal mass, a contaminated wound over the thorax that was not sutured and not infected, an uncomplicated umbilical hernia repair, a transphyseal bridge with a lag screw and an uncomplicated eye ablation (see Supplementary Item 1).

Data analysis

Data were downloaded from the survey software into spreadsheets (Microsoft Office Excel, 2016). The entire equine section of the survey had to be completed by each respondent to be included in the analysis of equine practitioner antimicrobial usage. Descriptive statistics were computed with percentages for each response, calculated as the proportion of the total number of respondents answering a particular question. Where respondents reported that they did not perform a specific surgery, they were excluded from the analysis for that question. The data were analysed using sampling weights, W_H, to provide an estimate of the inverse probability of a veterinarian's involvement in the survey, as the numbers of respondents varied by state or territory, which were quantified as follows:

$$W_H = \frac{N}{n} \qquad \text{Equation 1}$$

Where N is the number of registered veterinarians in each state or territory in 2016, and *n* is the number of veterinarians who completed the survey from each state. Throughout this paper, all profession level data are described using adjusted values based on survey design, sampling weights and finite correction factors. Proportions of questionnaire responses are reported as unadjusted counts.

A logistic regression model was used to identify individual veterinarian-level characteristics that were associated with appropriate antimicrobial usage. The explanatory variables assessed in the model included the type of practice in which the respondent worked (mixed species, large animal, equine only), practice location (rural, metropolitan), year of graduation (those who graduated up to and including 2011 and those who graduated after 2011), gender, position in the practice (owner-partner, associate, casual-locum), the size of the veterinary practice (one or two full time veterinarians, more than two full time veterinarians), whether or not the respondent had postgraduate qualifications, and the presence or absence of a practice antimicrobial use policy. The outcome of interest was a proportion, where the numerator was the count of questions in which the respondent was compliant with BEVA guidelines and the denominator was the total number of scenarios answered in the survey. Generalised linear regression models were fitted, and Z tests performed, using functions within Stata v13.

Unconditional associations between each of the hypothesised explanatory variables listed above and the outcome of interest were computed using the odds ratio. Explanatory variables with unconditional associations significant at the $P<0.20$ level (2-sided) were selected for multivariable modelling. All explanatory variables meeting this criterion were entered into the multivariable model. Explanatory variables that were not significant were then removed from the multivariable model one at a time, beginning with the least significant, until the estimated regression coefficients for all explanatory variables retained were significant at an alpha level of less than 0.05. Explanatory variables that were excluded at the initial screening stage were tested for inclusion in the final model and were retained in the model if their inclusion changed any of the estimated regression coefficients by more than 20%. Biologically plausible two-way interactions were tested and none were significant at an alpha level of 0.05.

Results

A total of 337 members of the Australian veterinary profession completed the survey. All states and territories were represented, as were recent and older graduates. Respondents were predominately from first opinion practice (87%), with the remainder from referral and university practice (13%). Equine-only practitioners represented 31% (95% CI, 21 to 40%) of respondents, while the remaining 69% (95% CI, 63 to 75%) treated a mixture of species (3.0% equine and bovine, 8.5% equine and companion animals, 56% equine, bovine and companion animals). The veterinarians completing the survey served a variety of client sectors (39% pleasure horses only, 7.5% racetrack only, 3.1% reproductive practice only and 50% crossing a mix of sectors). Few practices had an antimicrobial use policy (20%, 95% CI, 11 to 31%).

A very wide range of sources of information on antimicrobials for surgical prophylaxis were reported, with no single source of information predominating. Practitioners reported using experience (12%), continuing education (11%), and textbooks (11%) most frequently, with 7% reporting the label as an important source of information. Having an antimicrobial use policy did not change the sources of information reported by clinicians, with only 7.1% of practitioners with a policy in place reporting this as a source of information for antimicrobial therapy. The amount of contamination (33%) and surgical conditions (23%) were the most frequently reported influences on the decision to prescribe antimicrobials in the surgical scenarios.

Antimicrobial use

The five categories indicating the frequency of antimicrobial use for each surgical condition were combined into three groups (always/frequently, sometimes/rarely and never). Removal of a non-ulcerated dermal mass had the least antimicrobial use; antimicrobials were used always or frequently by 26% of respondents, sometimes or rarely by 34% of respondents and never by 40% of respondents. The frequency of antimicrobial use was high for all other types of surgery (Fig 1).

Overall, the most frequently prescribed antimicrobial class in this survey was the penicillins (70%), predominantly procaine penicillin (95%). The only other frequently prescribed antimicrobials were trimethoprim-sulphonamide (16%) and gentamicin (12%). All other classes represented less than 1.3% of all reported antimicrobials in the survey (Fig 2). Penicillin was the most commonly used antimicrobial for all the surgical scenarios (48-86% of respondents across scenarios). Use of trimethoprim-sulphonamide or a combination therapy of penicillin and gentamicin were also frequently reported for all scenarios except for castration (Fig 3). There was a very low incidence of use of antimicrobials with a high importance rating (0.7%), with third generation cephalosporins being the only drugs in this group with use not exceeding 1.9% of antimicrobials used in any one scenario. There was wide variation in duration of therapy between scenarios. Castration was the only scenario in which antimicrobial therapy was stopped within 24 h by most respondents (66%). Antimicrobial therapy was the longest for both wound scenarios, with 74% and 53% of respondents indicating they treated for 3-7 days for contaminated wounds (not infected and left open to heal by secondary intention) and clean wounds that were sutured, respectively.

Optimal compliance

Compliance with BEVA guidelines on the use or non-use of antimicrobials, drug choice, dose, and duration of therapy was evaluated as well as overall agreement with these guidelines. A 10% margin of error was allowed when assessing compliance with guidelines for dosage. Compliance was classed as optimal if the therapy complied with all recommendations, suboptimal if the correct drug choice was made but dose, duration of therapy or timing of antimicrobial therapy prior to surgery were not compliant, and non-compliant if drug choice was inappropriate or if an antimicrobial was administered when none was recommended by the guidelines. The frequency of optimal compliance for the different surgical scenarios ranged from 1.1% to 42%. Except for removal of a non-ulcerated dermal mass, optimal compliance was low for all scenarios (1.1% to 25%) (Fig 4). Suboptimal compliance was common for all scenarios, with most respondents selecting the appropriate antimicrobial agent (36% to 68%) (Fig 4). Suboptimal compliance was not evaluated for the contaminated wound scenario as antimicrobials were not indicated.

Suboptimal compliance

Optimal compliance was low due to inappropriate dose, inappropriate timing of administration of drug and/or inappropriate duration of therapy. Timing of administration was the aspect that was the least appropriate in all scenarios, except when creating a transphyseal bridge with a lag screw, with fewer than 20% of respondents reporting timing their administration of antimicrobials to generate effective serum antimicrobial concentrations at the time of surgery. In the vast majority of cases the penicillin administered was intramuscular procaine penicillin, with 38% of respondents administering this within 30 mins before surgery and 33% administering it after surgery. As the time required to reach maximal plasma concentrations of penicillin after intramuscular administration of procaine penicillin in horses is 3.5 hours [21], administration in the 30 minutes before surgery was classed as inappropriate. The dose of antimicrobials was also commonly inappropriate, with fewer than 30% of respondents reporting using appropriate doses of antimicrobials in all scenarios except transphyseal bridging. Sub-therapeutic dosing of penicillin accounted for the majority of under-dosing, with 68% of all procaine penicillin dose rates being lower than that recommended in the literature, whereas only 12% of gentamicin dose rates were lower than those recommended in the literature. Duration of therapy was also moderately to highly inappropriate in all scenarios, except when performing castration, as they exceeded the recommendation in all instances (Fig 5).

An individual's overall optimal and suboptimal compliance was calculated as the proportion of optimal or suboptimal compliant scenarios among the total number of scenarios completed in the questionnaire. There was marked variation between individual respondents, ranging from 1% to 100% overall optimal compliance. The distribution of the proportion of scenarios that were compliant was not normally distributed. After adjusting for the effect of practice type, species treated, size and location, gender, position in practice, the presence or absence of post-graduate qualifications and the presence or absence of a practice antimicrobial use policy, the odds of compliance was 3.2 times higher in university veterinarians compared with general practitioners (95% CI, 1.14 to 8.91). There was a trend towards lower odds of compliance in recent graduates (graduated after 2011) compared with older graduates (veterinarians who graduated in or before 2011) (OR 0.60; 95% CI, 0.35 to 1.01; P = 0.056) and in practitioners from Western Australia (OR 0.5; 95% CI, 0.26 to 1.01; P = 0.056).

Discussion

This is the first survey to investigate antimicrobial use by equine practitioners in Australia and the first to report on compliance with antimicrobial guidelines in equine surgery. Consistent with BEVA's PROTECT-ME guidelines [16], antimicrobial use for surgical prophylaxis was commonly reported and the choice of antimicrobial drug was appropriate, in most instances, for all scenarios in which they were indicated. The predominant use of procaine penicillin differed from a survey of antimicrobial use by equine practitioners in the UK, in which the use of trimethoprim-sulphonamide predominated [14], but this survey also included medical conditions and this may have affected the choice of antimicrobial. The frequent use of prophylactic antimicrobials for routine elective surgeries such as castration and dermal mass removal might be expected in ambulatory practice because of the need to perform surgery in exposed (outdoor) conditions. However, less than 25% of respondents selected surgical conditions as a factor important in the decision to use or not use antimicrobials. This implies that use of antimicrobials for surgical prophylaxis is routine in equine practice, even for clean surgeries, and there is little consideration of the actual need for antimicrobial therapy in these scenarios. There is evidence that, in some situations, clean surgical procedures performed without antimicrobial prophylaxis have similar complication rates to those performed with prophylactic antimicrobial therapy [22] suggesting a need for re-evaluation of the need for antimicrobial therapy in every surgical case.

Few respondents reported having an antimicrobial policy at the clinic in which they practiced (20%), although this was a higher proportion than was seen in a recent study in the UK, in which fewer than 1% of respondents reported having a written antimicrobial policy [14]. It was concerning that only 7% of practitioners with an antimicrobial use policy in place reported that this document was a source of information used to guide antimicrobial therapy. In contrast, companion animal practitioners who had an antimicrobial use policy in their practice reported using a range of different information sources to guide antimicrobial therapy compared with veterinarians whose practice did not have an antimicrobial use policy [18]. The failure of guidelines to influence prescribing behaviour is multifactorial in human medicine, with a lack of appreciation of an individual's role in addressing the bigger issue [23], failure to get senior practitioners to support the use of guidelines [24; 25], perceived inconvenience of appropriate timing of administration of drugs [26], and interference by guidelines in clinical autonomy [27] all reported to play a role in different scenarios. Some, or all, of these factors may also influence the successful implementation of guidelines in veterinary practices.

Compliance with BEVA's PROTECT ME guidelines was used as the gold standard for this survey. These guidelines represent a conservative approach to antimicrobial use in surgical prophylaxis; for many other species antimicrobials are not recommended for clean surgeries and therapy for less than 24 hours after surgery is recommended for clean-contaminated surgeries [28; 29]. The duration of therapy recommended by the BEVA PROTECT ME guidelines is arguably too long, but there is limited evidence in the literature to guide duration of antimicrobial administration for surgical prophylaxis in equine medicine. There were no instances where the duration of therapy was shorter than that recommended in the BEVA PROTECT-ME guidelines [16].

Levels of optimal compliance were very low across all scenarios in this survey. Levels of suboptimal compliance were higher, with the appropriate antimicrobial commonly selected but administration either at an inappropriate dose or frequency, or for too long after surgery. This inappropriate dosing and frequency of administration of procaine penicillin is concerning, as low dose antimicrobial therapy not only promotes antimicrobial resistance, but also fails to achieve serum drug concentrations above the minimum inhibitory concentrations for common equine pathogens. Appropriate drug doses are taught at all Australian universities (personal communication, 2016). Consistent with this, veterinarians practicing in university teaching hospitals had higher odds of optimal compliance with guidelines compared with general practitioners. The labelling of procaine penicillin by manufacturers in Australia is misleading (labelled dose 20 ml/500 kg intramuscularly daily [30]), with the doses recommended on the labels falling below those now recognised as appropriate (22,000 IU/kg body weight every 12 hours), and this may contribute to the problem of under dosing. The labelling for gentamicin is also misleading, with the labelled dose rate (2 mg/kg body weight three times daily) differing considerably from the current recommended dose rates (6.6 to 10 mg/kg once daily). Use of the dose rates suggested by the label is likely to significantly increase the risk of acute renal failure in treated horses. However, the doses for gentamicin therapy actually reported by respondents were largely appropriate (89% of dose rates appropriate) whereas those for procaine penicillin were largely inappropriate (32% of dose rates appropriate). The label is clearly not the only factor leading to use of inappropriate doses of penicillin by veterinarians. Changes to legislation are needed to ensure that antimicrobial drug labels are regularly updated to reflect the dose needed to effectively and safely treat common equine pathogens. Long-acting penicillin represented 3% of antimicrobials used for surgical prophylaxis in this survey. This formulation of penicillin is inappropriate in equine medicine, as it fails to generate plasma concentrations of penicillin above minimum inhibitory concentrations for common equine pathogens [31].

Practitioners commonly reported that they used gentamicin for surgical prophylaxis in this survey (12% of antimicrobials reported). In Australia, the current label dictates that gentamicin only be used after culture and sensitivity testing that indicates that it is the only appropriate antimicrobial, a requirement that clearly cannot be met for use in surgical prophylaxis. This "do not use unless" clause is legally binding, but to the authors' knowledge there has been no enforcement of this requirement by authorities. If this situation was to change, this label requirement may drive veterinarians towards using antimicrobials with a higher importance rating, as alternatives for treating Gram negative infections are limited in equine practice. The labelling of gentamicin should be updated to allow for empirical use in equine practice.

The scenario of a contaminated wound over the thorax (that heals by secondary intention) of a horse had the lowest level of optimal or suboptimal compliance in this survey. This was due to near uniform treatment with broad-spectrum antimicrobials, when the guidelines recommend no antimicrobial therapy. Such over treatment of wounds was also identified in a UK study in which 96.8% of respondents reported prescribing antimicrobial therapy for a contaminated leg wound [14]. An education campaign targeting antimicrobial therapy for wounds in horses is clearly needed.

There was a statistically insignificant trend towards lower optimal compliance with guidelines for recent graduates compared with older graduates. Recent graduates were also found to have lower optimal compliance in a survey of prophylactic antimicrobial therapy in companion animal surgery [18]. It is possible this is due to poor university teaching, but it seems more likely that lack of confidence in recently graduated veterinarians results in their overuse of antimicrobials for surgical prophylaxis. Inappropriate labelling may also contribute, as recently graduated veterinarians may rely more heavily on the label as a source of information than more experienced practitioners.

There are several features of this study that may have influenced the results. Recall bias is a common problem with questionnaire-based surveys where study participants are asked to recall past events. Hypothetical scenarios were posed rather than asking clinicians to recall specific cases to minimise this. Respondents were self-selected in this study and many were recruited at conferences, so practitioners who were more likely to complete continuing education, and had more awareness of recommended prescribing practices, may be over-represented. Veterinarians from the states in which the conferences were held may also be over-represented, but the results were adjusted to correct for this lack of equivalence in sampling. Other adjustments to correct for population differences were not possible because there are no population statistics for the Australian veterinary profession. However, all age-groups were represented, as were rural and urban veterinarians. The survey was anonymous, to minimise response bias.

In conclusion, this survey has shown that antimicrobials are commonly used for surgical prophylaxis in equine practice in Australia, that appropriate antimicrobial agents are generally chosen, with procaine penicillin the most commonly used drug and antimicrobials of high importance rating rarely used. Education is warranted to improve drug dosing, timing of administration prior to surgery and to shorten the duration of surgical prophylaxis. Legislation should also be amended to require that product labels carry appropriate current dosing advice. In addition, the use of antimicrobials for uncomplicated wounds should be discouraged much more strongly across the veterinary profession.

Authors' declaration of interests

No competing interests have been declared.

Ethical animal research

This research was approved by the University of Melbourne Faculty of Veterinary and Agricultural Sciences Human Ethics Advisory Group under Approval No. 1646102. Completion of the questionnaire was taken as participant consent.

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Authorship

L. Hardefeldt, G. Browning, K Thursky, J. Gilkerson, H. Billman-Jacobe and K. Bailey were involved in the study design. L. Hardefeldt, G. Browning, J. Gilkerson and K. Bailey were involved in study execution. L. Hardefeldt and M. Stevenson were involved in the data analysis and interpretation. L. Hardefeldt was the primary author of the manuscript, with the assistance of K. Bailey and G. Browning. All authors reviewed the manuscript and gave final approval.

Table 1: Estimated regression coefficients and their standard errors from a logistic regression model of risk factors for compliance with guidelines for prophylactic antimicrobial usage in surgery.

Variable	Comp[a]	Scenario[b]	Coefficient(SE)	t	P	OR(95%CI)
Intercept[c]	281	1419	-1.25 (0.539)	-2.33	0.02	0.47 (0.25, 0.86)
Type of practice						
General Practice	207	1183	Reference			
Referral	35	148	0.078 (0.393)	0.20	0.9	1.08 (0.50, 2.34)
University	35	81	1.160 (0.522)	2.22	0.03	3.19 (1.14, 8.91)
Practice location						
Rural	190	1048	Reference			
Metropolitan	91	371	-0.138 (0.268)	-0.52	0.6	0.87 (0.51, 1.47)
Graduation						
≤2011	212	1017	Reference			
>2011	69	402	-0.513 (0.267)	-1.92	0.06	0.60 (0.35, 1.01)
Gender						
Male	109	596	Reference			
Female	172	823	0.200 (0.217)	0.92	0.4	1.22 (0.80, 1.87)
Position in practice						
Owner/partner	92	514	Reference			
Associate	139	736	0.098 (0.274)	0.36	0.7	1.10 (0.64, 1.89)
Casual/locum	8	62	-1.04 (0.621)	-1.68	0.09	0.35 (0.10, 1.20)
Other	42	107	-0.371 (0.433)	0.86	0.4	1.45 (0.62, 3.40)
Size of practice						
≤ 2 veterinarians	50	300	Reference			
>2 veterinarians	231	1119	0.175 (0.250)	0.70	0.5	1.19 (0.73, 1.95)

Postgraduate qualifications						
No	184	1041	Reference			
Yes	97	378	0.253 (0.242)	1.05	0.3	1.28 (0.80, 2.07)
Antimicrobial use policy						
No	236	1126	Reference			
Yes	45	293	-0.411 (0.263)	-1.56	0.1	0.66 (0.40, 1.11)
Species treated						
Equine only	130	560	Reference			
Equine/bovine	7	51	-0.170 (0.656)	-0.26	0.8	0.84 (0.23, 3.06)
Mixed	119	701	-0.174 (0.287)	-0.61	0.6	0.84 (0.48, 1.48)
Small/equine	25	107	0.613 (0.420)	1.46	0.2	1.85 (0.81, 4.22)
State of practice[c]						
NSW	84	383	Reference			
NT	11	20	0.736 (0.429)	1.72	0.09	2.10 (0.90, 4.86)
SA	12	97	-0.920 (0.543)	-1.70	0.09	0.40 (0.14, 1.16)
QLD	56	253	-0.117 (0.288)	-0.41	0.7	0.89 (0.50, 1.57)
TAS	9	42	0.003 (0.454)	0.01	>0.9	1.00 (0.41, 2.45)
VIC	87	467	-0.319 (0.248)	-1.29	0.2	0.73 (0.45, 1.18)
WA	22	157	-0.673 (0.350)	-1.92	0.06	0.51 (0.26, 1.01)

[a]Number of optimally compliant scenarios

[b]Total number of scenarios answered

[c]Baseline compliance adjusted for sampling fraction

SE, standard error; OR, odds ratio; CI, confidence interval

Figure legends

Fig 1: Frequency of antimicrobial usage for surgical prophylaxis in seven scenarios.

Fig 2: Overall proportions of antimicrobials reported as being used in surgical prophylaxis. *TMS: Trimethoprim sulphonamide

Fig 3: Antimicrobials used for prophylaxis in each of the surgical scenarios. *LIRA: Low importance rating antimicrobial

Fig 4: Proportions of veterinarians reporting optimal and suboptimal compliance with BEVA guidelines for prophylactic antimicrobial use in different surgical scenarios. Suboptimal compliance reflects appropriate drug choice but inappropriate doses or timing of antimicrobial administration to allow for adequate serum antimicrobial concentrations at the time of surgery, or a duration of therapy that was not compliant with guidelines.

Fig 5: Proportions of veterinarians reporting sub-optimal compliance with antimicrobial prophylaxis guidelines evaluated by factor.

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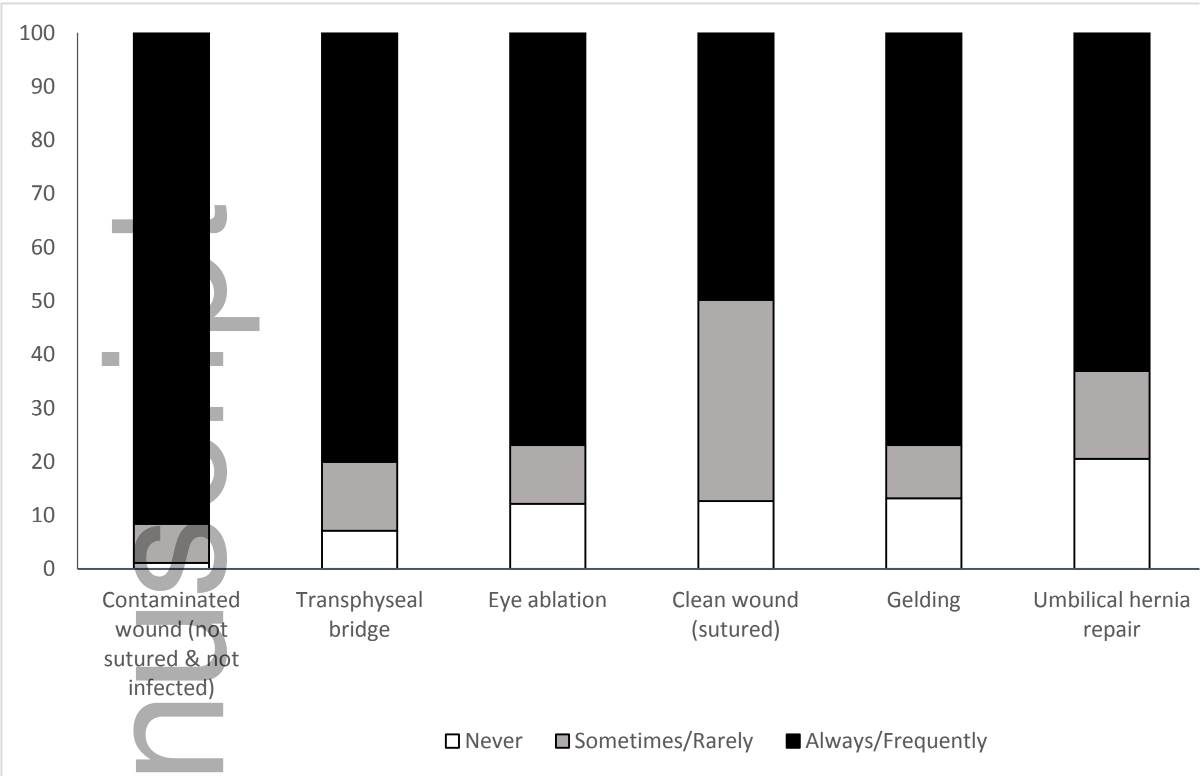
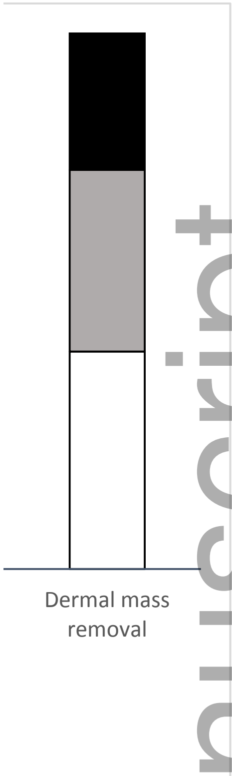
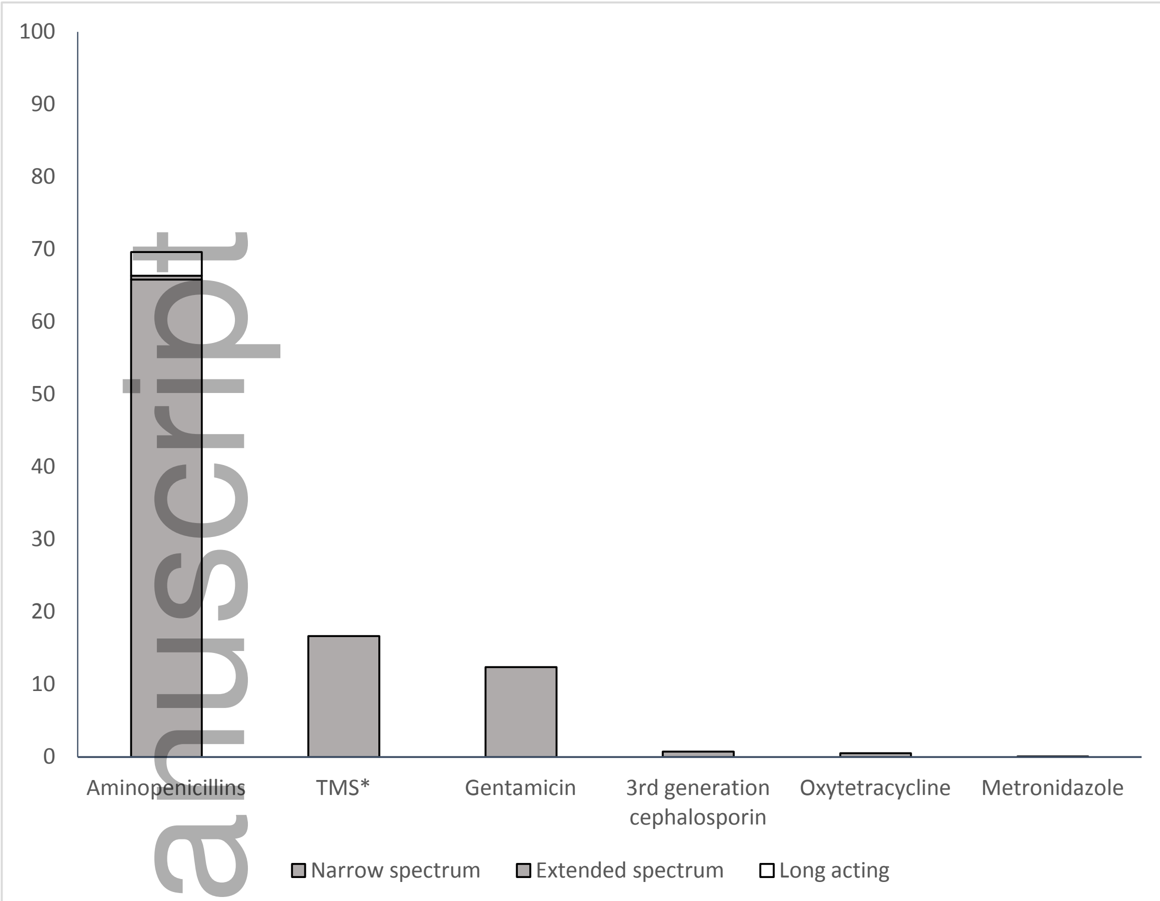
Supplementary Information

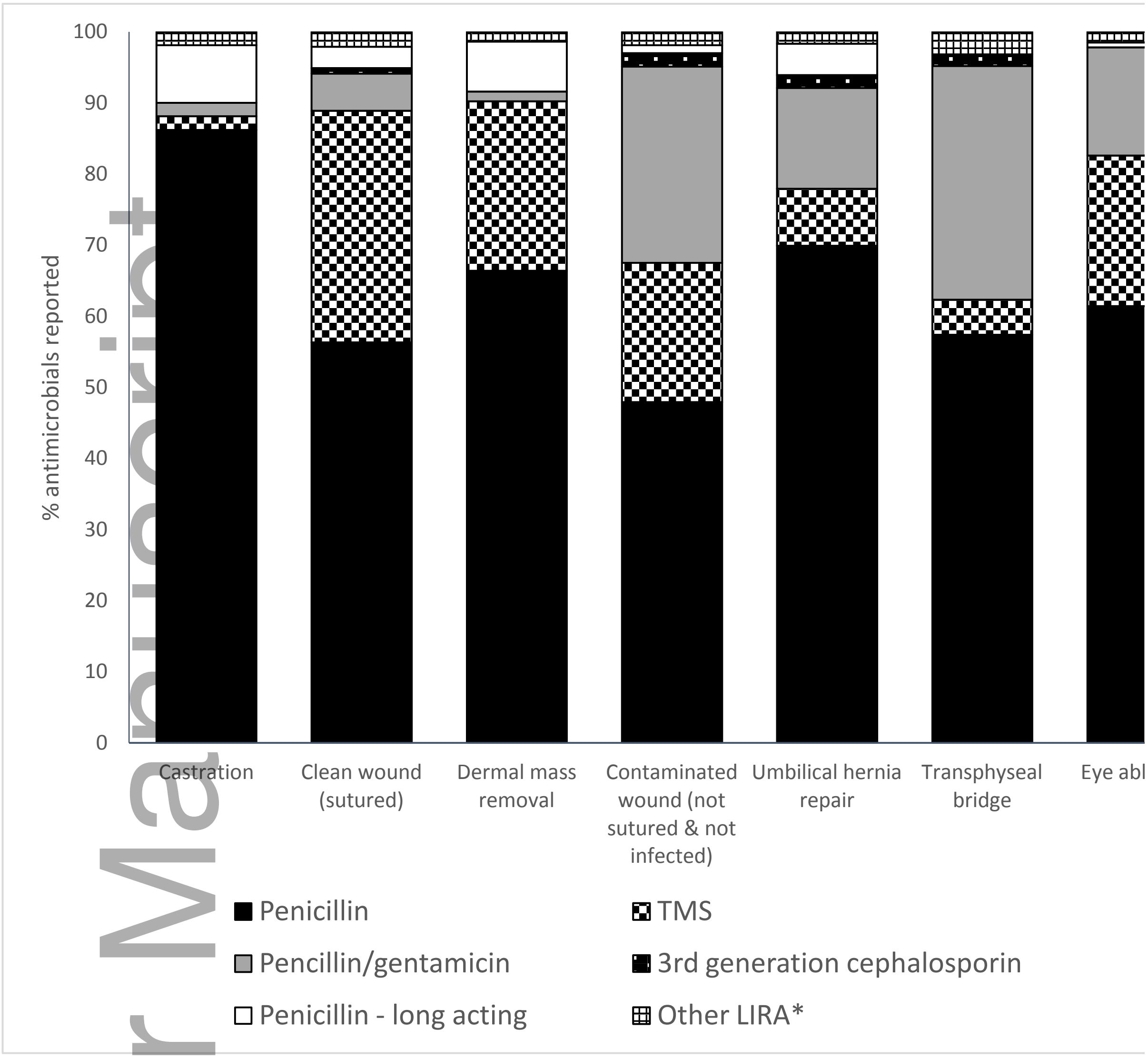
Supplementary Item 1: Copy of questionnaire used in the survey.

evj_12709_f1.xlsx

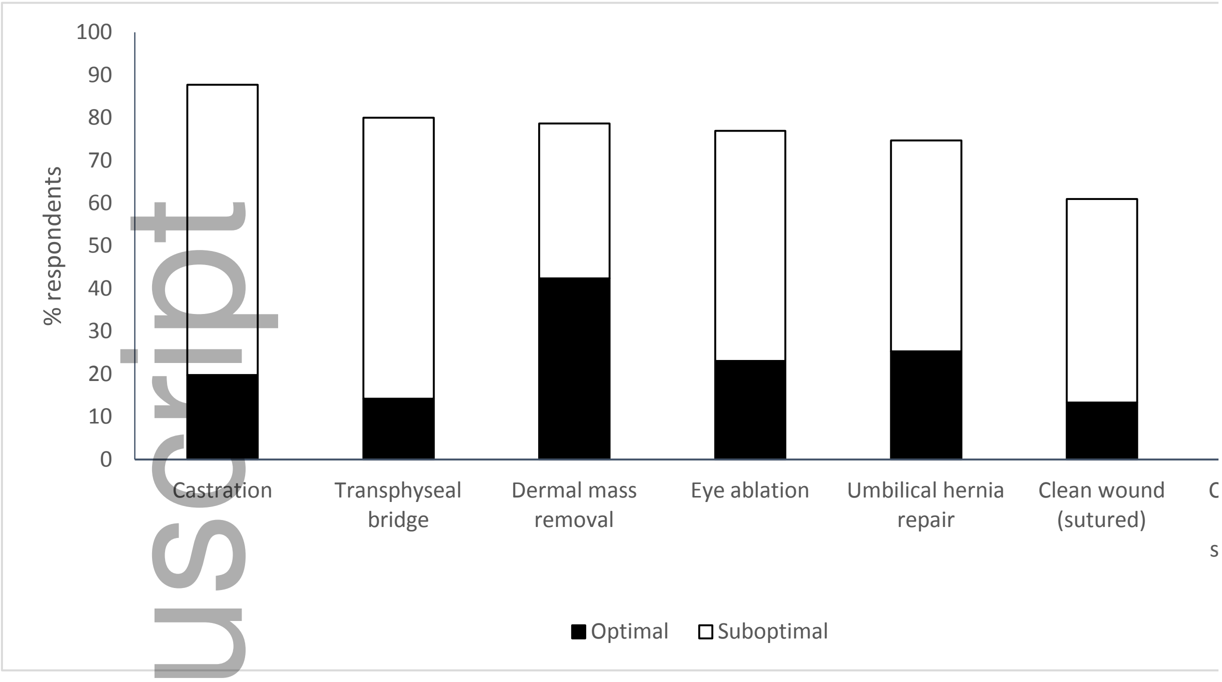



Dermal mass
removal

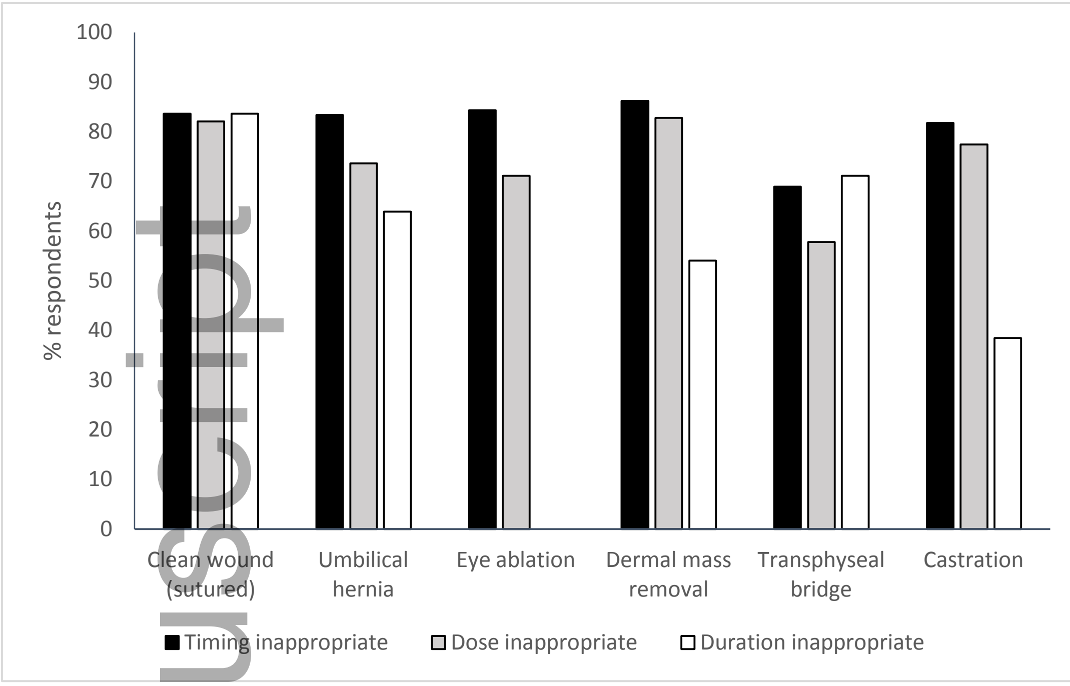

100
90
80
70
60
50
40
30
20
10
0
Aminopenicillins
TMS*
Gentamicin
3rd generation cephalosporin
Oxytetracycline
Metronidazole
Narrow spectrum
Extended spectrum
Long acting


% antimicrobials reported
100
90
80
70
60
50
40
30
20
10
0
Castration
Clean wound (sutured)
Dermal mass removal
Contaminated wound (not sutured & not infected)
Umbilical hernia repair
Transphyseal bridge
Eye abl
Penicillin
TMS
Pencillin/gentamicin
3rd generation cephalosporin
Penicillin - long acting
Other LIRA*


lation


100
90
80
70
60
50
40
30
20
10
0
% respondents
Castration
Transphyseal bridge
Dermal mass removal
Eye ablation
Umbilical hernia repair
Clean wound (sutured)
Optimal
Suboptimal


Contaminated wound (not sutured & not infected)


100
90
80
70
60
50
40
30
20
10
0
% respondents
Clean wound (sutured)
Umbilical hernia
Eye ablation
Dermal mass removal
Transphyseal bridge
Castration
Timing inappropriate
Dose inappropriate
Duration inappropriate