Article

Bacterial isolates from equine infections in western Canada (1998–2003)

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Abstract — All bacterial samples of equine origin submitted to the diagnostic laboratory at the Western College of Veterinary Medicine from January 1998 to December 2003 from either "in-clinic" or Field Service cases were accessed (1323 submissions). The most common bacterial isolates from specific presenting signs were identified, along with their in vitro antimicrobial susceptibility patterns. The most common site from which significant bacterial isolates were recovered was the respiratory tract, followed by wounds. *Streptococcus zooepidemicus* was the most common isolate from most infections, followed by *Escherichia coli*. Antimicrobial resistance was not common in the isolates and acquired antimicrobial resistance to multiple drugs was rare. The results are compared with previous published studies from other institutions and used to suggest appropriate antimicrobial treatments for equine infections in western Canada.

Résumé — Isolats de bactéries provenant d'infections équines dans l'Ouest du Canada (1998–2003). Tous les échantillons bactériens d'origine équine en provenance de l'hôpital ou de la clinique ambulatoire, soumis au laboratoire de diagnostic au Western College of Veterinary Medicine de janvier 1998 à décembre 2003, ont été évalués (1323 dossiers). Les isolats bactériens les plus fréquents ont été identifiés à partir des signes cliniques distinctifs et simultanément, leurs motifs de susceptibilité in-vitro aux antimicrobiens ont été déterminés. Le tractus respiratoire constituait le site le plus fréquent de recouvrement d'isolats bactériens significatifs alors que les plaies en constituaient le 2e. *Streptococcus zooepidemicus* constituait l'espèce bactérienne la plus commune isolée de la plupart des infections suivi d'*Escherichia coli.* La résistance aux antimicrobiens n'était pas fréquente dans les isolats et la multirésistance acquise demeurait un fait rare. Les résultats sont comparés à ceux d'études déjà publiées provenant d'autres institutions et servent à proposer des traitements antimicrobiens efficaces aux infections équines dans l'ouest du Canada.

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Introduction

In recent years, there have been important changes in antimicrobial therapy in equine practice. New antimicrobials are available and there is a greater database of pharmacokinetic information, allowing for more accurate drug dosing. Concerns over drug residues in food animals and antimicrobial resistance led to the development of the Canadian Veterinary Medical Association's prudent use guidelines (1); these guidelines stress obtaining a diagnosis and selecting appropriate antimicrobial therapy. In practice situations, it is often difficult to submit samples for microbiologic culture and in vitro antimicrobial susceptibility testing, or it may not be prudent to delay treatment until such results are available. Empirical antimicrobial selection has been based on data from university teaching hospitals and veterinary diagnostic laboratories from eastern Canada, the United States, and Europe (2–4). These reviews were from tertiary care facilities with caseloads not typical of general practice. Information from these studies may not be applicable to equine cases in western Canada, as differences in antimicrobial availability and local disease occurrence may affect bacterial populations and their in vitro antimicrobial susceptibility patterns (1). The Western College of Veterinary Medicine (WCVM) at the University of Saskatchewan has a varied equine caseload that includes a large number of 1st opinion cases, so bacterial isolates and their in vitro antimicrobial susceptibilities are likely to be similar to cases seen in western Canadian practices. The purpose of this study was to identify the causes of bacterial infections and to formulate appropriate antimicrobial therapy guidelines for treating horses in western Canada.

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Materials and methods

The Prairie Diagnostic Services (PDS) database at WCVM was searched to identify all bacteriological submissions of equine

Table 1. Criteria for characterizing a sample site. The anatomical sites and clinical presentation of cases from which the samples for bacteriologic study were obtained were divided into categories

Sample site	Number of submissions resulting in significant isolates	Sample criteria
Eye	19	Any bacterial sample collected from the eye or orbit
Guttural pouch	38	Guttural pouch washes via endoscope
Other	161	Samples collected from all other sites
Pleural fluid	8	Samples from pleurocentesis
Postprocedural (orthopedic)	12	A nosocomial infection after a veterinary procedure involving either bone or a synovial structure
Postprocedural (soft tissue)	29	A nosocomial infection after a veterinary procedure involving soft tissues
Septic foal	14	Samples from neonatal foals (< 1 week of age) excluding umbilical submissions
Trachea	195	Any samples from either tracheal wash or broncho-alveolar lavage (BAL)
Umbilicus	12	Samples collected from the umbilicus of neonatal foals
Urine	25	Any urine submissions
Uterine	67	Routine uterine culture from pre-breeding examination
Wound (acute)	16	Any wound < 24 h old
Wound (chronic)	53	Any wound > 24 h old
Total	664	—

origin from the Veterinary Teaching Hospital (VTH) between 1st January 1998 and 31st December 2003 (Table 1). The majority of the cases (~75%) were 1st opinion cases from the Saskatoon area. The remainder were referral cases from British Columbia, Alberta, Saskatchewan, and Manitoba. All submissions were examined individually; submissions that resulted in no growth or the growth of nonsignificant organisms were not used in the remainder of the study. The clinical significance of isolated bacteria was based on the number of bacteria grown, the opinion that the veterinary bacteriologist expressed in the bacteriology report, and the examination of the medical record by a diplomate of the American College of Veterinary Internal Medicine in large animal medicine (Clark). Bacterial isolates were categorized according to sampling site (Table 1). In the review of the WCVM data, musculoskeletal infections were subdivided into traumatic wounds (involving skin, muscle, bone, and synovial structures) (both acute and chronic) and postprocedural infections associated with either soft tissue or orthopedic procedures. Isolates recovered from septicemic foals were considered separately and divided into 2 categories: those isolated from the umbilicus and those isolated from all other tissues and fluids, including blood cultures and joint fluid.

In vitro antimicrobial susceptibility testing was performed on significant aerobic bacterial isolates (antimicrobial susceptibility testing is not routinely performed on anaerobes by PDS) by using the disk diffusion method of Bauer et al (5), according to the standards of the Clinical and Laboratory Standards Institute (CLSI, formerly known as NCCLS) (6). Isolates were reported as susceptible to an antimicrobial if the diameter of the zone of inhibition was greater than the breakpoint for that drug, according to NCCLS Standard M31-A2 (6).

Results

Thirteen hundred and twenty-three equine submissions from clinic cases were made to the PDS bacteriology laboratory from 1998 to 2003. Six hundred and sixty-four submissions with 1026 significant bacterial isolates were consistent with bacterial infection. Although most samples were from active clinical cases, 84 of the isolates were recovered at postmortem examination. Bacterial isolates were categorized according to sampling site (Table 2). *Streptococcus equi* subspecies *zooepidemicus* (*S. zooepidemicus*) was the most common isolate from all submission sites, accounting for 22% (221/1026) of all isolates. This was followed by *Escherichia coli* (82/1026), *Actinobacillus suis* (69/1026), alpha-hemolytic streptococci (45/1026), and *Enterobacter* spp. (42/1026). *Rhodococcus equi* (6/1026) and *Salmonella* spp. (4/1026) were infrequent causes of bacterial infections in horses in western Canada. The in vitro antimicrobial susceptibility data for the most common bacterial isolates is presented in Table 3.

The respiratory tract was the most frequently sampled site in the study, with 334 isolates cultured from 195 transtracheal washes, 65 isolates cultured from 37 nasal swabs, and 49 isolates cultured from 38 guttural pouch washes. A few isolates were also obtained from cultures of lung and pleural fluid. From all sites, the most common isolate was *S. zooepidemicus* (150/334), followed by *A. suis* (57/334), *A. equuli* (40/334), and alpha-hemolytic streptococci (30/334). Infections from *S. equi*

Table 2. The numbers of submissions and most common bacterial isolates from various anatomical sites

Site	Number of sample submissions	Total number of bacterial isolates	Bacterial isolate	Number of isolates (% of cases with this isolate)
Trachea	195	334	*Streptococcus zooepidemicus*	79 (40.5%)
			Actinobacillus suis	44 (22.6%)
			Actinobacillus equuli	30 (15.4%)
			Streptococcus spp. (α-hem)	27 (13.8%)
			Enterobacter spp.	21 (10.8%)
			Escherichia coli	21 (10.8%)
			Actinobacillus spp.	14 (7.2%)
			Pseudomonas spp.	11 (5.6%)
			Serratia spp.	9 (4.6%)
			Staphylococcus aureus	7 (3.6%)
			Pseudomonas aeruginosa	7 (3.6%)
			Pasteurella spp.	7 (3.6%)
			Other	57
Uterine	67	87	*Streptococcus zooepidemicus*	31 (46.3%)
			Escherichia coli	12 (17.9%)
			Staphylococcus spp.	9 (13.4%)
			Enterococcus spp.	5 (7.5%)
			Streptococcus spp. (α-hem)	4 (6.0%)
			Other	26
Wound (chronic)	53	83	*Streptococcus zooepidemicus*	23 (43.4%)
			Escherichia coli	10 (18.9%)
			Enterococcus spp.	6 (11.3%)
			Actinobacillus suis	5 (9.4%)
			Pasteurella spp.	5 (9.4%)
			Other	34
Guttural pouch	38	49	*Streptococcus zooepidemicus*	10 (26.3%)
			Actinobacillus suis	7 (18.4%)
			Streptococcus equi	7 (18.4%)
			Enterobacter spp.	5 (13.2%)
			Actinobacillus equuli	5 (13.2%)
			Other	15
Postprocedural (soft tissue)	29	53	*Escherichia coli*	10 (34.5%)
			Staphylococcus aureus	7 (24.2%)
			Pseudomonas aeruginosa	5 (17.2%)
			Streptococcus zooepidemicus	4 (13.8%)
			Enterobacter spp.	4 (13.8%)
			Enterococcus spp.	4 (13.8%)
			Other	19
Urine	25	37	*Escherichia coli*	9 (36%)
			Streptococcus spp. (α-hem)	5 (20%)
			Enterococcus spp.	5 (20%)
			Other	18
Eye	19	29	*Streptococcus zooepidemicus*	13 (68.4%)
			Staphylococcus spp.	3 (15.8%)
			Streptococcus spp. (α-hem)	2 (10.5%)
			Corynebacterium spp.	2 (10.5%)
			Other	9
Wound (acute)	16	22	*Streptococcus zooepidemicus*	6 (37.5%)
			Enterobacter spp.	3 (18.8%)
			Pseudomonas aeruginosa	2 (12.5%)
			Staphylococcus aureus	2 (12.5%)
			Actinobacillus equuli	2 (12.5%)
			Enterococcus spp.	2 (12.5%)
			Other	5
Septic foal	14	20	*Escherichia coli*	5 (35.7%)
			Actinobacillus equuli	3 (21.4%)
			Streptococcus zooepidemicus	2 (14.3%)
			Streptococcus spp. (α-hem)	2 (14.3%)
			Other	8
Umbilicus	12	23	*Escherichia coli*	6 (50%)
			Streptococcus zooepidemicus	5 (41.7%)
			Clostridium perfringens	4 (33.3%)
			Enterococcus spp.	3 (25%)
			Other	5
Postprocedural (orthopedic)	12	17	*Streptococcus zooepidemicus*	6 (50%)
			Enterococcus spp.	2 (16.7%)
			Other	9
Pleural fluid	8	15	*Fusobacterium* spp.	2 (25%)
			Streptococcus zooepidemicus	2 (25%)
			Streptococcus pneumoniae	2 (25%)
			Other	9

α-hem — alpha hemolytic

Table 3. Antimicrobial in vitro susceptibility data for the most common bacterial isolates (susceptibility determined using the Clinical and Laboratory Standards Institute [CLSI] breakpoints for veterinary pathogens [6]). Numbers refer to the percentage of isolates classified as sensitive to the appropriate antibiotic

Isolate	Number of isolates	Amp	Cef	Ceph	Enro	Gen	Neo	Pen	Tet	TMS	Ery	Co-Am	Ami	Spec
Streptococcus zooepidemicus	221	92	99	99	91	85	20	95	59	55	91	87	5	87
Escherichia coli	82	62	94	50	91	80	61	0	65	62	6	84	100	81
Actinobacillus suis	69	87	100	99	99	70	30	59	91	96	25	100	38	48
Streptococcus spp. (α-hem)	45	89	100	100	86	89	53	89	93	75	89	83	55	100
Actinobacillus equuli	44	91	98	100	100	79	47	67	93	93	39	100	46	40
Enterobacter spp.	42	37	88	29	98	88	67	3	62	79	7	71	96	56
Staphylococcus aureus	36	55	97	100	97	100	83	55	97	100	84	94	100	29
Enterococcus spp.	28	96	29	36	46	75	33	86	64	68	50	100	25	67
Staphylococcus spp.	29	52	90	97	93	86	93	48	79	86	86	93	100	69
Streptococcus equi	22	100	100	100	95	95	0	100	92	79	100	100	0	100
Pseudomonas spp.	25	24	33	16	68	64	47	16	40	52	8	63	100	33
Pseudomonas aeruginosa	26	0	0	0	30	56	13	0	0	0	0	13	92	7
Actinobacillus spp.	22	95	95	95	100	73	25	68	91	95	14	91	33	18
Pasteurella spp.	17	94	100	100	100	100	100	72	100	100	67	100	67	100

Amp — Ampicillin; Cef — ceftiofur; Ceph — cephalothin; Enro — enrofloxacin; Neo — neomycin; Pen — penicillin; Tet — tetracycline; TMS — trimethoprim sulfa; Ery — erythromycin; Co-Am — Co-amoxyclav; Ami — Amikacin; Spec — spectinomycin

subspecies *equi (S. equi)* were uncommon, with only 22 isolates identified. The low number of *S. equi* isolates was most likely due to practitioners not submitting samples from obvious cases of "strangles." Opportunistic pathogens, such as *Pseudomonas* spp., *Enterobacter* spp., *Serratia* spp., and *Staphylococcus aureus* were typically cultured from cases with advanced respiratory tract lesions, such as chronic pleuropneumonia with abscessation.

Ninety-five percent of *S. zooepidemicus* isolates were susceptible to penicillin and 99% were susceptible to ceftiofur. Of the *S. equi* isolates, 100% were susceptible to both penicillin and ceftiofur; only 55% of *S. zooepidemicus* and 79% of *S. equi* isolates were susceptible to trimethoprim/sulphonamide (TMS) combinations. Other antimicrobials with good in vitro activity against *S. zooepidemicus* were ampicillin (92%), cephalothin (99%), and erythromycin (91%). Only 59% of isolates were susceptible to oxytetracycline. For *S. equi* isolates, 100% were susceptible to ampicillin, cephalothin, erythromycin, and ampicillin/sulbactam, while 92% were susceptible to oxytetracycline.

The 2nd most common site for bacterial culture was the reproductive tract of mares, reflecting the large equine theriogenology caseload and routine culturing as part of the prebreeding examination. A total of 87 isolates were cultured from 67 uterine samples. A further 15 isolates were collected from 11 mares that had recently aborted. The majority of isolates were *S. zooepidemicus* (31/87). The next most common isolate was *E. coli* (12/87). *Pseudomonas* spp. were cultured from 2 mares.

From horses with urinary tract infections, 25 cultures grew 37 isolates and the most common pathogen isolated was *E. coli* (9/37), followed by alpha streptococci (5/37) and *Enterococcus* spp. (5/37). Submissions represent both free catch samples and samples collected by catheterization. *Pseudomonas* spp., *Enterococcus* spp., or *Enterobacter* spp. were found in 25% of submissions and were resistant to most antimicrobials. The remaining isolates were a mixture of gram-positive and gram-negative bacteria.

Traumatic wounds involved skin, muscle, bone, and synovial structures. *Streptococcus zooepidemicus* predominated in both acute (6/23) and chronic wounds (23/83). Chronic wounds were more likely to be a mixed infection (83 isolates from 53 submissions), with a greater variety of bacteria.

Orthopedic infections occurred after fracture fixation, arthroscopy, arthrocentesis, and joint injections. Mixed infections were less common (17 isolates from 12 cases), and half of all animals were affected by *S. zooepidemicus* (6/12).

Twenty-nine isolates were cultured from 19 eyes with infectious keratitis. The majority of infections were due to *S. zooepidemicus* (13/29). The other isolates were alpha hemolytic streptococci, *Staphylococcus* spp., and *Corynebacterium* spp.

Bacterial isolates from septic foals were divided into 2 categories: isolates from the umbilicus and isolates from all other tissues and fluids, including blood cultures and joint fluid. Isolates from the latter category were mainly *E. coli* (5/20 isolates), similar to previous reports (3). Bacterial isolates from the umbilicus were similar to other foal isolates, except that mixed infections were more common (23 isolates from 12 cases); *Clostridium perfringens* was also isolated.

Discussion

Bacterial submissions

The usefulness of a review of clinical material depends on the quality of the available data. In this study, all bacterial isolates of equine origin from WCVM cases were evaluated. However, samples were not submitted from all cases. The decision to submit a sample for bacterial culture rested with the attending veterinarian and the samples submitted were probably biased towards the more unusual or more complex cases. However, this bias may have been reduced because clinicians at a teaching institution are more likely to perform routine bacterial cultures than are veterinarians at a private practice.

Antimicrobial susceptibility

Diagnostic laboratories routinely perform in vitro antimicrobial susceptibility testing on clinical isolates, and veterinarians use the results to guide antimicrobial therapy. Many laboratories use the disk diffusion method to determine bacterial susceptibility to various antimicrobials, even though the breakpoints for susceptibility or resistance have been validated only for ampicillin, ceftiofur, and gentamicin in the horse (M. Papich, personal communication). The difficulties of applying laboratory susceptibility data to the clinical situation have been well described (7), so susceptibility test results should only be considered as a guide to choosing appropriate antimicrobial therapy, not as a guarantee of efficacy. The in vitro antimicrobial susceptibility data presented in Table 3 differ from previously published data from horses (4). Antimicrobial resistance was not an apparent problem in the WCVM isolates, probably reflecting the large proportion of 1st opinion cases seen at this facility. The in vitro susceptibility rates of *S. zooepidemicus* to TMS combinations were much lower in the WCVM isolates than in those reported from veterinary teaching hospitals in other countries (3,8,9). The availability of TMS products suitable for use in horses varies among countries. With the availability of injectable formulations and convenient oral formulations, TMS is frequently administered to horses in western Canada for treatment of respiratory disease and other infections. Such frequent use may be selecting for TMS resistant populations. A recent study by Feary et al (10) described a similar rate of TMS resistance in equine isolates of *S. zooepidemicus.* However, a false rate of resistance may be reported if disk diffusion is not performed according to the exact CLSI standards. The PDS laboratory in Saskatoon follows the CLSI standards for determining susceptibility to TMS, including the running of appropriate quality controls, so the errors described by Feary et al (10) were avoided. Even if culture and sensitivity results indicate efficacy, the correlation with clinical efficacy is poor. Ensink et al (11) demonstrated in a clinical study that even prophylactic administration of appropriate doses of trimethoprim/sulfadiazine did not prevent infection and abscess formation when *S. zooepidemicus* was inoculated into tissue cages placed in the neck muscle of ponies. Only 5% of *S. zooepidemicus* isolates were susceptible to amikacin. This finding is clinically important, due to frequent recommendations for amikacin in the treatment of equine musculoskeletal infections (8), especially in regional perfusion treatment protocols (12). For the western Canadian caseload with a high frequency of *S. zooepidemicus* musculoskeletal infections, gentamicin is a more appropriate 1st choice aminoglycoside. The pharmacodynamics of gentamicin are similar to those of amikacin (both are concentration dependent antimicrobials and work well for regional perfusion), but gentamicin has a broader spectrum of activity than amikacin, with good activity against *S. zooepidemicus.* Amikacin should be reserved for cases where bacterial culture confirms the presence of organisms, such as *Pseudomonas aeruginosa* or *S. aureus,* that are resistant to the more commonly used antimicrobials. The in vitro susceptibility profile of the *S. aureus* isolates in this study is different to that in other surveys, in particular antimicrobial resistance is less prevalent (4). The antimicrobial susceptibility profiles for *E. coli* are similar to those described previously (4). The only truly multidrug resistant bacterial species that are isolated in any frequency are *Pseudomonas aeruginosa* and *Enterococcus* spp. These pathogens are typically resistant to many routinely used antimicrobials. Such susceptibility profiles are similar to those described previously (4), as multiple antimicrobial resistance in these species is both inherent and easily acquired (13).

Bacterial etiology of infection in horses

At the WCVM, bacterial infections were most commonly caused by organisms considered to be commensals of horses. These data are very different to those from United States teaching hospitals with tertiary care caseloads, where staphylococci and gram-negative pathogens are the most common isolates from equine infections (3,8,9). At the WCVM, infections caused by opportunistic pathogens, such as *S. aureus* and *Pseudomonas* spp., were uncommon and typically associated with severe lesions; their antimicrobial susceptibility patterns are suggestive of previous antimicrobial use.

Respiratory tract infection — The role of *S. zooepidemicus* and *S. equi* in equine respiratory tract infections has been well documented (2,14–19). *Streptococcus zooepidemicus* is considered to be a normal flora of the upper respiratory tract that becomes problematic when it invades the lower respiratory tract. Besides its association with "strangles," *S. equi* is known to cause persistent, guttural pouch infection without clinical signs (20,21), although other bacteria may also colonize the guttural pouch (22).

Penicillin, ceftiofur, and TMS are the usual 1st line treatment choices for streptococcal infections in horses (9). The results of the WCVM study support the use of penicillin and ceftiofur for treatment of bacterial sinusitis and guttural pouch infections, since there was a high degree of in vitro susceptibility ($> 90\%$) to these antimicrobials, but they suggest that TMS should only be used with appropriate culture and sensitivity results.

Pneumonia and pleuropneumonia are often polymicrobic in horses, with the lower respiratory tract being colonized initially by *S. zooepidemicus,* followed by gram-negative and anaerobic pathogens (2). The gram-negative bacteria *A. suis* and *A. equuli* were the most common isolates from pneumonia and pleuropneumonia cases after *S. zooepidemicus.* This is in contrast to a previous study in which it was found that *E. coli* and *Pasteurella* spp. were the most common gram-negative isolates (2). Anaerobes are likely to be present in those cases with a putrid breath odor, although lack of a putrid odor does not rule out the possibility of an anaerobic infection (23). In the WCVM study, only 9 anaerobes were isolated from transtracheal washes and they tended to be from cases with advanced disease. More virulent pathogens, such as *Pseudomonas* spp., *Serratia* spp., and *S. aureus,* were isolated from chronic cases with severe lesions. Enrofloxacin or gentamicin showed the greatest activity against the respiratory pathogens isolated at the WCVM; however, neither drug is efficacious against obligate anaerobes, and the susceptibility of *Pseudomonas* spp. and *Klebsiella* spp. was variable to both drugs. *Mycoplasma* spp. appear to be opportunistic pathogens in equine respiratory tract infections (24). *Mycoplasma* spp. were isolated from 6 horses with respiratory disease and in each case were part of chronic, mixed infections. Isolates from pleural fluid were submitted only from severe cases of pleuropneumonia and were most often mixed infections. The bacterial populations isolated were similar to those previously described (2,25), except that anaerobes were not isolated as frequently.

From the WCVM data, the most logical treatment choice for bacterial pneumonia or pleuropneumonia is a combination of penicillin, ampicillin, or ceftiofur with gentamicin or enrofloxacin. The use of gentamicin or enrofloxacin for respiratory infections in horses is extralabel, but it is consistent with prudent use guidelines in that it is based on culture and sensitivity testing. Practitioners should be familiar with the potential for adverse effects from either of these drugs and client consent should be obtained before initiating treatment (9). Antimicrobial therapy targeted against anaerobes improves survival rates of horses with pleuropneumonia (23). Although the β-lactam antimicrobials are highly effective against most anaerobes, resistance by betalactamase-producing *Bacteroides fragilis* has been documented (2). Oral metronidazole can be added to β-lactam therapy, as it is inexpensive and has excellent activity against all anaerobes, including *B. fragilis,* and good tissue distribution characteristics. While the WCVM data can guide practitioners in choosing initial therapy of respiratory tract infections, due to the frequency of mixed infections and variable susceptibilities of gram-negative isolates, culture and susceptibility testing from a transtracheal wash or pleural fluid sample should always be performed. Follow-up sampling should be considered, as bacterial populations and susceptibility patterns may shift as the disease progresses.

Reproductive tract infections — Except for the low prevalence of *Pseudomonas* spp., the culture results agreed with those of previous studies from other teaching hospitals (26,27). The majority of reproductive tract infections are limited to the mucosa and superficial endometrium; therefore, intrauterine therapy is the preferred method of treatment (28). Systemic therapy should be limited to cases of postpartum metritis where the mare shows systemic illness or where a uterine biopsy suggests deep inflammation and infection. Currently, treatment regimens (including drug, dose, frequency, and method of infusion) for endometritis in the mare are based more on convenience and practicality than on scientific evidence (28). In Canada, only gentamicin and amikacin are approved for intrauterine use in mares with endometritis. Based on the results from the WCVM study, gentamicin is the first choice for intrauterine treatment of endometritis. Since only 5% of *S. zooepidemicus* isolates showed in vitro susceptibility to amikacin, its use should be reserved for gram-negative isolates with documented resistance to gentamicin.

Urinary tract infections — Infection of the urinary tract in horses typically occurs as an ascending infection from skin and gastrointestinal flora (9). Previous reports of bacterial isolates of urinary origin demonstrate similar results to those presented here (29). Disk diffusion susceptibility breakpoints are based on achievable plasma concentrations, but most antimicrobials are eliminated in high concentrations in the urine. Therefore, in vitro susceptibility results do not always predict therapeutic efficacy for bacterial cystitis, as drugs reported as "resistant" may be clinically effective. From the WCVM data, ceftiofur is appropriate for initial therapy, due to its activity against *E. coli* and streptococci, but gentamicin or enrofloxacin may be necessary for treatment of *Pseudomonas* spp. or *Enterobacter* spp. infections, and ampicillin is the best choice for enterococcal infections.

Wounds — Bacterial isolates from musculoskeletal infections have been extensively reviewed (8,30,31), but all forms of musculoskeletal infection (septic arthritis, iatrogenic infections, and neonatal septicemia) were grouped together, regardless of the etiology. Consequently, the most commonly isolated bacteria were *Enterobacteriaceae*, non-β-hemolytic streptococci, and coagulase negative staphylococci. Due to the inclusion of septic foals and iatrogenic infections, there was a high rate of antimicrobial resistance in these studies. From these data, the combination of a cephalosporin and amikacin became the standard recommended antimicrobial therapy for all musculoskeletal infections (8).

Bacterial isolates from acute wounds must be cautiously interpreted as they may represent environmental contamination rather than active infection. The distinction between contamination and colonization is not absolute and must be based on the type of bacterium, history of the wound, and number of bacteria isolated. As infections become established, the bacterial populations may change. *Streptococcus zooepidemicus* and *Enterococcus* spp. were the only bacteria found in both categories.

Based on the data in Table 2, when a traumatic open wound that is either contaminated or infected or likely to become infected is treated, the chosen antimicrobial must be active against *S. zooepidemicus.* Since mixed infections are common (Table 2), a broad spectrum antimicrobial, such as ampicillin or ceftiofur, may be indicated while awaiting the results of bacterial culture (Table 3). Although the WCVM results support the in vitro efficacy of amikacin against *S. aureus* and *Pseudomonas* spp. isolates (100% susceptible), its in vitro activity against other common isolates was poor. Very few *S. zooepidemicus* bacteria were susceptible to amikacin (5%). Although gentamicin was deemed poorly effective for musculoskeletal infections in a previous study (8), it was highly active ($>$ 90% in vitro susceptibility) against the pathogens from the WCVM cases and is considerably less expensive than amikacin. Ceftiofur is also an appropriate antimicrobial choice for WCVM pathogens, except for poor activity against enterococcal infections (29% in vitro susceptibility).

Postprocedural infections — Iatrogenic infections differed between those involving soft tissue and orthopedic procedures. The majority of soft tissue infections were suture line infections. Most occurred following laparotomy and were likely related to anesthetic recovery in a "recovery room" that was wet and contaminated by fecal material. Surgical contamination appeared unlikely as peritonitis was not a feature of these cases. Consequently, *E. coli* predominated (10/53) and mixed infections were common (53 isolates from 29 submissions). Unlike in traumatic wound infections, *S. aureus* was relatively common (7/53 isolates) in iatrogenic infections. *Staphylococcus aureus* can be isolated from normal equine skin lesions (32); however, the specific association with iatrogenic wounds in this study raises the question as to whether humans represent a potential source of infection. Conversely, *Pseudomonas aeruginosa* (5/53) is often an environmental opportunist with inherent antimicrobial resistance mechanisms. The routine use of certain antimicrobials may directly select for infections caused by this bacterium (33).

The antimicrobial susceptibility patterns of the gram-negative isolates were highly variable; however, the *S. aureus* isolates were routinely susceptible to cephalosporins, enrofloxacin, aminoglycosides, tetracycline, and TMS. The frequency of *S. zooepidemicus* isolates and the lack of multidrug resistant strains of *S. aureus* suggest that these infections result from contamination with cutaneous flora, in contrast to the multiresistant strains associated with environmentally acquired infections reported from other equine hospitals (34).

The data from the WCVM cases indicate that a β-lactam antimicrobial is the treatment of choice for prophylaxis of orthopedic infections and that gentamicin is a better choice for soft tissue infections. These recommendations are appropriate for initial treatment; however, culture and susceptibility testing is mandatory for postsurgical infections in order to select appropriate antimicrobial therapy and to identify emerging nosocomial problems.

Bacterial keratitis — The large number of *S. zooepidemicus* isolates differs from a previous report of 63 cases of infectious keratitis in horses, where 58% of cultured isolates were gram-positive organisms and 48% were gram-negative, with nearly 50% of the gram-negative isolates being *Pseudomonas* spp. (35) Due to the consequences of nonresponsive or inadequately treated corneal infections in horses, it is reasonable to initiate treatment with broad spectrum antimicrobial therapy effective against staphylococci and pseudomonads (36). Gentamicin or triple antibiotic preparations are good initial choices. Triple antibiotic contains neomycin, bacitracin, and polymixin. Neomycin has good activity against *Staphylococcus* spp. and gram-negative bacteria. Polymixin B is rapidly bactericidal against gram-negative bacteria, including *Pseudomonas* spp. Polymixin B also binds and inactivates endotoxin, reducing inflammation and tissue destruction. Due to systemic toxicity, polymixin B is only used topically, so, typically it is not included on susceptibility reports from microbiology services. However, *P. aeruginosa* veterinary isolates are routinely susceptible to polymixin B (33). Like polymixin B, bacitracin is a topical product not routinely included on susceptibility reports. Bacitracin is active against gram-positive bacteria, with a mechanism of action similar to that of the ß-lactam antibiotics. Penicillins and cephalosporins are not used as commercial ophthalmic formulations, because of the risk of contact sensitization, so bacitracin is their equivalent (37). Human ophthalmic formulations of tobramycin and ciprofloxacin are available for the treatment of resistant *Pseudomonas* infections.

Neonatal sepsis — Escherichia coli was the most common isolate from foals. However, recent reports of sepsis in humans indicate the reemergence of gram-positive bacteria, such as *Enterobacter* spp. and *Enterococcus* spp., as the major causes of systemic sepsis coupled with resistance to multiple antimicrobials (38). This trend was also documented in a study of critically ill neonatal foals from Pennsylvania (3); however, we found no evidence of this trend in our small sample of foals from western Canada.

The mixed bacterial isolates recovered from the foals' navels probably indicate environmental contamination of the umbilical remnant. A previous report of umbilical infection in foals isolated bacteria from only 4 of 16 cases (39). *Escherichia coli, Streptococcus* spp., and *Proteus* spp. were the only organisms isolated in that study. Data from the WCVM isolates emphasize the need for culture and susceptibility testing of samples from septic neonates, but the majority of foal bacterial isolates were susceptible to ceftiofur.

Conclusion

There has been much discussion about the importance and scale of antimicrobial resistance in veterinary medicine (40). The results of this survey indicate that while there are a few specific instances of acquired antimicrobial resistance, it is uncommon in bacteria of equine origin in western Canada. Procaine penicillin G and gentamicin still appear efficacious for most equine infections, but the results presented here suggest that *S. zooepidemicus* has developed resistance to TMS. Potent, narrow spectrum antimicrobials, such as amikacin, should be reserved for those cases in which their need has been confirmed by bacterial culture and susceptibility testing.

Computerization has made database review practical and such reviews need to be conducted periodically, as pathogenic organisms and their in vitro antimicrobial susceptibilities may change with time or treatment. Practitioners can use this information to select appropriate initial antimicrobial therapy. Final selection of the optimal antimicrobial must also consider other factors, such as the site of infection, pharmacokinetics of the drug, risks of adverse side effects, cost of therapy, and effect of underlying diseases. CVJ

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