~~Clinical Bacterial Isolates and~~ Antibacterial Susceptibility Patterns of Clinical Bacterial Isolates from Reptiles (2005-2016)

Pak Kan Tang BVetMed; Stephen Divers BVetMed; Susan Sanchez PhD

Royal Veterinary College, North Mymms, Hertfordshire, AL9 7TA, UK (Tang), Department of Small Animal Medicine and Surgery (Divers, Tang), and Department of Infectious Diseases (Sanchez), College of Veterinary Medicine, University of Georgia, GA, 30602, USA.

Dr. Tang's present address is School of Veterinary Medicine, University College Dublin, Belfield, Dublin 4, Ireland.

Email address correspondence to Dr. Tang (ptang1@rvc.ac.uk)

STRUCTURED ABSTRACT

Objective – To identify the bacterial isolates and their corresponding sensitivity patterns from clinical cases and establish appropriate empirical antimicrobial agents in reptiles.

Design – Single-institutional retrospective study.

Sample populations – 96 reptiles, 127 samples, 61 positive bacterial culture with a total of 129 identified organisms.

Procedures – A retrospective analysis of medical records to identify bacterial culture submissions and sensitivity results from reptiles presented between January 2005 and December 2016 to the Veterinary Teaching Hospital at the University of Georgia were evaluated. Prevalence of bacterial genera and species were analysed. Results were subcategorised into Gram-negative bacteria and Gram-positive bacteria, and their susceptibility patterns against antimicrobial agents were reviewed.

Results – 48% of the submitted samples were cultured positive with a total of 129 bacterial isolates. *Pseudomonas* spp. and *Enterococcus* spp. were the most frequently identified Gram-negative and Gram-positive bacteria in reptiles, respectively. Our isolated Gram-negative bacteria demonstrated high sensitivities towards gentamicin (95.2%), tobramycin (91.5%), amikacin (86.1%) and trimethoprim-sulfamethoxazole (82.9%). Majority of Gram-positive bacteria were highly susceptible to doxycycline (100%), gentamicin (100%), chloramphenicol (91.7%) and ampicillin (83.3%). Gram-positive bacteria were consistently resistant to ceftazidime in our study population.

Conclusions and clinical relevance – This study highlights the different antimicrobial susceptibility results in aerobic Gram-negative and Gram-positive bacteria. Our results demonstrated that aminoglycosides, particularly amikacin, and potentiated sulphonamides are

appropriate empirical antibiotic choices in the presence of Gram-negative bacteria, while doxycycline or ampicillin are preferred initial choices for Gram-positive bacteria.

Abbreviations

AMR – Antimicrobial resistance

AAVLD – American Association of Veterinary Diagnosticians

CLSI – Clinical and Laboratory Standards Institute

EUCAST – European Committee on Antimicrobial Susceptibility Testing

MALDI-TOF MS – Matrix assisted laser desorption ionization-time of ~~fliught~~flight mass spectrometry

The discovery of antimicrobial agents was a major breakthrough in medicine in the twentieth century[1]. Since then, antimicrobials have become fundamental therapeutic agents for treating bacterial infections in both human and animals. Although the phenomenon of intrinsic and acquired antimicrobial resistance (AMR) has long been recognised, a rising trend of prevalence has become critically apparent[2,3]. To a large extent this has been driven by the selection pressures provoked by the increased popularity of antimicrobial drugs in both humans and animals[4]. Widespread AMR reduces the effectiveness of antimicrobial therapies against bacterial infection, results in treatment failure and increases clinical complications, leading to increased morbidity and mortai~~i~~liy[5]. AMR is considered a global crisis affecting humans, animals and the environment.

Some genera of bacteria are innately resistance to certain classes of antimicrobial agents through their inherent structural and/or functional characteristics; for example, *Enterococcus* is intrinsically resistant cephalosporins, clindamycin macrolides and fusidic acid and displays

low-level resistance to aminoglycoside[6–8], while *Pseudomonas* is naturally resistant to many antimicrobial agents, including most β-lactams, first generation quinolones, chloramphenicol, tetracycline, macrolides, potentiated sulfonamides and rifampicin[7,9]. Use of antimicrobial drugs exerts selective pressure on bacterial populations, allowing an emergence and spread of acquired resistance traits in the community. Many veterinary surgeons commonly treat reptiles empirically with broad-spectrum antibiotics, sometimes in the absence of a bacterial infection. This not only promotes the selection of resistant strains but also delays an accurate diagnosis. In addition, the unnecessary use of antimicrobials may cause adverse effects to the reptile[10]. Indeed, the routine use of broad spectrum antimicrobials implies a low level of expertise on the part of the clinician[11].

Reptiles have become increasingly popular as domestic pets over the last decades in Europe and United States[12,13]. As a result, captive reptiles are presented more frequently for veterinary attention and many of them have conditions with a bacteriological aetiology, either as a primary disease or secondary to husbandry deficiencies, viral infections and immunosuppression[14]. Nevertheless, it is noteworthy that clinically healthy reptiles have a resident gastrointestinal ~~microflora~~ microbiota which plays key roles in digestion and immune function; maintenance of commensal microflora is of paramount importance[11]. Therefore, an accurate definitive diagnosis of bacterial infection relies upon the demonstration of both a host pathological effect (e.g. cytology, histopathology) and the causative agent (e.g. bacterial culture). Furthermore, sensitivity testing (e.g. diffusion disc) is also necessary to modify drug selection due to resistance. Obviously, administration of empirical antibiotics may be necessary prior to the culture and sensitivity results in critical cases; however, the routine use of Gram stains still provides vital information to guide initial drug selection.

The principle objective of this study was to determine the most common bacterial isolates from clinical reptile cases, and their antimicrobial sensitivity patterns. Subsequently, this data was used to modify our service's antimicrobial stewardship policy and help direct empirical drug selection while awaiting culture and sensitivity results. We hypothesised that (1) the antimicrobial susceptibility testing results would be vastly different between Gram-negative and Gram-positive bacteria in reptiles, and (2) commonly advocated first tier drugs (e.g. potentiated sulphonamides, basic penicillins) would be largely ineffective, necessitating the use of more advanced drugs (e.g. fluroquinolones and ~~advanced~~ third or fourth generations of cephalosporins).

MATERIALS AND METHODS

Medical records review

The Veterinary Teaching Hospital medical records and the Athens Veterinary Diagnostic Laboratory databases at University of Georgia, College of Veterinary Medicine was searched for all reptiles (lizard, chelonian, snake and crocodilian) presented between 2005 and 2016, inclusive, from which samples were submitted for aerobic bacterial culture, and sensitivity testing. Submitted samples (fresh tissue, fluids, swabs[a]) were generally processed the same day as collection. Samples collected outside of normal laboratory hours were refrigerated at 4^{o}C until the next business day.

Bacteriological methods

Samples u~~U~~pon receipt at the laboratory were processed according to the microbiology laboratory standard operating procedures. The laboratory is accredited (most recent

accreditation: January 2018) by the American Association of Veterinary Diagnosticians (AAVLD) and fellows. Culture methodology varied depending on the site of collection and type of samples that were submitted for culture[15]. Appropriate temperature and incubation conditions (30°C in ambient atmosphere) were used. Samples were incubated for 48 hours before they were determined to be negative for bacterial growth. Bacterial isolates were identified using traditional biochemical reactions until 2014[16–19], when automated mass spectrometry microbial identification system[b] was used for all isolates. Organisms that were unable to be identified by matrix assisted laser desorption ionization-time of flight mass spectrometry (MALDI-TOF MS) were likely to be environmental bacteria. Sensitivities were performed using disc diffusion. Human break point interpretation following Clinical and Laboratory Standards Institute (CLSI) guidelines and European Committee on Antimicrobial Susceptibility Testing (EUCAST – updated and reviewed each year over the retrospective period) were used for all antibiotics tested[20,~~21,30–39,22,40,~~41,~~23–29~~].

Data Analysis

Digital medical records and microbiologic results were reviewed and tabulated using a computerised spreadsheet[c]. Each specimen was assigned to a specific category depending on the source of origin. Faecal samples were excluded from this study due to the presence of commensal ~~microflora~~microbes. All culture results without an antimicrobial susceptibility pattern were also excluded. If multiple samples from the same patient were collected within a 3-month period from the same site, subsequent samples were excluded from this study. Distinctions were made between reptiles treated with antimicrobial agents within a 14-days period prior to sample collection (“treated”) and the remaining populations (“untreated”). Isolated organisms were initially subcategorized into Gram-negative and Gram-positive

bacteria and their antimicrobial sensitivities were recorded. In addition, the antimicrobial susceptibility patterns of the five most common bacterial isolates were analyzed individually.

Statistical Analysis

Descriptive statistics were used to report the bacterial isolates and the susceptibility results. Bacterial culture results (positive or negative) were compared between treated and untreated reptiles using Chi-square ($\chi 2$) test. Statistical analyses were performed using commercially available software[d]. For all statistical analyses, values of $P < 0.05$ were considered significant.

RESULTS

Between 2005 and 2016, 131 samples originating from nine different sites (Table 1) of 100 reptiles (40 lizards, 30 chelonians, 29 snakes and 1 crocodilian) were initially submitted for bacterial culture and sensitivity testing (including two fecal samples which were subsequently excluded from this study). Two repeated submissions (one ocular sample and one external lesion sample from two lizards) were also excluded from the study. The most prominent isolates from each anatomical site are illustrated in Table 1. Out of the remaining 127 samples, 48% (n=61) cultured positive (21 lizards, 26 chelonians and 14 snakes), in which 14.8% (n=9) had come from reptiles that had received antimicrobial therapy, either systemically or topically, within the previous 14-days; no significant difference in the prevalence of positive culture was identified between treated (50%) and untreated groups (47.7%) (P=0.857) (Figure 1). Out of the 61 positive cultures, 129 isolates were identified (Table 2**)**. Of those, 74.4% were Gram-negative (n=96) and 25.6% were Gram-positive bacteria (n=33). The antimicrobial sensitivity results based upon Gram staining are reported

in Table 2. A total of 34 genera of bacteria were identified, and the five most frequently isolated were *Pseudomonas* (n=19), *Enterococcus* (n=15), *Morganella* (n=9), *Staphylococcus* (n=7) and *Escherichia* (n=7) (Table 3). Antimicrobial sensitivity results for each of these five genera are reported in Figures 2-6 and Supplementary materials~~Tables 4-8~~. Antimicrobials to which an important proportion of each genus of bacteria might be expected to exhibit intrinsic resistance are indicated by asterisks[7].

Gram-negative bacteria were generally susceptible to most aminoglycosides (except neomycin), second generation fluoroquinolones, advanced β-lactams and third generation cephalosporins. Sensitivity to trimethoprim-sulfamethoxazole (% S = 82.9%) was comparable to enrofloxacin (%S = 81.5%) or ceftazidime (%S = 81.0%). There was widespread resistance against penicillins, first and second generation cephalosporins, clindamycin, and azithromycin.

All Gram-positive isolates were susceptible to doxycycline, gentamicin and imipenem. Many isolates were susceptible to chloramphenicol, first and second generation cephalosporins, penicillins, tetracyclines, and bacitracin. However, they displayed resistance to third and fourth generation cephalosporins, clindamycin, fluoroquinolones, amikacin, and trimethoprim-sulfamethoxazole.

Pseudomonas spp. (n=19) were isolated from six different sources and were predominant~~ly~~ in external lesion/abscess (n=7) and oral specimens (n=6). They were susceptible to most aminoglycosides (except neomycin), second and fourth generation fluoroquinolones, third generation cephalosporins and advanced β-lactams. Interestingly, our analysis showed reduced efficacy of extended-spectrum penicillins, trimethoprim-sulfamethoxazole and

second generation of fluoroquinolones including enrofloxacin and orbifloxacin against *Pseudomonas* spp.

Enterococcus spp. (n=15) were isolated from seven remote sources and were principally in coelomic cavity (n=4), external lesion/abscess (n=3) and blood (n=3). All isolates were susceptible to doxycycline and gentamicin. Many isolates were also susceptible to broad spectrum beta-lactam antimicrobial agents. However, they showed resistance to most aminoglycosides (except gentamicin), ceftazidime, clindamycin, tetracycline, trimethoprim-sulfamethoxazole, and second generation fluoroquinolones.

Morganella morganii (n=9) was isolated from four different sample sites with external lesion/abscess (n=4) and oral cavities (n=3) being the prime locations. All isolates were susceptible to most of the antimicrobials, including aminoglycosides, fluoroquinolones, doxycycline, florfenicol and ticarcillin; a few isolates showed reduced sensitivity to trimethoprim-sulfamethoxazole (%S = 87.5%) and tetracycline (%S = 85.7%). However, there was widespread resistance against first generation cephalosporin, aminopenicillin and azithromycin.

Escherichia coli (n=7) was isolated from three different sample sites with external lesion/abscess (n=5) being the predominant location. The isolates were fully susceptible to almost all antimicrobial agents tested, including aminoglycosides, many second and third generation cephalosporins, chloramphenicol, doxycycline, trimethoprim-sulfamethoxazole and ticarcillin. However, first generation cephalosporin and aminopenicillin demonstrated antimicrobial resistance.

Staphylococcus spp. (n=7) was isolated from three remote origins with ocular being the predominant site (n=4). All isolates were generally susceptible to an extensive variety of antimicrobials, except some penicillins, ceftiofur, clindamycin and erythromycin.

A total of 22 isolated bacteria were collected from nine reptiles that had received either systemic and/or topical antibiotics, in which eight organisms from four samples displayed resistance to the antimicrobial agent administered: two *Pseudomonas* sp. and one *Monganella morganii* isolated from the oral cavity were resistant to azithromycin; one *Stenotrophomonas maltophilia* isolated from the nasal cavity showed resistance to ciprofloxacin; one *Enterococcus* sp. and one Gram-positive bacilli isolated from an external abscess/lesion showed resistance to ceftazidime; one *Streptococcus sobrinus* and one *Pseudomonas* sp. isolated from the oral cavity were resistant to enrofloxacin.

DISCUSSION

There are currently limited studies and reviews on the use of antimicrobial agents in reptiles and to date there is a lack of consensus on empirical antibacterial therapy[42]. Commonly, tThe rationale and justification on the empirical antibiotic therapy in reptiles is often imprudent and unconsidered[10,42]. Broad-spectrum antibiotics, especially enrofloxacin (second generation fluoroquinolone) and ceftazidime (third generation cephalosporin), have been overused as first-line antibiotics by primary veterinarians and it is common practice to employ antimicrobial therapy in the absence of a diagnosed infection[10]. Therefore, an appropriate antimicrobial stewardship program is of paramount importance in minimizing the development and implication of AMR. Despite position statements and publications on antibiotic stewardship from various domesticated animal veterinary groups and organizations,

the zoological field has been notably deficient in addressing this problem. To the authors' knowledge, this study is the first to report the clinical isolates and the corresponding antimicrobial susceptibility patterns from reptilian samples in the United States.

In the study reported here, a large proportion (52%) of samples submitted were cultured negative; although there are numerous factors that could have influenced the culture results including the locations and techniques of sampling, this may also reflect the inappropriateness of bacterial culture requested by the attending veterinarians. Of the positive cultures, Gram-negative bacteria are more commonly identified than Gram-positive bacteria, with a prevalence of 74.4% and 25.6%, respectively. While this predominance of Gram negatives has been well appreciated previously, it is important to note that isolated bacteria vary based on the source of sample (reptile species and anatomical location) due to their predilection for different environments[14]. Therefore, the prevalence of isolated bacteria cannot be determined and is beyond the scope of this study.

The findings from our study demonstrated that the Gram-negative isolates displayed high levels of sensitivities towards aminoglycosides, especially gentamicin, tobramycin and amikacin; of which the top three identified Gram-negative bacteria (*Pseudomonas* spp., *Morganella morganii* and *Escherichia coli*.) were all fully susceptible. Despite the well-known risk of renal injury associated with aminoglycosides they remain crucial first-line bactericidal agents against Gram-negative bacterial infections[43–45]. Gentamicin has a narrow margin of safety and has been reported to be more nephrotoxic than amikacin[45,46]. Consequently, when confronted with an initial Gram-negative result, the empirical use of tobramycin, amikacin or trimethoprim-sulfamethoxazole (83.6%S) may be safer and effective. However, it is noteworthy that the most frequently identified Gram-negative

bacteria (*Pseudomonas* sp.) and Gram-positive bacteria (*Enterococcus* sp.) are both innately resistant to trimethoprim-sulfamethoxazole[7]; empirical use of trimethoprim-sulfamethoxazole should be reconsidered in the presence of *Pseudomonas* sp. or *Enterococcus* sp. and antimicrobial therapy should be adjusted according to the sensitivity testing results. Despite the small number of *Salmonella* sp. isolated in the study, this organism is of importance regarding human health due to its nature of zoonotic risk[12,13]. We found that all isolates were all fully susceptible to trimethoprim-sulfamethoxazole, tobramycin and gentamicin.

Gentamicin was also highly effective *in-vitro* against Gram-positive bacteria in this study. However, it is worth noting that *Enterococcus* is considered innately resistant to aminoglycosides[7] and the results obtained from using the high concentration discs in antibiograms may not be applicable as monotherapy clinically. Of the effective alternatives, doxycycline or ampicillin are obvious choices for a first line drug, because imipenem (carbapenems) and vancomycin (glycopeptides) should be avoided and reserved for more serious life-threatening and multi-resistant infections[47–50]. Chloramphenicol should also be reserved given its bacteriostatic nature and only used when required by sensitivity results[10]. Surprisingly, all Gram-positive isolates were resistant to ceftazidime (third generation cephalosporin), a semi-synthetic, broad-spectrum, bactericidal, beta-lactam antibiotic commonly used in reptile medicine[51,52]. This drug should be reserved for refractory infections to decrease the risk of beta-lactamase development and resistance[53,54]. As a result, the routine use of ceftazidime as a first-line drug is discouraged, unless specifically indicated by Gram stain or sensitivity results.

In this study, samples were obtained from both untreated and antibiotic-treated reptiles. Although this may limit the validity of results, it reflects the reality of clinical reptile cases

presented to referral hospitals or for second opinions. Our results also demonstrated that the prevalence of positive culture did not differ significantly between treated and untreated reptiles, which raises questions of appropriate drug dosing and efficacy. Repeated submissions from the same animal collected from the same site within a 3-month period were excluded from this study to avoid selection bias of organisms and the corresponding susceptibility patterns. Nevertheless, any samples collected from different body sites and/or obtained at least three months apart were included; however, the occurrence of multiple submissions from the same animal was 6.3% (n=8).

The most important limitation of this study pertains to its retrospective nature, including the variation of drug discs used in antibiograms for susceptibility testing across the study timeframe according to the recommended methods for disk diffusion susceptibility testing[32,33]. Some drug discs appear in antibiograms intermittently and infrequently; this reduced the validity of the susceptibility results from those antimicrobial drugs. Another limiting factor was the small number of culture and sensitivity results obtained from most genera. Additional limitation includes the absence of Gram-staining results in this study and the current lack of published agreement between Gram-staining results and bacterial culture in reptiles. Nevertheless, Gram staining remains an easy and rapid technique for the detection and differentiation of Gram-positive and Gram-negative bacteria in clinical practice, and should be used to help direct initial drug selection while pending culture and sensitivity results.

Initial selection of antimicrobials cannot be guided by the results of bacterial culture and sensitivity assays. In critical cases where bacterial infections are strongly indicated, such as septicemia and other acute, life-threatening infections, empirical selection of antimicrobial

agent should be directed by direct Gram smears as well as the likely organisms found at specific anatomical locales, spectrum of antimicrobial activity, potential adverse effects, pharmacokinetics, and practicality of administration[53,55]. Antibacterial drugs with the narrowest spectrum of activity should always be considered first; not only does this allow veterinarians to select antimicrobials that are most likely to be effective, but also limits the collateral damage to the commensal microflora and minimizes the development of resistant pathogens[53,55].

Prospective investigations are required to further evaluate the pharmacokinetics and pharmacodynamics of the first-line antimicrobial agents in different species of reptiles. Future study to investigate the trends of antimicrobial susceptibility in bacterial isolates from reptiles is warranted and standardization of antimicrobial drug discs used in antibiograms, or a move to a more quantifiable approach (e.g. minimal inhibitory concentration) is recommended. Further prospective studies are also needed to evaluate the correlation between results from bacterial cultures and Gram's stains in reptiles as only fair agreement was shown in amazon parrots.[56] In addition, further investigation of clinical antibiotic drug efficacy is required, since the *in vitro* susceptibility results may not always predict the clinical response.

In conclusion, the findings from this retrospective study highlight the different antibacterial susceptibility results from Gram-negative and Gram-positive bacteria cultured from clinical reptiles cases. It is recommended to perform Gram staining technique on direct smears when considering the initial use of empirical antibiotic therapy. As such, the presence of Gram-negative bacilli (most likely *Pseudomonas* spp., *Morganella morganii*. and/or *Escherichia coli*.) may indicate that amikacin, tobramycin or trimethoprim-sulfamethoxazole are appropriate first-line choices, while awaiting bacterial culture and sensitivity results. In

addition, doxycycline or ampicillin appears to be the most suitable first-line choices against Gram-positive infections (most likely *Enterococcus* spp. and/or *Staphylococcus* spp.). Our *in-vitro* susceptibility results demonstrate the complete ineffectiveness of ceftazidime against Gram-positive bacteria and it has no superior efficacy against Gram-negative bacteria compared with other antimicrobial agents (including trimethoprim-sulfamethoxazole). Future reptile pharmacokinetic studies should focus on first line drugs like doxycycline, trimethoprim-sulfamethoxazole and basic penicillins, rather than the newest fluoroquinolones, cephalosporins or advanced penicillins.

FOOTNOTES

a. BBL culture swab, Becton Dickinson, Franklin Lakes, NJ.

b. Vitek® MS, BioMérieux, Durham, NC.

c. Excel version 15.38 for Mac, Microsoft Corporation, Redmond, WA.

d. SPSS Version 24, IBM Corporation, Armonk, NY.

AUTHOR NOTE

Data from this study was presented in abstract form at ExoticsCon 2018, Atlanta, GA.

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Table 1. Summary of the origin of samples and the predominant isolates.

Sample Location	Number	Isolates	Most common isolates
External lesion/abscess	21	20	*Pseudomonas* sp. (15.2%, n=7)
Ocular	10	13	*Staphylococcus* sp. (18.2%, n=4)
Oral cavity	11	14	*Pseudomonas* sp. (24%, n=6)
Respiratory	8	11	*Stenotrophomonas* sp. (21.4%, n=3)
Coelomic cavity	6	7	*Enterococcus* sp. (36.4%, n=4)
Blood	2	4	*Enterococcus* sp. (50%, n=3)
Miscellaneous	2	3	*Salmonella* sp. (50%, n=2)
Bone	1	1	*Clostridium* sp. (100%, n=1)

Figure 1. Proportion of reptiles in retrospective study classified by culture results and status of prior antimicrobial treatment. The prevalence of positive culture did not differ significantly between reptiles received antibiotics 14-days prior to sample collection (50%) and untreated reptiles (47.7%) (P=0.857).

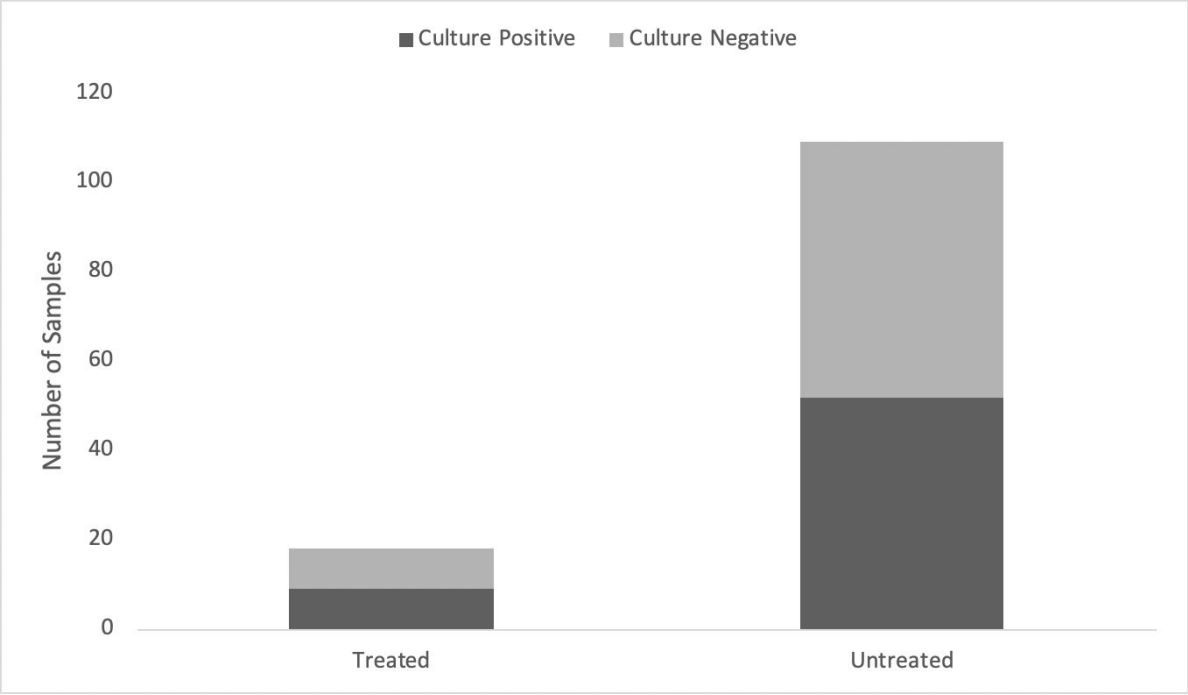

Table 2. Antimicrobial susceptibility patterns of Gram-negative and Gram-positive bacteria isolated from reptilian samples obtained from the Zoological Medicine Service in the Veterinary Teaching Hospital, University of Georgia (2005-2016).

Antimicrobial	Gram-negative Bacteria (n=96)				Gram-positive Bacteria (n=33)			
	Total Number	% S	% R	% I	Total Number	% S	% R	% I
Amikacin	79	86.1	10.1	3.8	16	43.8	56.3	0.0
Amox/Clav	70	38.6	60.0	1.4	26	80.8	7.7	11.5
Ampicillin	50	36.0	62.0	2.0	18	83.3	16.7	0.0
Azithromycin	22	13.6	72.7	13.6	9	44.4	44.4	11.1
Bacitracin	11	18.2	81.8	0.0	8	87.5	12.5	10.0
Carbenicillin	9	66.7	22.2	11.1	-	-	-	-
Cefazolin	12	33.3	58.3	8.3	9	66.7	33.3	0.0
Cefotaxime	12	25.0	58.3	16.7	-	-	-	-
Cefotetan	10	40.0	50.0	10.0	-	-	-	-
Cefpodoxime	22	59.1	36.4	4,5	1	0.0	0.0	100.0
Ceftazidime	42	81.0	16.7	2.4	11	0.0	100.0	0.0
Ceftiofur	24	70.8	25.0	4.2	14	64.3	28.6	7.1
Cephalothin	53	37.7	60.4	1.9	6	83.3	16.7	0.0
Chloramphenicol	34	82.4	5.9	11.8	12	91.7	0.0	8.3
Ciprofloxacin	31	74.2	19.4	6.5	11	36.4	18.2	45.5
Clindamycin	19	0.0	100.0	0.0	17	11.8	82.4	5.9
Doxycycline	19	68.4	26.3	5.3	6	100.0	0.0	0.0
Enrofloxacin	81	81.5	9.9	8.6	26	34.6	23.1	42.3

Erythromycin	1	0.0	0.0	100	17	41.2	35.3	23.5
Florfenicol	22	59.1	31.8	9.1	11	81.8	9.1	9.1
Gatifloxacin	7	85.7	14.3	0.0	7	71.4	14.3	14.3
Gentamicin	62	95.2	4.8	0.0	6	100.0	0.0	0.0
Gentamicin (120mcg)	1	100.0	0.0	0.0	7	100.0	0.0	0.0
Imipenem	7	85.7	14.3	0.0	4	100.0	0.0	0.0
Marbofloxacin	1	100.0	0.0	0.0	2	50.0	0.0	50.0
Neomycin	19	52.6	26.3	21.1	9	66.7	33.3	0.0
Nitrofurantoin	5	20.0	80.0	0.0	1	0.0	100.0	0.0
Ofloxacin	19	94.7	5.3	0.0	9	55.6	33.3	11.1
Orbifloxacin	32	53.1	25.0	21.9	20	10.0	60.0	30.0
Oxacillin	1	0.0	100.0	0.0	6	33.3	66.7	0.0
Penicillin	23	4.3	95.7	0.0	22	77.3	22.7	0.0
Polymyxin B	19	78.9	21.1	0.0	9	55.6	22.2	22.2
Rifampin	-	-	-	-	5	80.0	0.0	20.0
Tetracycline	55	72.7	23.6	3.6	19	78.9	21.1	0.0
Ticarcillin	62	75.8	19.4	4.8	-	-	-	-
Tobramycin	71	91.5	8.5	0.0	9	66.7	33.3	0.0
Trimethoprim/Sulfa	70	82.9	11.4	5.7	17	52.9	41.2	5.9
Vancomycin	3	100.0	0.0	0.0	1	100.0	0.0	0.0

Table 3. Genera of bacteria isolated from all reptilian samples submitted for culture and sensitivity from the Zoological Medicine Service in the Veterinary Teaching Hospital, University of Georgia (2005-2016). The top five identified genera of bacteria are highlighted in bold. *Pseudomonas* sp. (n=19) and *Enterococcus* sp. (n=15) were the most common Gram-negative and Gram-positive bacteria isolated, respectively.

Genus	Number
Pseudomonas	**19**
Enterococcus	**15**
Aerobic Gram-negative Bacilli (non-specific)	10
Morganella	**9**
Escherichia	**7**
Staphylococcus	**7**
Corynebacterium	5
Proteus	5
Stenotrophomonas	5
Salmonella	4
Enterobacter	4
Providencia	4
Aeromonas	3
Chryseobacterium	3
Citrobacter	3
Klebsiella	3
Pasteurella	3
Acinetobacter	2
Moraxella	2

Streptococcus	2
Aerobic Gram-positive Bacilli (non-specific)	1
Actinomycete	1
Alcaligenes	1
Bordetella	1
Chryseomonas	1
Comamonas	1
Clostridium	1
Empedobacter (*Flavobacterium*)	1
Aerobic Gram-positive Cocci	1
Ochrobactrum	1
Pantoea	1
Psychrobacter	1
Serratia	1
Vibrio	1

Figure 2. Percentage sensitive (% S) and percentage resistance (% R) of *Pseudomonas* spp. isolated from reptilian samples obtained from the Zoological Medicine Service in the Veterinary Teaching Hospital, University of Georgia (2005-2016). Antimicrobials to which an important proportion of *Pseudomonas* spp. might be expected to exhibit intrinsic resistance are indicated by asterisks.

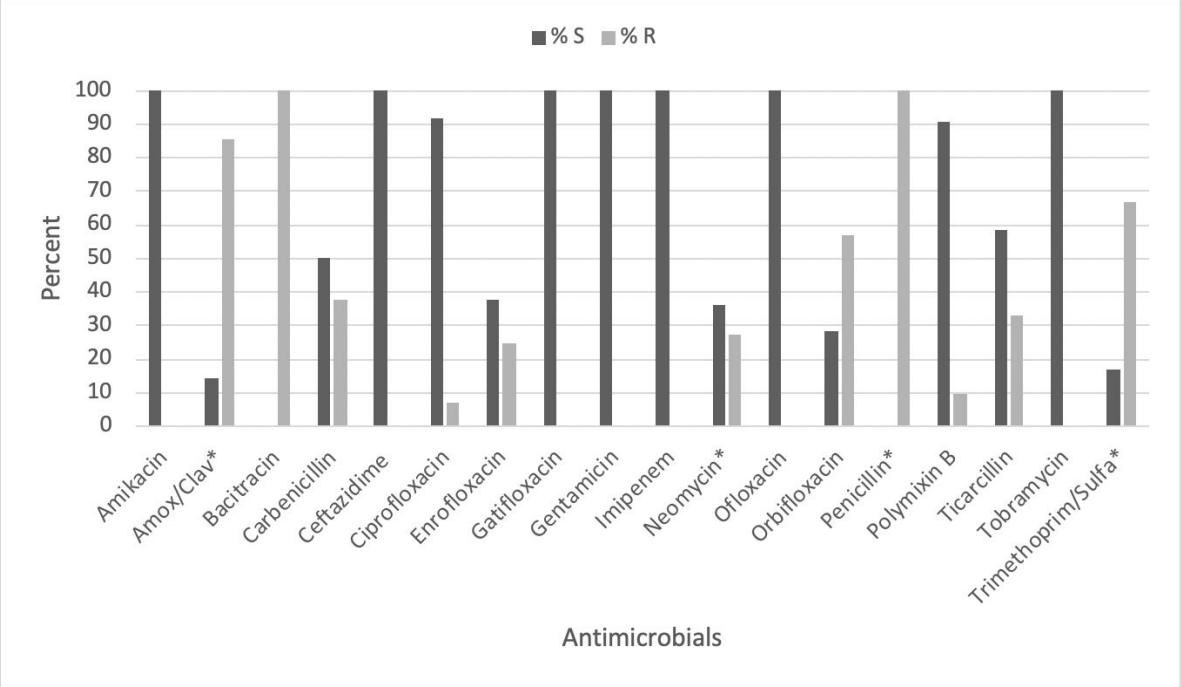

Figure 3. Percentage sensitive (% S) and percentage resistance (% R) of *Enterococcus* spp. isolated from reptilian samples obtained from the Zoological Medicine Service in the Veterinary Teaching Hospital, University of Georgia (2005-2016). Antimicrobials to which an important proportion of *Enterococcus* spp. might be expected to exhibit intrinsic resistance are indicated by asterisks.

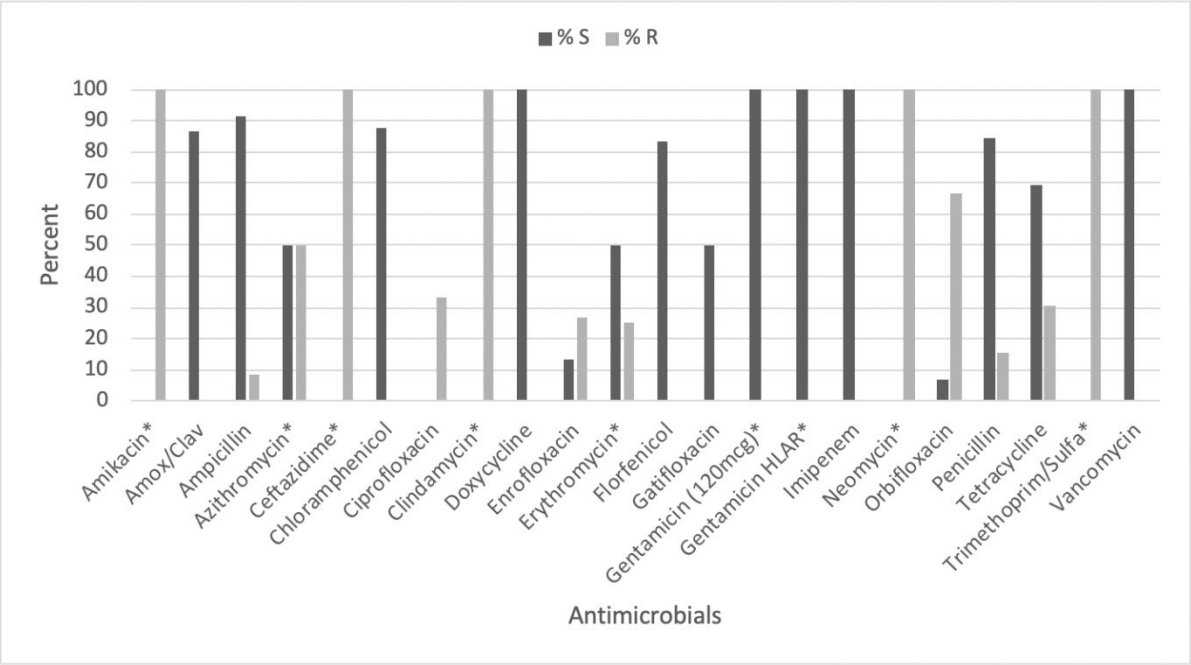

Figure 4. Percentage sensitive (% S) and percentage resistance (% R) of *Morganella morganii*. isolated from reptilian samples obtained from the Zoological Medicine Service in the Veterinary Teaching Hospital, University of Georgia (2005-2016).

Antimicrobials to which an important proportion of *Morganella morganii* might be expected to exhibit intrinsic resistance are indicated by asterisks.

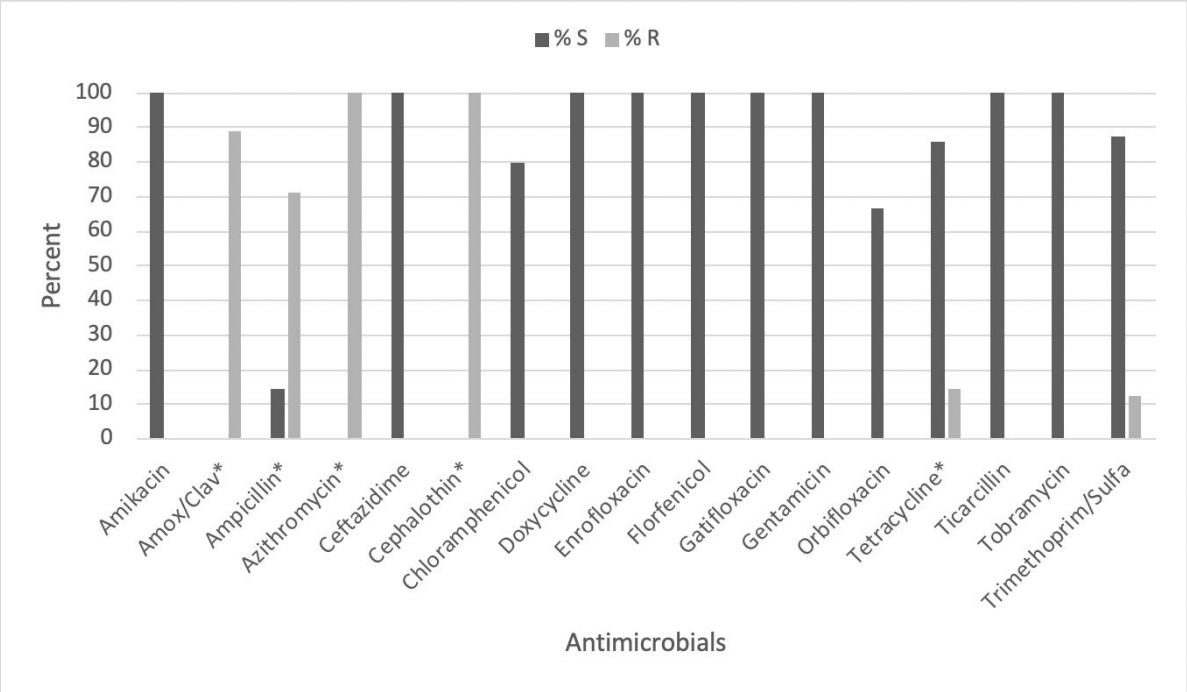

Figure 5. Percentage sensitive (% S) and percentage resistance (% R) of *Escherichia Coli* isolated from reptilian samples obtained from the Zoological Medicine Service in the Veterinary Teaching Hospital, University of Georgia (2005-2016).

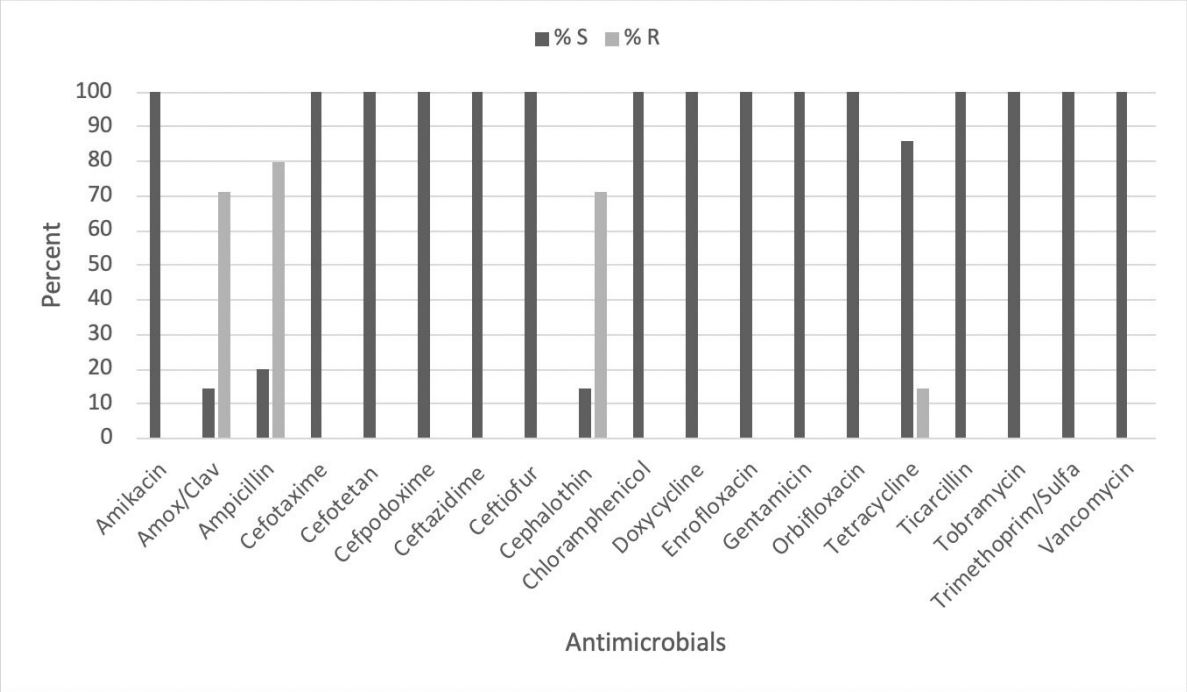

Figure 6. Percentage sensitive (% S) and percentage resistance (% R) of *Staphylococcus* spp. isolated from reptilian samples obtained from the Zoological Medicine Service in the Veterinary Teaching Hospital, University of Georgia (2005-2016). Antimicrobials to which an important proportion of *Staphylococcus* spp. might be expected to exhibit intrinsic resistance are indicated by asterisks.