UCDAVIS
VETERINARY MEDICINE
Students Training in Advanced Research

Predicting Antimicrobial Resistant Bacteriuria in Dogs Using Machine Learning

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Introduction

Antimicrobial resistance is increasing and having a substantial impact on both human and animal health. According to a published report from the CDC [1], about 2.8 million infections in people were caused by an organism harboring antimicrobial resistance. In dogs, methicillin resistance in *Staphylococcus pseudintermedius* isolates increased from <5% to near 30% over six years [2]. Another study assessing urinary tract infections (UTIs) in companion animals demonstrated that organisms most commonly responsible for UTIs, including *Escherichia coli*, *Proteus* spp., and *Enterobacteriaceae* spp., had significant increases in resistance over 16 years [3].

Clinical Significance in Veterinary Medicine

Current standard of care for simple UTIs in dogs allows for empiric treatment with amoxicillin [4]. Increasingly, dogs are not responding to empiric antimicrobials because of increasing antimicrobial resistance.

The goal of this project is to ultimately provide veterinarians with a tool that will act as a guide to alert clinicians when a patient may have high risk for antimicrobial resistant UTI and ineffectual empiric antimicrobial therapy.

Machine Learning

A machine learning (ML) model is a series of statistical models that can learn patterns in datasets to make predictions about new pieces of information.

Applications in veterinary medicine:

- Prediction of kidney disease in cats up to 2 years prior to clinical diagnosis [5]
- Accurate screening for Addison's disease in dogs [6]
- Prediction of fecal shedding of multidrug resistant bacteria in cows [7]
- Accurate calculation of canine heart size from radiographs [8]

Hypothesis

Patient risk factors and clinical data can be used to train a machine learning model that can predict the presence of antimicrobial resistant (AMR) bacteriuria.

Specific Aim 1: Machine learning model that can predict resistance to Amoxicillin

Specific Aim 2: Machine learning model that can predict multidrug resistance (MDR). For this study, MDR was defined as resistance to 3 or more different antimicrobial drug classes.

Study Design

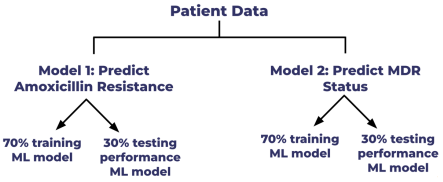
- Retrospective study (January 5, 2015 – February 8, 2021)
- Dogs presenting to the VMTH
- Inclusion criteria: urinalysis and positive urine culture and susceptibility
- Target sample size determined by the number of features included in the machine learning models

Methods and Procedures

Phase 1 – Data Curation and Labeling

- Underlying conditions: Cushing's disease, Addison's disease, hyperthyroidism, hypothyroidism, kidney disease, history of urinary stones, hind limb paralysis

Phase 2 – Model Training and Performance Assessment



Utilized PyCaret, a machine learning library in Python coding software, to train the machine learning models with jinja2, pandas, sklearn, and matplotlib packages.

Results and Conclusions

1,192 patients included in the study

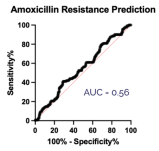
- 36% (430/1,92) had an organism that was resistant to amoxicillin.
- 53% (634/1,192) had an organism that was multidrug resistant.

Model 1: Amoxicillin Resistance Prediction Model

Random Forest Classifier Model

Total: 357	Amoxicillin resistant (+)	Amoxicillin resistant (-)
Prediction (+)	TP 20	FP 24
Prediction (-)	FN 121	TN 192
	141	216

Accuracy 82% | Sensitivity 14% | Specificity 89%



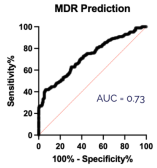
- Poor predictive performance
- No reliable clinical application

Model 2: Multidrug Resistance Prediction Model

Gradient Boosting Classifier Model

Total: 358	MDR (+)	MDR (-)
Prediction (+)	TP 122	FP 62
Prediction (-)	FN 64	TN 110
	186	172

Accuracy 65% | Sensitivity 66% | Specificity 64%



- Fair predictive performance
- Potential clinical usage with tuning and an increased population size

Limitations

- Bias: body of patients included in the study may not be representative of the general population
- Sample size
  - A conservative estimate of 11 features to be included in the models was initially decided
  - 27 features were ultimately included for the amoxicillin resistance prediction model and 26 were included for the MDR model

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