Cleveland Clinic Innovations

Machine learning algorithms to predict urine culture resistance to antibiotics

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PRODUCT

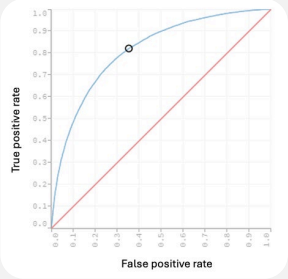
Adaptable and dynamic machine learning algorithm that accurately predicts antibiotic resistance.

VALUE PROPOSITION

Assists clinician in optimizing antibiotic selection up to 3 days prior to culture results, improve patient outcomes, reduce time to resolution of symptoms, limit adverse sequelae of prolonged antibiotic burden, and reduce clinical workload.

DEVELOPMENT STAGE

Machine learning algorithms and models were trained and validated using 560,653 cultures, and were tested on 6.5 million cases.



The graph of vancomycin shows the receiver operating characteristic (ROC) curve for the machine learning algorithm prediction for vancomycin resistance of an isolated organism on urine culture. The algorithm is indicated in blue, and the line of ignorance, which corresponds to random guessing, is indicated in red. The area under the receiver operating characteristic curve (AUC) is 0.81.

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UNMET NEED

Antibiotic resistance is serious and growing global problem. The standard method for diagnosing urinary tract infections (UTI) is a urine culture, which can take up to 72 hours to produce results. During the time window from culture collection to final results, patients with suspected UTIs are given antibiotics based on their symptoms and risk factors. However, this approach often leads to prescribing antibiotics that are not effective against the bacteria causing the infection, which requires changing the treatment later. To improve the quality, safety, and value of care for patients with UTIs, we developed machine learning algorithms that can predict antibiotic resistance based on individual patient characteristics at the time of urine culture collection, three days before the final results are available at our multi-hospital healthcare system. These algorithms can help clinicians choose the best antibiotic for each patient, which can improve patient outcomes by reducing the time to symptom relief and minimizing the negative effects of unnecessary or prolonged antibiotic use. They can also reduce the clinical workload for clinicians and the healthcare costs for society.

MATERIALS & METHODS

Urine cultures with sensitivities were identified from the electronic medical record (EMR) for the past seven years. Patient factors known or hypothesized to be associated with antibiotic resistance were also collected from the EMR and used for model training. A series of machine learning algorithms were trained to predict resistance in eleven of the most clinically relevant antibiotics used to treat UTIs. Bootstrapping and external validation methods were used to calculate the areas under the receiver operating characteristic curve (AUC).

RESULTS & CONCLUSION

We used 560,653 cultures with sensitivity/resistance data to train and validate our models. This cohort enabled us to test 6.5 million antibiotic sensitivity/resistance cases. The top performing models were ensemble algorithms, which could predict antibiotic resistance for most of the tested antibiotics with an AUC of 0.75 before culture data was available. For example, the models accurately predicted vancomycin resistance with AUC 0.81 (accuracy 0.73, precision 0.70, recall 0.82). We identified the most relevant factors in each model using a drop-out method. When an organism was identified via culture, but sensitivities were not yet available, the algorithms were increasingly accurate. For example, when an organism is identified, nitrofurantoin resistance was predicted with AUC 0.93.

We have now incorporated these algorithms into an application, which allows for antibiotic selection suggestions. The application iteratively updates as new data (urinalysis, urine culture data) become available, and will incorporate patient allergies and expert rules associated with intrinsic resistance of organisms to specific antibiotics. Machine learning algorithms have been successfully developed to accurately predict microbial resistance to clinically relevant antibiotics for urinary tract infection, approximately 72 hours prior to receiving cultures results. The results have important implications for the reduction of antibiotic resistance pressure, through more accurately targeted therapy. Further, clinical implementation of such algorithms will reduce time to resolution of symptoms and healthcare expenditures at the individual and population levels, improving the value of care for all parties.