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Machine Learning Application to Combat Superbugs in Hospitals: A Primer to Infection Prevention Practitioners

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Abstract

Healthcare-Associated Infections (HAIs) which defined as infections arising and developing during hospital stay or during the process of medical care in healthcare facilities. HAIs represent the most serious threat to patient safety, and it also represent global public health concern. HAIs have a significant clinical as well as financial impact due to prolonged hospitalization, increased mortality, and morbidity, increased antimicrobial resistance and increased direct costs for medical services. Surviellance in its conventional way, in which every patient's file is reviewed for the presence of HAIs, is time consuming and labor intensive. To improve the efficiency and strength of infection prevention and surveillance systems, information technology, data science and artificial intelligence have been recently applied. We need tools that help prediction, early diagnosis, surveillance, and treatment of HAIs to prevent human efforts of disease containment from being overwhelmed.

Keywords: Machine learning; Hospital infections; Artificial intelligence; Prediction; Infection control; Help prediction; Early diagnosis; Surveillance; Pneumonia; Surgical Site Infections

Abbreviations: AI: Artificial intelligence; AISE: Artificial Intelligence Sepsis Expert; AMR: Antimicrobial resistance; BSI: Blood stream infection; CDI: Clostridium difficile infection; CDS: Clinical decision support; EHR: Electronic health record; HAIs: Healthcare-associated infections; IPC: Infection prevention and control; MDR: Multi-drug resistant; ML: Machine learning; SSI: Surgical site infection; UTI: Urinary tract infection

Introduction

Healthcare-Associated Infections (HAIs) which defined as infections arising and developing during hospital stay or during the process of medical care in healthcare facilities. It is also defined as infections which are not present or incubating when the patient is hospitalized and are acquired after 48 hours of hospital stay [1]. HAIs represent the most serious threat to patient safety, and it also represent global public health concern [2]. HAIs have a significant clinical as well as financial impact due to prolonged hospitalization, increased mortality, and morbidity, increased antimicrobial resistance and increased direct costs for medical services [2]. Antimicrobial resistance is on the rise, raising worries about the impact on individuals with multidrug resistance bacteria [3]. As a result, significant efforts have been made to investigate the clinical outcomes of patients infected with such pathogens, which have shown higher mortality and treatment failure rates than those infected with susceptible isolates [3]. The rise of resistant hospital pathogens has posed a difficulty to providing high-quality in-patient treatment. The overuse of antibiotics in hospitals is largely to blame for this problem [4]. Resistant bacterial infections have a negative impact on the treatment outcomes, cost, disease spread, and sickness duration, offering a severe challenge to future chemotherapies [4].

The systematic collection of data on the occurrence of HAIs, analysis, and transformation of the data into valuable information, and dissemination of this knowledge with those who may take action to avoid HAIs are all part of HAIs surveillance systems [5]. The first criteria in an infection preventionist's minimum standard of practice are surveillance and epidemiology [5]. Already 40 years ago, many studies proved that there is 32% reduction in HAIs rates in hospitals with active surveillance programs compared with those without such programs [6]. The first goal of any surveillance system is to determine infection rates, infection sites, common pathogens, and antibiotic use, as appropriate empiric therapy is recognized to be the most crucial component in patient's outcome. As a result, it is crucial to identify the microorganisms that cause infections as well as their antimicrobial resistance pattern to find the optimal antimicrobial treatment [6]. Surviellance in its conventional way, in which every patient's file is reviewed for the presence of HAIs, is time consuming and labour intensive [5]. To improve the efficiency and strength of infection prevention and surveillance systems, information technology, data science and artificial intelligence have been recently applied. We need tools that help prediction, early diagnosis, surveillance, and treatment of HAIs to prevent human efforts of disease containment from being overwhelmed.

Definition of Artificial Intelligence and Machine Learning

Artificial Intelligence (AI), which is defined as computer algorithms with cognitive-like characteristics such as learning capabilities, is already having an impact on our lives in a variety of ways [7]. In radiology, dermatology and pathology, AI-assisted image analysis has already established a significant position. In genomics, another data-intensive science, AI aids in the prediction of phenotypes from genotypes [7]. Also, AI has been applied in infectious disease management specially to aid the detection and prevention of diseases [7]. The application of AI in healthcare began with the creation of expert systems based on rules extracted from interviews with medical specialists and experts, which were then translated and programmed [8]. The first expert system in medicine was developed in 1976 aiming at suggesting antimicrobial treatment for severe bacterial infections [8]. Machine Learning (ML) considered a subset of AI, demonstrates the experiential "learning" associated with human intelligence, while also having the ability to learn and improve its analysis via the use of computing algorithms [9]. These algorithms recognize patterns and effectively "learn" to teach the computer to make autonomous suggestions or decisions using vast volumes of data inputs and outputs. The machine can take and input and anticipate a result with enough repetitions and modifications to the algorithm [9]. The algorithm's accuracy is then judged by comparing the output to a collection of known outcomes, which is then iteratively changed to perfect the capacity to anticipate future results [9]. The predictive capabilities of machine learning are rapidly being employed in the realm of healthcare. ML models have been presented and evaluated as potential answers to a range of challenges involving diagnostic errors, treatment errors, workflow inefficiencies and obstacles to value-based care as a convergence between health and data science [9].

Machine Learning Methods

ML is divided into three main categories: supervised learning, unsupervised learning, and reinforcement learning. The term "supervised learning" refers to algorithms that use labelled data as a training dataset. Labelled data are datasets in which the outcome of interest has already been determined; for example, to train an algorithm for sepsis prediction, we utilize a dataset in which patients are already classified as having sepsis or not. The algorithm will then select the best model to predict the desired outcome [8]. Unsupervised learning is the utilization of data without a specified or predefined outcome of interest. Algorithm are left to detect patterns and extract hidden structure from data on their own, with no expert labelling. Unsupervised learning is mostly used in medicine for clustering with the goal of discovering groups in data, such as related groups of patients based on clinical data [8]. Through trial and error, reinforcement learning algorithms uncover activities that provide the greatest rewards. In this category, the algorithm is set up to consider survival or a shorter hospital stay as a reward. The approach employs a training dataset to run several tests to generate the model with the highest reward [8].

ML In Infection Prevention and Control

AI and ML offer huge potential in Infection Prevention and Control (IPC) [10]. Its applications in IPC have enormous promise for implementing WHO core components [10]. AI and ML have potential benefits in the three main areas highlighted by the WHO: 1-HAIs surveillance, 2-Improved laboratory diagnosis to facilitate IPC interventions, 3-Hand hygiene practice [10]. In HAIs surveillance, ML application have been used to monitor trends, identify clusters and outbreaks in a timely manner. It is also used in outbreak simulation to mitigate interventions. Also, ML is a very helpful tool in predicting the risk of nosocomial infections as nosocomial Clostridium difficile infection [10]. While more research is needed to validate these findings, this method has the potential to change HAIs surveillance and IPC [10]. ML data mining tools as well could use the clinical microbiology laboratory results to detect and predict clusters or outbreaks of multidrug resistant pathogens in healthcare settings [10]. AI and ML enhanced laboratory microscopy could speed up infection diagnosis and aid AMR prevention initiatives by facilitating targeted antibiotic management and IPC intervention [10]. Studies showed that gram stain interpretation with AI-assisted tools could lower cost and time with good accuracy [10]. Wearable technology using ML applications provide benefits for healthcare environment in general and IPC in specific in the form of supporting healthcare staff IPC education, audit, and behavior change.

ML In Prediction and Early Detection of Hais

AI and ML are being used by researchers in public health surveillance to predict disease outbreaks and evaluate surveillance tools [11]. Identifying patients at increased risk of HAIs in ICUs is a serious public health concern. ML could improve patient risk classification and lead to more specific infection prevention and control study. ML models could be made for surveillance of Blood Stream Infections (BSI), CD Infections (CDI), Urinary Tract Infections (UTI), pneumonia and Surgical Site Infections (SSI). Vab der Werff et al. [12] developed a fully automated surveillance algorithm for hospital acquired UTI using electronic health record (EHR) data. This study concluded that a fully automated surveillance algorithm based on artificial intelligence and machine learning to detect UTI symptoms from EHR had acceptable performance HA-UTI compared to manual record review. Taylor et al. [13] showed that machine learning algorithms accurately diagnosed positive urine culture results and accurately predict UTIs in emergency department. Mancini et al [14] built a predictive model using a cloud platform (DSaaS), online and user-friendly platform, to predict Multi-Drug Resistant (MDR) UTI in hospitals. DSaas can help physicians to build easy prediction models that could help them to treat hospitalized patients. Their model is based on supervised ML regression and classification algorithms. They developed this model to assist in the antimicrobial stewardship program implemented in their hospital [14]. Nemati et al. [15] developed an Artificial Intelligence Sepsis Expert (AISE) algorithm for early prediction of sepsis. Using data available in the ICU in real time, AISE can accurately predict the onset of sepsis in an ICU patient 4 to 12 hours prior to clinical recognition [15]. Many studies showed that ML based Clinical Decision Support (CDS) tools embedded within electronic medical record improve early detection and therapy in patients with early blood stream infections and can predict septic shock [15,16].

Conclusion

Many studies suggest that machine learning algorithms outperforms conventional statistical approaches in term of predictive performance, implying that the machine learning approaches could be used to identify and predict patients at higher risk of HAIs at hospital admission, giving clinicians enough time to potentially prevent HAIs and mitigate their severity by targeting specific infection prevention and control interventions at high-risk groups to improve quality of care.

Conflict of Interest

No conflict of interest.

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