The Use of Artificial Intelligence in Critical Care Medicine

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ABSTRACT

Artificial intelligence (AI) technologies are rapidly changing healthcare in many aspects. Our study provides a brief background and explanation of artificial intelligence and machine learning and how they can be integrated into critical care medicine. Furthermore, we discuss how AI can be used in critical care medicine in four different ways, along with examples demonstrating how it can be easily integrated into the field.

KEYWORDS - artificial intelligence, healthcare, critical care medicine, machine learning, intensive care unit

INTRODUCTION

Artificial intelligence (AI) has allowed us to see a drastic change in the medical world. AI is the development of computer systems that can perform tasks that typically require human intelligence [8]. It also works to find patterns within a complex multidimensional and multidomain data environment. [1] This technology can also be enhanced by machine learning (ML), where the use of data and algorithms helps AI gradually improve accuracy without being explicitly programmed. There are three main types of machine learning approaches, which include random forest (RF), support vector machine (SVM), and logistic regression (LR).

Random forest constructs decision trees and carries out a majority vote. Support vector machine constructs a two-class pattern classifier using a linear input component. Finally, logistic regression calculates the class membership likelihood for two classes by fitting the log odds and explanatory variables to a model. [2] Artificial intelligence (AI) technologies are rapidly changing healthcare in many aspects. There has been a growing role of artificial intelligence in medicine and critical care medicine, ranging from online check-ins to scheduling online appointments, and it can even assist doctors in complex medical decisions in various practices. Furthermore, the technology is used to quickly compile and share patient data to make it more accessible to physicians. It can also be used in disease evolution predictions, identification, and guiding clinical decisions. While our understanding of AI in the specific field of critical care medicine still needs to be at the highest level, further usage, investigations, and tests can aid in our depth of comprehension. The world of AI in critical care medicine is ever-changing and evolving, helping improve patient outcomes and the overall physician environment in such a crucial part of the healthcare system. The goal of this article is to improve understanding and awareness of AI applications in critical care medicine and how they affect patient care.

AI APPLICATIONS IN PAIN ASSESSMENT

AI predictive devices are increasingly resulting in the automation of a diagnosis via comprehensive patient health monitoring. AI tools can provide automated and continuous pain assessments that can eliminate the outcomes of uncertainty that many doctors and nurses face daily. AI systems can develop predictive modeling tasks that are useful for pain research and can derive their information from complex datasets to reach an accurate conclusion. Vital signs have been known to be indicators of pain; however, they can be deemed unreliable due to their constant change over time. However, The Critical Care Pain Observation Tool (CPOT) successfully evaluated pain continuously, semi-automatically, and objectively for critically ill patients using factors such as vital signs, sedation levels, and age group. The CPOT study was done using three machine-learning methods: random forest (RF), support vector machine (SVM), and logistic regression (LR). These were used to predict pain levels using age group, sedation levels, and vital signs. Before the CPOT study, vital signs in the intensive care unit (ICU) were considered ineffective in evaluating pain. A bedside device is being developed using the prediction algorithm proposed in the study. [2] This can instantly help reduce the pain in critically ill patients who cannot articulate their pain while simultaneously increasing their life expectancy. Therefore, more studies are recommended to be conducted in various scenarios to enhance our understanding of this potential application.

AI IN DISEASE EVOLUTION PREDICTION

AI and machine learning technologies are currently being used to detect and predict disease evolution, which is crucial for physicians caring for critically ill patients in the ICU. Rapid clinical deterioration is common in the ICU, meaning efforts to predict such instances before they occur are essential to prevent the patient's mortality. A dynamic random forest model, a machine learning method, is best suited to predict disease evolution in the critical care setting. As new data becomes available, the various "decision trees" adapt and update in real time. The models update the prognosis in real time as well. Using a machine-learning model to reduce intraoperative hypotension is just one example of how the technology is currently being utilized. Using electronic health records (EHR) and physiologic numeric vital sign data, hypotension events were predicted using the random forest model, reaching a high sensitivity percentage of 92.7%. Additionally, respiratory distress and hypoxia among critically ill patients have also been key for prediction. [11] AI models were used to predict the progression of COVID-19 during the first few months of the pandemic. [1] This was done using biological and clinical variables, as well as imaging. Cardiac arrest, which, according to the Centers for Disease Control and Prevention, affects more than 356,000 people in out-of-hospital incidents in the United States every year [3], has also been predicted. This has been done using an electronic Cardiac Arrest Triage (eCART) score from electronic health record (EHR) data.

AI-ASSISTED DIAGNOSIS AND TREATMENT

More often than not, finding the cause of illness in critically ill patients can be complex and challenging. This can happen because co-existing conditions could mask the actual problem or insidious aspects of early disease progression. As a result of this, timely and adequate management could be delayed, significantly harming positive patient outcomes. This is where AI can come in and assist physicians by obtaining a more precise diagnosis, given the technology's advanced image and text processing capability. Also, with AI's ability to quickly interpret and analyze data, physicians can quickly provide life-saving treatment to patients. For example, the results of convolutional neural networks in the context of traumatic brain injury (TBI) on a head computed tomography (CT) could be examined and assessed with even greater accuracy

compared to a manual reading. This affects overall patient health extensively and could help them recover quicker due to earlier treatment [1].

AI'S ROLE IN CLINICAL DECISION SUPPORT

AI technologies can play a significant role in helping guide the decisions of ICU physicians. These advanced models can aid physicians in deciding which patients need medical interventions based on risk and identifying patients at the highest risk of imminent decompensation. Additionally, the technology can evaluate numerous small outcomes to optimize overall patient outcomes [5]. As a result of machine learning (ML), AI algorithms constantly learn and advance as more information is inputted into medical databases. This is extremely important because as the information is continuously updated, ICU physicians can consult the technology to ensure that they are making the best possible decisions for the health of their patient(s). AI can provide individualized solutions using reinforcement learning as well.

Reinforcement learning detects numerous variables to build an action model in a given situation. This action model learns from the reward or penalty from the results of its actions [1]. Since AI treatment recommendations are created from retrospective datasets, results produced by the algorithms must be thoroughly analyzed, checked over, and tested before clinical implementation.

DISCUSSION

There is a plethora of benefits when it comes to using artificial intelligence and machine learning in critical care medicine, as illustrated in Table 1. AI can help ICU physicians make pressing decisions about critically ill patients' health. Machine learning will allow the technology to adapt and update as more data is input into databases.

AI can further assess patients' pain levels if they are not able to articulate their symptoms to the doctor. This can help patients receive treatment quicker, which can help them recover faster. AI is also able to predict disease evolution and identify diseases, which can typically be a difficult task for physicians. If diseases can be tracked in such ways, then care can be administered to patients faster, helping with their overall recovery.

AI can also help guide clinical decisions by identifying which can help doctors identify which patients are most at risk for decompensation. Based on the constant flow of information the algorithm is receiving, it is then able to make more individualized decisions for patients. Finally, AI can easily be implemented in ventilators and IV pumps. For ventilators, AI can adjust the airflow through the ventilator based on the patient's breathing patterns, ensuring that the patient does not fight the ventilator. Next, on IV pumps, AI can monitor and display real-time fluid movements so the doctor can make adjustments as needed. Additionally, AI can also continuously monitor and adjust patient fluid inputs accordingly to ensure the patient is stable. As AI is ever-changing and evolving as time goes on, it will only get better at completing such tasks. There are more potentially practice-changing clinical trials and studies in the field of AI and critical care medicine. The first is a Reinforcement Learning (RL) algorithm called VentAI to optimize mechanical ventilation settings for ICU patients [10]. It uses a patient's clinical data to dynamically select settings over time. VentAI was trained and validated on over 11,000 ventilation events from the MIMIC-III database. It considers 44 features like lab values, vitals, comorbidities, etc.

The algorithm aims to maximize 90-day survival by choosing settings for tidal volume, PEEP, and FIO2. It was evaluated against physician choices in the same patients. When tested on MIMIC-III and a separate eICU dataset, VentAI consistently achieved higher estimatedperformance returns than physicians. This suggests that it may improve outcomes. VentAI recommended lower tidal volumes more often than higher ones. It also favored higher PEEP levels and avoided high FIO2 values compared to physicians. The number of setting changes VentAI proposed per patient was higher, showing it dynamically adapts settings over time better than static physician approaches. Further testing is still needed, but an RL algorithm like VentAI shows promise for precision machines by individualizing ventilation optimization over time based on the patient's evolving clinical condition. It could potentially benefit critically ill patients if proven safe in prospective studies. While there are many benefits of using AI in critical care medicine and ICU settings, there are drawbacks that do exist. First, it would be challenging for an AI algorithm to include the broad spectrum of human beliefs and opinions that dramatically influence the personal choices of each patient in its decision process. Diversity and cultural differences are fundamental and crucial factors in how care is executed in critical care patients.

Additionally, there is always room for error, whether technology or a human making the decision. The AI model may find false associations between data and interpret them as genuine relationships between events, interpreting incorrect causation. A solution for this is to have humans constantly oversee the outcomes of machine learning algorithms and verify the results produced to avoid misinterpretation of any kind.

Another limitation is related to data availability and quality. The results produced by AI technology depend on the quality of the underlying data. AI models need large amounts of high-resolution and high-quality data. However, there is a disadvantage, as most clinical knowledge on patient care is explicitly transmitted during oral transmissions between colleagues or through natural language within clinical charts. These forms exclude AI algorithms, putting them at a disadvantage. Furthermore, different software systems, medical practices, and local protocols between different hospitals or the same hospitals

in the same country or a different country may additionally hinder the performance of AI models. Finally, there is the one-on-one aspect of being a physician that an "AI clinician" could never engage in. A human physician can actually communicate with the patient, sit with them, and discuss how they are feeling based on their symptoms. In addition, a human physician can use the best words to communicate with the patient about their medical condition and discuss treatment options. [4] AI cannot solely take over all the jobs of physicians, but it can co-exist with them to help in the fight to cure patients.

Further, there are ethical concerns related to the use of AI in the ICU. One issue is data sharing and privacy. During the process of collecting, analyzing, and manipulating the data, leakage of confidential information can possibly occur. Another concern would be the safety of AI for patient care. The stage of AI is not at the maturity level where it can be fully autonomous, meaning physician oversight is still needed. AI recommendations may not always align with patient preferences as well. In order to address such ethical concerns, clinicians and researchers must be aware of the problems that exist and find ways to mitigate their effects and solve them. This also includes gaining a deeper understanding of patient preferences and perspectives and then incorporating them into the development of such ethical solutions [9].

Table 1. Pros and Cons of AI in Critical Care Medicine

Pros	Cons
Monitoring patient	Lack of human opinion and input in decision-making
Assessment and prognosis of drug levels and interactions	Data and pattern misinterpretation, which leads to error
Disease evolution prediction and identification	Lack of quality data within the AI database
Administering appropriate medications	Lack of human-to-human interaction
Pain assessment	Variety of software leading to difficulty in data transmission
Guiding clinical decisions and formulating treatment algorithms	
Ease of integration (Ex. ventilators and IV pumps)	

CONCLUSIONS

Critical care medicine cares for the critically ill who are either enduring or recovering from life-threatening illnesses or injuries. The use of artificial intelligence is vital in critical care medicine, helping evolve and advance the field of medicine. This technology can be used in a variety of different ways to aid physicians. However, we have only uncovered the surface of AI in healthcare as a whole, and further research will only help us learn more. AI can assist in critical care medicine in the following ways: pain assessment, disease evolution prediction, guiding clinical decisions, and ventilators and IV pumps. AI algorithms can be easily implemented in each of these ways, and once they are more prevalent within critical care, we will be able to see how effective they indeed are. There are many avenues for enriching the artificial intelligence components in healthcare education. One avenue is through curriculum development and integration, where research can focus on designing and implementing health care courses that incorporate information technology (IT) components. Even though there are many benefits of the technology, there are still shortcomings that must be addressed. Some of these include data acquisition, lack of human opinion, data misinterpretation, a variety of software that make it hard to transmit data, and human-to-human interaction. There are also ethical concerns regarding AI in the ICU that must be addressed by clinicians and researchers alike. AI can never completely subsume the jobs of all physicians. Still, it can be a vital tool to aid in clinical decision-making and help provide more efficiency to the ICU, decreasing mortality rates.

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