Original Article

The Role of Artificial Intelligence in Management of Critical COVID-19 Patients

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Abstract

Coronavirus disease 2019 (COVID-19) outbreak has created a great challenge for the healthcare system worldwide. One of the most critical points of this challenge is the management of COVID-19 patients needing acute and/or critical respiratory care. This study was performed to discover an AI based model to improve the critical care of the COVID-19 patients. In a descriptive study, all the published research available in PubMed, Web of Science, Google scholar and other databases were retrieved. Based on these studies, a three stage model of input, process and output was created. Three stages model of AI application in intensive care unit (ICU) was completed. Input included clinical, paraclinical, personalized medicine (OMICS) and epidemiologic data. The process included artificial intelligence (i.e. artificial neural network, machine learning, deep learning and expert systems). The output which was ICU decision making included diagnosis, treatment, risk stratification, prognosis and management. Efforts of the healthcare system to defeat COVID-19 could be supported by an AI-based decision-making system which would double them up and help manage these patients much more efficiently, especially those in COVID-19 ICU.

Keywords: Artificial intelligence, COVID-19, Critical care

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Introduction

The coronavirus (SARS-CoV-2) infection outbreak started in December 2019 (COVID-19) in Wuhan, China; the aftermath worldwide pandemic with its fast outbreak has created an extraordinary challenge to the world in the 21st century (1, 2). The problem has many unique and even unknown features that human being has never been faced with (3-5).

COVID-19 mortality rate (MR) and case fatality rate (CFR) depend on a few numbers of important factors; among them, the care of the critical patients is one of the most important ones (6). Therefore, one of the most critical points of this challenge is the management of COVID-19 patients needing acute and/or critical respiratory care.

How can we manage the critical care of the COVID-19 patients using AI? Consider the scene in an intensive care unit (ICU) with several COVID-19 patients; some are intubated while others possibly receiving noninvasive ventilation while doctors and nurses challenge the virus in personal protection equipment and a percentage of them have been exhausted. Add to this fact, the potential several fold demand for ICU beds at the doors of the ward and the quality of care which is a direct function of the performance in ICU wards in each country and the resulting worldwide outcome.

However, after a couple of months, human being has started novel approaches to manage this challenge (7-10). Many would suggest that artificial intelligence (AI) would be one of the most efficient potential arsenals. Nevertheless, how it could help us? The role of AI in such a dynamic atmosphere needs to be an innovative one; otherwise the process of patient care and clinical decision making would be disturbed (11-13).

A few studies have reviewed AI role in COVID-19 ICU patients. The aim of this study was to assess the role of Artificial Intelligence in management of critical COVID-19 patients. This study was performed to discover an AI based model to improve the critical care of the COVID-19 patients.

Methods

The study proposal was assessed and approved by Research Ethics Committee, Shahid Beheshti University of Medical Sciences, Tehran, Iran; coded: IR.SBMU.RETECH.REC.1399.018.

The search strategy was based on the following items:

Search topic: studies on use of artificial intelligence in ICU regarding respiratory diseases specially COVID-19 management

Search engines: PubMed, Web of Science, Google scholar, the other databases according to its user guide

Hand search: yes; for two specialized journals on public health topic: "JMIR Public Health and Surveillance" and "Lancet Digital health"

Search terms: MeSH terms and keywords related to AI, ICU, COVID-19 and lung diseases

Second order search: the references of the retrieved articles in the search results were screened for potentially relevant studies

Publication date search limit: no time limitation on publication date was applied

MeSH words for search: included the following: (COVID-19[Title/Abstract]) AND artificial intelligence[Title/Abstract] OR (MERS[Title/Abstract]) AND artificial intelligence[Title/Abstract] AND artificial intelligence[Title/Abstract] OR (lung[Title/Abstract]) AND artificial intelligence[Title/Abstract] AND artificial intelligence[Title/Abstract] OR (respiratory[Title/Abstract]) AND artificial intelligence[Title/Abstract] AND artificial intelligence[Title/Abstract] OR ((("Respiration, Artificial"[Mesh]) AND ICU [Title/Abstract])) AND artificial intelligence[Title]

After completion of the search, 3 stages process of input, process and output was developed and the search results were categorized in one of the 3 stages; this model was based on the methods of previous studies (8, 12-20).

Results

Based on three stages model of input, process and output of this study, the main current AI applications in COVID-19 pandemic are listed; this model aims to improve the critical care of COVID-19 patients; each of three stages are divided to subcategories (Figure 1 & Table 1).

Discusion

Developing an AI models to predict whether a patient have a high risk of having a health crisis or not based on specific information from the patients is possible. Moreover, creating software services, which can automatically categorize the risk of crisis on different patients, is considered as a solution to have a personalized medicine (21, 22). Furthermore, reducing frequent lab testing and the potential clinical and financial implications are an important issue in ICU, which an AI can predict the laboratory tests with high accuracy and in predicting the probable information (23). Further, various surveillance systems have been developed to monitor the emergence of respiratory-tract infections (19).

Those items that could be categorized under Input are briefed here.

Clinical Symptoms and signs of COVID-19 could be flagged before clinicians discover them; this is an alarming property of AI. In fact, if clinicians could discover the symptoms with a considerable time interval, the facilities for detection of the high-risk patients would be more available (11).

Epidemiological aspects of viral spread, which could be detected and predicted using data mining approaches. Using this method, *flagging epidemics* before health authorities discover them would be an attractive and beneficial option. In addition, defining *hot points* and the *emerging epicenters* using data mining approaches, air traffic maps, mobile phone contacts, social media data, etc. would be an easily done task (10, 24-29). Another point of view is the AI assisted approaches used for defining the patterns of community spread and foretelling the possible effects of the health interventions on the next steps of the outbreak (8, 28, 29). During COVID-19 outbreak in China, active case finding through mobile phones was an effective approach to limit the epidemic; which was an AI-based method (10).

AI could boost personalized medicine; when AI could potentially identify the most susceptible people based on personalized genetic & physiological characteristics (27, 28, 30). Add to the above, the role of AI (including but not limited to machine learning, deep learning, etc.) in personalized medicine and genomics, epigenetics, transcriptomics, proteomics, metabolomics and other multi-OMICS (30-34). The genomic studies of COVID-19 for assessing the 8 subtypes of the virus are AI-backed processes which are discussed under the website https://nextstrain.org; all these approaches lead to discover novel diagnostics and therapeutics; which are also, part of the *output* (35, 36).

Regarding *process*, the following items could be briefed as follows. In differential diagnosis of COVID-19 from other types of Community acquired *pneumonia*, *deep learning* (deep structured learning) could be a very useful tool. On the other hand, machine learning analysis of genetic variants from asymptomatic, mild or severe COVID-19 patients can be performed to classify and predict potential patients; this approach would be performed based on the vulnerability or resistance of patients to potential COVID-19 infection; which is a "deep learning-based" approach (8, 10, 11, 28, 29). Another study showed that AI based monitoring of critically ill patients is associated with especial focus on pervasive sensing and deep learning system (37). Other approaches like using AI for improving risk communication strategies in the affected population using Google Trends is another approach which could be based on timing of and defining the location of the patients (29).

Regarding *output* the following items could be mentioned. Diagnostic approaches: COVID-19 is a systemic disease with its most severe and lethal complications occurring in the lungs; however, like any other disease, before starting treatment, a definitive diagnosis is mandatory which relies on history, physical examination and paraclinical data. Chest CT scan remains one of the most sensitive items; even more than RT-PCR tests from deep nasotracheal samples (38, 39). Add to the above, further improvements in diagnostic speed and accuracy of the tests including the role of CRISPR-based COVID-19 detection assay which are supplementary methods of detection (40). An AI

Table 1- A three stage model of AI application in ICU (8, 12-20).

Input	• Clinical data • Paraclinical data • Personalized Medicine (OMICS) data • Epidemiologic data
Process	• Artificial Intelligence: 1. Artificial Neural Network 2. Machine Learning & Deep Learning 3. Expert Systems
Output	• ICU Decision Making 1. Diagnosis 2. Treatment 3. Risk Stratification 4. Prognosis 5. Management

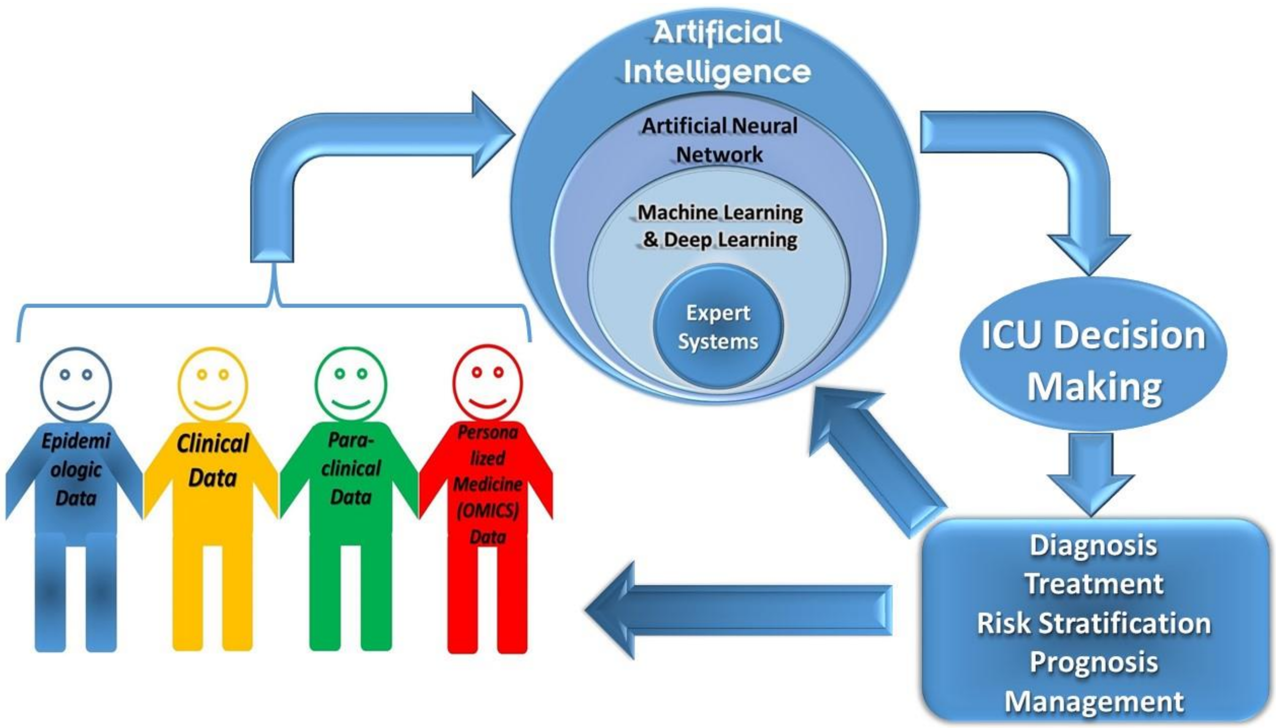

Figure 1. A three stage model of AI application in ICU (8, 12-20).

system can also analyze the efficacy of diagnostic lab tests and so, improve the efficiency of the critical care in ICU (23).

Based on previous experiences, *Therapeutic approaches* for COVID-19 patients would be improved by the help of AI-based methods. One of the challenges in ICU patients is the algorithm for management and early detection of patients who may undergo prolonged mechanical ventilation and tracheostomy; AI has created an effective solution for it (41). Besides, for patients with difficult airway, AI has created novel approaches based on the Random Forest algorithm to predict and manage difficult airway (42-45). Some other examples include the in silico pharmacological methods used for drug redesign or drug repurposing or at times for designing novel drugs and/or discovering potential drug candidates specifically against SARS-CoV-2 or even repurposing clinically-approved drugs to overcome SARS-CoV-2 (9, 46, 47). During the current era, a challenge in healthcare systems all over the world is to produce COVID-19 vaccine; a newly developed Vaxign reverse vaccinology tool integrated with machine learning has proposed candidates. In silico models of vaccine production (like vaccine investigation and online information network: VIOLIN; http://www.violinet.org) have been claimed useful which rely on AI, databases and in silico tools (47-50).

Whenever the care of ICU patients is discussed, an important aspect is the difficulties in the decision-making processes; AI and related mechanisms could enable us make more efficient decisions. This starts from risk stratification, diagnostic data, prognosis & survival trends, risk classification, risk prediction and finally survival prediction; all of them would be appropriate for COVID-19 patients. During the outbreaks, ICU management for bed allocation becomes an important issue with great ethical aspects; AI could help us decide in a cost-effective manner while considering ethics. Add to the above, the healthcare personal protection issues which could be improved using AI approaches (8, 11-13, 28).

The challenge in managing COVID-19 patients admitted to ICU in critical condition is a new model of an old problem. Patients admitted to the ICU often receive multiple concurrent therapies due to their condition, and at the same time, there is usually lack of sufficient and strong guidelines; which has made physicians' decisions largely dependent on personal knowledge, experience and commonsense (14).

However, AI is capable of finding complex relationships in a large volume of data with simultaneous rapid analysis of a large databank and complex variables. Finally, answering difficult questions with good validity and reliability like the chance of survival in sepsis in each individual patient, using AI and AI-based methods would make it more probable to overcome these complexes and multilateral problems. This is why a large number of studies in the field of pulmonary infectious diseases and other respiratory problems and in the management of ICU patients have demonstrated that the application of AI could be an effective approach in this setting (12-16).

Critical care practitioners are often need making critical decisions based on large volumes of complex and heterogeneous data. AI, if used effectively, can reduce this complexity by converting data into relevant information (16-18, 22, 23, 49). Besides, AI has been demonstrated to have a determining role in diagnosis of obstructive lung disease and respiratory infectious disease (51). However, large-scale studies are still required to validate these findings and to increase their acceptance by the medical community. From another point of view, errors in medicine, which are very costly, could be largely preventable with the help of AI and Machine Learning. Of particular interest is the role of AI in decision making; especially when sufficient and/or conclusive evidence are not available (52).

Deep learning architectures are widely used in forecasting, classification and bioinformatics and are recognized as a powerful tool for infectious disease analysis (53).

The use of artificial neural networks to design a model for automatic classification of respiratory crisis patients has yielded in brilliant results (54-56). This technology can also be used to monitor the trend of care and therapy in ICU so that the following aspects would be tangible in clinical practice (37):

- face detection
- face recognition
- facial action unit detection
- facial expression recognition
- posture recognition
- extremity movement analysis
- sound pressure level detection
- light level detection to realize
- visitation frequency detection

To better manage patients with COVID-19 admitted to the ICU, the use of medical assisted decision systems (CDSS) or artificial intelligence-based reasoning engines will assist the decision-making team. The design of this argument engine requires the availability of accurate and comprehensive data. Collecting and storing data on COVID-19 patients is very important in this regard. In this regard, the existence of COVID-19 disease registry systems is essential. Now, since most countries' health systems focus on control of the epidemic and treatment of patients, and on the manufacturing and production of drugs and vaccines, attention has been given to the design and implementation of a rapid, yet accurate and complete registry system related to the disease. However, the efforts of the healthcare system to defeat COVID-19 could be supported by an AI-based decision-making system which would double them up and help manage these patients much more efficiently, especially those in COVID-19 ICU.

Conclusion

Efforts of the healthcare system to defeat COVID-19 could be supported by an AI-based decision-making system which would double them up and help manage these patients much more efficiently, especially those in COVID-19 ICU.

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Conflicts of Interest

The authors declare that there are no conflicts of interest.

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