Predicting optimal medical interventions

February 23 2024, by Alistair Jones

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Welcome to the world of modern medicine. Computer vision tools can accurately detect suspicious skin lesions or predict coronary artery disease from scans. Data-driven robots are guiding minimally invasive surgery.

Machine learning can be applied to analyses of patients' genomic and molecular data to detect diseases such as Alzheimer's or to help choose the best medication for a patient. Deep learning methods can be utilized to model electronic health record data to predict health outcomes for patients.

Is it any wonder that the application of artificial intelligence (AI) tools in health care has been described as one of the most significant industrial revolutions of our time?

"While I agree that AI tools in health care represent a significant industrial revolution, I believe there's still a considerable journey ahead before AI can truly revolutionize the core aspects of health care services provided by physicians," says Daniel Zheng, an Associate Professor of Operations Management at Singapore Management University (SMU).

The research team designed a personalized decision support tool that uses predictive information to help make better decisions on the continuation of medical treatment in intensive care units (ICU).

Specifically, the study considered the optimal point at which mechanical support for breathing could be removed from a patient (extubation). The methodologies can apply to the discontinuation of other critical treatments.

"Our application of predictive analysis for future patient health states isn't entirely new. Physicians have long been integrating their predictions into clinical decisions," Professor Zheng says.

"But our approach aims to formalize this process, integrating machine-generated predictions into clinical decision protocols, thereby enhancing decision-making and improving patient outcomes and operational efficiencies."

Future states

The flood of patients requiring intensive care during the COVID pandemic highlighted that ICUs are a pressure point in health care systems already facing increasing demand from aging populations, financial constraints and shortages of specialist staff.

Since critical care is expensive for both patients and hospitals and the number of ICU beds is limited, these resources need to be managed as efficiently as possible.

Patients are not allowed to be discharged from an ICU while still intubated. The decision to extubate is vital for patients and the time to extubation is usually considered the primary service outcome for surgical care in hospitals.

"We chose extubation decisions as our focus due to their critical nature in ICU, particularly post-cardiac surgery," Professor Zheng says. "This topic was initially proposed by our collaborating physicians seeking data-driven support for these decisions."

The existing protocols on the continuation decision of medical treatment only consider current or historical details of patient condition without considering the likely future condition.

Using a comprehensive hospital dataset, the researchers evaluated the effectiveness of various policies and demonstrated that incorporating predictive information can reduce ICU length of stay by up to 3.4 percent and, simultaneously, decrease the extubation failure rate by up to 20.3 percent, compared with the optimal policy that does not utilize prediction. These benefits are more significant for patients with poor initial conditions upon ICU admission.

"Our analysis indicates that as long as the prediction model is reasonably accurate, its integration into decision protocols is beneficial, despite potential over-reliance or misinterpretation by physicians," Professor Zheng says.

Additional effect

The researchers derived their empirical data from 5,566 ICU admissions to the cardiothoracic ICU at Singapore's National University Hospital. Patient-level admission data such as age, gender, race and time of admission was compiled, and during the ICU stay comprehensive physiological data, such as body temperature, heart rate and blood pressure, were documented by a digital tracking system.

Laboratory test outcomes, medications, procedures and nursing care notes were also integrated into the dataset. And while the method used for cleaning so much raw data wasn't new, it was "a thorough and critical one."

"Data cleaning was a challenging yet crucial process, involving extensive collaboration with physicians and nurses to understand clinical notes and variables," Professor Zheng says.

To extend their risk prediction models to the ICU management setting, the researchers adopted the framework of uplift modeling, a predictive modeling technique used in data analytics and operations research. It differs from traditional predictive modeling by focusing on the change in probability caused by a specific action or treatment, rather than just predicting the likelihood of the outcome itself.

In simpler terms, it tries to answer the question: What is the additional effect of this treatment or intervention on this particular individual or group?

"Uplift modeling, which predicts the incremental impact of continued ventilation, was used as input for our extubation decision model. It generates predictions but does not dictate their application, which is where our model comes into play, suggesting how these predictions should be utilized," Professor Zheng says.

The research team's integration of advanced mathematical modeling and data analytics with critical medical decisions demonstrates that an interdisciplinary approach can offer valuable insights into actual health care challenges.

Wider usage

"Predictive-assisted decision-making has potential applications across various clinical and operational health care decisions," Professor Zheng says.

"Our project, for instance, has implications for dialysis and ICU discharge decisions, demonstrating the wide applicability of systematically leveraging new predictive models and algorithms."

So, what comes next for the researchers? Could their work on extubation lead to a product?

"We are in the preliminary stages of exploring a partnership with a biotechnology company that specializes in centralized ventilator management solutions," Professor Zheng says.

"Their suite of products includes hardware for data collection, encryption, and transmission, as well as a software platform designed for data visualization and patient risk monitoring."

"We see a potential opportunity to integrate our model into their existing

system, which could significantly enhance ventilator risk monitoring and support the process of making extubation decisions."

"This collaboration represents a promising step towards transitioning our research from theoretical constructs to practical, real-world applications within medical settings," Professor Zheng says.

Provided by Singapore Management University