Stroke

EDITORIAL

Simulation and Machine Learning Provide New Approaches to Examine Quality of Acute Stroke Management

Noreen Kamal, PhD; Kamakshi Lakshminarayan, MBBS, PhD, MS

Machine learning and computer simulation are relatively recent approaches to assess stroke systems of care through secondary use of data available in existing databases and registries.[1,2,3] Allen et al[4] use both approaches in their study on factors influencing thrombolysis rates across England and Wales. The goal of this study was to assess how much variation is due to differences in local patient populations, and how much is due to differences in clinical decision-making and stroke pathway performance. This variability in thrombolysis treatment rates is a common problem globally and contributes to disparities in stroke outcomes.

See related article, p XXX

In this study, hospital-level machine learning models were developed to predict thrombolysis decisions (yes/no) for individual patients using data from 132 hospitals in the Sentinel Stroke National Audit Programme. More than 200 000 emergency stroke admissions were used in model development. Specific input variables included patient demographics, stroke pathway variables (eg, symptom onset to arrival, mode of arrival), patient comorbidities, and stroke clinical features including stroke severity. Thirty high-performing hospitals were designated as benchmark hospitals using predicted thrombolysis rates on a separate cohort of 10 000 patients. Subsequently, an optimal thrombolysis decision was predicted for each patient in the system using the majority vote from benchmark hospitals. The authors conclude that if all cases were thrombolysed based on the majority benchmark decision, estimated thrombolysis rates could increase by 7 percentage points in eligible arriving within 4 hours of stroke symptom onset. At the level of individual patient decisions on whether to provide thrombolytic treatment or not, there was more consensus on nontreatment versus treatment: 85% agreement not to treat versus 60% agreement to treat by majority of hospitals. This study shows a novel application for machine learning modelling to predict thrombolysis eligibility and assess hospital performance.

Simulation provides a modeling tool for stochastic systems where different scenarios can be trialed to determine the effect on specific outcomes. For example, a discrete-event simulation for a door to treatment process includes the distribution of treatment times for each process step; different change strategies are run to determine the effect on treatment times.[3] System dynamic simulation modeling is used to determine larger policy effects on incidence of stroke and other diseases.[5] Allen et al uses a Monte Carlo simulation technique to model a simple 4-step process from onset to the start of thrombolysis and then uses clinical trial data to determine patient outcomes. This simulation was used to assess the impact of the following scenarios: (1) faster treatment (30 minutes from arrival); (2) increasing the proportion of patients that arrive within 4 hours of treatment; (3) increasing the proportion of patients with known onset time; and (4) increasing the proportion of patients that receive thrombolysis based on the optimal benchmark decision from the machine learning models above. The simulations found that changing the proportion of patients with known onset times, increasing speed of

Key Words: Editorials ■ clinical decision-making ■ demography ■ goal ■ hospital

The opinions expressed in this article are not necessarily those of the editors or of the American Heart Association.
Correspondence to: Noreen Kamal, PhD, Department of Industrial Engineering, Dalhousie University, Halifax, NS, Canada. Email noreen.kamal@dal.ca
For Disclosures, see page XXX.

Stroke is available at www.ahajournals.org/journal/str

EDITORIAL

scan and treatment, and following the decisions as made by the benchmark hospitals could substantially increase the rates of thrombolysis and improve outcomes.

This work is a substantial effort and very instructive for those seeking to perform quality improvement for thrombolysis. There are of course limitation to these modeling techniques. The biggest limitation is the accuracy of the data, the variables included, and the amount of data available to build the models. If the data input into models are inaccurate, the models will be unreliable. It is, therefore, critical that we develop validation studies. In addition, mathematical computer generated models can be complex and difficult to describe, which can create a "black-box" in applying them that can result in incorrect reuse of the models by others. For this reason, researchers should adequately describe the methodologies and limitations in the use of their models to ensure that the results are interpreted correctly. Furthermore, this analysis is tied to the enormously detailed data resources of Sentinel Stroke National Audit Programme available in the United Kingdom. Similar resources are not uniformly available in other countries.

Despite the limitations, both machine learning and simulation modeling provide an exciting new frontier for acute stroke research. These approaches can provide insight for process improvements that will result in better patient outcomes.

ARTICLE INFORMATION

Affiliations

Department of Industrial Engineering, Dalhousie University, Halifax, Nova Scotia, Canada (N.K.). Department of Clinical Neurosciences, University of Calgary, Alberta, Canada (N.K.). Division of Epidemiology and Community Health, School of Public Health, University of Minnesota, Minneapolis (K.L.).

Disclosures

None.

REFERENCES

1. Asadi H, Dowling R, Yan B, Mitchell P. Machine learning for outcome prediction of acute ischemic stroke post intra-arterial therapy. *PLoS One*. 2014;9:e88225. doi: 10.1371/journal.pone.0088225
2. Heo J, Yoon JG, Park H, Kim YD, Nam HS, Heo JH. Machine learning-based model for prediction of outcomes in acute stroke. *Stroke*. 2019;50:1263–1265. doi: 10.1161/STROKEAHA.118.024293
3. Bulmer T, Volders D, Blake J, Kamal N. Discrete-event simulation to model the thrombolysis process for acute ischemic stroke patients at urban and rural hospitals. *Front Neurol*. 2021;12:746404. doi: 10.3389/fneur.2021.746404
4. Allen M, James C, Frost J, Liabo K, Pearn K, Monks T, Everson R, Stein K, James M. Use of clinical pathway simulation and machine learning to identify key levers for maximizing the benefit of intravenous thrombolysis in acute stroke. *Stroke*. 2022;53:xxx-xxx. doi: 10.1161/STROKEAHA.121.038454
5. Ansah JP, Inn RLH, Ahmad S. An evaluation of the impact of aggressive hypertension, diabetes and smoking cessation management on CVD outcomes at the population level: a dynamic simulation analysis. *BMC Public Health*. 2019;19:1105. doi: 10.1186/s12889-019-7429-2