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Correspondence

Hospital transfer risk scoring system for a Taiwan COVID-19 medicalized hotel based on graph convolutional networks

Dear Editor,

The outbreak of coronavirus disease 2019 (COVID-19) since late 2019 has imposed a heavy burden on health facilities worldwide. In New Taipei City, the government designated Far Eastern Memorial Hospital (FEMH) to establish two medicalized hotels to provide basic medical care for asymptomatic or mildly symptomatic patients with COVID-19.[1,2] One of the medicalized hotels in Banqiao used a virtual cloud-based ward care system for medical staff to execute daily ward rounds, medical consultations, and vital signs measurements on a social media platform. During the pandemics, symptomatic patients in New Taipei City were advised to visit an emergency department of a nearby hospital. If tested COVID positive, the patients with stable clinical conditions were transferred to designated quarantine facilities. When arriving, a medical staff would evaluate the patients in the ambulance for triage and transfer unstable patients immediately to FEMH for further treatment.

We retrospectively collected the data of 679 patients transferred to a FEMH-operated medicalized hotel in Banqiao between 28 May and 7 July, 2021. After excluding 47 patients being referred to FEMH at triage, a total of 632 patients were admitted to the medicalized hotel during the 41 days of operation, with a mean age of 41.5 $\pm$ 19.11. Basic vital signs, including body temperature (BT), pulse rate (PR), peripheral oxygen saturation (SpO2), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were measured at least twice per day, 8 h apart for all patients. Between the severe and non-severe groups, patient age (51 $\pm$ 20 vs 40 $\pm$ 19, $p < 0.001$) and T2DM as a comorbidity (15% vs. 4.7%, $p = 0.002$) demonstrated statistical significance in univariate analysis.

Hospital transfer risk scoring system

To identify patients at risk in time, we developed and evaluated a deep learning-based hospital transfer risk scoring system (website: http://med-ai-demo.lab.nycu.edu.tw). Unlike existing COVID severity risk scoring systems,[4,5] our method was based only on longitudinal vital signs and demographic data collected at the medicalized hotel. Particularly, we designed a Graph Convolutional Network (GCN)[3] model to capture daily patient similarities and temporal dependencies for potential disease progression.

An overview of our approach is shown in Fig. 1, including the following. First, patients were aligned at the day of arrival and daily vital signs were extracted as features. Second, a patient similarity graph was constructed using the K Nearest Neighbors (KNN) algorithm and weighted by a Gaussian kernel. Third, a temporal transition matrix was calculated, based on which a graph convolutional network classification model was built for transfer risk prediction. The probabilistic nature of the proposed model allowed us to predict current and next day transfer risk based on a patient's past t days' records.

For model validation on the testing set, the area under the ROC curve (AUC) scores for current day predictions for $t = 1, 2, 3$ were 0.98, 0.84, and 0.94, respectively, while those for the next day predictions were 0.86, 0.96, and 0.69, respectively. A scoring system ranging from 0 to 100, was designed based on the predicted transfer probabilities. As shown in Fig. 1(F), individuals with scores 0–60 were defined to be at low risk, 60–90 at middle risk, and 90–100 at high risk. Overall, our proposed hospital transfer risk scoring system was able to make real-time predictions

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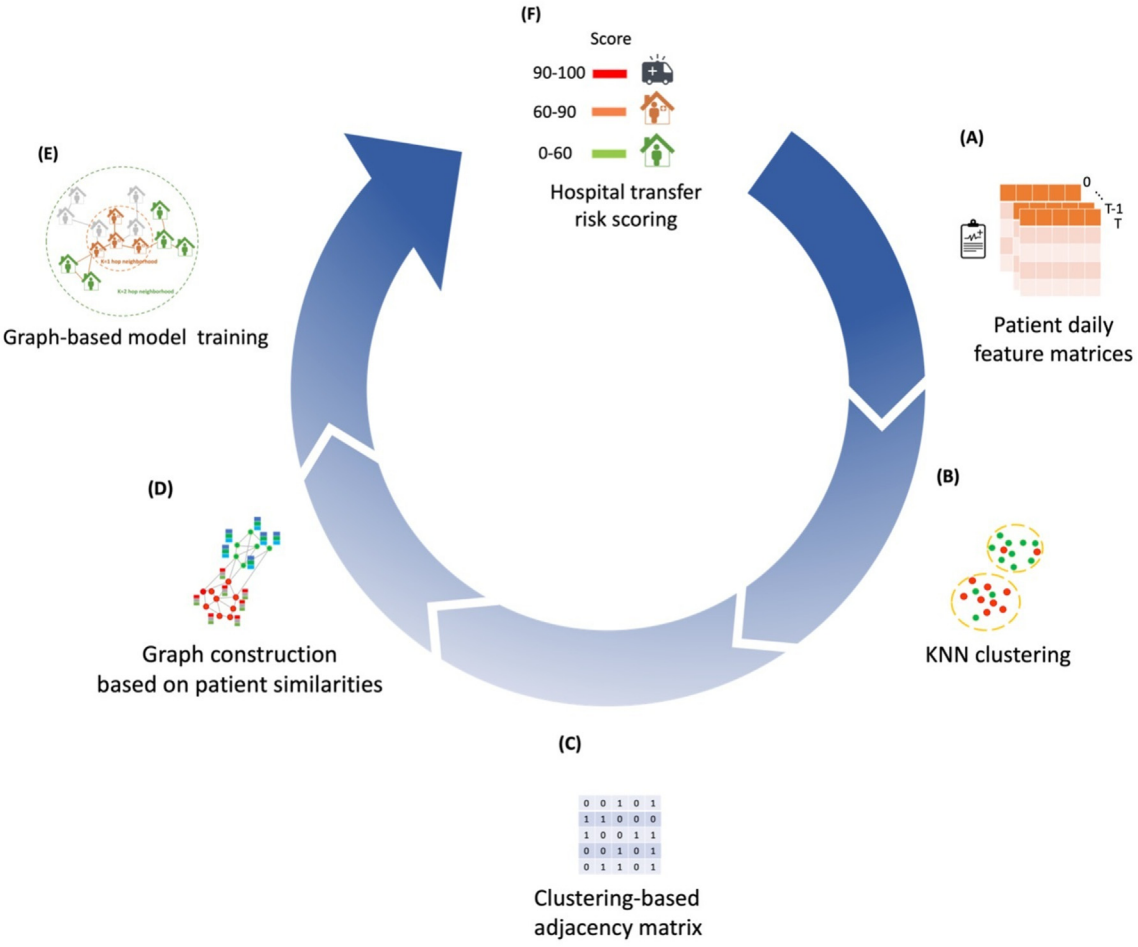

Figure 1 The workflow of the proposed hospital transfer risk scoring system.

based on the limited vital signs and demographic data collected from medicalized hospitals.

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Ethics approval and consent to participate

The case was reviewed and approved by the Institutional Review Boards at FEMH (Reference FEMH No.: 111043-E) and the trial period was from March 8, 2022 to February 9, 2024. The validity period of the license is from March 8, 2022 to March 7, 2023.

Declaration of competing interest

The authors of this study do not have any conflicts of interest related to this article.

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References

1. Tsai HW, Hung FM, Liao CH, Lin HF. Hotel-based quarantine. Center as a rapid response to COVID-19 outbreak, New Taipei, Taiwan, May to july 2021. *J Formos Med Assoc* July 2021;**2022**: 19—21. https://doi.org/10.1016/j.jfma.2022.01.001.
2. Lim KX, Chen YT, Chiu KM, Hung FM. Rush hour: transform a modern hotel into cloud-based virtual ward care center within 80 hours under COVID-19 pandemic. Far eastern Memorial Hospital's experience [Internet] *J Formos Med Assoc* 2022; **121**(4):868—9. Available from: https://doi.org/10.1016/j.jfma.2021.10.023.
3. Hamilton W, Ying Z, Leskovec J. Inductive representation learning on large graphs [Internet]. In: Guyon I, Luxburg UV, Bengio S, Wallach H, Fergus R, Vishwanathan S, et al., editors. *Advances in neural information processing systems*. Curran

Associates, Inc.; 2017. Available from: https://proceedings.neurips.cc/paper/2017/file/5dd9db5e033da9c6fb5ba83c7a7ebea9-Paper.pdf.
4. Zhang C, Qin L, Li K, Wang Q, Zhao Y, Xu B, et al. A novel scoring system for prediction of disease severity in COVID-19. *Front Cell Infect Microbiol* December 2019;**2020**(10). https://doi.org/10.3389/fcimb.2020.00318.
5. Liang W, Liang H, Ou L, Chen B, Chen A, Li C, et al. Development and validation of a clinical risk score to predict the occurrence of critical illness in hospitalized patients with COVID-19. *JAMA Intern Med* 2020 Aug 1;**180**(8):1081—9. https://doi.org/10.1001/jamainternmed.2020.2033.

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