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Original Article

Intelligent system to predict intradialytic hypotension in chronic hemodialysis

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Background: Intradialytic hypotension (IDH) is a serious complication and a major risk factor of increased mortality during hemodialysis (HD). However, predicting the occurrence of intradialytic blood pressure (BP) fluctuations clinically is difficult. This study aimed to develop an intelligent system with capability of predicting IDH.
Methods: In developing and training the prediction models in the intelligent system, we used a database of 653 HD outpatients who underwent 55,516 HD treatment sessions, resulting in 285,705 valid BP records. We built models to predict IDH at the next BP check by applying time-dependent logistic regression analyses.
Results: Our results showed the sensitivity of 86% and specificity of 81% for both nadir systolic BP (SBP) of <90 mmHg and <100 mmHg, suggesting good performance of our prediction models. We obtained similar results in validating via test data and data of newly enrolled patients (new-patient data), which is important for simulating prospective situations wherein dialysis staff are unfamiliar with new patients. This compensates for the retrospective nature of the BP records used in our study.

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Conclusion: The use of this validated intelligent system can identify patients who are at risk of IDH in advance, which may facilitate well-timed personalized management and intervention.

Introduction

Blood pressure (BP) monitoring is a fundamental and essential for patients with chronic kidney disease (CKD).[1] The BP was measured in frequent intervals during hemodialysis (HD) to ensure patient safety. BP management among HD patients has been very difficult because a significant BP fluctuation and variation was found at pre-, intra- and post-dialysis. The extreme changes in blood volume during HD often make obtaining a clear picture of the actual blood pressure in HD patients difficult.[2]

Intradialytic hypotension (IDH) is recognized as a major risk factor for increased morbidity and mortality.[3,4] It is the leading complication of HD treatments, occurring in 15%—30% of all treatments[5] and at least once in 75% of HD patients.[6] Although there is no evidence-based consensus definition of IDH, in one well-conducted study, among the commonly used definitions, results suggest that nadir BP-based definitions best capture the association with mortality and that the addition of symptom and intervention criteria to nadir BP did not strengthen the association.[7]

IDH induces symptoms, such as abdominal discomfort, muscle cramps, sighing, anxiety, restlessness, nausea, vomiting, headaches, dizziness, or fainting. Aside from worsening patients' quality of life, IDH creates barriers to achieve adequate dialysis dose and ultrafiltration (UF), and leads to cardiovascular complications (arrhythmia, ischemic heart events), more hospitalization, and higher mortality over the long term. Vulnerable patients are the elderly and those with diabetes, cardiovascular disease, longer dialysis vintage, lower pre-dialysis BP, lower albumin, higher body mass index, and higher UF volume.[6] IDH is often the result of attempts to correct extracellular fluid (ECF) accumulation associated with end-stage renal disease (ESRD). It is mainly caused by a reduction in blood volume because of the imbalance between the UF and plasma refilling rates.[8] A structurally or functionally compromised cardiovascular system increases the sensitivity of patients to changes in fluid status.

Obvious symptomatic hypotension requires immediate nursing intervention. Drastic measures may include stopping UF or HD entirely, taking the Trendelenburg position, and/or administering intravenous α-1 adrenergic agonist midodrine,[9,10] and supplemental oxygen. Alongside the increased understanding of pathophysiology and available interventions, the greatest potential in minimizing IDH lies in intelligent systems that enable continuous timely adjustment of dialysis settings throughout the treatment based on real-time hemodynamic changes and the patient's past record of hemodynamic performance. Modifiable dialysis settings include reducing blood flow, optimizing UF rate and dialyzate sodium concentration, cool temperature dialyzate, and avoidance of a low magnesium and low calcium bath.[7,9] To date, however, no study has focused on the simulation or prediction of intradialytic BP profiles. In the current clinical practice, we can only observe rather than prognosticate or preclude the onset of IDH. Hence, in this study, we applied machine learning algorithms to develop an intelligent early warning system capable of predicting the insurgence of IDH and providing timely suggestions regarding dialysis settings. We also validated the system via test dataset and new-patient dataset to assess the model performance.

Patients and methods

Patient population and data collection

This study was performed retrospectively in unselected patients of an outpatient HD unit in a tertiary medical center between June 2013 and November 2015, and was approved by the Institutional Review Board of MacKay Memorial Hospital (16MMHIS044). HD treatments were performed twice to thrice a week, with each treatment lasting up to 240 min. For most patients, the initial dialysis settings were as follows: dialyzate sodium concentration, 138 mmol/L; dialyzate calcium concentration, 3.0 mmol/L; dialyzate flow rate, 500 mL/min; and dialyzate temperature, 36.5 °C. Bicarbonate-containing dialyzate and biocompatible artificial kidneys were used for all patients. Due to the retrospective nature of the BP records used in our study, the new-patient dataset is important for simulating prospective situations wherein dialysis staff are unfamiliar with new patients, thereby precluding proactive nursing interventions drawn upon their longitudinal patient relationships, enriched by knowledge about such patient's historical BP trends, treatment tolerance, volume status, prescription medications, health status, etc.

During HD, BP and pulse rate were measured hourly by electronic sphygmomanometers several times from the start to the end of the session and additionally based on clinical need, e.g., cramps. At each BP check, concurrent dialysis settings encompassing blood flow rate, UF rate, total UF volume, dialyzate sodium concentration, and dialyzate temperature were recorded. Due to the massive volume and complexity of the data, we used Wistron Corporation's Vital Info Portal gateway device to collect the vital signs and corresponding dialysis recording from the HD equipment. Structured Query Language was used to manage individual electronic medical records, which were then stored in the Oracle database. Wistron also provided the big data analytics algorithms, including feature