Construction and Validation of a Prediction Model and Bedside Tool for Acute Kidney Injury Complicated by Acute Pancreatitis Based on Liquid Neural Networks: A Postprint Study

Authors: Chen Jian, Zhu Menglin, Kaijian Xia, Xiao Liu, Wang Ganhong, Xu Xiaodan, Xu Xiaodan

Date: 2026-04-29T16:39:41+00:00

Abstract

Background: Acute pancreatitis (AP) is frequently complicated by acute kidney injury (AKI), which significantly increases mortality and the medical burden. There is a lack of early, simple, and accurate prediction tools in clinical practice, creating an urgent need to construct effective models for identifying high-risk patients. Objective: To construct a prediction model based on Liquid Neural Networks (LNN) and its bedside tool to achieve early prediction of AKI in patients with AP. Methods: A total of 586 patients who visited Changshu First People' s Hospital (Dataset 1, n=325), Changshu Shanghu Central Hospital (Dataset 2, n=117), and Changshu Traditional Chinese Medicine Hospital (Dataset 3, n=144) for AP between June 2020 and February 2025 were included. Datasets 1 and 2 were collected retrospectively and primarily used for model construction, internal validation, and bedside tool development; Dataset 3 was collected prospectively for external testing of the bedside tool. Using Python, the model development group data (comprising Datasets 1 and 2) were randomly divided into a training cohort and a validation cohort at a ratio of 8:2. Clinical data from patients in the training and validation cohorts were collected, including 31 potential features such as demographic characteristics, medical history, and laboratory examinations. After processing missing values, performing feature selection, and balancing samples using the Synthetic Minority Over-sampling Technique (SMOTE), prediction models were constructed using Logistic Regression (LR), Decision Tree (DCT), Random Forest (RF), Extreme Gradient Boosting (XGBoost), and LNN, respectively. Model performance was compared using metrics such as Receiver Operating Characteristic (ROC) curves, sensitivity, specificity, and accuracy to select the optimal model. Interpretability analysis was performed using the SHapley Additive Ex-

planations (SHAP) method. A web application was developed based on the Streamlit framework to implement bedside risk prediction. Results: Among the 586 AP patients, 136 (23.21%) developed AKI. There were no statistically significant differences in baseline data between the training and validation cohorts (P>0.05). LASSO regression analysis identified 6 key predictive features: albumin, blood urea nitrogen, alkaline phosphatase, serum potassium, serum creatinine, and the neutrophil-to-lymphocyte ratio (NLR). In the validation cohort, the LNN model performed best, outperforming logistic regression and other machine learning models, with an AUC of 0.91 (95% CI = 0.86–0.95). Feature importance ranking showed that the six indicators—NLR, creatinine, serum potassium, urea nitrogen, alkaline phosphatase, and albumin—contributed most to AKI prediction. Visual analysis using force plots clearly presented the impact of each feature on individual risk. Based on the Python-Streamlit framework, the best-performing LNN model was developed into an AI bedside tool with a visual interface. In the test set, the accuracy, sensitivity, and specificity of the AI bedside tool for predicting AKI in AP patients were 94.4%, 89.29%, and 95.69%, respectively. Conclusion: The LNN-based prediction model and bedside tool can achieve early identification of AKI risk in AP patients and possess significant clinical application value.

Full Text

A Liquid Neural Network-Based Model and Bedside AI Tool for Early Prediction of Acute Kidney Injury in Acute Pancreatitis: Development and Validation Study

Authors: CHEN Jian[1,2], ZHU Menglin[1], XIA Kaijian[2], LIU Xiao[3], WANG Ganhong[4], XU Xiaodan[1*]

1. Department of Gastroenterology, Changshu No.1 People' s Hospital/Changshu Hospital Affiliated to Soochow University, Suzhou 215500, China
2. Center of Intelligent Medical Technology Research, Changshu No.1 People' s Hospital/Changshu Hospital Affiliated to Soochow University, Suzhou 215500, China
3. Department of Gastroenterology, Changshu Shanghu Central Hospital, Suzhou 215500, China
4. Department of Gastroenterology, Changshu Hospital of Traditional Chinese Medicine/Changshu New District Hospital, Suzhou 215500, China

---

Abstract

Background: Acute kidney injury (AKI) is a frequent and severe complication of acute pancreatitis (AP), significantly increasing patient morbidity and mortality. Early identification of high-risk patients is crucial for clinical in-

tervention. While traditional machine learning models have been applied to this challenge, they often struggle with the temporal dynamics and non-linear complexities inherent in clinical data.

Objective: To develop and validate a prediction model and a corresponding bedside tool based on Liquid Neural Networks (LNN) to achieve early prediction of AKI in patients with AP.

Methods: A total of 586 patients diagnosed with AP between June 2020 and February 2025 were included from three hospitals: Changshu First People' s Hospital (Dataset 1, $n = 325$), Changshu Shanghu Central Hospital (Dataset 2, $n = 117$), and Changshu Traditional Chinese Medicine Hospital (Dataset 3, $n = 144$). Datasets 1 and 2 were used for model construction and internal validation, while Dataset 3 served as a prospective external test set. The development cohort was randomly partitioned into training and validation sets (8:2). Feature selection was performed using LASSO regression, and the Synthetic Minority Over-sampling Technique (SMOTE) was applied to balance the samples. Five models—Logistic Regression (LR), Decision Tree (DCT), Random Forest (RF), Extreme Gradient Boosting (XGBoost), and LNN—were constructed and compared. Model interpretability was analyzed using SHapley Additive exPlanations (SHAP). A web application was developed using the Streamlit framework for bedside risk prediction.

Results: Among the 586 patients, 136 (23.21%) developed AKI. LASSO regression identified six key predictive features: albumin, blood urea nitrogen (BUN), alkaline phosphatase (ALP), serum potassium, serum creatinine, and the neutrophil-to-lymphocyte ratio (NLR). The LNN model demonstrated superior performance in the validation cohort with an AUC of 0.91 (95% CI = 0.86–0.95). In the external test set, the AI bedside tool achieved an accuracy of 94.4%, sensitivity of 89.29%, and specificity of 95.69%.

Conclusion: The LNN-based prediction model and bedside tool enable early identification of AKI risk in patients with AP, demonstrating significant clinical utility for real-time risk assessment.

Keywords: Acute pancreatitis; Acute kidney injury; Machine learning; Liquid neural networks; Bedside tool

---

1. Introduction

Acute pancreatitis (AP) is a common emergency of the digestive system, with a global incidence ranging from 4.9 to 73.4 per 100,000 individuals [**?**]. While most patients recover with symptomatic treatment, approximately 20% progress to severe AP, often accompanied by systemic inflammatory response syndrome and organ dysfunction [**?**]. Acute kidney injury (AKI) is one of the most frequent and severe complications, occurring in 10% to 42% of cases, with mortality rates reaching 25% to 75% [**?**].

Traditional clinical scoring systems, such as Ranson's criteria or the BISAP score, often lack the specificity or dynamic adaptability required for precise individual risk assessment. While machine learning (ML) has shown promise in medical prognosis, few studies have utilized Liquid Neural Networks (LNN) for AP-AKI prediction. LNNs, characterized by continuous-time dynamics and adaptive time-constants, are particularly suited for processing clinical data. This study aims to construct an LNN-based early risk prediction model and develop a user-friendly bedside tool for rapid clinical decision-making.

2. Materials and Methods

2.1 Research Subjects and Data Collection This study included 586 patients diagnosed with AP meeting the 2012 revised Atlanta classification criteria [**?**]. Exclusion criteria included missing data (>10%), pre-existing chronic kidney disease, recent exposure to nephrotoxic agents, or comorbid malignancies.

Collected features included: 1. **Demographics:** Age, sex, and BMI. 2. **Clinical Characteristics:** Fasting blood glucose (FBG), etiology, blood pressure, and smoking history. 3. **Laboratory Indicators:** PTA, albumin, bilirubin, cholesterol, triglycerides, hemoglobin, ALT, AST, ALP, BUN, electrolytes, creatinine, PCT, WBC, amylase, CRP, and the calculated TyG index and NLR.

AKI was defined according to KDIGO guidelines: an increase in serum creatinine ≥ 0.3 mg/dL within 48 hours, or ≥ 1.5 times baseline within 7 days, or urine output < 0.5 ml/kg/h for 6 hours [**?**].

2.2 Model Construction and Comparison The development data (Datasets 1 and 2) was split 8:2 into training and validation cohorts. LASSO regression was used for feature selection, identifying the optimal penalty parameter (λ) via 5-fold cross-validation. SMOTE was applied to the training set to address class imbalance.

Five models (LR, DCT, RF, XGBoost, and LNN) were optimized using grid search. LNNs model dynamic relationships using neural ordinary differential equations (neural ODEs), providing high parameter efficiency and robustness against noise. The structural framework of the LNN model is shown in [Figure 1: see original paper].

2.3 Model Interpretability and Bedside Tool Development SHAP values were used to quantify the contribution of each feature to the prediction. Force plots were utilized to visualize individual risk drivers. The final LNN model was deployed as a web application using the Streamlit framework (https://lnn-for-ap-aki.streamlit.app/), allowing clinicians to input parameters and receive real-time risk assessments and SHAP visualizations.

3. Results

3.1 Baseline Characteristics and Feature Selection There were no statistically significant differences in baseline characteristics between the training and validation cohorts ($P > 0.05$), as shown in . LASSO regression [Figure 2: see original paper] identified six key predictors: albumin, BUN, ALP, serum potassium, creatinine, and NLR.

3.2 Model Performance As shown in [Figure 3: see original paper], the AUC values for all models improved after applying SMOTE. The LNN model achieved the highest performance with an AUC of 0.91 (95% CI = 0.86–0.95), accuracy of 84.47%, and specificity of 91.82%. Calibration curves [Figure 4A: see original paper] and Decision Curve Analysis [Figure 4B: see original paper] confirmed the model' s high degree of calibration and clinical net benefit.

3.3 Interpretability and External Validation SHAP analysis [Figure 5: see original paper] identified NLR and creatinine as the most significant predictors. Force plots [Figure 6: see original paper] illustrated how these features influenced individual risk (e.g., an 86% predicted probability of AKI). In the external test set (Dataset 3, $n = 144$), the AI bedside tool correctly classified 136 cases, achieving 94.4% accuracy, 89.29% sensitivity, and 95.69% specificity [Figure 9: see original paper].

4. Discussion

This study successfully developed an LNN-based prediction model for AP-AKI that relies on only six routine clinical indicators, ensuring cost-effectiveness and ease of use in primary care settings. Unlike previous models requiring specialized biomarkers [**?**, **?**], our model achieves comparable or superior accuracy (AUC 0.91) using standard laboratory tests.

The selected features—NLR, creatinine, BUN, ALP, potassium, and albumin —reflect critical pathological pathways including inflammation, volume status, and electrolyte balance. The LNN architecture' s ability to handle noise and its stability in small-sample scenarios contributed to its superior performance over traditional ML models like XGBoost or RF.

The developed Streamlit bedside tool addresses the limitations of traditional nomograms by providing "one-click" assessments and visual explanations of risk factors. This enhances clinical transparency and supports individualized treatment strategies.

Limitations: The study did not fully exploit LNN' s time-series capabilities as it used static admission data. Future work will focus on integrating dynamic follow-up data and multi-center validation to further enhance generalizability.

5. Conclusion

The LNN-based prediction model and its corresponding bedside tool provide a robust, accurate, and interpretable method for the early identification of AKI in patients with acute pancreatitis, offering significant potential for clinical application.

Note: Figure translations are in progress. See original paper for figures.