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Deep Learning-Based Anomaly Detection Using Creatinine and eGFR Time-Series Data to Identify Kidney Injury in ICU Patients

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Objectives : Current acute kidney injury (AKI) diagnosis relies primarily on discrete creatinine changes. However, these static criteria may miss subtle, dynamic changes in kidney function, particularly in rapidly changing intensive care unit (ICU) environments. Deep learning-based anomaly detection may address these limitations by analyzing patient-specific temporal patterns of creatinine.
Methods : This study analyzed intensive care unit (ICU) patients from the Medical Information Mart for Intensive Care (MIMIC)-IV and eICU databases, excluding those with end-stage kidney disease or prior kidney replacement therapy (KRT). Serum creatinine and estimated glomerular filtration rate collected at 24-hour intervals—from 24 hours before ICU admission until discharge, death, or KRT initiation—were linearly interpolated, with physiologically permissible noise added. Kidney injury by anomaly detection using an Anomaly Transformer model was defined when creatinine increased at the final measurement with an anomaly score above the 5th percentile threshold. Performance for predicting KRT and mortality was internally and externally validated.
Results : A total of 61,373 ICU patients (81,876 admissions) from MIMIC-IV generated 381,700 seven-day datasets (80% training, 5% validation, 15% test). External validation utilized 494,684 datasets from 124,348 patients (140,237 admissions) in the eICU database. Kidney injury by anomaly detection occurred in 3.91% of test cases, slightly higher than AKI stage ≥2 (3.79%). Anomaly detection outperformed AKI stage ≥2 criteria in predicting KRT initiation at 96h (test F1-score: 0.265 vs. 0.206; external F1-score: 0.161 vs. 0.132). Combining both criteria improved mortality prediction at 96h (test F1-score: 0.175 vs. 0.153 for AKI stage ≥2 alone). Anomaly scores were significantly higher in patients with AKI stage ≥2 and adverse outcomes, consistently across datasets.
Conclusions : Deep learning-based anomaly detection effectively identifies kidney dysfunction, offering an improved criterion for predicting key clinical outcomes in ICU patients. This novel approach may serve as a complementary diagnostic tool in AKI research and clinical ICU practice, pending further validation.

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Table 1. Outcome prediction metrics of anomaly detection in test data

Outcome	Method	Accuracy	F1
KRT within 24hr	Anomaly Transformer	0.960	0.118
	AKI stage ≥ 2	0.960	0.098
KRT within 48hr	Anomaly Transformer	0.959	0.204
	AKI stage ≥ 2	0.958	0.159
KRT within 72hr	Anomaly Transformer	0.958	0.254
	AKI stage ≥ 2	0.956	0.191
KRT within 96hr	Anomaly Transformer	0.957	0.265
	AKI stage ≥ 2	0.955	0.206
Mortality within 24hr	Anomaly Transformer	0.952	0.080
	AKI stage ≥ 2	0.954	0.085
Mortality within 48hr	Anomaly Transformer	0.944	0.124
	AKI stage ≥ 2	0.945	0.120
Mortality within 72hr	Anomaly Transformer	0.936	0.141
	AKI stage ≥ 2	0.937	0.138
Mortality within 96hr	Anomaly Transformer	0.929	0.152
	AKI stage ≥ 2	0.931	0.153

KRT, kidney replacement therapy; AKI, acute kidney disease.

Table 2. Outcome prediction metrics of anomaly detection in external validation data

Outcome	Method	Accuracy	F1
KRT within 24hr	Anomaly Transformer	0.958	0.153
	AKI stage ≥ 2	0.958	0.133
KRT within 48hr	Anomaly Transformer	0.957	0.161
	AKI stage ≥ 2	0.957	0.132
KRT within 72hr	Anomaly Transformer	0.957	0.161
	AKI stage ≥ 2	0.957	0.132
KRT within 96hr	Anomaly Transformer	0.957	0.161
	AKI stage ≥ 2	0.957	0.132
Mortality within 24hr	Anomaly Transformer	0.957	0.071
	AKI stage ≥ 2	0.959	0.086
Mortality within 48hr	Anomaly Transformer	0.946	0.113
	AKI stage ≥ 2	0.949	0.125
Mortality within 72hr	Anomaly Transformer	0.936	0.127
	AKI stage ≥ 2	0.938	0.135
Mortality within 96hr	Anomaly Transformer	0.927	0.130
	AKI stage ≥ 2	0.930	0.138

KRT, kidney replacement therapy; AKI, acute kidney disease.

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Figure 1. Anomaly scores according to acute kidney injury

(A) Test data (B) External validation

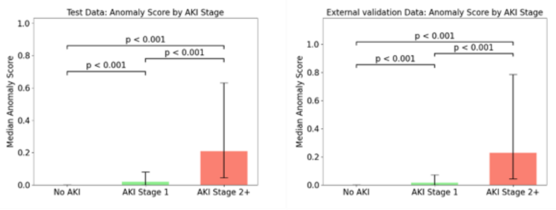


Figure 2. Anomaly scores according to outcomes

(A) Test data (B) External validation

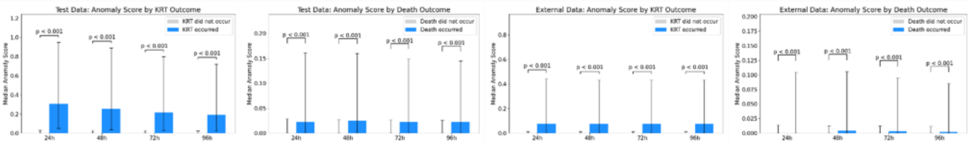
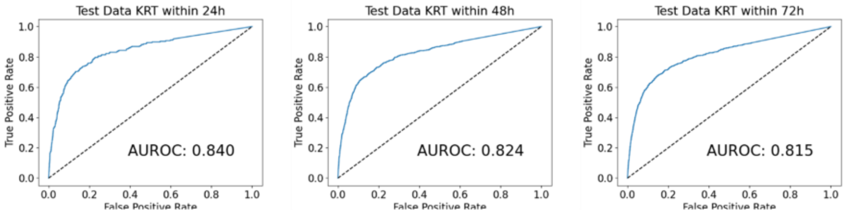


Figure 3. Receiver operating characteristic curve of anomaly scores for predicting kidney replacement therapy

(A) Test data



(B) External validation

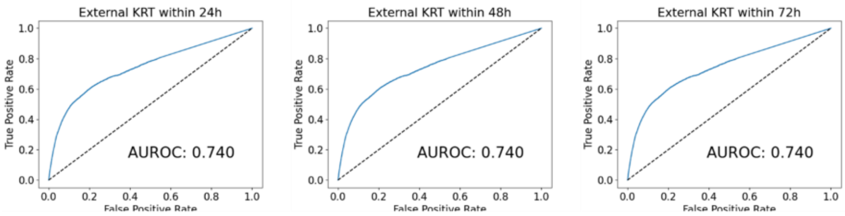


Figure 4. Example of anomaly detected samples