Real-time Prediction of Intracranial Hypertension Events in Traumatic Brain Injury Patients Using Ensemble Deep Learning Models

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Tianchen Luo, Ping Wen

PrimaNova Technologies Limited

PrimaNova

Background

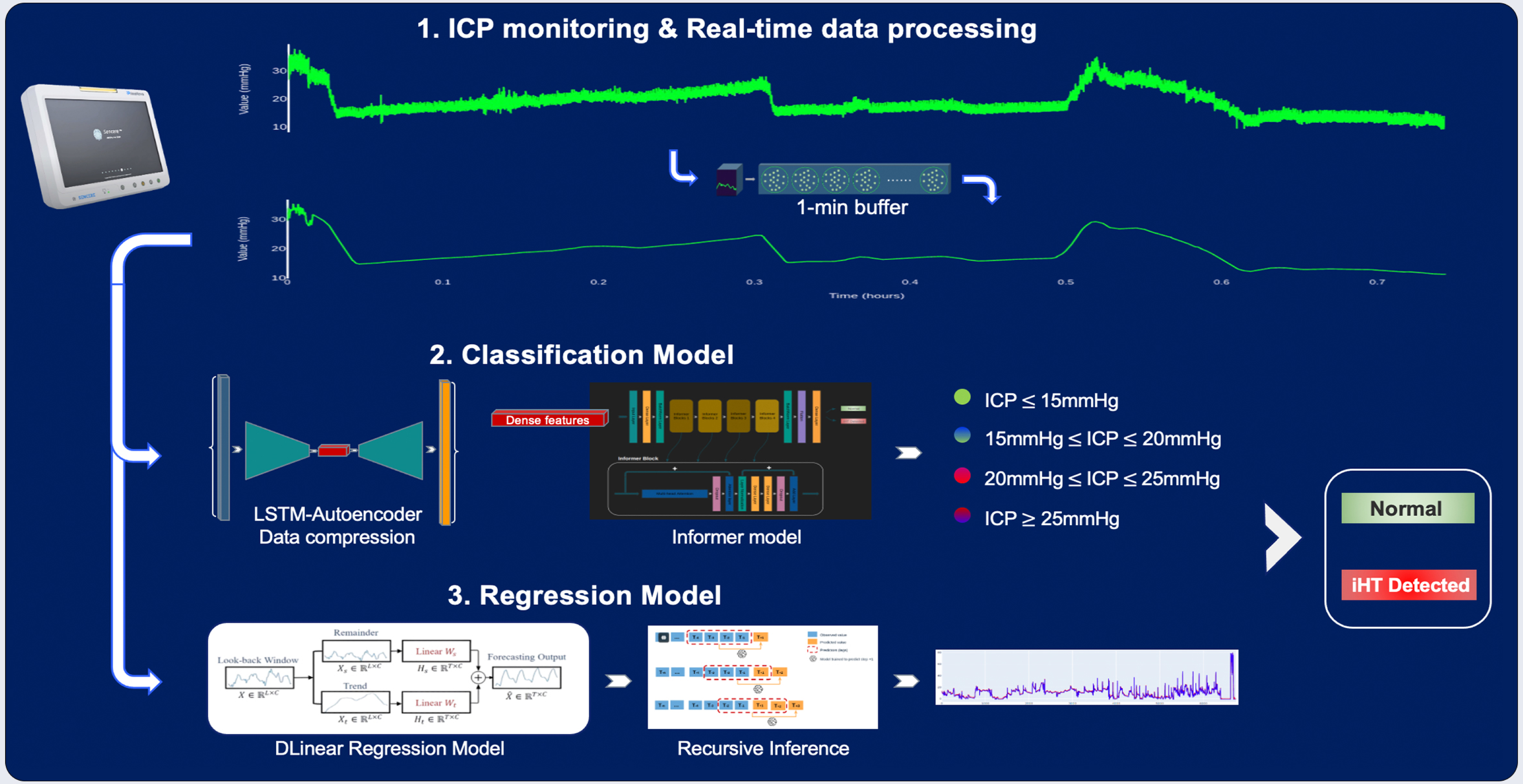
Intracranial pressure (ICP) is a critical indicator for assessing the condition of patients with traumatic brain injuries (TBI). Intracranial hypertension(iHT) can lead to further damage to brain tissue, resulting in severe complications such as brain herniation and cerebral ischemia, and may even be life-threatening. While current research primarily focuses on retrospective analysis, there is a pressing need for real-time predictive models that can be implemented in clinical settings. Traditional monitoring methods often detect critical events too late for preventive intervention, highlighting the necessity for predictive approaches.

Methods

1. Data Sources
   Charis database: 13 patients (Codman monitor, 50 Hz)
   Clinical trials: 47 patients (PrimaNova monitor, 1000 Hz)
   (All patients monitored >24 hours)
2. Data Processing
   Real-time one-minute processing buffer
   Features: denoising, normalization, smoothing
   (Validation: Pearson correlation coefficient = 0.9748)
3. The prediction framework comprises two components:

- DLinear-based regression model with self-attention that predicts ICP values 30 minutes ahead using previous 30-minute data
- LSTM auto-encoder with Informer architecture that classifies ICP into four levels (<15 mmHg, 15-20 mmHg, 20-25 mmHg, >25 mmHg).

The integrated system combines regression and classification model outputs for joint decision-making to predict high intracranial pressure events



Experiments and Results

The model's performance was rigorously evaluated on 1,486 independent test segments, demonstrating predictive capabilities with an AUC of 0.933. The sensitivity of 0.921 indicates successful identification of 92.1% of high ICP events, significantly reducing the risk of missed diagnoses. The specificity of 0.945 shows accurate identification of 94.5% of normal ICP states, minimizing false alarms.

Conclusion

This study presents a real-time deep learning model for ICP monitoring, utilized dual-model approach that combines regression and classification predictions enhanced by autoencoder feature extraction. The four-level risk stratification enables targeted clinical interventions, while the model's high accuracy and early warning capabilities support effective clinical decision-making. Future work will expand datasets, establish multi-center databases, and conduct prospective clinical trials.