Prediction and Prevention of Intracranial Hypertension Crises in Severe Traumatic Brain Injury

NeuroSight™ | Real-time ICP-only forecasting 30 minutes before crisis onset

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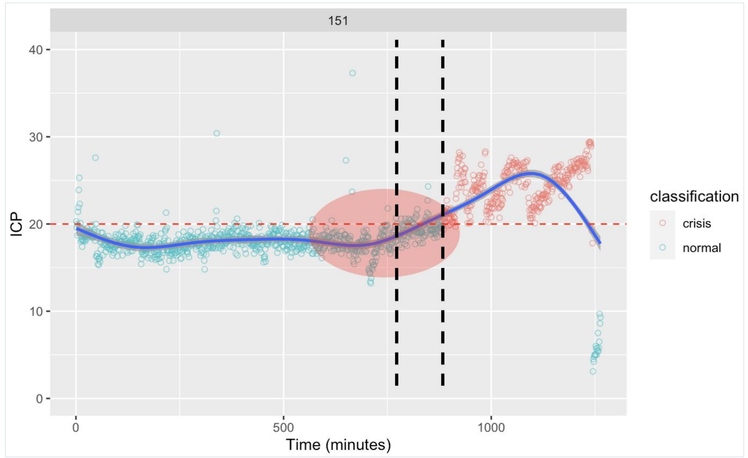
CRISIS DEFINITION	DEVELOPMENT	EXTERNAL VALIDATION	FORECAST	WORKFLOW
ICP ≥20 mmHg for ≥15 min	817 adults · > 13M readings	88 patients · PREDICT + BOOST-3	30 min before onset · ICP only	5 min data + 5 min compute · q10 min

1 Forecast the event

INTRODUCTION & OBJECTIVE

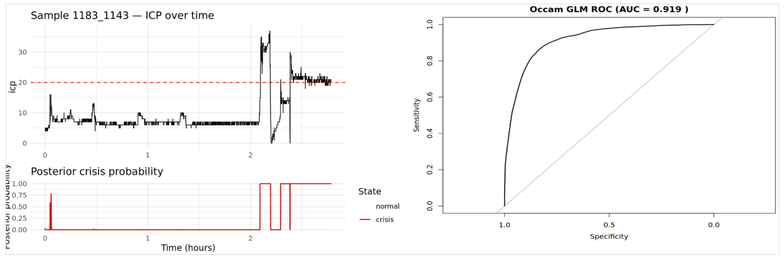
Clinical problem. Secondary brain injury is a major modifiable driver of poor outcome after severe TBI. Conventional ICP alarms are reactive—they notify clinicians after the treatment threshold has already been crossed.
Objective. Estimate the probability of entering an ICP crisis 30 minutes later using continuously collected ICP alone.



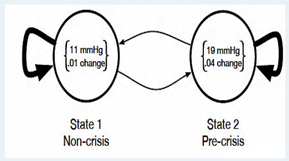
Prediction target: the pre-crisis trajectory (shaded window), not observations already inside a crisis. This reframes bedside monitoring from threshold detection to forecasting.

2 Combine ICP dynamics with latent HMM state

METHODS



Hidden Markov features



Six compact predictors

- HMM state
- State dwell time
- Crisis index
- Time since crisis
- 5-min crisis frequency
- 5-min mean ICP

Model architecture. A two-state HMM supplies decoded state and dwell-time information; supervised logistic regression combines those latent-state features with recent ICP dynamics and prior crisis burden.
Output: a calibrated 0–100% probability of crisis within the next 30 minutes.

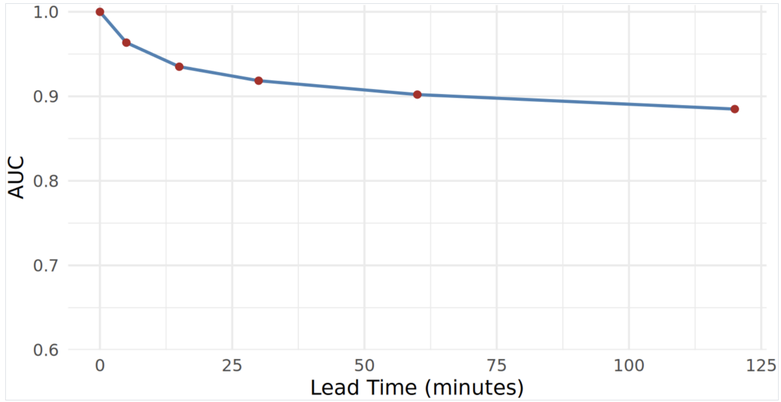
Development: 817 patients / >13 million readings (1989–2013) **Validation:** 88 prospective PREDICT + BOOST-3 patients (2022–2026)

3 Discrimination persists across lead times

RESULTS

0.92	0.92	0.54	0.96
AUC	Accuracy	Sensitivity	Specificity

External validation at the 30-minute operating horizon



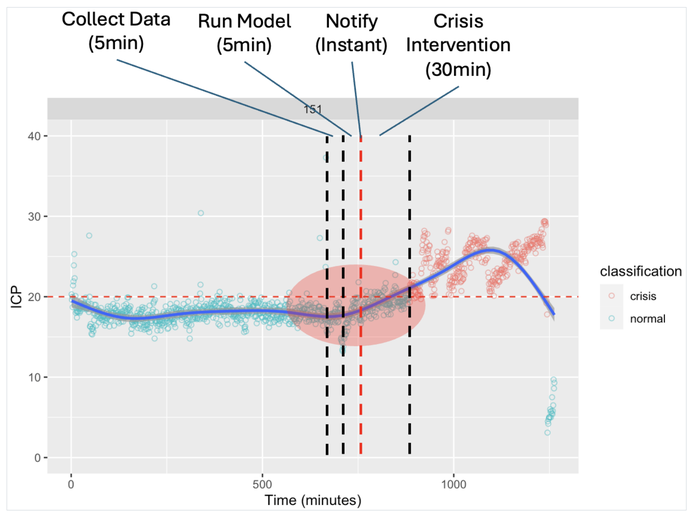
Key result. Performance declines gradually rather than collapsing as the forecast horizon lengthens. The selected 30-minute horizon retains AUC ≈0.92, and AUC remains ≈0.88 at 120 minutes.

The operating horizon can therefore be chosen around clinical actionability, not only maximum discrimination.

4 Preserve time for preemptive intervention

METHODS → CLINICAL ACTION

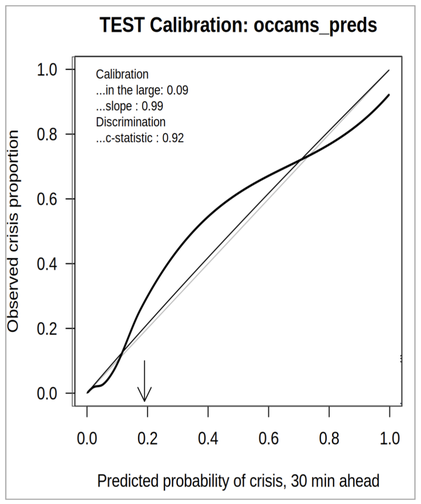
Operational sequence: collect 5 minutes of ICP → run the model in 5 minutes → notify immediately → retain up to 30 minutes for intervention.



Prediction cadence: every 10 minutes, enabling repeated risk assessment before threshold-defined crisis onset.

5 Calibrate risk and tune the alert trade-off

RESULTS



Observed vs predicted risk at the 30-minute horizon

0.99	0.09	0.92
Calibration slope	Calibration-in-the-large	C-statistic

Balanced operating point
Sensitivity 0.543 • Specificity 0.958
Precision 0.751 • F1 0.547

Threshold Tuning (Average 12 Crises / Day)

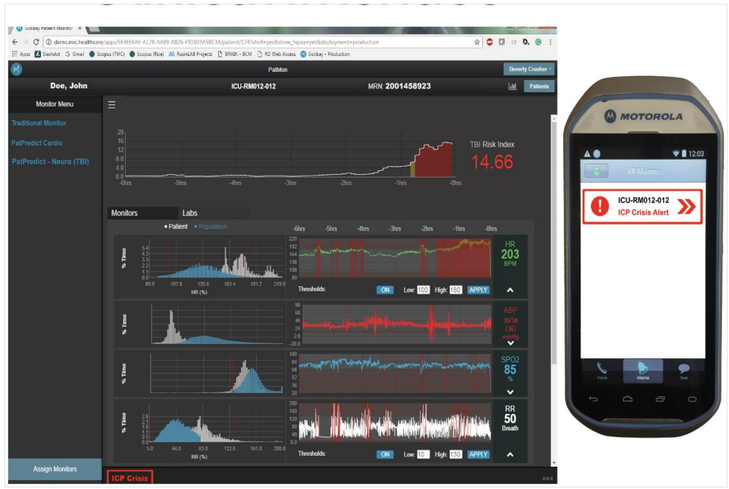
10-min windows	UNTUNED	BALANCED	HIGH SENS.
Sensitivity	0.326	0.543	0.741
Missed / day	6.9	5.7	3.2
False+ / day	5.8	5.5	12.2

Per patient-day at a 10-minute prediction cadence

Interpretation. Calibration supports probability-based decisions. Threshold tuning reduces missed crisis windows; a more aggressive setting raises sensitivity to 0.741 but increases false-positive windows and alert burden.

6 Deliver calibrated risk at the bedside

CONCLUSION



NeuroSight™ adds a software forecasting layer to existing bedside infrastructure: real-time waveform context, a calibrated risk index, and a crisis alert—without new hardware.
Next steps: prospective deployment, alert gating and refractory rules, clinical impact testing, and extension to brain-tissue hypoxia forecasting.

- Waveform context
- Risk index
- Crisis alert

FINANCIAL DISCLOSURES

Program Clinical Trial Award - Research Level 1 CDMRP Log Number: TP210464 Grants.gov ID Number: GRANT13518109 PI: Lazaridis

ACKNOWLEDGMENTS

PREDICT and BOOST-3 participants, investigators, and clinical teams.

REFERENCES

1. Lazaridis C, Rusin CG, Robertson CS. Neuropharmacology. 2019;145:145–152.
2. Fleuren LM et al. Intensive Care Med. 2020;46:1486–1488.

VALIDATION STUDIES

PREDICT (NCT06966713)
BOOST-3 (NCT03754114)
Prospective data, 2022–2026