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Developing a Multidimensional TBI Classification System in Emergency Care

Early Progress from the PIONEER Prognosis Study

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Korley

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THE PROBLEM

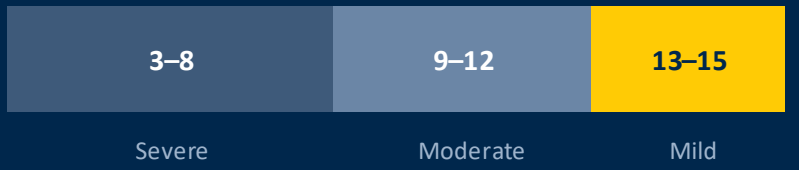
The GCS Ceiling Effect: Not every GCS 15 is “Mild”

~80 - 85% of all TBI is classified “mild,” and most of these present with a GCS of 15

Up to 50% of GCS 15 patients still report symptoms — cognitive, headache, mood — at one year

44–60% accuracy of ED clinician judgment in predicting 3-month recovery on the day of injury

Where the scale runs out



Every GCS 15 patient scores the same 15 — with brisk, equal pupils.
The scale has no headroom to separate the patient who recovers in days from the one still impaired a year later.

Clinical assessment tools built on GCS and pupillary response cannot further stratify this group — the very group that dominates ED TBI volume.

THE FRAMEWORK

A Multidimensional Alternative: NINDS CBI-M

Four integrated dimensions replace a single-number severity label — combining what we observe, what we measure, what we image, and the context the patient carries.

C Clinical

Injury mechanism, symptom burden, neuro-cognitive exam

- Minimally symptomatic
- Moderately symptomatic
- Severely symptomatic

B Biomarker

Blood-based GFAP & UCH-L1 (whole-blood i-STAT)

- Non-elevated
- Mildly elevated
- Very elevated

I Imaging

Head CT findings when clinically indicated

- CT negative / not done
- CT positive

M Modifiers

Age, sex, prior conditions, intoxication, social context

- Low burden
- Intermediate
- High burden

Integrated into a single, patient-level prognostic profile → predicted recovery trajectory

THE GAP WE ADDRESS

A Concept Without an Operating Manual

NINDS proposed CBI-M at a workshop. The details of how to implement it — especially for GCS 15 — remain undefined.

1

No existing classification tool for the largest category of TBI patient (GCS 15)

This group of patients is heterogeneous both at presentation and several months afterwards

2

No operational category definitions

How many biomarker bins? What thresholds? What counts as a modifier, and how is burden scored? None of this is specified.

3

No prototype to test

CBI-M has never been operationalized and deployed prospectively in a real ED GCS 15 population.

OUR PLAN

PIONEER Prognosis: Building & Testing a GCS 15 Prototype

Prospective **I**mplementation **O**f **N**ovel **E**vidence-Based Biomarkers for **E**valuating T**R**aumatic Brain Injury

500 patients — GCS 15 ED patients enrolled prospectively

4 sites — sites across OR, MI, and CA — Level 1 & community EDs already

90 day follow-up — days of follow-up per participant

8 Point scale — GOS-E score defining complete functional recovery (primary outcome)

What we capture at the index ED visit

- Clinical: mechanism, ACRM criteria, RPQ symptom burden,
- Biomarker: GFAP + UCH-L1 (whole-blood i-STAT)
- Imaging: head CT when clinically indicated
- Modifiers: age, sex, prior conditions, intoxication, social context

Plus continuous recovery signal

Wearable (WHOOP) captures HRV, resting HR, and sleep daily across all 90 days — a high-resolution recovery trajectory alongside GOS-E, RPQ, and cognition at 14 & 90 days.

DESIGN CHALLENGE · BIOMARKER

Biomarkers: Do We Need Categories — and Which Ones?

Categories vs. continuous

Does bucketing (non-/mildly/very elevated) beat keeping the raw value? Bins aid bedside use but discard information a model could exploit.

How many, and where to cut

Two bins? Three? Where do the thresholds fall for GCS 15 patients specifically — not the broader TBI populations where existing cutoffs were derived?

One marker or the pair

GFAP and UCH-L1 carry different temporal and biological signals. Combined index, ratio, or kept separate?

Timing sensitivity

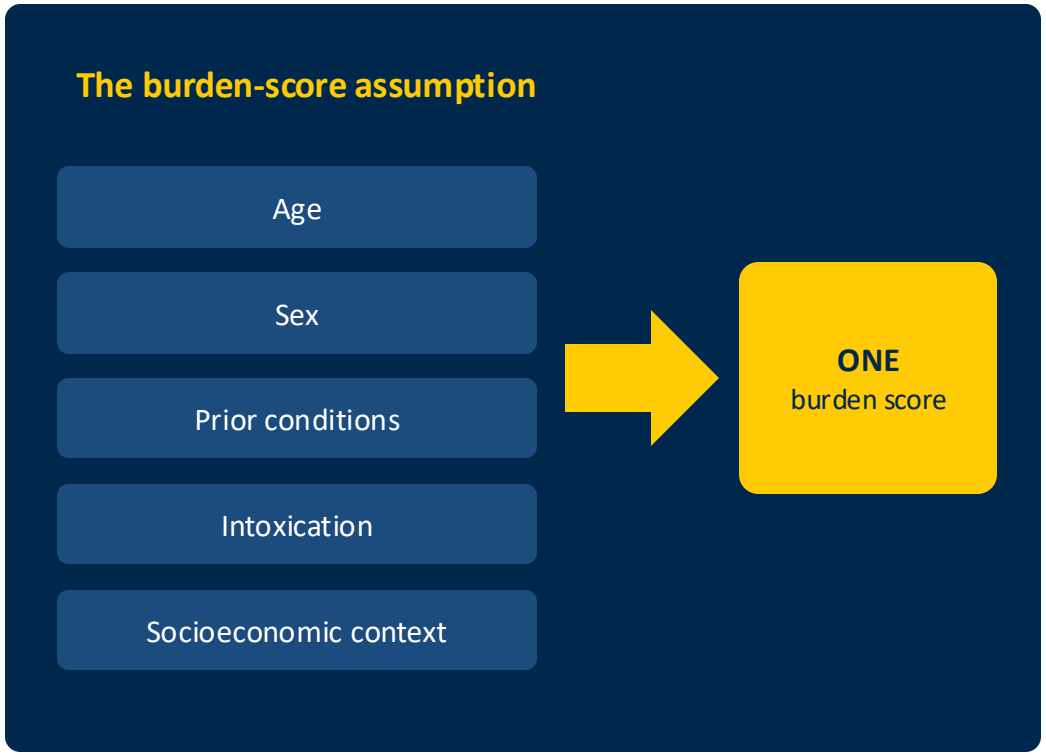
Levels shift by hours from injury. Categories must be robust to realistic ED collection windows.

Our approach: derive data-driven cut points from the cohort, and let modeling default-include C/B/I while testing whether categorization loses predictive value versus the continuous signal.

DESIGN CHALLENGE · MODIFIERS

Modifiers: Is a Single "Burden Score" the Right Construct?

The framework collapses age, sex, prior conditions, intoxication, and social context into one high–low burden dimension. That is a strong, untested assumption.



Sum vs. structure

Does a scalar burden score capture modifiers as well as keeping them as distinct predictors that a model can weight independently?

Which modifiers matter

Not all carry equal prognostic weight in GCS 15. Some may not matter at all; interactions may dominate.

Whose weights

Should weighting be clinically assigned, or learned from the data for this specific population?

FROM DATA TO PROTOTYPE

Deriving the Prototype — Letting the Cohort Define the Classes

We do not hard-code the categories in advance. The prototype is derived from the data, then tested for whether each dimension adds prognostic value.

1 Derive categories

Data-driven cut points for C, B, I; empirical modifier structure — not thresholds borrowed from other TBI populations.

2 Assemble the classes

Supervised prediction of 90-day recovery plus unsupervised clustering to surface CBI-M sub-classes that share recovery patterns.

3 Test what each layer adds

Ask whether Biomarkers add to Clinical + Imaging, and whether Modifiers add on top — the value question, kept deliberately brief here.

Output: a prototype CBI-M classification for GCS 15 — plus recovery trajectories per sub-class, delivered as a freely available R Shiny prediction tool.

EARLY PROGRESS & NEXT STEPS

Where We Are, and Where We're Headed

PROGRESS TO DATE

- ✓ Protocol finalized (v2.0) and framework operationalized for GCS 15
- ✓ Four enrolling EDs engaged — all running whole-blood i-STAT GFAP/UCH-L1
- ✓ CBI-M data model + REDCap capture and WHOOP wearable pipeline in place
- ✓ Data-driven categorization strategy defined for C, B, I, and Modifiers

WHAT COMES NEXT

- → **Complete enrollment toward 500 GCS 15 participants**
- → **Derive & internally validate the prototype CBI-M classes**
- → **Test the added value of Biomarkers and Modifiers layers**
- → **Release the open R Shiny prognostic tool for ED use**

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OUR PATIENTS AND THEIR FAMILIES

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