Title: Clinical Gestalt for Early Prediction of Delayed Functional and Symptomatic Recovery from Mild Traumatic Brain Injury is Inadequate.

Running Head: Clinical Gestalt Is Not Adequate for Predicting Mild Traumatic Brain Injury Outcome

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There are limited prognostic tools to guide clinicians in acute risk-stratification of adult mild TBI patients (mTBI). While the majority of mTBI patients achieve full recovery within 7-14 days, approximately 25-30% remain symptomatic for 3 or more months post-injury.(1;2) Early identification of the subset of mTBI patients at high risk for protracted recovery will: (a) facilitate administering the right discharge instructions and sub-specialty referral to the right at-risk mTBI patients; (b) enable individualized education of patients regarding their expected course of recovery; (c) allow targeted administration of cognitive and behavioral therapy that has been found to be efficacious when implemented during the acute phase of injury; (3,4,5) and (d) enable enrichment of study populations of mTBI clinical trials with patients who are at-risk for protracted recovery and therefore decrease the sample size required for demonstrating therapeutic efficacy.(6)

We performed a sub-study of participants who were enrolled in the Head Injury Serum Markers for Assessing Response to Trauma (HeadSMART) study, an observational prospective cohort study. HeadSMART study design and methods have been previously published.(7) Briefly, ED patients 18 years or older; who presented to an urban academic medical center within 24 hours of injury; met the American College of Emergency Physicians' (ACEP) criteria for evaluation of TBI with a head CT scan; received head CT imaging; and provided written informed consent. The study was approved by the local Institutional Review Board (IRB).

Demographic and injury characteristics were based on participants' self-report obtained by trained research coordinators and a review of the electronic medical record. The resident physician or midlevel provider responsible for the clinical care of an enrolled participant was interviewed regarding the participant's prognosis. The treating attending physician was also

interviewed independently. Interviews occurred after results of diagnostic tests were available. The text of the prognosis questions asked is presented in Figure 1.

Follow-up was conducted either via telephone or an in-person assessment at 1, 3 and 6 months post-injury. Functional recovery was ascertained using the Glasgow Outcome Scale Extended (GOSE) and symptomatic recovery was ascertained using the Rivermead Post-Concussion Questionnaire (RPQ). Delayed functional recovery was defined as GOSE<8 at 3 months post-injury. Delayed symptom recovery was defined as having 3 or more post-concussive symptoms at 3-months post-injury that were graded as mild or more severe problems compared to their pre-injury status. Outcome assessments were performed by trained research coordinators and reviewed by a board-certified neuropsychologist for accuracy.

Head CT scans were re-read by one board-certified neuroradiologist and classified as having either a traumatic intracranial abnormality/skull fracture or not.The professional experience of clinicians was quantified based on the number of years since graduating from professional school into: 0-1 years; 1-2 years; 3-4 years; and greater than 4 years for resident physicians and midlevel providers and 0-9 years; 10-19 years and 20 years or greater for attending physicians. Clinicians were asked to rate the certainty of their prediction on a scale of 0 – 100%. These ratings were then categorized into 3 groups: low (0 – 49); moderate (50 – 89) and high (90% or greater).

The accuracy of clinician gestalt was determined by comparing clinical prediction to participant outcome. The discriminative ability of clinical gestalt was quantified with the area under the receiver operator curve (AUC). We tested for differences in the predictive accuracy of clinical gestalt according to professional experience and certainty of prediction, using the χ^2 test. Accuracy was defined as the number of correct predictions (true positives + true negatives) divided by the total number of predictions. A two-tailed p-value of <0.05 was considered statistically significant.

A total of 217 subjects met the inclusion criteria for this analysis. Included subjects were predominantly male (59.6%), and Caucasian (50.7%) and had a median age of 43 years. The most common mechanism of injury was falls (31.8%). At presentation, 192 (88.5%), 23 (10.6%) and 2 (0.9%) subjects had a Glasgow Coma Scale (GCS) of 15, 14 and 13 respectively. Traumatic intracranial injuries were identified on the head CTs of 32 (17.1%) subjects. The distribution of GOSE scores at 3 months were: Among the 217 subjects studied, 115 (53.0%) had delayed functional recovery and 105 (49.3%) had delayed symptom recovery. At 3 months 5, 1, 3 17, 33, 56, and 102 subjects had GOSE of 1 to 8 respectively. A total of 80 residents and

midlevel providers were interviewed at least once. Among these clinicians, 23 (28.8%), 27 (33.8%), 28 (35.0%), 13 (16.2%) and 19 (23.8%) had 0-1 year, 1-2 years, 3-4 years and >4 years of professional experience respectively. A total of 32 attending physicians were interviewed at least once. Among attending physicians, 13 (40.6%), 13 (40.6%) and 6 (18.8%) had 0-9 years; 10-19 years and 20 years or greater of professional experience.

Resident physicians and midlevel providers predicted that 9 (4.2%) of subjects will have delayed functional recovery at 3-months post-injury (Table 1), yielding an accuracy of 48.4% (95% CI: 41.7%-55.1%) and an AUC of 0.51 (95% CI: 0.48–0.54). Among resident/midlevel providers, 3 (1.4%), 67 (31.0%), and 146 (67.6%) had low, moderate and high certainty of the accuracy of their prediction of functional recovery respectively. The accuracy of predicted functional recovery was 33.3%, 31.3% and 56.8% (p=0.003) among those with low, moderate and high certainty respectively.

Residents and midlevel providers predicted that 55 (25.3%) participants will have persistent PCS at 3-months post-injury, yielding an accuracy of 59.6% (53.0% - 66.3%) and an AUC of 0.60 (95% CI: 0.54–0.65). Among resident/midlevel providers, 9 (4.2%), 100 (46.3%), and 107 (49.5%) had low, moderate and high certainty of the accuracy of their prediction of symptom recovery respectively. The accuracy of predicted symptom recovery was 44.4%, 58.3% and 62.0% (p=0.52) among those with low, moderate and high certainty respectively.

Attending physicians provided their clinical gestalt in 77 (36.5%) of cases. Attending physicians predicted that 6 (7.8%) of participants will have complete functional recovery at 3-months post-injury, yielding an accuracy of 51.9% (95% CI: 40.5%–63.4%) and an AUC of 0.50 (95% CI: 0.44–0.56). Among attending physicians, 0 (0%), 24 (31.6%) and 52 (68.4%) had low, moderate and high certainty of the accuracy of their prediction of functional recovery respectively. The accuracy of predicted functional recovery was 33.3% and 59.6% (p=0.03) among those with moderate and high certainty respectively.

Attending physicians also predicted that 19 (25.0%) of participants will have persistent PCS at 3-months post-injury, yielding an accuracy of 60.8% (95% CI: 49.4%–72.2%) and an AUC of 0.59 (95% CI: 0.49–0.69). Among attending physicians, 4 (5.6%), 33 (43.4%) and 39 (51.3%) had low, moderate and high certainty of the accuracy of their prediction of symptom recovery respectively. The accuracy of predicted symptom recovery was 50%, 53.1% and 68.4% (p=0.38) among those with low, moderate and high certainty respectively. The accuracy of clinical gestalt did not vary according to the number of year of clinical experience.

To our knowledge this is the first study of the accuracy of emergency physicians' clinical gestalt for predicting mTBI outcome in adult participants on the day of injury. We report four major findings. First, clinicians studied had an optimistic view regarding the prognosis of mTBI, despite the fact that the study cohort consisted of significantly injured subjects (17% positive CT and a high rate of delayed recovery). They expected more than 90% of subjects to have complete functional recovery whereas in reality, approximately 50% of the cohort studied had delayed functional recovery and persistent PCS. Second, ED resident/midlevel provider accuracy for predicting functional recovery and persistent PCS are low (48.2% and 59.8% respectively). The accuracy of resident/midlevel providers' gestalt was low even among residents/midlevel providers who were more than 90% certain of the accuracy of their prediction. However, there was a trend towards higher accuracy with higher degree of certainty of prediction. Third, the accuracy of attending clinician gestalt for functional recovery and PCS is also low (51.9% and 60.8% respectively). Similar to residents/midlevel providers, there was a trend towards higher accuracy with higher degree of certainty of prediction. Fourth, clinician experience did not influence the accuracy of predicting mTBI outcome.

Despite its strengths, our study also has a number of limitations. First, the observed prevalence of poor outcomes following mTBI in our cohort was higher than the prevalence reported in other mTBI studies (approximately 50%(1;2;8) versus 30%), but similar to a recently published large observational study.(9) Thus our population may be more severely injured than others. However, this should not affect the sensitivity or specificity of clinical gestalt. Second, our study was performed at two hospitals that are part of one health system and therefore it is possible, that findings may not be generalizable. A prior multi-center study reported similar findings in a pediatric population.(10) Third, although the RPQ is one of the most commonly used tools for ascertaining mTBI outcomes, it is limited in its ability to distinguish between concussion and non-concussion related symptoms.

The accuracy of clinical gestalt for predicting mTBI outcomes on the day-of-injury is poor. Data-driven strategies are needed to provide clinical decision support for mTBI risk stratification in acute care settings.

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Table 1: Diagnostic Accuracy of Clinical Gestalt for Predicting Functional and Symptom Recovery

		Delayed functional Recovery	Delayed Symptom Recovery
Resident/ Midlevel	Sensitivity	5.2%	34.3%
	Specificity	97.1%	84.3%
	Positive Predictive Value	66.7%	67.9%
	Negative Predictive Value	52.4%	43.1%
Attending	Sensitivity	8.1%	54.5%
	Specificity	92.5%	82.5%
	Positive Predictive Value	50.0%	63.2%

Figure 1: Interview Questions for Clinicians

- Based on what you know now about this patient's presentation, do you think this patient will have a complete functional recovery i.e. they will be back to their pre-TBI functional state at 3 months after injury? (Yes or No)
- How certain are you that your prediction will be right? (0 – 100)
- Based on what you know now about this patient's presentation, do you think this patient will have 3 or more post-concussive symptoms (for example: headache, fatigue, insomnia, loss of concentration, noise and light sensitivity, memory loss, dizziness) at 3 months after injury? (Yes or No)
- How certain are you that your prediction will be right? (0 – 100)