Derivation and Validation of a Brief Emergency Department-Based Prediction Tool for Posttraumatic Stress After Motor Vehicle Collision

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Study objective: To derive and initially validate a brief bedside clinical decision support tool that identifies emergency department (ED) patients at high risk of substantial, persistent posttraumatic stress symptoms after a motor vehicle collision.

Methods: Derivation (n=1,282, 19 ED sites) and validation (n=282, 11 separate ED sites) data were obtained from adults prospectively enrolled in the Advancing Understanding of RecOvery afteR traumA study who were discharged from the ED after motor vehicle collision-related trauma. The primary outcome was substantial posttraumatic stress symptoms at 3 months (Posttraumatic Stress Disorder Checklist for Diagnostic and Statistical Manual of Mental Disorders-5 $\geq$38). Logistic regression derivation models were evaluated for discriminative ability using the area under the curve and the accuracy of predicted risk probabilities (Brier score). Candidate posttraumatic stress predictors assessed in these models (n=265) spanned a range of sociodemographic, baseline health, peritraumatic, and mechanistic domains. The final model selection was based on performance and ease of administration.

Results: Significant 3-month posttraumatic stress symptoms were common in the derivation (27%) and validation (26%) cohort. The area under the curve and Brier score of the final 8-question tool were 0.82 and 0.14 in the derivation cohort and 0.76 and 0.17 in the validation cohort.

Conclusion: This simple 8-question tool demonstrates promise to risk-stratify individuals with substantial posttraumatic stress symptoms who are discharged to home after a motor vehicle collision. Both external validation of this instrument, and work to further develop more accurate tools, are needed. Such tools might benefit public health by enabling the conduct of preventive intervention trials and assisting the growing number of EDs that provide services to trauma survivors aimed at promoting psychological recovery. [Ann Emerg Med. 2023;81:249-261.]

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INTRODUCTION

Approximately 4 million patients seek care in US emergency departments (EDs) each year after motor vehicle collision-related trauma.[1] More than 90% of these patients do not have a major traumatic injury and are discharged from the ED after evaluation.[2] Despite the absence of life-threatening injury, one out of every 4 to 5 of these discharged individuals experiences substantial enduring posttraumatic stress symptoms.[3-6] Such posttraumatic stress symptoms cause great suffering, morbidity, and social/occupational dysfunction and are manifested as symptoms of intrusion (eg, frightening dreams or flashbacks),

Editor's Capsule Summary

What is already known on this topic

Posttraumatic stress occurs frequently in patients with non-life threatening injury discharged from the emergency department.

What question this study addressed

Could a brief bedside questionnaire, with elements informed through machine learning, assess the probability of posttraumatic stress after injury and discharge from the emergency department?

What this study adds to our knowledge

An 8-question survey demonstrated preliminary success in recognizing patients at risk of posttraumatic stress symptoms 3 months after injury.

How this is relevant to clinical practice

Emergency evaluation after injury might include risk assessment for posttraumatic stress with associated intervention to reduce development of symptoms. Machine learning techniques can inform the development of a simple bedside prediction tool.

avoidance of stimuli associated with the experience, negative alterations in cognition and mood, and alterations in reactivity (eg, constantly feeling on edge, irritable, and angry) lasting at least one month.[7]

If individuals at high risk for substantial, persistent posttraumatic stress symptoms could be identified at the time of their initial ED visit, this would facilitate the conduct of trials to test interventions intended to prevent substantial, persistent posttraumatic stress symptoms. In addition, identifying high-risk individuals at the time of ED presentation would also assist the growing number of EDs that provide services to trauma survivors aimed at promoting psychological recovery.[8,9] We recently developed a clinical prediction tool for posttraumatic stress that requires the use of complex machine-learning algorithms, but simple and effective posttraumatic stress risk stratification tools for use at the bedside are not yet available.[10]

In the present study, we sought to derive and preliminarily validate such a tool for patients presenting to the ED after motor vehicle collision-related trauma who are discharged from the ED after evaluation. Analyses were performed using data from a large-scale prospective study of individuals presenting to the ED after trauma.[11] The formal diagnosis of posttraumatic stress disorder (PTSD) requires a clinical interview. In this study, substantial posttraumatic stress symptoms 3 months after motor vehicle collision were identified by a score of $\geq$38 on the PTSD checklist for Diagnostic and Statistical Manual of Mental Disorders (DSM)-5 (PCL-5), demonstrating good accuracy for identifying PTSD cases.[12-14] In secondary analyses, we also explored the tool's utility to risk-stratify individuals for substantial posttraumatic stress symptoms 3 months after nonmotor vehicle collision trauma and 6 months after a motor vehicle collision.

MATERIALS AND METHODS

Study Design and Setting

This investigation is a preplanned analysis of data collected as part of Advancing Understanding of RecOvery afteR traumA (AURORA), a multicenter prospective cohort study of adverse posttraumatic neuropsychiatric sequelae among trauma survivors.[11] Participants were enrolled at 30 participating US EDs, most of which are urban academic centers. Institutional review board approval was obtained for each site.

Selection of Participants

Emergency department patients were eligible for inclusion in AURORA if they were 18 to 75 years old, presented to a participating ED for evaluation within 72 hours of an event with the potential to cause serious or life-threatening injury, were fluent in English, and had a smartphone for at least 1 year. (A smartphone was required because components of AURORA data collection were through a smartphone.) In addition, patients were excluded if they were diagnosed with an American Association for the Surgery of Trauma solid organ injury $\geq$Grade 2, had an indication for chest tube placement or operation with general anesthesia, had a laceration with significant hemorrhage, or if the trauma was due to a self-inflicted or work-related accident. Further details regarding eligibility criteria are described in Appendix E1, available online at http://www.annemergmed.com. Study coordinators at each participating ED screened patients for eligibility, obtained written informed consent from eligible patients, and performed data collection for the ED-based assessments.

AURORA participants were included if they were injured while operating or riding in a motor vehicle or were struck by a motor vehicle, they were not admitted to the hospital, and they completed 2-week and 3-month follow-up assessments by March 8, 2021. For this analysis, participating EDs were divided into 19 derivation and 11 validation sites (Table E1, available online at http://www.annemergmed.com). Additional validation was performed

in AURORA participants with nonmotor vehicle collision-related mechanisms of injury.

Methods of Measurement

After providing written informed consent, each participant performed an ED assessment, including a baseline questionnaire. Follow-up evaluations included 2-week, 3-month, and 6-month internet-based follow-up assessments. If necessary, the assessments could be completed by telephone. Candidate predictive tool questions (n=265) were obtained from these assessments. For descriptive purposes, these items can be categorized into 10 domains:

Motor Vehicle Collision Characteristics: Patient-reported motor vehicle collision characteristics assessed included whether the patient's vehicle made contact with an object or vehicle, the amount of vehicle damage, the severity of injuries, and the timing of transport to the ED.

Peritraumatic Characteristics: Peritraumatic characteristics assessed included participant vital signs, the severity of current pain and somatic symptoms in the ED, peritraumatic distress and dissociation in the ED,[15] and participant expectations regarding how long it would take them to physically and emotionally recover.

Pretrauma Stressors: Pretrauma stressors assessed included stress related to finances, career, health, love life, other relationships, and life overall in the 30 days prior to trauma[16] as well as overall perceived stress.[17]

Prior Lifetime Trauma: Childhood maltreatment and bullying were assessed using World Health Organization World Mental Health Survey measures.[18]

Pretrauma Psychological and Somatic Characteristics: Pretrauma psychological and somatic symptoms during the 30 days prior to trauma were assessed, including posttraumatic stress, depression, generalized anxiety disorder, panic, and substance abuse.[19-22] In addition, questions regarding anger, dissociation, rumination, and somatic symptom burden during the 30 days preceding trauma were also assessed.

Physical Health: General health in the past 30 days was assessed with the 12-item Short Form Health Survey.[23] Standard self-report checklists were administered for chronic conditions and medications.

Past 30-Day Role Impairment: Role impairment in the past 30 days due to mental or physical health problems was assessed with the Sheehan Disability Scale, which measures the extent to which symptoms have disrupted work, social life/leisure, and family/home responsibilities.[24]

Sociodemographics: Sociodemographic characteristics assessed included age, sex, race/ethnicity, marital status, number of children, education, employment status, and family income.

Social Support: Social support-related characteristics assessed included social network size, affiliative interaction frequency, and access to social support.[25]

Personality: Brief screening scales assessed the Big 5 personality dimensions, anxiety sensitivity, and distress tolerance.[26-28]

A detailed list of constructs, citations of prior research justifying their inclusion, and scoring rules for each of these potential predictor variables is presented in Table E2 (available at http://www.annemergmed.com). In addition, to limit participant questionnaire assessment burden in the ED, a subset of premotor vehicle collision characteristics were assessed at a 2-week follow-up, including prior lifetime traumatic experiences, social support, and personality.

Outcome Measures

Posttraumatic stress symptoms were assessed using the PTSD Checklist for DSM-5 (PCL-5).[19] This 20-item self-report scale assesses how much the patient was "bothered by" each of the 20 DSM-5 PTSD Criteria B-E symptoms during the preceding 30 days (Cronbach's α=.96).[19] The primary outcome was substantial posttraumatic stress symptoms, defined as a score of $\geq$38 on the PTSD Checklist for DSM-5 (PCL-5)[12-14] at a 3-month follow-up.

Primary Data Analysis

Inverse missing probability weighting using all candidate predictor variables available at the time of the initial ED visit was performed to balance baseline characteristics between the sample used for analyses (participants with ED, 2-week, and 3-month data) and the complete sample (including participants who were dropped or failed to complete either the 2-week or the 3-month survey). After weighing the sample, we first identified subsets of highly correlated survey items (r>0.8) within the 265 standardized candidate predictor variables. Among such subsets, only the predictor with the strongest association with posttraumatic stress was retained. The remaining candidate predictor variables were then ranked according to the absolute value of the average regression coefficient from 10 lasso logistic regressions performed in randomly selected (bootstrapped) cohort subsamples. After determining the relative predictive importance of each variable in the context of other predictors, we then selected the number of items to use in the final stage of model development by comparing the performance of models with the most highly ranked 10, 20, and 30 variables, respectively, considering

both discrimination (assessed using the area under the receiver operating characteristic curve [AUC]) and accuracy of predicted risk probabilities (assessed using Brier score).

The final stage of model development used binary variables. These binary variables were developed by dividing ordinal survey questions with N response options into N-1 binary variables, in which each binary variable dichotomizes the ordinal survey question at each ordered response. For example, an ordinal question with 3 response options of mild, moderate, and severe was converted into 2 binary variables: mild versus moderate/severe and mild/moderate versus severe. This was done to determine influential cut-offs, simplify questions as much as possible for clinical use, and assign scoring weights. Highly correlated binary variables were removed using the methods above, along with those with a frequency below 5%. Models between 4 and 50 predictor variables were compared with 10 cross-validation samples. Three different models were constructed for each set of predictor variables, including regular logistic regression, integer coefficient logistic regression (rounding), and Risk-calibrated Supersparse Linear Integer Model logistic regression.[29] The final derivation model was selected based on performance, a number of variables, and ease of assessment. The performance of the final derivation model was assessed through the ability to predict substantial posttraumatic stress 3 months after motor vehicle collision-related trauma in the validation cohort. In addition, the ability of the final derivation model to predict posttraumatic stress at 6-month follow-up among motor vehicle collision patients was also explored.

We performed an additional post hoc validation of the derived model by assessing the tool's ability to predict substantial posttraumatic stress symptoms at 3 months among individuals enrolled in AURORA with a traumatic mechanism unrelated to motor vehicle collision. This included individuals seeking ED care after physical assaults, falls, sexual assaults, and mass casualty incidents. Patients with self-inflected injuries or trauma experienced during an occupational exposure were ineligible. As with the motor vehicle collision group, tool performance among nonmotor vehicle collision participants was evaluated through AUC and Brier scores. Analyses were performed using Python, version 3.8, and scikit-learn package version 0.24.0.

RESULTS

Characteristics of Study Subjects

The main cohort (n=2,678) consisted of participants discharged from the ED after a motor vehicle collision-related trauma (in/on the vehicle or struck by a vehicle). Within this overall cohort, data from 1,570 individuals (59%) who completed ED, 2-week, and 3-month surveys (Figure E1, available online at http://www.annemergmed.com) were used in analyses. Inverse probability weighting was used to balance the baseline characteristics of the overall and analysis cohort. The mean participant age in the overall cohort was 36 years; 68% were women. More than half were non-Hispanic Blacks, and one-third were non-Hispanic White. The analysis cohort was split into derivation and validation samples (1,282 patients enrolled at 19 ED sites and 288 patients enrolled at 11 separate ED sites, respectively (Table E1, available online at http://www.annemergmed.com). The incidence of substantial persistent posttraumatic stress 3 months after trauma was 27% in the derivation cohort and 26% in the validation cohort. After applying inverse missing probability weighting, baseline characteristics of the derivation and validation cohorts were similar (Table 1). The generalizability of the prediction tool was also assessed in 534 nonmotor vehicle collision patients.

Model Derivation

Relative predictive utility ("variable importance") of each survey question/item, in the presence of other predictors, was ranked for all 265 items. Personality characteristics, peritraumatic somatic symptoms, psychological symptoms in the month prior to trauma, and childhood trauma history constituted the strongest predictors of persistent posttraumatic stress (Figure 1). Model discrimination (assessed using AUC) and accuracy (assessed using Brier score) increased only marginally as the number of predictors increased above 20 (eg, 20 item AUC 0.85, 30 item AUC 0.86, Table E3, available online at http://www.annemergmed.com). Therefore only the 20 most predictive survey questions were retained for further model development.

These 20 most predictive survey questions were converted to 71 binary variables. (As described above, binary variables were used in the final stage of model development to identify the most influential responses and assign scoring weights.) Lasso logistic regression models with 4 to 50 binary items were then developed and compared (Table 2), and a prediction tool consisting of 9 questions were selected. The question regarding "upset stomach" complaints prior to trauma had unstable parameter estimates and was removed, with minimal effect on model performance (Figure E2, available online at http://www.annemergmed.com). Thus the final risk prediction tool consisted of 8 survey questions (Figure 2 and Figure E3, available online at http://www.annemergmed.com) containing 9 weighted responses. (Risk-calibrated Supersparse Linear Integer Model and

Table 1. Participant characteristics.

Characteristic	Unweighted Derivation Cohort (N=1,282)	Unweighted Validation Cohort (N=288)	Weighted Derivation Cohort (N=1,282)	Weighted Validation Cohort (N=288)
Sex, female	851 (66.4%)	215 (74.7%)	809 (63.1%)	205 (71.2%)
Age, y; mean (SD)	36.6 (13.2)	35.4 (12.7)	34.8 (12.7)	33.7 (12.1)
Race				
Hispanic	119 (9.3%)	45 (15.6%)	124 (9.7%)	49 (17.2%)
Non-Hispanic White	433 (33.8%)	81 (28.1%)	425 (33.3%)	75 (26.3%)
Non-Hispanic Black	672 (52.4%)	151 (52.4%)	674 (52.8%)	152 (53.2%)
Non-Hispanic other	51 (4.0%)	10 (3.5%)	53 (4.1%)	10 (3.4%)
Employment				
Employed	951 (74.2%)	227 (78.8%)	962 (75.2%)	228 (79.3%)
Total Family Income				
<=$19K	414 (32.3%)	86 (29.9%)	428 (33.6%)	88 (30.8%)
$19K-$35K	413 (32.2%)	88 (30.6%)	413 (32.4%)	92 (32.0%)
$35K-$50K	173 (13.5%)	44 (15.3%)	169 (13.2%)	42 (14.7%)
$50K-$75K	108 (8.4%)	33 (11.5%)	105 (8.2%)	31 (10.9%)
$75K-$100	89 (6.9%)	13 (4.5%)	85 (6.7%)	12 (4.1%)
>$100K	78 (6.1%)	23 (8.0%)	76 (5.9%)	21 (7.5%)
Marital Status				
Married or cohabitating	540 (42.1%)	106 (36.8%)	520 (40.7%)	105 (36.4%)
Posttraumatic stress at 3 months*	336 (27.2%)	68 (25.3%)	330 (26.7%)	68 (25.5%)

SD, Standard Deviation.
*Missing values were excluded and percentages are based on nonmissing values.

noninteger methods of developing scoring weighting were also developed and did not yield improved model performance.) Within the derivation cohort, the AUC of this final tool was 0.83, with a Brier score of 0.14.

Model Performance and Validation

In the validation cohort (288 patients enrolled at 11 separate ED sites), the tool had overall discrimination and calibration indices of 0.77 AUC and 0.17 Brier score, respectively. Performance characteristics of the final tool at different score cut-offs are shown in Table 3. (To obtain the most stable estimates for each cut-off, data from all participants were used for this assessment.) For example, more than half of individuals with a cut-off score of $\geq$16 had substantial posttraumatic stress symptoms 3 months after motor vehicle collision-related trauma, this score identified nearly 70% of all individuals with substantial posttraumatic stress and nearly 80% of those without substantial posttraumatic stress were below this cut-off.

To further explore the generalizability of the final clinical decision support tool, we assessed its performance in predicting substantial posttraumatic stress symptoms (1) among individuals presenting to the ED after nonmotor vehicle collision-related trauma and (2) 6 months after motor vehicle collision-related trauma. Six-month outcome data were available from 1,160 motor vehicle collision survivors; substantial posttraumatic stress symptoms were present in 23% of these individuals. Among this cohort, the tool had overall discrimination and calibration indices of 0.76 AUC and 0.15 Brier score, respectively. In addition, data were available from 534 individuals who presented to the ED after nonmotor vehicle collision-related trauma, including 180 physical assaults, 153 falls, 54 animal-related events, 40 nonmotorized collisions, 11 sexual assaults, and 96 other trauma exposures. Substantial posttraumatic stress symptoms were present in 24% of these individuals at 3 months. Among this cohort, the tool had overall discrimination and calibration indices of 0.78 AUC and 0.15 Brier score, respectively. Additional test characteristics of the tool among the nonmotor vehicle collision cohort are presented in Table E4 (available at http://www.annemergmed.com).

LIMITATIONS

Several limitations should be considered when interpreting these results. First, following derivation of the 3-month posttraumatic stress symptom prediction tool, we

Table 2. Summary of performance (AUC and Brier score) of models with different numbers of binary predictor variables.*

		Derivation Cohort		Validation Cohort	
Number of Survey Questions	Number of Binary Variables†	AUC (Integer)	Brier Score (Integer)	AUC (Integer)	Brier Score (Integer)
4	4	0.764	0.159	0.768	0.159
5	5	0.790	0.154	0.790	0.155
6	6	0.800	0.151	0.780	0.158
7	7	0.805	0.149	0.786	0.156
8	8	0.817	0.147	0.784	0.158
8	9	0.825	0.143	0.766	0.168
9	10	0.825	0.142	0.756	0.169
10	11	0.833	0.14	0.749	0.173
11	12	0.834	0.14	0.754	0.169
11	13	0.838	0.138	0.762	0.163
11	14	0.839	0.137	0.755	0.167
12	15	0.844	0.136	0.757	0.165
14	20	0.848	0.134	0.755	0.163
19	30	0.851	0.133	0.775	0.159
20	40	0.847	0.135	0.772	0.159
20	50	0.846	0.136	0.780	0.155

AUC, Area under the receiver operating characteristic curve.
*Shaded row corresponds to the final selected prediction model.
†The final stage of model development used binary variables. These binary variables were developed by dividing ordinal survey questions with N response options into N-1 binary variables, in which each binary variable dichotomizes the ordinal survey question at each ordered response. For example, an ordinal question with 3 response options of mild, moderate, and severe was converted into 2 binary variables: mild vs. moderate/severe and mild/moderate versus severe. This was done to determine influential cut-offs and assign scoring weights.

validated its performance among a separate motor vehicle collision validation cohort and a nonmotor vehicle collision cohort and also assessed the tool's performance at predicting 6-month posttraumatic stress symptoms among motor vehicle collision patients. However, the tool has not achieved true external validation because 4 of the tool's 8 component questions were collected at 2-week follow-up rather than at the time of the index ED visit. Specifically, questions assessing mood traits (ie, the degree to which individuals think of themselves as "depressed, blue" and "relaxed, handle stress well") and anxiety sensitivity ("When I cannot keep my mind on a task, I worry that I might be going crazy" and "Unusual body sensations scare me") were administered 2 weeks after the trauma rather than in the ED. Although substantial evidence indicates that these moods and anxiety sensitivity traits are stable over a 2-week time period, and peritraumatic symptoms influencing these assessments at 2 weeks would also be very likely to have been present in the ED (symptoms at these timepoints were highly correlated), answers to these questions could be influenced by recall bias, and therefore a true assessment of the tool requires all questions to be asked at the time of the ED visit.[30,31] Second, a large number of candidate predictor variables were considered for inclusion in the final model, raising the possibility that a candidate predictor could have been selected for model inclusion based on a false positive result. Both of these limitations highlight the need to externally validate the derived model.

Additionally, most participating EDs serve economically disadvantaged urban populations, and the tool may perform differently in other settings. However, a strength of the study is that, although marked social disadvantage and systemic racism create conditions that increase rates of posttraumatic stress for Black Americans, no simple bedside ED prediction tools for posttraumatic stress from majority black samples have been performed.[32] Similarly, the external validity of the tool among individuals admitted with major injuries was not assessed. Furthermore, participants in the present study were asked to complete a relatively intensive battery of assessments after discharge, and a significant proportion of potentially eligible participants missed some of the follow-up assessments. Despite weighing the complete-case sample to match the entire cohort's baseline characteristics, some degree of selection bias undoubtedly remains. Although we observed no clinically significant differences between the unweighted

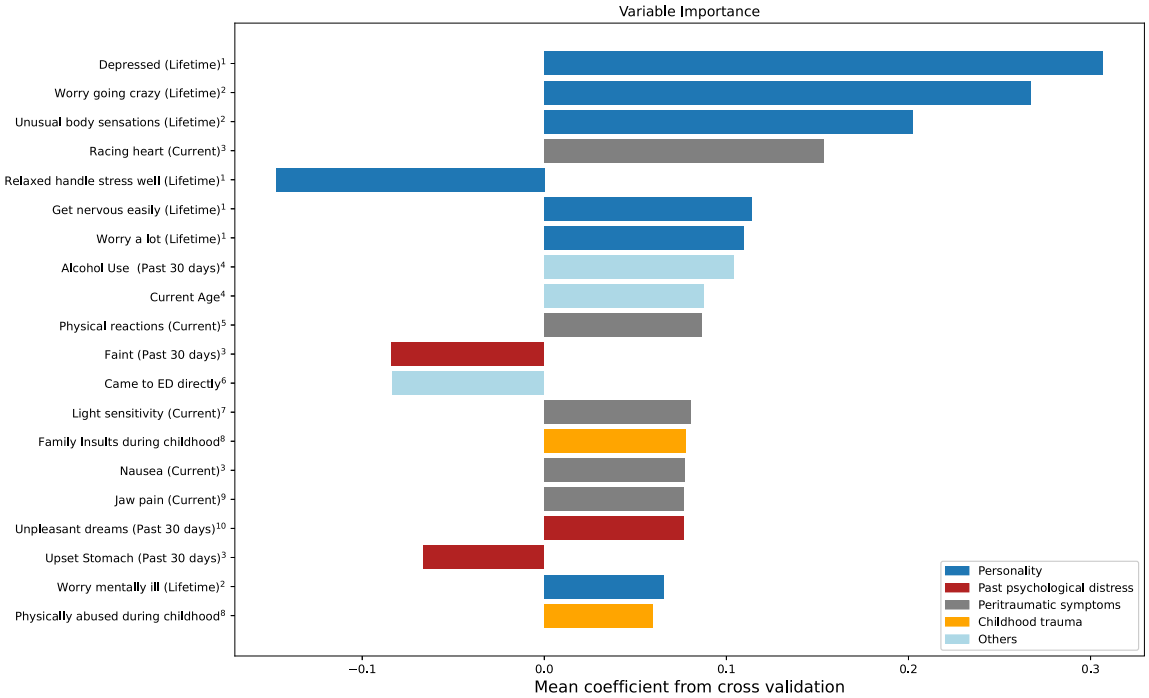

Figure 1. The top 20 predictors' variable importance is measured by the absolute value of standardized mean coefficients of 10 cross-validation samples. 1: Big 5 inventory (BFI)-neuroticism; 2: Anxiety sensitivity index (ASI); 3: Pennebaker inventory of limbic languidness (PILL); 4: PhenX toolkit; 5: Peritraumatic distress inventory (PDI); 6: Standard items; 7: The rivermead postconcussion symptoms questionnaire (RPQ); 8: ChildhoodTrauma Questionnaire (CTQ); 9: Regional Pain Scale (RPS); 10: Clinician-administered posttraumatic stress disorder scale (CAPS-IV).

and weighted cohorts, the effect of this bias on tool development and evaluation is unknown. Finally, this epidemiologic study used a score of $\geq$38 to define significant posttraumatic stress symptoms and not a "gold standard" clinician interview. However, the PCL-5 is a well-validated measure of posttraumatic stress symptoms, and the chosen cut-off has demonstrated good accuracy in identifying individuals with confirmed PTSD.[12,33]

DISCUSSION

This analysis describes the derivation and initial validation of a brief 8-question bedside tool (Figure 2) to identify individuals at high risk for persistent posttraumatic stress 3 months after motor vehicle collision-related trauma. The tool also demonstrated substantial promise to identify those at high risk of persistent posttraumatic stress 6 months after motor vehicle collision-related trauma and to identify those at high risk after other types of traumas. Questions within the tool are simple, nontraumatizing (eg, do not ask about childhood or past life trauma), and together provide useful discrimination and calibration of individual risk. Of note, unlike clinical decision support tools that focus on a particular situation/action (eg, "obtain a D-dimer") and specify an optimal cut-point for that action, the optimal cut-point for the present tool will depend on the proposed use. For example, if the tool were used to enrich the study population of a randomized controlled trial testing an intervention to reduce posttraumatic stress after a motor vehicle collision, a trial of low-cost, low-burden intervention might choose a lower cut-off score for the trial enrichment (eg, cut-off score $\geq$16, with sensitivity 69% and specificity 78%) than a randomized controlled trial involving a higher cost, more high burden intervention (eg, cut-off score $\geq$24, with sensitivity 47% and specificity 88%).

As noted above, although posttraumatic stress causes tremendous suffering, functional impairment, disability, and high health care costs in trauma survivors,[34-42] the prevention of posttraumatic stress in patients evaluated in the ED after trauma exposure (eg, motor vehicle collision and sexual assault) has not yet been attained. The continued development and exposition of bedside risk stratification tools are important to this effort and, as with most medical progress, are likely to proceed in an incremental fashion. This tool builds on a recently developed machine learning algorithm to identify individuals at high risk of posttraumatic stress.[10] The present tool differs from that algorithm in that it uses just 8

Instructions: Mark responses to each question. Add or subtract scores from each question as indicated within parentheses to calculate total score.

Did you come to the ED directly from the event?
No (0), Yes (-4)

During the 30 days before the event, how often did you have unpleasant dreams?
Less than once per week (0), 1 or more nights per week (+7)

In general, how much do the following statements apply to you?

When I cannot keep my mind on a task, I worry that I might be going crazy
Not at all (0), A little (+9), Some (+9), A lot (+9), Extremely (+9)

Unusual body sensations scare me
Not at all (0), A little (0), Some (0), A lot (+8), Extremely (+13)

Here's a list of things people might say about themselves. How much do you disagree or agree with each as a description of you?

Depressed, blue
Disagree strongly (0), Disagree moderately (+10), Disagree a little (+10), Neither agree nor disagree (+10), Agree a little (+10), Agree moderately (+10), Agree strongly (+10)

Relaxed, handle stress well
Disagree strongly (0), Disagree moderately (0), Disagree a little (0), Neither agree nor disagree (0), Agree a little (-5), Agree moderately (-5), Agree strongly (-5)

How much of a problem do you have with each of the following symptoms right now?

Nausea
None (0), Mild (0), Moderate (+7), Severe (+7)

Light sensitivity
None (0), Mild (0), Moderate (0), Severe (+6)

Total score: _____

Total score	2	10	16	20	24	28	32	38	46
Risk of Post-Traumatic stress	10%	20%	30%	40%	50%	60%	70%	80%	90%

Figure 2. Three-month posttraumatic stress prediction instrument including scores for each response.

items and requires only simple bedside scoring, rather than the use of a more complex machine learning approach involving 40 input variables without compromising model performance. Further work to develop predictive tools is needed, including assessment of different candidate predictors and methods, patient populations, trauma exposures, and care settings. Such tools could enable the development of effective preventive interventions, as well as the referral of patients for early treatment interventions in the months after trauma with interventions that have been demonstrated to be effective posttraumatic stress treatments (eg, trauma-focused cognitive behavioral therapy).[43]

Several other algorithms have been developed to predict substantial posttraumatic stress at 3 months (AUC 0.85) and 12 to 15 months (AUC 0.75 to 0.89).[44-47] However, these tools have generally not undergone subsequent validation efforts, and most rely on inputs from large numbers of predictor variables or more difficult to obtain

Table 3. Performance characteristics of a clinical decision support tool to identify individuals at high risk for substantial posttraumatic stress (Posttraumatic Stress Disorder Checklist for Diagnostic and Statistical Manual of Mental Disorders-5 ≥38) 3 months after motor vehicle collision-related trauma.

	Combined Derivation and Validation Cohorts				
Raw Score	Sensitivity (95% CI)	Specificity (95% CI)	Positive Predictive Value	Proportion of False Positive Results	N (%) of Total Trauma Survivors with Substantial Posttraumatic Stress Identified at Each Threshold
46	0.03 (0.02-0.04)	1.00 (1.00-1.00)	1.00	0	10 (2.5%)
38	0.09 (0.07-0.12)	0.99 (0.99-1.00)	0.86	0.14	37 (9.3%)
32	0.16 (0.14-0.19)	0.98 (0.97-0.99)	0.74	0.26	65 (16.3%)
28	0.24 (0.21-0.28)	0.96 (0.95-0.97)	0.69	0.31	97 (24.3%)
24	0.38 (0.34-0.42)	0.93 (0.91-0.94)	0.65	0.35	152 (38.1%)
20	0.57 (0.53-0.61)	0.84 (0.82-0.86)	0.56	0.44	227 (56.9%)
16	0.69 (0.66-0.73)	0.78 (0.76-0.79)	0.53	0.47	277 (69.4%)
10	0.84 (0.81-0.86)	0.63 (0.60-0.65)	0.45	0.55	333 (83.5%)
2	0.95 (0.93-0.97)	0.37 (0.35-0.39)	0.35	0.65	379 (95.2%)

measures such as blood test results. In addition, some of these tools focus on ED patients admitted to the hospital, limiting utility for ED providers.[48,49] This is because >90% of ED motor vehicle collision patients are discharged to home after ED evaluation,[2] yet these patients have the same rate of posttraumatic stress as admitted patients.[3,50-53] Thus ED patients discharged to home account for the overwhelming majority of those who develop posttraumatic stress after a motor vehicle collision.

Prior studies have identified a strong association between peritraumatic distress and dissociation and posttraumatic stress development, but these peritraumatic symptoms were not selected for in our final model.[54,55] This may be because such peritraumatic indicators are markers of underlying vulnerability factors represented in our final model (eg, depression and anxiety). This differs from prior work and also reflects the complex risk factors and causal relationships that influence the development of posttraumatic stress. Additionally, individuals with past trauma and posttraumatic stress symptoms related to that trauma are at increased risk of developing substantial, prolonged posttraumatic stress symptoms related to new trauma.[56,57] (A question selected for the final prediction tool regarding experiencing unpleasant dreams the month before the ED visit is likely a marker of this.) Disadvantaged ED populations, who have a high burden of previous trauma exposure, could potentially be spared a tremendous burden of posttraumatic suffering if effective interventions/pathways to prevent and treat posttraumatic stress were developed and integrated into ED care.

The derivation and validation of our prediction instrument provide clinicians with a brief, easy-to-use tool to aid in predicting substantial posttraumatic stress symptoms following trauma exposure (Figure 2, also available at https://unc.live/3b6BLyV). Clinicians may choose to use the tool to identify a subset of patients at particularly high risk for developing substantial posttraumatic stress in order to provide anticipatory guidance or to facilitate follow-up with mental health specialists, where evidence-based treatments such as trauma-focused cognitive behavioral therapy can be implemented for patients who develop substantial symptoms.[58] Additionally, as noted above, the tool has the potential to help facilitate the performance of interventional studies aimed at the secondary prevention of posttraumatic stress among ED trauma patients by allowing investigators to more accurately define an eligible study population based on the desired risk.

In conclusion, we describe the derivation and initial validation of an ED-based brief screening tool which appears to have a good discriminative ability for predicting significant posttraumatic stress symptoms 3 months after a motor vehicle collision. However, as with many areas of medicine, we view the development of tools to identify individuals vulnerable to significant persistent posttraumatic stress as a work in progress. Therefore, external validation of this tool is needed, as are continued efforts to develop improved methods of identifying individuals at high risk of persistent posttraumatic stress in the ED and effective preventive interventions for those at high risk.

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Future Meetings of the American College of Emergency Physicians

The following are the planned sites and dates for the future annual meetings of the American College of Emergency Physicians:

October 9-12, 2023	Philadelphia, PA
September 29-October 2, 2024	Las Vegas, NV
October 27-30, 2025	Dallas, TX
October 5-8, 2026	Chicago, IL
October 25-28, 2027	Boston, MA
September 18-21, 2028	Las Vegas, NV