



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

Christopher W. Jones, MD; Xinming An, PhD; Yinyao Ji, MS; Mochuan Liu, MS; Donglin Zeng, PhD; Stacey L. House, MD, PhD; Francesca L. Beaudoin, MD, PhD; Jennifer S. Stevens, PhD; Thomas C. Neylan, MD; Gari D. Clifford, DPhil; Tanja Jovanovic, PhD; Sarah D. Linnstaedt, PhD; Laura T. Germine, PhD; Kenneth A. Bollen, PhD; Scott L. Rauch, MD; John P. Haran, MD, PhD; Alan B. Storrow, MD; Christopher Lewandowski, MD; Paul I. Musey, Jr, MD; Phyllis L. Hendry, MD; Sophia Sheikh, MD; Brittany E. Panches, PhD, RN; Michael S. Lyons, MD, MPH; Michael C. Kurz, MD; Robert A. Swor, DO; Meghan E. McGrath, MD; Lauren A. Hudak, MD, MPH; Jose L. Pascual, MD, PhD; Mark J. Seamon, MD; Elizabeth M. Datner, MD; Erica Harris, MD; Anna M. Chang, MD; Claire Pearson, MD; David A. Peak, MD; Roland C. Merchant, MD, MPH; Robert M. Domeier, MD; Niels K. Rathlev, MD; Brian J. O'Neil, MD; Paulina Sergot, MD; Leon D. Sanchez, MD, MPH; Steven E. Bruce, PhD; Mark W. Miller, PhD; Robert H. Pietrzak, PhD, MPH; Jutta Joormann, PhD; Deanna M. Barch, PhD; Diego A. Pizzagalli, PhD; John F. Sheridan, PhD; Jordan W. Smoller, MD; Steven E. Harte, PhD; James M. Elliott, PhD; Karestan C. Koenen, PhD; Kerry J. Ressler, MD, PhD; Ronald C. Kessler, PhD; Samuel A. McLean, MD, MPH\*

\*Corresponding Author. E-mail: [smclean@aims.unc.edu](mailto:smclean@aims.unc.edu).

**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.]

Please see page 250 for the Editor's Capsule Summary of this article.

Readers: click on the link to go directly to a survey in which you can provide **feedback** to *Annals* on this particular article.

A **podcast** for this article is available at [www.annemergmed.com](http://www.annemergmed.com).

0196-0644/\$-see front matter

Copyright © 2022 by the American College of Emergency Physicians.

<https://doi.org/10.1016/j.annemergmed.2022.08.011>

## INTRODUCTION

Approximately 4 million patients seek care in US emergency departments (EDs) each year after motor vehicle collision-related trauma.<sup>1</sup> More than 90% of these patients do not have a major traumatic injury and are discharged from the ED after evaluation.<sup>2</sup> Despite the absence of life-

threatening injury, one out of every 4 to 5 of these discharged individuals experiences substantial enduring posttraumatic stress symptoms.<sup>3-6</sup> 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.<sup>7</sup>

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.<sup>8,9</sup> 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.<sup>10</sup>

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.<sup>11</sup> 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.<sup>12-14</sup> 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.<sup>11</sup> 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,<sup>15</sup> 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<sup>16</sup> as well as overall perceived stress.<sup>17</sup>

*Prior Lifetime Trauma:* Childhood maltreatment and bullying were assessed using World Health Organization World Mental Health Survey measures.<sup>18</sup>

*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.<sup>19-22</sup> 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.<sup>23</sup> 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.<sup>24</sup>

*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.<sup>25</sup>

*Personality:* Brief screening scales assessed the Big 5 personality dimensions, anxiety sensitivity, and distress tolerance.<sup>26-28</sup>

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).<sup>19</sup> 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  $\alpha=.96$ ).<sup>19</sup> The primary outcome was substantial posttraumatic stress symptoms, defined as a score of  $\geq 38$  on the PTSD Checklist for DSM-5 (PCL-5)<sup>12-14</sup> 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.<sup>29</sup> 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-inflicted 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)
<b>Race</b>				
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%)
<b>Employment</b>				
Employed	951 (74.2%)	227 (78.8%)	962 (75.2%)	228 (79.3%)
<b>Total Family Income</b>				
≤\$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%)
<b>Marital Status</b>				
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.\*

Number of Survey Questions	Number of Binary Variables <sup>†</sup>	Derivation Cohort		Validation Cohort	
		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.

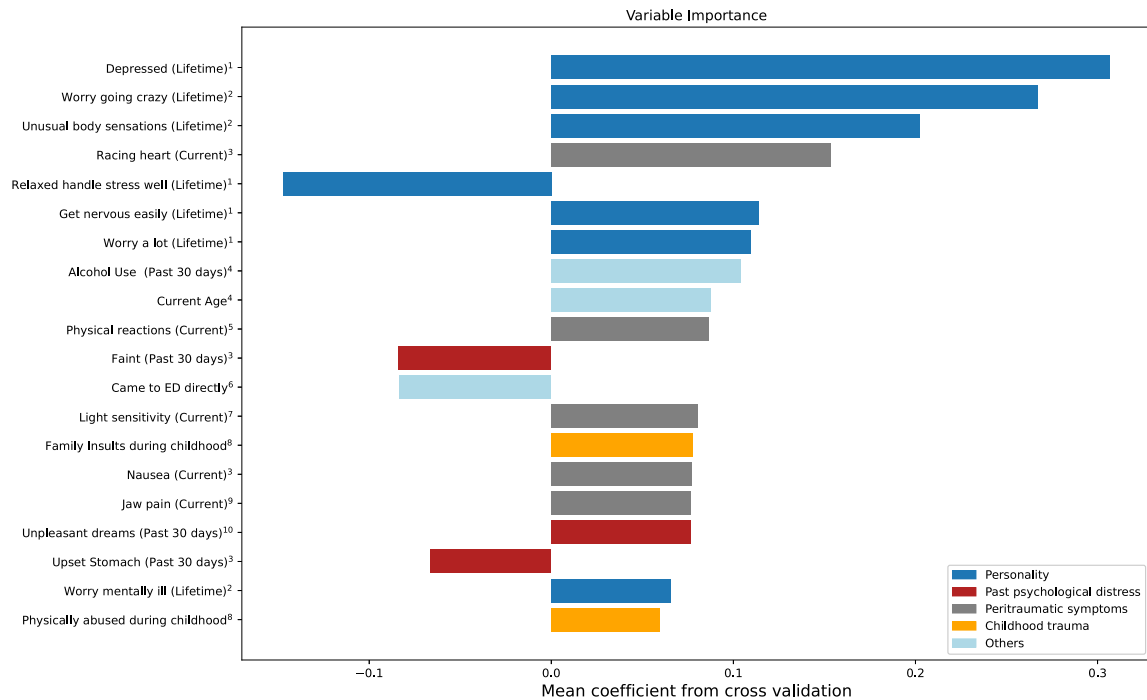
\*Shaded row corresponds to the final selected prediction model.

<sup>†</sup>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.<sup>30,31</sup> 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.<sup>32</sup> 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.<sup>12,33</sup>

## 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,<sup>34-42</sup> 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.<sup>10</sup> 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).<sup>43</sup>

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).<sup>44-47</sup> 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  $\geq 38$ ) 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.<sup>48,49</sup> This is because >90% of ED motor vehicle collision patients are discharged to home after ED evaluation,<sup>2</sup> yet these patients have the same rate of posttraumatic stress as admitted patients.<sup>3,50-53</sup> 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.<sup>54,55</sup> 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.<sup>56,57</sup> (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.<sup>58</sup> 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.

*The investigators wish to thank the trauma survivors participating in the AURORA Study. Their time and effort during a challenging period of their lives make our efforts to improve recovery for future trauma survivors possible.*

Supervising editor: Stephen Schenkel, MD, MPP. Specific detailed information about possible conflict of interest for individual editors is available at <https://www.annemergmed.com/editors>.

**Author affiliations:** From the Department of Emergency Medicine, Cooper Medical School of Rowan University, Camden, NJ (Jones); Department of Anesthesiology, Department of Psychiatry, Institute for Trauma Recovery, University of North Carolina at Chapel Hill, Chapel Hill, NC (An, Linnstaedt); Department of Biostatistics, University of North Carolina Gillings School of Global Public Health, Chapel Hill, NC (Liu, Zeng); Department of Emergency Medicine, Washington University School of Medicine, St Louis, MO (House); Department of Emergency Medicine and Department of Health Services, Policy, and Practice, The Alpert Medical School of Brown University, Rhode Island Hospital and The Miriam Hospital, Providence, RI (Beaudoin); Department of Psychiatry and Behavioral Sciences, Emory University School of Medicine, Atlanta, GA (Stevens); Department of Psychiatry and Neurology, University of California San Francisco, San Francisco, CA (Neylan); Department of Biomedical Informatics, Emory University School of Medicine and Department of Biomedical Engineering, Georgia Institute of Technology and Emory University, Atlanta, GA (Clifford); Department of Psychiatry and Behavioral Neurosciences, Wayne State University, Detroit, MI (Jovanovic); Institute for Technology in Psychiatry, McLean Hospital, Belmont, MA (Germine, Rauch); The Many Brains Project, Belmont, MA (Germine); Department of Psychiatry, Harvard Medical School, Boston, MA (Germine, Rauch, Pizzagalli, Ressler); Department of Psychology and Neuroscience and Department of Sociology, University of North Carolina at Chapel Hill, Chapel Hill, NC (Bollen); Department of Psychiatry, McLean Hospital, Belmont, MA (Rauch); Department of Emergency Medicine, University of Massachusetts Medical School, Worcester, MA (Haran); Department of Emergency Medicine, Vanderbilt University Medical Center, Nashville, TN (Storrow); Department of Emergency Medicine, Henry Ford Health System, Detroit, MI (Lewandowski); Department of Emergency Medicine, Indiana University School of Medicine, Indianapolis, IN (Musey); Department of Emergency Medicine, University of Florida College of Medicine - Jacksonville, Jacksonville, FL (Hendry, Sheikh); Department of Emergency Medicine, University of Cincinnati College of Medicine (Punches, Lyons), and College of Nursing, University of Cincinnati, Cincinnati, OH (Punches); Department of Emergency Medicine, Division of Acute Care Surgery, Department of Surgery, University of Alabama School of Medicine, and Center for Injury Science, University of Alabama at Birmingham, Birmingham, AL (Kurz); Department of Emergency Medicine, Oakland University William Beaumont School of Medicine, Rochester, MI (Swor); Department of Emergency Medicine, Boston Medical Center, Boston, MA (McGrath); Department of Emergency Medicine, Emory University School of Medicine, Atlanta, GA (Hudak); Department of Surgery, Department of Neurosurgery, University of Pennsylvania, Pennsylvania, PA (Pascual); Perelman

School of Medicine, University of Pennsylvania, Pennsylvania, PA (Pascual, Seamon); Division of Traumatology, Department of Surgery, Surgical Critical Care and Emergency Surgery, University of Pennsylvania, Pennsylvania, PA (Seamon); Department of Emergency Medicine, Einstein Healthcare Network, and the Sidney Kimmel Medical College, Thomas Jefferson University, Pennsylvania, PA (Datner); Einstein Medical Center, Philadelphia, PA (Harris); Department of Emergency Medicine, Jefferson University Hospitals, Pennsylvania, PA (Chang); Department of Emergency Medicine, Wayne State University, Ascension St John Hospital, Detroit, MI (Pearson); Department of Emergency Medicine, Massachusetts General Hospital, Boston, MA (Peak); Department of Emergency Medicine, Brigham and Women's Hospital, Boston, MA (Merchant, Sanchez); Department of Emergency Medicine, Saint Joseph Mercy Hospital, Ypsilanti, MI (Domeier); Department of Emergency Medicine, University of Massachusetts Medical School-Baystate, Springfield, MA (Rathlev); Department of Emergency Medicine, Wayne State University, Detroit Receiving Hospital, Detroit, MI (O'Neil); Department of Emergency Medicine, McGovern Medical School, University of Texas Health, Houston, TX (Sergot); Department of Emergency Medicine, Harvard Medical School, Boston, MA (Sanchez); Department of Psychological Sciences, University of Missouri - St Louis, St Louis, MO (Bruce); National Center for PTSD, Behavioral Science Division, VA Boston Healthcare System, and Department of Psychiatry, Boston University School of Medicine, Boston, MA (Miller); Clinical Neurosciences Division, National Center for PTSD, VA Connecticut Healthcare System, West Haven, CT (Pietrzak); Department of Psychiatry (Pietrzak), and the Department of Psychology (Joormann), Yale School of Medicine, New Haven, CT; Department of Psychological and Brain Sciences, Washington University in St Louis, St Louis, MO (Barch); Division of Depression and Anxiety, McLean Hospital, Belmont, MA (Pizzagalli, Ressler); Department of Biosciences, and the Institute for Behavioral Medicine Research, OSU Wexner Medical Center, Columbus, OH (Sheridan); Department of Psychiatry, Psychiatric and Neurodevelopmental Genetics Unit, Massachusetts General Hospital, Boston, and Stanley Center for Psychiatric Research, Broad Institute, Cambridge, MA (Smoller); Department of Anesthesiology, and Department of Internal Medicine-Rheumatology, University of Michigan Medical School, Ann Arbor, MI (Harte); Kolling Institute of Medical Research, University of Sydney, St Leonards, and Faculty of Medicine and Health, University of Sydney, Northern Sydney Local Health District, New South Wales, Australia, and Physical Therapy and Human Movement Sciences, Feinberg School of Medicine, Northwestern University, Chicago, IL (Elliott); Department of Epidemiology, Harvard T H Chan School of Public Health, Harvard University, Boston, MA (Koenen); Department of Health Care Policy, Harvard Medical School, Boston, MA (Kessler); Departments of Emergency Medicine and Psychiatry, University of North Carolina at Chapel Hill, Chapel Hill, NC (McLean).

**Author contributions:** SAM, CWJ, XA, RCK conceived and designed the study. SAM, RCK, KJR, and KCK supervised the conduct of the study and data collection. SLH, FLB, JSS, TCN, GDC, TJ, LTG, JPH, ABS, CL, PIM, PLH, SS, CWJ, BEP, MSL, MCK, RAS, MEM, LAH, JLP, MJS, EMD, EH, AMC, CP, DAP, RCM, RMD, NKR, BJO, PS, LDS, and SEB undertook data collection

and data management. XA, YJ, ML, and DZ provided statistical advice on study design and analyzed the data. SAM, CWJ, and XA drafted the manuscript, and all authors contributed substantially to its revision. SAM takes responsibility for the paper as a whole.

**Authorship:** All authors attest to meeting the four [ICMJE.org](http://www.icmje.org) authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

**Funding and support:** By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see [www.icmje.org](http://www.icmje.org)). The authors have stated that no such relationships exist. Dr Jones has no competing interests related to this work, though he has been an investigator on studies funded by AstraZeneca, Vapotherm, Abbott, and Ophirex. In the last 3 years, Dr Clifford has received research funding from the NSF, NIH, and LifeBell AI, and unrestricted donations from AliveCor Inc, Amazon Research, the Center for Discovery, the Gates Foundation, Google, the Gordon, and Betty Moore Foundation, MathWorks, Microsoft Research, Nextsense Inc, One Mind Foundation, Otsuka US, the Rett Research Foundation, and Samsung Research. Dr Clifford has a financial interest in AliveCor Inc and Nextsense Inc. He is also the CTO of MindChild Medical and CSO of LifeBell AI and owns both companies. These relationships are unconnected to the current work. Dr Rauch reports grants from NIH during the conduct of the study; personal fees from SOBP (Society of Biological Psychiatry) paid role as secretary, other from Oxford University Press royalties, other from APP (American Psychiatric Publishing Inc) royalties, other from VA (Veterans Administration) per diem for the oversight committee, and other from Community Psychiatry/Mindpath Health paid board service, including equity outside the submitted work; other from National Association of Behavioral Healthcare for paid Board service; and Leadership roles on Board or Council for SOBP, ADAA (Anxiety and Depression Association of America), and NNDC (National Network of Depression Centers). Dr Sheikh has received funding from the Florida Medical Malpractice Joint Underwriter's Association. Dr Alvin E. Smith Safety of Healthcare Services Grant; Allergan Foundation; the NIH/NIA-funded Jacksonville Aging Studies Center (JAX-ASCENT; R33AG05654); and the Substance Abuse and Mental Health Services Administration (1H79TI083101-01); and the Florida Blue Foundation. Dr Joormann receives consulting payments from Janssen Pharmaceuticals. Over the past 3 years, Dr Pizzagalli has received consulting fees from Albright Stonebridge Group, Boehringer Ingelheim, Compass Pathways, Concert Pharmaceuticals, Engrail Therapeutics, Neumora Therapeutics (former BlackThorn Therapeutics), Neurocrine Biosciences, Neuroscience Software, Otsuka Pharmaceuticals, and Takeda Pharmaceuticals; honoraria from the Psychonomic Society (for editorial work) and Alkermes, and research funding from NIMH, Dana Foundation, Brain and Behavior Research Foundation, and Millennium Pharmaceuticals. In addition, he has received stock

options from Neumora Therapeutics (former BlackThorn Therapeutics), Compass Pathways, Engrail Therapeutics, and Neuroscience Software. Dr Elliott reports support from the National Institutes of Health (NIH) through Grant Numbers R01HD079076 & R03HD094577; Eunice Kennedy Shriver National Institute of Child Health & Human Development; National Center for Medical Rehabilitation Research. He also reports funding from New South Wales Health, Spinal Cord Injury Award (2020-2025), and consulting fees (<\$15,000 per annum) from Orofacial Therapeutics, LLC. Dr Koenen's research has been supported by the Robert Wood Johnson Foundation, the Kaiser Family Foundation, the Harvard Center on the Developing Child, Stanley Center for Psychiatric Research at the Broad Institute of MIT and Harvard, the National Institutes of Health, One Mind, the Anonymous Foundation, and Cohen Veterans Bioscience. She has been a paid consultant for Baker Hostetler, Discovery Vitality, and the Department of Justice. She has been a paid external reviewer for the Chan Zuckerberg Foundation, the University of Cape Town, and Capita Ireland. She has had paid speaking engagements in the last 3 years with the American Psychological Association European Central Bank. Sigmund Freud University – Milan, Cambridge Health Alliance, and Coverys. She receives royalties from Guilford Press and Oxford University Press. Dr Ressler has received consulting income from Alkermes and Takeda, research support from NIH, Alkermes, Genomind, and Brainsway, and has served on advisory boards for Takeda, Resilience Therapeutics, Janssen, and Verily/Google. In the past 3 years, Dr Kessler was a consultant for Datastat, Inc, Holmusk, RallyPoint Networks, Inc, and Sage Therapeutics. He has stock options in Mirah, PYM, and Roga Sciences. Dr Ressler has served on advisory boards for Takeda, Resilience Therapeutics, Janssen, and Verily/Google. In addition, his research has been sponsored by Alkermes and Brainsway, and he has worked as a consultant for Alkermes. This project was supported by the National Institute of Mental Health (NIMH) under U01MH110925, the US Army MPMC, One Mind, and The Mayday Fund. The content is the sole responsibility of the authors and does not necessarily represent the official views of any funders. Data and/or research tools used in preparing this manuscript were obtained from the NIMH Data Archive (NDA). NDA is a collaborative informatics system created by the National Institutes of Health to provide a national resource to support and accelerate research in mental health. Dataset identifier(s): 10.15154/1524655. This manuscript reflects the authors' views and may not reflect the opinions or views of the NIH or the submitters submitting original data to NDA. Support for title page creation and format was provided by AuthorArranger, a tool developed at the National Cancer Institute.

**Publication dates:** Received for publication January 27, 2022. Revisions received June 2, 2022, and July 28, 2022. Accepted for publication August 4, 2022.

Presented the preliminary results from this study at the American College of Emergency Physicians (ACEP) *Research Forum* (Boston, MA) on October 27, 2021.

## REFERENCES

1. Albert M, McCaig LF. Emergency department visits for motor vehicle traffic injuries: United States, 2010-2011. *NCHS Data Brief*. 2015;185:1-8.

2. Platts-Mills TF, Hunold KM, Esserman DA, et al. Motor vehicle collision-related emergency department visits by older adults in the United States. *Acad Emerg Med*. 2012;19:821-827.
3. Ehlers A, Mayou RA, Bryant B. Psychological predictors of chronic posttraumatic stress disorder after motor vehicle accidents. *J Abnorm Psychol*. 1998;107:508-519.
4. Kenardy J, Heron-Delaney M, Hendrikz J, et al. Recovery trajectories for long-term health-related quality of life following a road traffic crash injury: results from the UQ SuPPORT study. *J Affect Disord*. 2017;214:8-14.
5. Platts-Mills TF, Nebolisa BC, Flannigan SA, et al. Post-traumatic stress disorder among older adults experiencing motor vehicle collision: a multicenter prospective cohort study. *Am J Geriatr Psychiatry*. 2017;25:953-963.
6. Kessler RC. Posttraumatic stress disorder: the burden to the individual and to society. *J Clin Psychiatry*. 2000;61(suppl 5):4-12; discussion 13-14.
7. Yehuda R. Post-traumatic stress disorder. *N Engl J Med*. 2002;346:108-114.
8. Corbin TJ, Rich JA, Bloom SL, et al. Developing a trauma-informed, emergency department-based intervention for victims of urban violence. *J Trauma Dissociation*. 2011;12:510-525.
9. Fischer KR, Bakes KM, Corbin TJ, et al. Trauma-informed care for violently injured patients in the emergency department. *Ann Emerg Med*. 2019;73:193-202.
10. Ziobrowski HN, Kennedy CJ, Ustun B, et al. Development and validation of a model to predict posttraumatic stress disorder and major depression after a motor vehicle collision. *JAMA Psychiatry*. 2021;78:1228-1237.
11. McLean SA, Ressler K, Koenen KC, et al. The Aurora Study: a longitudinal, multimodal library of brain biology and function after traumatic stress exposure. *Mol Psychiatry*. 2020;25:283-296.
12. Wortmann JH, Jordan AH, Weathers FW, et al. Psychometric analysis of the PTSD Checklist-5 (PCL-5) among treatment-seeking military service members. *Psychol Assess*. 2016;28:1392-1403.
13. Bovin MJ, Marx BP, Weathers FW, et al. Psychometric properties of the PTSD Checklist for Diagnostic and Statistical Manual of Mental Disorders-Fifth Edition (PCL-5) in veterans. *Psychol Assess*. 2016;28:1379-1391.
14. Zuromski KL, Ustun B, Hwang I, et al. Developing an optimal short-form of the PTSD Checklist for DSM-5 (PCL-5). *Depress Anxiety*. 2019;36:790-800.
15. Brunet A, Weiss DS, Metzler TJ, et al. The Peritraumatic Distress Inventory: a proposed measure of PTSD criterion A2. *Am J Psychiatry*. 2001;158:1480-1485.
16. Kessler RC, Mickelson KD, Walters EE. Age and depression in the MIDUS survey. In: Brim OG, Ryff CD, Kessler RC, eds. *How Healthy Are We: A National Study of Well-Being at Midlife*. University of Chicago Press; 2004:227-251.
17. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. *J Health Soc Behav*. 1983;24:385-396.
18. Benjet C, Bromet E, Karam EG, et al. The epidemiology of traumatic event exposure worldwide: results from the World Mental Health Survey Consortium. *Psychol Med*. 2016;46:327-343.
19. Blevins CA, Weathers FW, Davis MT, et al. The posttraumatic stress disorder checklist for DSM-5 (PCL-5): development and initial psychometric evaluation. *J Trauma Stress*. 2015;28:489-498.
20. Cella D, Riley W, Stone A, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005-2008. *J Clin Epidemiol*. 2010;63:1179-1194.
21. Kessler RC, Calabrese JR, Farley PA, et al. Composite International Diagnostic Interview screening scales for DSM-IV anxiety and mood disorders. *Psychol Med*. 2013;43:1625-1637.
22. Gibbons LE, Frederickson R, Merrill JO, et al. Suitability of the PROMIS alcohol use short form for screening in a HIV clinical care setting. *Drug Alcohol Depend*. 2016;164:113-119.
23. Ware Jr J, Kosinski M, Keller SD. A 12-Item Short-Form Health Survey: construction of scales and preliminary tests of reliability and validity. *Med Care*. 1996;34:220-233.
24. Leon AC, Olfson M, Portera L, et al. Assessing psychiatric impairment in primary care with the Sheehan Disability Scale. *Int J Psychiatry Med*. 1997;27:93-105.
25. Schuster TL, Kessler RC, Aseltine Jr RH. Supportive interactions, negative interactions, and depressed mood. *Am J Community Psychol*. 1990;18:423-438.
26. Gosling SD, Rentfrow PJ, Swann Jr WB. A very brief measure of the Big-Five personality domains. *J Res Pers*. 2003;37:504-528.
27. Rodriguez BF, Bruce SE, Pagano ME, et al. Factor structure and stability of the Anxiety Sensitivity Index in a longitudinal study of anxiety disorder patients. *Behav Res Ther*. 2004;42:79-91.
28. Gruber-Baldini AL, Vellozo C, Romero S, et al. Validation of the PROMIS® measures of self-efficacy for managing chronic conditions. *Qual Life Res*. 2017;26:1915-1924.
29. Ustun B. Simple linear classifiers via discrete optimization: learning certifiably optimal scoring systems for decision-making and risk assessment [PhD]: Department of Electrical Engineering and Computer Science. Massachusetts Institute of Technology; 2017.
30. Hovenkamp-Hermelink JHM, van der Veen DC, Oude Voshaar RC, et al. Anxiety sensitivity, its stability and longitudinal association with severity of anxiety symptoms. *Sci Rep*. 2019;9:4314.
31. Calvo MG, Cano-Vindel A. The nature of trait anxiety. *Eur Psychol*. 1997;2:301-312.
32. Roberts AL, Gilman SE, Breslau J, et al. Race/ethnic differences in exposure to traumatic events, development of post-traumatic stress disorder, and treatment-seeking for post-traumatic stress disorder in the United States. *Psychol Med*. 2011;41:71-83.
33. Murphy D, Ross J, Ashwick R, et al. Exploring optimum cut-off scores to screen for probable posttraumatic stress disorder within a sample of UK treatment-seeking veterans. *Eur J Psychotraumatol*. 2017;8:1398001-1398002.
34. Gaskin DJ, Richard P. The economic costs of pain in the United States. *J Pain*. 2012;13:715-724.
35. Dobie DJ, Kivlahan DR, Maynard C, et al. Posttraumatic stress disorder in female veterans: association with self-reported health problems and functional impairment. *Arch Intern Med*. 2004;164:394-400.
36. Outcalt SD, Kroenke K, Krebs EE, et al. Chronic pain and comorbid mental health conditions: independent associations of posttraumatic stress disorder and depression with pain, disability, and quality of life. *J Behav Med*. 2015;38:535-543.
37. Stewart WF, Ricci JA, Chee E, et al. Cost of lost productive work time among US workers with depression. *JAMA*. 2003;289:3135-3144.
38. Bleich A, Solomon Z. Evaluation of psychiatric disability in PTSD of military origin. *Isr J Psychiatry Relat Sci*. 2004;41:268-276.
39. McNally RJ, Frueh BC. Why are Iraq and Afghanistan War veterans seeking PTSD disability compensation at unprecedented rates? *J Anxiety Disord*. 2013;27:520-526.
40. Surís A, Lind L. Military sexual trauma: a review of prevalence and associated health consequences in veterans. *Trauma Violence Abuse*. 2008;9:250-269.
41. Lew HL, Otis JD, Tun C, et al. Prevalence of chronic pain, posttraumatic stress disorder, and persistent postconcussive symptoms in OIF/OEF veterans: polytrauma clinical triad. *J Rehabil Res Dev*. 2009;46:697-702.
42. Haskell SG, Gordon KS, Mattocks K, et al. Gender differences in rates of depression, PTSD, pain, obesity, and military sexual trauma among Connecticut war veterans of Iraq and Afghanistan. *J Womens Health (Larchmt)*. 2010;19:267-271.
43. Mavranzeouli I, Megnin-Viggars O, Daly C, et al. Psychological treatments for post-traumatic stress disorder in adults: a network meta-analysis. *Psychol Med*. 2020;50:542-555.



44. Papini S, Pisner D, Shumake J, et al. Ensemble machine learning prediction of posttraumatic stress disorder screening status after emergency room hospitalization. *J Anxiety Disord.* 2018;60:35-42.
45. Galatzer-Levy IR, Karstoft KI, Statnikov A, et al. Quantitative forecasting of PTSD from early trauma responses: a Machine Learning application. *J Psychiatr Res.* 2014;59:68-76.
46. Schultebrucks K, Sijbrandij M, Galatzer-Levy I, et al. Forecasting individual risk for long-term Posttraumatic Stress Disorder in emergency medical settings using biomedical data: a machine learning multicenter cohort study. *Neurobiol Stress.* 2021;14:100297-100298.
47. Karstoft KI, Galatzer-Levy IR, Statnikov A, et al. members of Jerusalem Trauma Outreach and Prevention Study (J-TOPS) group. Bridging a translational gap: using machine learning to improve the prediction of PTSD. *BMC Psychiatry.* 2015;15:30-31.
48. deRoon-Cassini TA, Hunt JC, Geier TJ, et al. Screening and treating hospitalized trauma survivors for posttraumatic stress disorder and depression. *J Trauma Acute Care Surg.* 2019;87:440-450.
49. Hunt JC, Herrera-Hernandez E, Brandolino A, et al. Validation of the Injured Trauma Survivor Screen: an American Association for the Surgery of Trauma multi-institutional trial. *J Trauma Acute Care Surg.* 2021;90:797-806.
50. Ryb GE, Dischinger PC, Read KM, et al. PTSD after severe vehicular crashes. *Ann Adv Automot Med.* 2009;53:177-193.
51. Shih RA, Schell TL, Hambarsoomian K, et al. Prevalence of posttraumatic stress disorder and major depression after trauma center hospitalization. *J Trauma.* 2010;69:1560-1566.
52. Mayou R, Bryant B. Outcome in consecutive emergency department attenders following a road traffic accident. *Br J Psychiatry.* 2001;179:528-534.
53. Zatzick D, Jurkovich G, Russo J, et al. Posttraumatic distress, alcohol disorders, and recurrent trauma across level 1 trauma centers. *J Trauma.* 2004;57:360-366.
54. Schultebrucks K, Shalev AY, Michopoulos V, et al. A validated predictive algorithm of post-traumatic stress course following emergency department admission after a traumatic stressor. *Nat Med.* 2020;26:1084-1088.
55. Saxe GN, Ma S, Ren J, et al. Machine learning methods to predict child posttraumatic stress: a proof of concept study. *BMC Psychiatry.* 2017;17:223-224.
56. Breslau N, Chilcoat HD, Kessler RC, et al. Previous exposure to trauma and PTSD effects of subsequent trauma: results from the Detroit Area Survey of Trauma. *Am J Psychiatry.* 1999;156:902-907.
57. Breslau N, Peterson EL, Schultz LR. A second look at prior trauma and the posttraumatic stress disorder effects of subsequent trauma: a prospective epidemiological study. *Arch Gen Psychiatry.* 2008;65:431-437.
58. Coventry PA, Meader N, Melton H, et al. Psychological and pharmacological interventions for posttraumatic stress disorder and comorbid mental health problems following complex traumatic events: systematic review and component network meta-analysis. *PLOS Med.* 2020;17:e1003262-e1003263.

### 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