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Prospective Development and Validation of the Computerized Adaptive Screen for Suicidal Youth

Cheryl A. King, PhD; David Brent, MD; Jacqueline Grupp-Phelan, MD, MPH; T. Charles Casper, PhD; J. Michael Dean, MD; Lauren S. Chernick, MD, MSc; Joel A. Fein, MD, MPH; E. Melinda Mahabee-Gittens, MD, MS; Shilpa J. Patel, MD, MPH; Rakesh D. Mistry, MD, MS; Susan Duffy, MD; Marlene Melzer-Lange, MD; Alexander Rogers, MD; Daniel M. Cohen, MD; Allison Keller, MD; Rohit Shenoi, MD; Robert W. Hickey, MD; Margaret Rea, PhD; Mary Cwik, PhD; Kent Page, MStat; Taylor C. McGuire, BS; Jiebiao Wang, PhD; Robert Gibbons, PhD; for the Pediatric Emergency Care Applied Research Network

IMPORTANCE The rate of suicide among adolescents is rising in the US, yet many adolescents at risk are unidentified and receive no mental health services.

OBJECTIVE To develop and independently validate a novel computerized adaptive screen for suicidal youth (CASSY) for use as a universal screen for suicide risk in medical emergency departments (EDs).

DESIGN, SETTING, AND PARTICIPANTS Study 1 of this prognostic study prospectively enrolled adolescent patients at 13 geographically diverse US EDs in the Pediatric Emergency Care Applied Research Network. They completed a baseline suicide risk survey and participated in 3-month telephone follow-ups. Using 3 fixed Ask Suicide-Screening Questions items as anchors and additional items that varied in number and content across individuals, we derived algorithms for the CASSY. In study 2, data were collected from patients at 14 Pediatric Emergency Care Applied Research Network EDs and 1 Indian Health Service hospital. Algorithms were independently validated in a prospective cohort of adolescent patients who also participated in 3-month telephone follow-ups. Adolescents aged 12 to 17 years were consecutively approached during randomly assigned shifts.

EXPOSURES Presentation at an ED.

MAIN OUTCOME AND MEASURE A suicide attempt between ED visit and 3-month follow-up, measured via patient and/or parent report.

RESULTS The study 1 CASSY derivation sample included 2075 adolescents (1307 female adolescents [63.0%]; mean [SD] age, 15.1 [1.61] years) with 3-month follow-ups (72.9% retention [2075 adolescents]). The study 2 validation sample included 2754 adolescents (1711 female adolescents [62.1%]; mean [SD] age, 15.0 [1.65] years), with 3-month follow-ups (69.5% retention [2754 adolescents]). The CASSY algorithms had excellent predictive accuracy for suicide attempt (area under the curve, 0.89 [95% CI, 0.85-0.91]) in study 1. The mean number of adaptively administered items was 11 (range, 5-21). At a specificity of 80%, the CASSY had a sensitivity of 83%. It also demonstrated excellent accuracy in the study 2 validation sample (area under the curve, 0.87 [95% CI, 0.85-0.89]). In this study, the CASSY had a sensitivity of 82.4% for prediction of a suicide attempt at the 80% specificity cutoff established in study 1.

CONCLUSIONS AND RELEVANCE In this study, the adaptive and personalized CASSY demonstrated excellent suicide attempt risk recognition, which has the potential to facilitate linkage to services.

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Supplemental content

Author Affiliations: Author affiliations are listed at the end of this article.

Group Information: A complete list of the members of the Pediatric Emergency Care Applied Research Network appears at the end of this article.

Corresponding Author: Cheryl A. King, PhD, Department of Psychiatry, University of Michigan, 4250 Plymouth Rd, Rachel Upjohn Building, Ann Arbor, MI 48109-2700 (kingca@umich.edu).

In 2018, the US reported the highest annual number of adolescent suicide deaths to date, with 1750 suicides among adolescents 12 to 17 years of age.[1] In fact, the suicide rate among adolescents in the US in this age range has increased by 62% since 2000.[1] Recent National Violent Death Report System data indicate that only 41.2% of adolescents who die by suicide have ever been treated for a mental health problem.[2]

Improved suicide risk detection through effective screening has the potential to facilitate treatment linkage, reduce morbidity, and prevent mortality. Emergency departments (EDs) are particularly well suited for suicide risk screening, since approximately 19% of US adolescents visit the ED in a 1-year period.[3] Further, ED visits for youth suicide risk have recently doubled,[4] and EDs are a common point of access for mental health services.[5,6] Many chief complaints place adolescents at increased risk for suicidal behavior (eg, trauma, alcohol abuse)[7]; boys, who account for most suicides,[1] are well represented[8]; and parents and adolescents have favorable views of suicide risk screening in the ED.[9]

A substantial challenge to universal suicide risk screening in EDs is the accurate identification of youth at risk in a setting where efficiency is highly valued and mental health concerns represent only a small minority of chief complaints.[10] Existing tools such as the Ask Suicide-Screening Questions (ASQ)[11,12] and the Multifactor Youth Suicide Risk Screen[13] have shown effectiveness in identifying previously unrecognized suicide risk. Moreover, the predictive validity of the ASQ as a universal screen was demonstrated in a large retrospective medical record review study[14]; it demonstrated sensitivity and specificity of 60.0% and 92.7%, respectively, for prediction of an ED visit for a suicide-associated concern. Despite these overall favorable results, the moderate sensitivity indicates that many individuals at risk were not identified. Given the morbidity and mortality associated with suicide risk, research aimed at improving tools for universal screening in the ED is warranted.[15]

A computerized adaptive testing (CAT) strategy offers the possibility of developing an improved youth suicide risk screening tool. The CAT is grounded in a multidimensional extension of item response theory, in which an individual's initial item responses are used to determine a provisional estimate of their standing on the measured trait (eg, risk of suicide attempt [SA]).[16] The number and content of items presented to individuals varies to achieve the same precision of measurement.[17] This strategy was used by Gibbons et al[18] to develop a dimensional measure of depression severity that outperformed standard screening instruments, and the validity and usefulness of a CAT strategy has been demonstrated for multiple mental health disorders among adults.[19,20] Gibbons et al[21] recently developed a Kiddie-CAT that demonstrates excellent accuracy for assessing presence and severity of child and adolescent depression and anxiety, among other conditions. The eAppendix in Supplement 1 provides information about CAT-based measurement accomplishments and their dissemination.

To develop and validate a computerized adaptive screen for suicidal youth (CASSY), we conducted 2 independent studies in collaboration with the US Pediatric Emergency Care Applied Research Network (PECARN). In study 1, we used CAT to develop a universal screen that targets items to adolescents' personal risk profiles and provides a continuous risk score (rather than binary classification) for the likelihood of an SA within 3 months. In study 2, we prospectively validated the CASSY in an independent sample. We chose SA as the outcome because it was the outcome of interest specified by the National Institute of Mental Health, and a 3-month time frame because this is a period of high risk.[22]

Key Points

Question Can use of a computerized adaptive screen reliably predict a youth suicide attempt within 3 months?

Findings This prognostic study with a derivation cohort of 2075 adolescents and an independent prospective validation cohort of 2754 adolescents developed and validated the Computerized Adaptive Screen for Suicidal Youth (CASSY) to predict a suicide attempt within 3 months. In the independent validation cohort, the area under the curve for the CASSY was 0.87 (95% CI, 0.85-0.89) for prediction of a suicide attempt within 3 months.

Meaning In this study, the CASSY had a strong, validated classification accuracy, and it may improve recognition of youth suicide risk.

Methods

Study Design and Settings

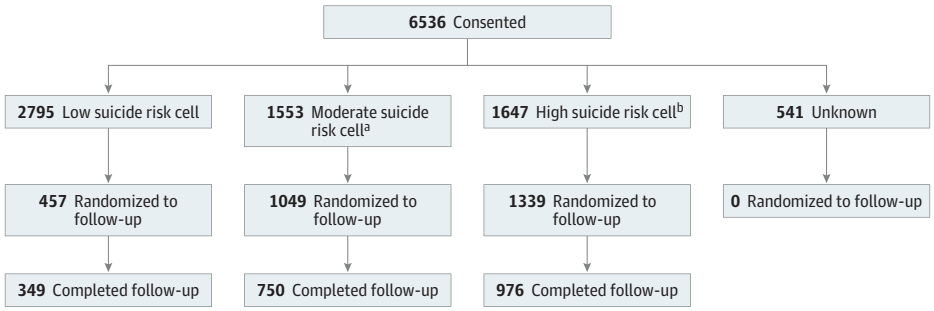
This study uses data from PECARN EDs that participated in the ED Screen for Teens at Risk for Suicide (ED-STARS) study 1[23] and study 2 cohorts of 6536 and 4031 adolescents, respectively. In study 1, we recruited from 13 PECARN EDs between June 2015 and July 2016; in study 2, we recruited from 14 PECARN EDs and 1 Indian Health Services ED between July 2017 and September 2018. The EDs were located in the US, in the West (study 1, n = 2 [15%]; study 2, n = 4 [27%]), Southwest/Central (study 1, n = 2 [15%]; study 2, n = 2 [13%]), Midwest (study 1, n = 4 [31%]; study 2, n = 4 [27%]), and the Mid-Atlantic/New England (study 1, n = 5 [38%]; study 2, n = 5 [33%]) regions.

Adolescents completed baseline assessments in the ED on a computer tablet. Interviewers, blinded to baseline data, conducted 3-month computer-assisted telephone follow-up interviews. Adolescents were remunerated with online certificates. We obtained institutional review board approval from all sites, parent/guardian written informed consent, and adolescent assent. We followed the Standards for Reporting of Diagnostic Accuracy Studies 2015 guidelines (reported in eTable 1 in Supplement 1).[24]

Participants

Adolescents, ages 12 to 17 years, were recruited during screening shifts randomly selected for each site from times when research staff were available (primarily afternoons and evenings). In study 2 only, patients were also recruited from an Indian Health Services ED. Exclusion criteria were being a ward

Figure 1. Study 1 Participant Flow for Adolescents in Cells at Low, Moderate, and High Suicide Risk



[a] Criteria for adolescent assignment to cells with moderate suicide risk involved suicidal ideation (without a method, plan, or intent), homicidal ideation without a plan or intent, more than 2 other suicide risk factors (eg, hopelessness, alcohol misuse, physical fighting, sexual or gender minority status).

[b] Criteria for adolescent assignment to cells with high suicide risk involved a lifetime history of suicide attempt (including interrupted and aborted attempts); a lifetime suicidal ideation with intent, method, or plan; homicidal ideation with an intent or plan; and 5 or more incidents of nonsuicidal self-injury in past 12 months.

of the state, non-English speaking, and medically unstable or severely cognitively impaired (as determined by the clinician). Patients were not eligible to participate in both studies.

Study 1

A subset of 2845 adolescents was randomly assigned to follow-ups. To establish this subset, we first stratified adolescents into low, moderate, and high risk groups, based on their baseline endorsement of suicide risk factors.[7] We followed more adolescents at moderate or high risk (**Figure 1**), randomizing risk groups to follow-up in proportions needed to obtain preestablished numbers, to balance obtaining a sample with a full range of suicide risk with the need for a statistically sufficient number of attempt outcomes.

Study 2

The enrolled sample was enriched for suicide risk by requiring each site to maintain at least a 2:3 enrollment ratio between adolescents with psychiatric vs other chief complaints. All patients were assigned to follow-up.

Measures

Study 1

Adolescents completed a self-report survey (92 primary questions and up to 27 additional questions) at baseline, which included the ASQ[11,12] and Columbia-Suicide Severity Rating Scale (C-SSRS),[25-27] which assess suicidal ideation; suicidal rumination; SA history; nonsuicidal self-injury; depression; hopelessness; homicidal ideation; anxiety; agitation; sleep disturbance; functional impairment; alcohol and drug misuse; impulsive aggression; physical fighting; family, school, and social connectedness; being bullied by peers; physical and sexual abuse; negative life events; and sexual or gender minority identity. We used brief or adapted scales to minimize respondent burden (eMethods in Supplement 1).

Study 2

Adolescents completed the CASSY at baseline. This was followed by a subset of 37 to 59 items from the study 1 baseline survey to ensure measurement of key demographic and clinical variables to describe the sample and differences in retention by these characteristics (eMethods in Supplement 1).

Outcome of Studies 1 and 2

The main outcome was an SA between baseline and 3-month follow-up. This was defined by (1) an adolescent or parent report of adolescent ED visit or hospitalization with an SA, and/or (2) adolescent endorsement of the statement "In the past 3 months, have you made a suicide attempt?" or "In the past 3 months, have you tried to harm yourself because you were at least partly trying to end your life?" from an adapted C-SSRS.[26]

Statistical Analysis

Study 1

To develop the CASSY, we applied a multidimensional item response theory model[28,29] to the 92-item bank using the subdomains of suicidal ideation and behavior, psychopathology, posttraumatic stress disorder, social adjustment, sleep, anger/aggression, and substance use, in addition to the overall primary dimension. The bifactor model allows each item to load on the primary dimension, which includes items from the suicidal ideation and behavior subdomain and highly correlated subdomains, and the single subdomain from which it was drawn. Items with loadings less than 0.30 on the primary dimension were deleted, leaving 72 items. In developing algorithms, we used 3 fixed ASQ items (morbid ideation, suicidal ideation, and history of suicide attempt) as anchors to ensure measurement of commonly assessed constructs, and we allowed the content and number of other items to vary across individuals. The CASSY score is expressed as a continuous score (0%-100%). Additional details are in the eMethods in Supplement 1.

We then used a logistic regression model (primary CASSY dimension score and suicide subdomain score as independent variables) to predict suicide attempt during the next 3 months. We report sensitivity for 2 fixed points on the receiver operating characteristic curve (specificity of 0.80% and 0.90%). Area under the curve (AUC), an overall index of predictive accuracy, was estimated based on 3-fold cross-

validation (estimation in two-thirds of the sample, with validation and classification in remainder). This process was repeated 3 times; sensitivity, specificity, and AUC are reported based on participants whose data were not used to estimate the logistic regression. These analyses were performed using the POLYBIF program version 1.0 (University of Illinois at Chicago Center for Health Statistics; https://www.healthstats.org/) from December 2016 to July 2017.

Study 2

We calculated AUC for prediction of an SA in addition to sensitivity and specificity at the fixed values of the CASSY corresponding to specificities of 0.80% and 0.90% in study 1. We evaluated study 2 data at thresholds derived in study 1 to assess reproducibility of classification accuracy. We conducted sensitivity analyses to assess changes attributable to missing data (eMethods in Supplement 1). These analyses were performed using Stata version 16 (StataCorp) from May 2020 to September 2020. The significance threshold was $P < .05$, 2-tailed.

Results

Study 1

Participant Characteristics

Among the 10 544 eligible patients approached for participation, 6536 were enrolled (62.0%), 6344 (97.1% of those enrolled) completed the baseline survey (≥80% of questions), and 2845 were randomized to follow-up. Adolescents who did not complete the survey or whose risk group was unknown because of missing data were ineligible for follow-up. Follow-up data were obtained for 2075 adolescents (72.9% retention) from adolescents and parents (n = 1774 [85.5%]), adolescents only (n = 183 [8.8%]), or parents only (n = 118 [5.7%]). Figure 1 reports the percentages of adolescents in each baseline suicide risk cell who were randomized to follow-up and retained. Female adolescents (1307 of 1841 [71.0%] vs male adolescents: 768 of 1003 [76.6%]; $P = .001$), Latinx adolescents (455 of 665 [68.4%]; vs adolescents who were not Latinx: 1381 of 1814 [76.1%] and those of unknown ethnicity: 126 of 191 [66.0%]; $P < .001$), and those with lower parental education levels (eg, at least 1 parent having a college degree or professional training: 993 of 1274 adolescents [77.9%] vs both parents having less education: 834 of 1200 adolescents [69.5%]; $P < .001$) were less likely to be retained (eTable 2 in Supplement 1). Of these, only female sex was associated with SA (male adolescents: 19 of 768 [2.5%]; female adolescents: 83 of 1307 [6.4%]; $P < .001$). Associations between demographics and attempt outcomes were reported previously.[30]

The 2075 participants in this study (1307 female adolescents [63%]) had a mean (SD) age of 15.1 (1.6) years. **Table 1** presents demographic and suicide risk characteristics of participants in baseline and follow-up samples. Retention data are in the eMethods in Supplement 1.

Table 1. Study 1 Demographic and Suicide Risk Characteristics of Adolescents in Baseline and Follow-up Samples

Characteristic	Analysis population, No. (%)[a]	
	Baseline (n = 6536)	Follow-up (n = 2075)
Age at enrollment, mean (SD), y	15.0 (1.65)	15.1 (1.61)
Male	2657 (41)	768 (37)
Race		
American Indian or Alaska Native	95 (1)	31 (1)
Asian or Native Hawaiian or other Pacific Islander	126 (2)	32 (2)
Black or African American	1464 (22)	486 (23)
White	3379 (52)	1122 (54)
Multiracial	358 (5)	132 (6)
Unknown or unavailable	1114 (17)	272 (13)
Ethnicity		
Hispanic or Latino	1523 (25)	455 (23)
Not Hispanic or Latino	4052 (68)	1381 (70)
Unknown	403 (7)	126 (6)
Education		
Mother/stepmother		
High school graduate or less	1928 (32)	570 (28)
Some college/technical training	1632 (27)	575 (29)
College graduate/professional training	2400 (39)	808 (40)
Do not know/not applicable	154 (3)	49 (2)
Father/stepfather		
High school graduate or less	2490 (41)	777 (39)
Some college/technical training	1223 (20)	399 (20)
College graduate/professional training	1806 (30)	625 (31)
Do not know/not applicable	567 (9)	191 (10)
Family receives public assistance	2587 (43)	889 (45)
Psychiatric chief complaint	919 (14)	489 (24)
Baseline suicide risk subgroup		
Low	2795 (43)	349 (17)
Moderate	1553 (24)	750 (36)
High	1647 (25)	976 (47)
Unknown	541 (8)	0 (0)
High suicide risk indicators		
Suicidal ideation, lifetime		
With intent	912 (14)	557 (27)
With planning	673 (11)	408 (20)
Suicide attempt, lifetime	1167 (18)	680 (33)
Preparatory steps for suicide attempt, lifetime	763 (12)	458 (22)
Suicide attempt, lifetime		
Interrupted	925 (14)	550 (27)
Aborted	924 (14)	550 (27)
Suicidal intent or plan	37 (1)	13 (1)
≥5 Nonsuicidal self-injuries in past 12 mo	402 (6)	256 (12)

[a] Groups are not mutually exclusive.

Suicidal Ideation and Suicide Attempts

At baseline, 832 adolescents (40.1%) had a lifetime C-SSRS suicidal ideation severity score of 3 or more, indicating suicidal thoughts with a method, plan, and/or intent; 1071 (51.7%) reported suicidal ideation (score ≥2). The number of lifetime SAs was distributed as follows: 0 (1451 [69.9%]), 1 (163 [7.9%]), multiple (430 [20.7%]), and unknown (31 [1.5%]).

A total of 102 adolescents (4.9%) made at least 1 SA between baseline and follow-up. Associations between baseline suicide risk factors and SA outcomes were reported previously.[30]

CASSY Algorithm and Predictor Model

Simulated adaptive testing from the complete response patterns revealed that a mean of 11 items (range, 5-21), including 3 ASQ items and a varying number of adaptively administered items, provided a correlation (*r*) of 0.94 with the 72-item total bank score. The median time required for administration of 11 items was 1 minute 24 seconds (interquartile range, 59 seconds to 2 minutes 4 seconds). With the exception of the 3 ASQ items included for all youth, the frequency with which other items were included varied, in keeping with their contribution to measuring each youth's risk for SA (**Table 2**).

The predictor model with the highest balance between sensitivity and specificity yielded a 3-fold cross-validated sensitivity of 83% at the fixed specificity of 80%. At a specificity of 90%, sensitivity was 61% (cross-validated). The AUC for the entire receiver operating characteristic curve (**Figure 2**) was 0.89 (95% CI, 0.85-0.91). The addition of demographic variables (age, sex, and race) did not improve predictive accuracy. In selecting an optimal set of items for each adolescent, the CASSY used a mean (SD) of 15.3% (5.6%) of the 72 items available in the bank for any given individual. The mean (SD) of the CASSY score was 0.19 (0.08) and 0.04 (0.14), respectively, for those who did vs did not make an SA.

Study 2

Participant Characteristics

Among the 6513 eligible adolescents approached for participation, 4050 were enrolled (62.2%). Adolescents with complete baseline evaluations, (n = 3965 [97.9%]) were eligible for follow-up. Three-month follow-ups were obtained for 2754 adolescents (69.5% retention) from adolescents and parents (n = 2443 [88.7%]), adolescents only (n = 120 [4.4%]), or parents only (n = 191 [6.9%]). Black adolescents (471 of 769 [61.2%] vs, eg, White adolescents 1621 of 2261 [71.7%] $P < .001$) and adolescents with unknown ethnicity (220 of 364 [60.4%]; Latinx youths: 685 of 993 [69.0%]; non-Latinx youths: 1849 of 2608 [70.9%]; $P < .001$), lower parental education level (eg, at least 1 parent having a college degree or professional training: 1465 of 1969 adolescents [74.4%] vs both parents having less education: 985 of 1515 adolescents [65.0%]; $P < .001$), psychiatric complaints (1112 of 1657 adolescents [67.1%] vs those with nonpsychiatric complaints: 1642 of 2304 adolescents [71.3%]; $P = .005$), and families who received public assistance (1106 of 1639 [67.5%]; vs those who did not, 1595 of 2250 [70.9%]; $P = .02$) were less likely to be retained. Retention data are in eTable 3 in Supplement 1.

The 2754 study participants (62% female) had a mean (SD) age of 15.0 (1.65) years. **Table 3** presents demographic and suicide risk characteristics of participants in baseline and follow-up samples.

Suicide Attempts

The number of lifetime SAs at baseline was distributed as follows: 0 (1970 [71.5%]), 1 (249 [9.0%]), multiple (501 [18.2%]), and unknown (34 [1.2%]). A total of 165 adolescents (6.0%) made at least 1 SA between baseline and follow-up.

Table 2. Items Used in Derivation of Computerized Adaptive Screen for Suicidal Youth (CASSY) and Number of Youth Presented Each Item in Calibration Phase[a]

Item	Youths presented with item, No.
Ask Suicide-Screening Questions	
In the past few weeks, have you wished you were dead?	1452
In the past few weeks, have you felt that you or your family would be better off if you were dead?	59
In the past week, have you been having thoughts about killing yourself?	1452
Have you ever tried to kill yourself?	1452
Columbia–Suicide Severity Rating Scale	
Have you ever in your life wished you were dead or wished you could go to sleep and not wake up?	430
Have you ever in your life had any thoughts of killing yourself?	648
How many times in your life have you made a suicide attempt?	26
Have you ever in your life made a suicide attempt?	88
Have you ever in your life tried to harm yourself because you were at least partly trying to end your life?	63
How many times in your life have you tried to harm yourself because you were at least partly trying to end your life?	8
Have you ever in your life taken any steps toward making a suicide attempt or preparing to kill yourself?	53
Have you ever in your life started to do something to end your life but someone or something stopped you before you did anything?	19
Have you ever in your life started to do something to end your life but stopped yourself before you actually did anything?	12
Youth Risk Behavior Survey	
In the past 12 mo, have you ever harmed or hurt your body on purpose, such as cutting or burning your skin, or hitting yourself, without wanting to die?	11
Functional Assessment of Self-Mutilation	
Over the past 12 mo, how many of the following methods have you used to harm or hurt your body on purpose, without wanting to die?	17
Mood and Feelings Questionnaire	
I thought there was nothing good for me in the future.	138
Patient Health Questionnaire-9, item 9	
Over the past 2 wk, have you had thoughts that you would be better off dead or of hurting yourself in some way?	290
Columbia–Suicide Severity Rating Scale intensity	
If you have ever had suicidal thoughts, how long do they last?	697
Created for study	
If you have had suicidal thoughts, how likely are you to act on these thoughts?	762
Rumination	
When I have suicidal thoughts, it is hard to think about other things.	769
My suicidal thoughts repeat over and over in my head.	734
Parent-family connectedness	
How much do people in your family understand you?	0
How much does your family pay attention to you?	144
Social connectedness	
I have friends I'm really close to and trust completely.	1
You feel close to people at your school.	0
You feel like you are part of your school.	282

(continued)

Table 2. Items Used in Derivation of Computerized Adaptive Screen for Suicidal Youth (CASSY) and Number of Youth Presented Each Item in Calibration Phase[a] (continued)

Item	Youths presented with item, No.
Questionnaire on being bullied by a peer/ perpetrating bullying	
How often have you…	
Been bullied in school this term?	165
Been bullied away from school property this term?	0
Taken part in bullying other students away from school property this term?	0
Life Events Checklist	
If breaking up with a boyfriend/girlfriend..last 3 mo, how much…negative or positive impact on your life?	0
If your parents were separated or divorced in the last 3 mo, how much…negative or positive impact on your life?	0
DSM-IV Trauma Screen	
Have you ever been in a situation where you or someone close to you was going to be killed… or be hurt very badly?	0
Child Trauma Questionnaire-Short (2-item screener)	
People in my family have hit me so hard that it left me with bruises or marks.	0
Someone has tried to touch me in a sexual way or tried to make me touch them.	0
Patient Health Questionnaire-9	
Over the past 2 wk,	
…Little interest or pleasure in doing things	0
…Feeling down, depressed, or hopeless	157
…Have you had trouble falling or staying asleep, or sleeping too much	675
…Feeling tired or having little energy	212
…Poor appetite or been overeating	272
Have you been feeling bad about yourself—or that you are a failure or have let yourself or your family down?	115
Have you had trouble concentrating on things, such as reading or watching television?	521
…Moving or speaking so slowly that other people …noticed, or the opposite, being so fidgety or restless that …moving around a lot more than usual	123
How hard has it been for you to do what you need to do and get along with others?	25
Urgency, Premeditation, Perseverance, Sensation Seeking-urgency subscale	
When I feel rejected, I will often say things that I wish I hadn't.	72
It is hard for me to not act on my feelings.	0
I often make matters worse because I act without thinking when I am upset.	0
Sometimes I do impulsive things that I wish I hadn't.	8
Brief Agitation Measure	
Recently (in the past wk), I want to crawl out of my skin.	21
Recently (past wk), I feel so stirred up inside I want to scream.	242
Recently (past wk), I feel a lot of emotional turmoil in my gut.	396
Screen for Child Anxiety Related Disorders (short version)	
In the past 3 mo…	
People told me that I worry too much.	517
I have been scared to go to school.	1
I got really frightened for no reason at all.	2
I have been afraid to be alone in the house.	8
Positive and Negative Affect Schedule	
In the past few weeks I have been…	
Joyful.	0
Cheerful.	748
Happy.	711
Lively.	611
Proud.	512
Patient-Reported Outcomes Measurement Information System Sleep-Short	
In the past 7 d…	
My sleep quality was:[b]	339
My sleep was refreshing.	265
I had a problem with my sleep.	171
I had difficulty falling asleep.	320
Homicidal thoughts	
In the past mo, have you had any thoughts about wanting to kill someone else?	178
Impulsive Aggression quick screen	
How many times in the past 3 mo have you been angry and enraged with others in a way that was out-of-control or inappropriate?	0
Over the past 6 mo, when you have become angry and enraged with others, have you thrown things or destroyed objects?	0
Youth Risk Behavior Survey	
During the past 30 d, did you take any diet pills, powders, or liquids without a doctor's advice, or did you vomit or take laxatives to lose weight or to keep from gaining weight?	0
Drug Use Scale	
In the past 3 mo, have you used…	
Prescription stimulants to get high, used more than prescribed, or that belonged to someone else?	0
Prescribed (pain medication) opioids to get high, more than prescribed, or that belonged to someone else?	0
Sedatives or sleeping pills to get high, more than prescribed, or that belonged to someone else?	0
Eating Attitudes Test	
I have gone on eating binges … I feel I may not be able to stop.	0

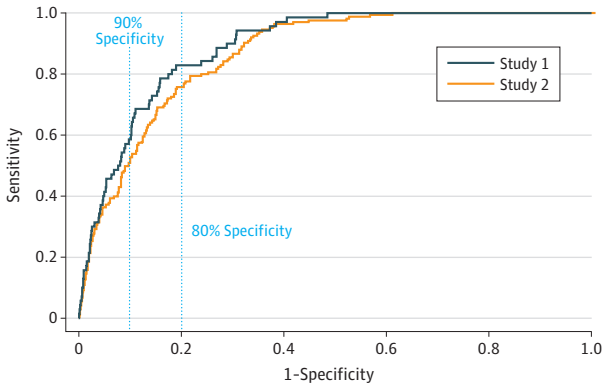
[a] All Ask Suicide-Screening Questions were administered to youths at baseline. Three of these questions were included in the CASSY calibration for all youths to ensure inclusion of responses about suicidal ideation and behavior. The remaining Ask Suicide-Screening Questions item (No. 2) was included only if it contributed to measurement of risk for suicide attempt.

[b] The response options for this question were on a scale of 0 to 4, from "very poor" to "very good."

CASSY Performance

The AUC for application of CASSY algorithms, developed in study 1 and applied to the study 2 sample, was 0.87 (95% CI, 0.85-0.89). At the 80% specificity cutoff established in study 1, CASSY's sensitivity for the prediction of an SA within 3 months in study 2 was 82.4%, and specificity was 72.5%. Figure 2 presents the receiver operating characteristic curves

Figure 2. Receiver Operating Characteristic Curves for the Computerized Adaptive Screen for Suicidal Youth (CASSY) in Study 1 and Study 2



The vertical lines indicate the 80% and 90% specificity cut points.

Table 3. Study 2 Demographic and Suicide Risk Characteristics of Adolescents in Baseline and Follow-up Samples

Characteristic	No. (%)	
	Baseline (n = 4031)	Follow-up (n = 2754)
Age at enrollment, mean (SD), y	15.0 (1.66)	15.0 (1.65)
Male	1453 (36)	996 (36)
Race		
American Indian or Alaska Native	152 (4)	106 (4)
Asian or Native Hawaiian or other Pacific Islander	82 (2)	63 (2)
Black or African American	773 (19)	471 (17)
White	2268 (56)	1621 (59)
Multiracial	233 (6)	161 (6)
Unknown or unavailable	523 (13)	332 (12)
Ethnicity		
Hispanic or Latino	997 (25)	685 (25)
Not Hispanic or Latino	2641 (66)	1849 (67)
Unknown	393 (10)	220 (8)
Education		
Parent 1		
High school graduate or less	1282 (33)	807 (30)
Some college/technical training	937 (24)	608 (22)
College graduate/professional training	1689 (43)	1272 (47)
Do not know/not applicable	27 (1)	16 (1)
Parent 2		
High school graduate or less	1534 (40)	999 (38)
Some college/technical training	630 (16)	447 (17)
College graduate/professional training	1207 (31)	909 (34)
Do not know/not applicable	464 (12)	284 (11)
Family public assistance	1662 (42)	1106 (41)
Psychiatric chief complaint	1669 (42)	1112 (40)
Suicide attempt, lifetime	1197 (30)	799 (29)
>5 Nonsuicidal self-injuries in past 12 mo	433 (11)	318 (12)

for the CASSY in study 2. The mean (SD) of the CASSY score was 0.18 (0.11) and 0.05 (0.07), respectively, for those who did vs did not make an SA.

Discussion

The ED-STARS study is the first initiative to develop and independently validate a computerized adaptive youth suicide risk screen for risk of suicide attempt. The CASSY, which includes 3 ASQ items and a wide range of additional, adaptively administered items that vary in number and content across adolescents, is a dimensional suicide risk severity indicator. In this collaborative initiative with the PECARN, CASSY's cross-validated AUC was 0.89 and 0.87 in study 1 and study 2, respectively, for the prediction of 1 or more SAs within 3 months of the ED visit, which is considered excellent classification accuracy.[31,32]

The CASSY is a combination of a multidimensional item response theory model and a prediction model designed to measure interrelated domains of suicide risk and use estimates of these to predict future suicidal behavior. In the derivation study, the CASSY had a cross-validated sensitivity of 83% at specificity of 80% for the prediction of an SA within 3 months, with an overall AUC of 0.89. Perhaps of equal or greater importance, the CASSY also performed strongly in the independent validation sample with an AUC of 0.87, which is considered excellent classification accuracy.[31,32] Requiring a mean of 11 self-report items per adolescent, the CASSY requires 1 to 2 minutes for administration.

It is difficult to directly compare the performance of the CASSY and ASQ, because the CASSY is a screen for risk of SA and provides a dimensional risk estimation, whereas the ASQ was designed to screen for suicide risk more broadly and provides a dichotomous positive or negative result.[11,12] Nevertheless, recent data regarding the ASQ warrant consideration. In a large, universal sample of youth who presented to the ED with psychiatric or nonpsychiatric complaints, the ASQ demonstrated a sensitivity of 60% and a specificity of 92.7% for the prediction of subsequent ED visits for suicide risk, measured by retrospective medical record review.[14] Although the CASSY showed an equivalent level of sensitivity at specificity of 90% for the outcome of suicide attempt, the CASSY, as a dimensional screen, offers the option of choosing a lower specificity (eg, 80%) to achieve higher sensitivity. From a public health perspective, it can be argued that sensitivity—capturing all youth at risk—should be the priority as we strive to improve care models to adequately meet the needs of patients with behavioral health complaints.[33] On the other hand, the ASQ demonstrated high specificity in the DeVylder et al study,[10] and minimizing false positive results and the incremental resources needed for the mental health evaluations in the ED is also important.

The CASSY has several advantages over classical screens such as the ASQ, wherein all adolescents respond to a fixed set of questions: (1) questions are tailored to the severity or risk level of the adolescent, (2) different items are likely to be presented on repeated administration, eliminating response bias, and (3) it provides dimensional severity. Despite these advantages, a standard screen such as the ASQ, which consists of fewer items, may be preferred in some settings, particularly those in which the cost and technical setup of a computerized adaptive screen poses too high a barrier. The CASSY is a

proprietary tool; its screening algorithms are available to the public for development of screening software. Input from ED stakeholders about screening priorities will be important to facilitate implementation.[34]

Limitations

Several study limitations may affect the generalizability of these findings. We conducted the study in the pediatric EDs of academic health systems, which are not representative of a full range of EDs. We do not have data on study participation refusals and, although we enrolled parents who did not speak English, we did not enroll adolescents who did not speak English. We did not enroll adolescents if they needed surveys read to them, because of privacy concerns. Our loss to follow-up rate was considerable, and these differences may have introduced bias, although with the exception of sex in study 1 and psychiatric chief complaints in study 2, these variables were not associated with SA at the 3-month follow-up. In addition, a significant number of adolescents were approached for study participation but did not enroll, which also creates the potential for selection bias and may limit CASSY accuracy. Under plausible scenarios for the association between the CASSY and risk of suicide attempt, our sensitivity analyses show that performance would remain relatively good, even in the worst cases. We used brief, adapted scales, which may have reduced measurement reliability and validity; however, each clinical risk factor measured was a significant predictor of SAs.[30] Mental health evaluations were conducted for youth at high risk, and some youth were referred for treatment, which may have prevented some SAs and reduced the ability to predict them. Finally, we do not know if those lost to follow-up had more self-injury morbidity or mortality.

Conclusions

In summary, we developed and independently validated a computerized adaptive screen (CASSY) for adolescent suicide risk and more specifically the prediction of SAs. We developed and validated this screen with prospective data from geographically diverse EDs. The CASSY demonstrated a high AUC for the prediction of an SA, with an excellent balance of sensitivity and specificity, and is suitable for administration in busy EDs. Important next steps will be to measure the CASSY's test-retest reliability and develop triage recommendations and conduct implementation studies.

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Author Affiliations: Department of Psychiatry, University of Michigan, Ann Arbor (King, McGuire); Department of Psychiatry, University of Pittsburgh, Pittsburgh, Pennsylvania (Brent); Department of Emergency Medicine, University of California, San Francisco, San Francisco (Grupp-Phelan); The University of Utah School of Medicine, Salt Lake City (Casper, Dean, Page); Department of Emergency Medicine and Pediatrics, Columbia University Medical Center, New York, New York (Chernick); Center for Violence Prevention, Children's Hospital of Philadelphia, Division of Emergency Medicine, University of Pennsylvania, Philadelphia (Fein); Department of Pediatrics, University of Cincinnati, Cincinnati, Ohio (Mahabee-Gittens); Division of Emergency Medicine, Children's National Hospital, Washington, DC (Patel); Department of Pediatrics–Emergency Medicine, University of Colorado School of Medicine, Aurora (Mistry); Department of Emergency Medicine, Alpert Medical School at Brown University, Providence, Rhode Island (Duffy); Department of Pediatrics, Alpert Medical School at Brown University, Providence, Rhode Island (Duffy); Department of Pediatrics, Medical College of Wisconsin, Milwaukee (Melzer-Lange); Department of Emergency Medicine, University of Michigan, Ann Arbor (Rogers); Department of Pediatrics, University of Michigan, Ann Arbor (Rogers); Division of Emergency Medicine, Nationwide Children's Hospital, Columbus, Ohio (Cohen); Department of Pediatric Emergency Medicine, The University of Utah, Salt Lake City (Keller); Department of Pediatrics, Baylor College of Medicine, Houston, Texas (Shenoi); Department of Pediatrics, University of Pittsburgh, Pittsburgh, Pennsylvania (Hickey); Medical Center at the University of California School of Medicine, Davis, Sacramento (Rea); Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland (Cwik); Department of Statistics and Data Science, Carnegie Mellon University, Pittsburgh, Pennsylvania (Wang); Department of Medicine, The University of Chicago, Chicago, Illinois (Gibbons); Department of Public Health Sciences (Biostatistics), The University of Chicago, Chicago, Illinois (Gibbons); Department of Psychiatry and Behavioral Neuroscience, The University of Chicago, Chicago, Illinois (Gibbons); Department of Comparative Human Development, The University of Chicago, Chicago, Illinois (Gibbons).

Author Contributions: Drs Casper and Gibbons had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: King, Brent, Grupp-Phelan, Casper, Dean, Fein, Gibbons.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: King, Grupp-Phelan, Casper, Mistry, Page, McGuire, Wang, Gibbons.
Critical revision of the manuscript for important intellectual content: King, Brent, Grupp-Phelan, Casper, Dean, Chernick, Fein, Mahabee-Gittens, Patel, Mistry, Duffy, Melzer-Lange, Rogers, Cohen, Keller, Shenoi, Hickey, Rea, Cwik, Page, McGuire, Gibbons.
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Supervision: King, Brent, Grupp-Phelan, Dean, Fein, Mahabee-Gittens, Mistry, Melzer-Lange, Rogers, Shenoi, Rea, Cwik, Gibbons.

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