# It is illegal to post this copyrighted PDF on any website. Machine Learning Prediction of Suicide Risk Does Not Identify Patients Without Traditional Risk Factors

Maricela Cruz, PhD<sup>a,b,\*</sup>; Susan M. Shortreed, PhD<sup>a,b</sup>; Julie E. Richards, PhD, MPH<sup>a,c</sup>; R. Yates Coley, PhD<sup>a,b</sup>; Bobbi Jo Yarborough, PsyD<sup>d</sup>; Rod L. Walker, MS<sup>a</sup>; Eric Johnson, MS<sup>a</sup>; Brian K. Ahmedani, PhD<sup>e</sup>; Rebecca Rossom ,MD, MS<sup>f</sup>; Karen J. Coleman, PhD<sup>g</sup>; Jennifer M. Boggs, PhD, MSW<sup>h</sup>; Arne L. Beck, PhD<sup>h</sup>; and Gregory E. Simon, MD, MPH<sup>a</sup>

#### ABSTRACT

**Objective:** To determine whether predictions of suicide risk from machine learning models identify unexpected patients or patients without medical record documentation of traditional risk factors.

**Methods:** The study sample included 27,091,382 outpatient mental health (MH) specialty or general medical visits with a MH diagnosis for patients aged 11 years or older from January 1, 2009, to September 30, 2017. We used predicted risk scores of suicide attempt and suicide death, separately, within 90 days of visits to classify visits into risk score percentile strata. For each stratum, we calculated counts and percentages of visits with traditional risk factors, including prior self-harm diagnoses and emergency department visits or hospitalizations with MH diagnoses, in the last 3, 12, and 60 months.

**Results:** Risk-factor percentages increased with predicted risk scores. Among MH specialty visits, 66%, 88%, and 99% of visits with suicide attempt risk scores in the top 3 strata (respectively, 90th–95th, 95th–98th, and  $\geq$  98th percentiles) and 60%, 77%, and 93% of visits with suicide risk scores in the top 3 strata represented patients who had at least one traditional risk factor documented in the prior 12 months. Among general medical visits, 52%, 66%, and 90% of visits with suicide attempt risk scores in the top 3 strata and 45%, 66%, and 79% of visits with suicide risk scores in the top 3 strata represented patients who had a history of traditional risk factors in the last 12 months.

**Conclusions:** Suicide risk alerts based on these machine learning models coincide with patients traditionally thought of as high-risk at their high-risk visits.

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<sup>a</sup>Kaiser Permanente Washington Health Research Institute, Seattle, Washington

<sup>b</sup>Department of Biostatistics, School of Public Health, University of Washington, Seattle, Washington

<sup>c</sup>Department of Health Services, School of Public Health, University of Washington, Seattle, Washington

<sup>d</sup>Kaiser Permanente Northwest Center for Health Research, Portland, Oregon <sup>e</sup>Henry Ford Health System, Center for Health Policy & Health Services Research, Detroit, Michigan

<sup>f</sup>HealthPartners Institute, Minneapolis, Minnesota

<sup>g</sup>Kaiser Permanente Southern California, Department of Research and Evaluation, Pasadena, California

<sup>h</sup>Kaiser Permanente Colorado Institute for Health Research, Aurora, Colorado \**Corresponding author:* Maricela Cruz, Kaiser Permanente Washington Health Research Institute, 1730 Minor Ave Ste 1600, Seattle, WA 98101 (maricela.f.cruz@kp.org). O ver half of people who attempt or die by suicide have contact with health care in the prior 3 months.<sup>1,2</sup> Recognizing these opportunities for prevention, the Joint Commission and National Action Alliance for Suicide Prevention recommends systematic identification of suicide risk in mental health care.<sup>3,4</sup> Self-report measures can identify risk, but have shortcomings in both sensitivity and positive predictive value.<sup>5</sup> Statistical models based on health records data outperform self-report questionnaires in identifying risk,<sup>6–11</sup> and health systems have begun to implement such models to identify patients at risk of suicide and engage them in appropriate care.<sup>12,13</sup>

Concerns have been raised regarding the credibility and acceptability of prediction models to both patients and clinicians.<sup>12,14–17</sup> Some of these concerns assume that prediction models yield unexpected or disturbing results if patients without traditional risk factors are "flagged" as high-risk for suicide. Clinicians and health systems may be concerned that suicide assessment or outreach prompted by prediction models would seem unexpected or intrusive to patients with no history of suicidal ideation or behavior.

Published suicide risk prediction models do not appear to identify new or unexpected predictors of risk; the most heavily weighted predictors include prior suicidal behavior, prior inpatient or emergency department (ED) mental health care, reported suicidal ideation, and mental health diagnoses that have been shown to be associated with increased risk.<sup>6-10</sup> The fact that suicide risk prediction models do not identify unexpected risk factors, however, does not imply that those models do not identify unexpected patients. The goal of this study was to examine the previously unexplored concordance between patients identified as high-risk by machine learning-derived risk predictions and patients identified as high-risk by traditional clinical risk factors, using a large sample of visits to mental health specialty and general medical providers.

# METHODS

#### Setting

Data came from 7 large health systems (HealthPartners; Henry Ford Health System; and the Colorado, Hawaii,

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- Clinicians and health systems may be concerned that suicide assessment or outreach prompted by prediction models would seem unexpected or intrusive to patients without expected risk factors.
- In this sample of 27 million visits from 7 health systems, machine learning models identified patients with documented histories of self-harm, suicidal ideation, psychiatric hospitalization, or psychiatric emergency care.
- Rather than identifying new or unexpected risk, prediction models accurately and efficiently summarize large volumes of historical information, giving appropriate weight to risk factors already familiar to most clinicians.

Northwest, Southern California, and Washington regions of Kaiser Permanente). Patients are enrolled in the health systems via individual or employer-sponsored insurance, capitated Medicare and Medicaid programs, and other state-subsidized low-income programs. Electronic medical records and insurance claims from the 7 systems are organized in virtual data warehouses with agreed-upon definitions and common formats facilitating multisite population-based research.<sup>18</sup> Institutional review boards at each system approved use of deidentified data for this research.

#### Population

The study sample included outpatient visits by patients aged 11 years or older to a general medical provider with a recorded mental health diagnosis (henceforth simply "general medical visits") or to a mental health specialty provider. ED visits were excluded. The sample included visits between January 1, 2009, and September 30, 2017, for all health systems except Henry Ford, for which visits after December 1, 2012 (when their electronic medical records system was initiated), were included. Sampling was restricted to visits by individuals with the health system's insurance plan to guarantee availability of insurance claims data used to capture services received outside of the health system (see Supplementary Table 1 for patient characteristics for excluded visits).

# **Risk Factors**

We focus on 5 traditional risk factors identified in practice guidelines<sup>19,20</sup>: (1) prior suicide attempt or self-harm, (2) prior mental health ED visit, (3) prior psychiatric hospitalization, (4) current or prior suicidal ideation, and (5) current depressive mood. For each visit, we classified patients as having each of these risk factors in the prior 3, 12, or 60 months using the following criteria: (1) a diagnosis of probable self-harm (*ICD-9* e-code or *ICD-10-CM* diagnosis of self-harm or undetermined intent injury or poisoning code), (2) an ED visit with a mental health diagnosis (any code from the Mental Disorders chapter of either *ICD-9-CM* or *ICD-10-CM* exclusive of tobacco/nicotine use and substance use disorders in remission), and (3) hospitalization

	Mental H Samp	Gener Medical S	al ample	
	(15,986,90	6 Visits)	(11,104,476	5 Visits)
Characteristic	No.	%	No.	%
Sex				
Female	10.173.185	64	6.964.554	63
Male	5.812.614	36	4,139,147	37
Other	252	0.002	241	0.002
Unknown	855	0.005	534	0.005
Bace	000	0.000		0.000
Asian	672,140	4	458.324	4
Black	1.293.454	8	810,472	7
Hawaijan/Pacific Islander	76 998	0 482	44 511	0 401
Native American	74 639	0.467	62 403	0.562
White	10 822 254	68	7 777 572	70
More than 1 or other	505 467	3	368 959	3
Unknown	2 541 954	16	1 582 235	14
Ethnicity	2,541,754	10	1,502,255	14
Hispanic	3 876 703	24	2 384 026	21
Insurance Type	5,070,755	27	2,307,020	21
Commercial	11 228 281	71	6 203 870	56
Modicaid	015 116	6	0,203,070	0
Medicaro	2567666	16	2 2 1 2 0 5 7	20
Othor	2,307,000	7	3,313,037	50
Are v	1,175,645	/	/52,5//	/
Age, y	1 762 051	11	(02.202	~
11-17	1,/02,951	17	092,303	0
18-29	2,099,993	17	1,418,476	13
30-44	4,068,745	25	2,191,935	20
45-64	5,601,986	35	3,832,166	35
65 or older	1,853,231	12	2,969,596	27
Prior enrollment				
3 months or more	15,336,197	96	10,281,798	93
1 year or more	13,//3,514	86	9,198,753	83
5 years or more	2,338,710	15	1,516,565	14
Diagnosis of probable self-harm		_		
Any visit in prior year	379,342	2	91,903	1
Any visit in prior 5 years	674,447	4	209,236	2
ED visit with MH diagnosis				
Any visit in prior year	3,299,606	21	1,916,182	17
Any visit in prior 5 years	5,479,296	34	3,390,399	31
Hospitalization with MH diagnosi	S			
Any visit in prior year	2,132,572	13	1,184,423	11
Any visit in prior 5 years	3,754,651	23	2,341,169	21
PHQ-9 item 9 score of 2 or 3				
Index visit	13,449,479	84	10,130,056	91
Any visit in prior 3 months	3,255,869	20	715,598	6
Any visit in prior year	4,292,632	27	1,395,889	13
Visits followed by suicidal event				
Suicide attempt within 90 days	99,348	0.621	35,573	0.32
Suicide death within 90 days	3,199	0.02	1,510	0.014
Abbreviations: ED = emergency de	epartment, N	1H = men	tal health,	

bbreviations: ED = emergency department, MH = mental health PHQ-9 = 9-item Patient Health Questionnaire.

with a mental health diagnosis. Suicidal ideation was defined as a response of a 2 or 3 on the ninth question of the 9-item Patient Health Questionnaire (PHQ-9 item 9),<sup>21</sup> indicating the patient reported having thoughts that they would be better off dead or thoughts of hurting themselves in some way "more than half the days" (response of 2) or "nearly every day" (response of 3) in the prior 2 weeks. We restricted analysis examining the PHQ-9 to visits by patients with a recorded PHQ-9 item 9 response in the prior 12 months. Depressive mood was defined as a PHQ-9 total score greater than or equal to 20. We restricted depressive mood analysis to visits with a recorded PHQ-9 total score at that visit.

We did not limit our sample to visits from people with prior enrollment in the health system; thus, a complete history of the risk factors and other visit characteristics was

e.

Table 2. Count and Percentage of Mental Health Specialty Visits With a Prior History of Traditional Risk Factors in Strata With Predicted Risk Scores Greater Than the 90th Percentile

	Attempt								Deat	า		
	Last 3 Mo	nths	Last 12 Mo	onths	Last 5 Ye	ears	Last 3 Mo	nths	Last 12 M	onths	Last 5 Ye	ars
Variable	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Risk Score From 90th to < 95th Percentile	a											
Diagnosis of probable self-harm ED visit with MH diagnosis Hospitalization with MH diagnosis Any of the aforementioned diagnoses	10,785 246,190 182,581 307,708	1 32 24 40	37,722 416,458 325,540 502,371	5 55 43 66	116,185 544,567 447,847 615,086	15 71 59 81	20,073 231,280 158,874 281,273	3 33 23 40	42,888 359,899 268,914 421,843	6 51 38 60	63,412 428,434 354,298 490,182	9 61 51 70
Risk Score From 95th to < 98th Percentile	b											
Diagnosis of probable self-harm ED visit with MH diagnosis Hospitalization with MH diagnosis Any of the aforementioned diagnoses	41,812 209,956 180,840 263,113	9 46 40 58	101,546 340,084 306,281 401,776	22 74 67 88	177,868 395,709 364,645 438,060	39 86 80 96	29,637 207,151 159,991 242,964	7 49 38 58	59,054 286,257 235,212 323,438	14 68 56 77	69,732 312,464 272,681 346,114	17 74 65 83
Risk Score ≥ 98th Percentile <sup>c</sup>												
Diagnosis of probable self-harm ED visit with MH diagnosis Hospitalization with MH diagnosis Any of the aforementioned diagnoses	131,229 207,936 195,517 241,689	43 68 64 79	203,939 277,565 269,779 300,435	67 91 88 99	243,322 290,340 283,356 304,222	80 95 93 100	70,604 196,151 177,970 220,651	25 70 64 79	109,704 239,839 223,604 259,123	39 86 80 93	113,821 246,596 236,756 263,926	41 88 85 94

Total visits: Attempt, 762,452; Death, 699,028.

<sup>b</sup>Total visits: Attempt, 457,471; Death, 419,417.

Cotal visits: Attempt, 304,981; Death, 279,612. Abbreviations: ED = emergency department, MH = mental health.

not observed for visits with less than 3, 12, or 60 months of prior enrollment.

#### **Prediction Models**

The suicide attempt and death prediction models for mental health specialty visits and general medical visits with a mental health diagnosis evaluated in this study were previously developed and validated on a subsample of visits included in this study (visits before June 30, 2015).<sup>6</sup> Subsequently, these same models were validated to have performance in more recent years comparable to the estimated performance during the original model building and validation.<sup>22</sup> Specifically, the suicide attempt models had an area under the receiver operating curve (AUC) of 0.851, and using the 99th percentile for a cutoff, the sensitivity, specificity, negative predictive value (NPV), and positive predictive value (PPV) were 16.8, 99.1, 99.4, and 10.4, respectively, in mental health specialty visits, and in general medical visits, the AUC was 0.853 and 99th percentile sensitivity, specificity, NPV, and PPV were 23.5, 99.1, 99.8, and 6.1, respectively. Subsequent suicide death models in mental health specialty visits had an AUC of 0.861 and 99th percentile sensitivity, specificity, NPV, and PPV of 23.1, 99.0, 99.9, and 0.62, respectively, and in the general medical visit sample had an AUC of 0.833 and 99th percentile sensitivity, specificity, NPV, and PPV of 20.9, 99.0, 99.9, and 0.31, respectively. To account for variability in suicide attempt and suicide risk across visits for a given patient, the prediction models were developed at the visit level. The models were developed using 313 potential predictors including demographic characteristics (age, sex, race, ethnicity, and insurance type), prior suicide attempts, current and past mental health and substance use diagnoses, other prior injury or poisoning diagnoses, dispensed prescriptions for psychotropic medications, past

inpatient or ED mental health care, comorbidities (measured by Charlson Comorbidity Index<sup>23</sup> categories), and recorded PHQ-9 scores. All potential predictors were extracted from electronic medical records for up to 5 years before each visit and coded as dichotomous indicators.

Prior prediction models were estimated separately for suicide attempt (fatal and non-fatal) and suicide death in the 90 days following either a mental health specialty or primary care visit (4 models in total).<sup>6</sup> Non-fatal suicide attempts were captured from self-harm diagnoses in electronic medical records or insurance claims and suicide death (or fatal suicide attempt) from state mortality records with an ICD-10 diagnosis of self-inflicted injury or injury or poisoning with undetermined intent. Logistic regression with LASSO (least absolute shrinkage and selection operator) variable selection<sup>24</sup> was used to develop the prediction models on a random training sample composed of approximately 65% of visits in each sample with performance validated and reported for the remaining held-out 35% of encounters. See Simon et al<sup>25</sup> for a complete list of selected predictors and their corresponding estimated coefficients and detailed performance characteristics for each model. For additional detail, including final models, and methodological details, see Simon et al<sup>6</sup> and www.github.com/MHResearchNetwork.

#### **Statistical Methods**

We used the previously developed models to generate risk prediction scores for each visit and classified visits in the mental health specialty or general medical samples into suicide attempt and suicide risk score strata based on percentiles of these predicted risk scores: <25th percentile, 25th to <50th percentile, 50th to <75th percentile, 75th to <90th percentile, 90th to <95th percentile, 95th to <98th percentile, and  $\geq$ 98th percentile. To visualize trends, we used bands of size 5 percentiles (ie, <5, 5–10, and so on

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Table 3. Count and Percentage of General Medical Visits With a Prior History of Traditional Risk Factors in Strata With Predicted Risk Scores Greater Than the 90th Percentile

			Attem	pt			Death					
	Last 3 Mo	nths	Last 12 M	onths	Last 5 Ye	ars	Last 3 Mo	nths	Last 12 Mo	onths	Last 5 Ye	ars
Variable	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Risk Score From 90th to < 95th Percentile	1											
Diagnosis of probable self-harm ED visit with MH diagnosis Hospitalization with MH diagnosis Any of the aforementioned diagnoses	147 132,032 79,717 162,256	0 25 15 31	2,760 227,705 151,216 272,167	1 43 29 52	31,767 323,017 248,604 371,113	6 61 47 70	3,874 114,166 74,568 143,523	1 24 15 30	10,277 175,599 128,103 217,328	2 36 26 45	25,529 252,175 198,510 299,415	5 52 41 62
Risk Score From 95th to < 98th Percentile	0											
Diagnosis of probable self-harm ED visit with MH diagnosis Hospitalization with MH diagnosis Any of the aforementioned diagnoses	1,721 106,924 70,578 130,826	1 34 22 41	10,950 176,165 127,448 207,690	3 56 40 66	46,663 228,844 19,0425 255,253	15 72 60 81	6,631 116,956 79,481 143,543	2 40 27 49	15,124 160,818 125,359 192,377	5 55 43 66	32,141 199,855 164,892 227,784	11 69 57 78
Risk Score ≥98th Percentile <sup>c</sup>												
Diagnosis of probable self-harm ED visit with MH diagnosis Hospitalization with MH diagnosis Any of the aforementioned diagnoses	36,157 117,257 89,636 139,855	17 56 42 66	71,602 169,822 143,672 190,548	34 80 68 90	102,870 186,448 170,221 200,756	49 88 81 95	18,230 119,801 90,129 134,255	9 62 46 69	32,384 139,717 118,782 153,452	17 72 61 79	54,058 155,030 137,350 165,929	28 80 71 85

Total visits: Attempt, 527,593; Death, 485,662.

<sup>b</sup>Total visits: Attempt, 316,555; Death, 291,390.

CTotal visits: Attempt, 211,038; Death, 194,273.

Abbreviations: ED = emergency department, MH = mental health.

through 95–100). For each risk score strata, we calculated the percentage of visits with each traditional risk factor in the last 3, 12, and 60 months. We examined whether the percentages differ between patients assigned male and female at birth. In analyses restricted to visits with a PHQ-9 item 9 response in the past year, we calculated the percentage of visits in each stratum with the risk factors (including PHQ-9 item responses of a 2 or 3) in the previous 3 and 12 months.

#### RESULTS

The study included 15,986,906 mental health specialty visits across 1,589,996 patients and 11,104,476 general medical visits across 2,732,747 patients (Table 1). Both samples had numerous visits by people from underrepresented racial groups and by people identifying as Hispanic or Latina/o (eg, 672,140 [4%] visits by Asian patients, 1,293,454 [8%] visits by Black/African American patients, and 3,876,793 [24%] visits by Hispanic or Latina/o patients to a mental health specialty provider). In comparison to the mental health specialty sample, the general medical sample included more visits from older patients (27% vs 12% were 65 years of age or older) and fewer PHQ-9 item 9 responses in the prior year (13% vs 27%) and had lower rates of suicide attempt (0.32% vs 0.62%) and death (0.01% vs 0.02%) in the 90 days following a visit. The prediction models utilized were trained and validated on 10,275,853 (64%) of our mental health specialty visits and 9,685,206 (87%) of our general medical visits.

Table 2 provides counts and percentages of documented traditional risk factors in mental health specialty visits with risk predictions in the 90th to <95th, 95th to <98th, and  $\geq$ 98th percentiles. For all risk factors considered, prevalence increased from lower to higher stratum of predicted risk and with longer period of prior observation. The percentage of

visits with at least one risk factor in the prior 5 years was 81% for visits with suicide attempt risk scores between the 90th and 95th percentiles and 100% for visits with risk scores above the 98th percentile. Corresponding percentages for strata of suicide death risk scores were 70% for visits between the 90th and 95th percentile and 94% for visits above the 98th percentile.

Table 3 provides counts and percentages of documented traditional risk factors in general medical visits with risk predictions in the 90th to <95th, 95th to <98th, and  $\geq$ 98th percentiles. In comparison to the mental health specialty sample, somewhat lower percentages of general medical visits exhibited the risk factors (Table 3). The percentage of general medical visits with at least one risk factor in the prior 5 years was 70% for visits with suicide attempt risk scores from the 90th to < 95th percentiles and 95% for visits with risk scores  $\geq$  98th percentile. Corresponding percentages for strata of suicide death risk scores were 62% for visits between the 90th and 95th percentile and 85% for visits  $\geq$  98th percentile. The count and percentage of visits with a risk factor were consistently lower for strata with lower predicted risk (Supplementary Tables 2 and 3). These patterns held for patients assigned female and those assigned male at birth (Supplementary Tables 4-7).

Figures 1 and 2 plot the percentage of visits with each risk factor across the full range of predicted risk scores using strata of size 5 percentiles. The percentage of mental health specialty visits (Figure 1) with a prior self-harm diagnosis stayed relatively low until risk scores exceeded the 90th percentile and then increased sharply. Percentages of visits with prior mental health ED visits or hospitalizations increased more gradually across the top half of the risk score distribution. General medical visits (Figure 2) showed the same pattern with somewhat lower rates throughout for all risk factors.





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t is illegal to post this copy Supplementary Tables 8 and 9 and Supplementary Figures 1 and 2 provide results for analysis restricted to visits with a PHQ-9 item 9 response in the prior 12 months (approximately 13% of general medical visits and 27% of mental health specialty visits). For this subgroup of mental health specialty visits (Supplementary Table 8), 98% of visits with risk scores at or above the 98th percentile had at least 1 of the 3 previously considered risk factors (excluding PHQ-9) in the prior 12 months, and 100% of visits had any risk factors including PHQ-9 response. A similar pattern was seen for the subgroup of general medical visits with a PHQ-9 response (Supplementary Table 9). Plots of risk factors across the full range of risk scores (Supplementary Figures 1 and 2) showed results consistent with those of the unrestricted sample. Supplementary Tables 10 and 11 provide the count and percentages of mental health specialty and general medical visits, respectively, that had a current PHQ-9 total score greater than or equal to 20 for visits with a recorded PHQ-9 total score. The percentage of visits with a PHQ-9 total score of 20 or more increases in the strata with higher risk scores. Supplementary Table 12 provides the distribution of the observed absolute predicted risk scores by sample.

### DISCUSSION

This study used previously developed models to produce risk predictions of suicide attempt and death within 90 days of a mental health visit to examine the concordance between risk predictions and history of traditional risk factors in a mental health specialty sample of 16 million visits and a general medical sample of 11 million visits.

The percentage of visits with the risk factors increased as the risk predictions increased (in Figures 1 and 2). These trends indicate that in these samples of individuals seeking mental health care, the suicide prediction models are correctly identifying visits that clinicians would expect to be high-risk based on traditional clinical risk factors. Including additional history (eg, 5 vs 1 year) identified higher percentages of visits with a prior risk factor. The general medical sample had fewer visits with a history of at least one risk factor in comparison to the mental health specialty sample. This finding may indicate true differences in risk factor profiles or greater identification and recording of risk factors in mental health specialty settings. The percentage of visits with a history of risk factors was larger and more stable (eg, exhibited less variability around trends) for suicide attempt than suicide death risk prediction models in both samples. We saw the same patterns in the subsamples restricted to visits with a PHQ-9 item 9 response in the prior 12 months.

This study used one set of validated prediction models to determine the number and percentage of visits with a history of traditional suicide risk. We used self-harm codes to identify non-fatal suicide attempts but did not distinguish between self-harm with and without intent to die. It is entirely plausible that prediction models developed in different patient populations (such as people with no known

mental health condition or no insurance), with different data sources (such as general medical diagnoses or mining of clinical text), or with different model development methods (such as random forests or artificial neural networks) would more often identify patients without traditional clinical risk factors. Moreover, risk prediction algorithms are intended to augment, not substitute for, clinician judgment. In everyday practice, clinicians may be unaware of prior self-harm events or psychiatric hospitalizations and therefore unaware of risk identified by prediction models. If individuals have limited predictors documented in their records or if there is a lag in incorporating recent information into prediction algorithms, prediction models may not label patients as high-risk even if clinicians have seen the patient exhibiting escalating risky behavior. Conversely, prediction models may identify patients as high-risk when clinicians, based on recent protective factors in the patients' risk assessment, believe the patients are no longer high-risk. There are also several other practical and important issues around implementing machine learning models in clinical care, including poor PPV and legal and ethical concerns.<sup>15,26,27</sup> The prediction models used here have low PPV and were intended to direct clinicians' attention rather than determine treatment.

A previous meta-analysis by Franklin et al<sup>28</sup> of 365 studies conducted in the past 50 years attempting to longitudinally predict suicidal thoughts and behaviors found that no single category or subcategory of risk factors accurately predicted risk. History of probable self-harm diagnoses and ED visits and hospitalizations with mental health diagnoses were considered as risk factors, while PHQ-9 item 9 responses were not. The authors proposed that the poor predictive ability of existing risk factors stemmed from methodological limitations and not the derivation of the risk factors. To overcome these methodological limitations, the authors suggested a shift toward machine learning prediction models that can account for the combined effect of many risk factors in a complex and reproducible manner.

Our findings underscore how machine learning prediction models jointly using various categories of traditional risk factors may lead to better predictions than non-machine learning models based on single categories of risk factors. Visits labeled as high-risk by the prediction models considered in this study often were preceded by traditional risk factors. The combination of the traditional risk factor, as more informative than any individual risk factor, as most high-risk predictions had a history of at least one of many possible risk factors. Machine learning approaches are often especially good at estimating interaction effects when an individual has multiple risk factors.<sup>29</sup> The machine learning suicide prediction models used here appropriately classified visits as high-risk, aptly identifying patients with a history of traditional risk factors.

Clinicians and patients receiving suicide risk alerts based on these prediction models would likely find that alerts arise for expected patients, eg, patients with a history of risk factors. Among this population of patients seeking mental would often coincide with a prior history of probable selfharm diagnoses, ED visits and hospitalizations with mental health diagnoses, or PHQ-9 item 9 responses of a 2 or 3 (in settings with a PHQ-9 item 9 recorded). This study does not address all concerns regarding acceptability of alerts based on machine learning models, but it does address the concern regarding risk alerts that might surprise patients

It is illegal to post this copyrighted PDF on any website. health care, the predictions leading to suicide risk alerts or clinicians. These prediction models are useful tools for accurately and efficiently summarizing large volumes of historical information, giving appropriate weight to risk factors already familiar to most clinicians. With prediction models like these, we can accurately identify people at elevated risk at the appropriate visits, have an idea of why they are labeled high-risk, and provide patients with targeted resources and interventions appropriately.

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Editor's Note: We encourage authors to submit papers for consideration as a part of our Focus on Suicide section. Please contact Philippe Courtet, MD, PhD, at pcourtet@psychiatrist.com.

See supplementary material for this article at PSYCHIATRIST.COM.



CLINICAL PSYCHIATRY

# **Supplementary Material**

- Article Title: Machine Learning Prediction of Suicide Risk Does Not Identify Patients Without Traditional Risk Factor
- Author(s): Maricela Cruz, PhD; Susan M. Shortreed, PhD; Julie E. Richards, PhD, MPH; R. Yates Coley, PhD; Bobbi Jo Yarborough, PsyD; Rod L. Walker, MS; Eric Johnson, MS; Brian K. Ahmedani, PhD; Rebecca Rossom ,MD, MS; Karen J. Coleman, PhD; Jennifer M. Boggs, PhD, MSW; Arne L. Beck, PhD; and Gregory E. Simon, MD, MPH
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# List of Supplementary Material for the article

- 1. <u>Table 1</u> Characteristics of patients among visits by individuals without health system's insurance plans or complete suicide event data in the 90-days following the visit
- 2. <u>Table 2</u> Count and percentage of mental health specialty visits with history of traditional risk factors in lower strata
- 3. <u>Table 3</u> Count and percentage of general medical visits with history of traditional risk factors in lower percentile strata
- 4. <u>Table 4</u> Count and percentage of mental health specialty with a prior history of traditional risk factors in all risk strata for patients with sex listed as female
- 5. <u>Table 5</u> Count and percentage of general medical visits with a prior history of traditional risk factors in all risk strata for patients with sex listed as female
- 6. <u>Table 6</u> Count and percentage of general medical visits with a prior history of traditional risk factors in all risk strata for patients with sex listed as female
- 7. <u>Table 7</u> Count and percentage of general medical visits with a prior history of traditional risk factors in all risk strata for patients with sex listed as male
- 8. <u>Table 8</u> Count and percentage of mental health specialty visits with a prior history of traditional risk factors in all strata. Restricted to visits with a PHQ-9 item 9 response in the prior 12 months
- 9. <u>Table 9</u> Count and percentage of general medical visits with a prior history of traditional risk factors in all strata. Restricted to visits with a PHQ-9 item 9 response in the prior 12

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- 10. <u>Table 10</u> Count and percentage of mental health specialty visits with a recorded PHQ9 total score at that visit that had a total score greater than or equal to 20
- 11. <u>Table 11</u> Count and percentage of general medical visits with a recorded PHQ9 total score at that visit that had a total score greater than or equal to 20
- 12. Table 12 Distribution of absolute predicted risk by sample
- 13. Figure 1 Percentage of mental health specialty visits with each risk factor across the full range of predicted risk scores using strata of size 5 percentiles for visits with a prior PHQ9 item 9 response in the last year
- 14. Figure 2 Percentage of general medical visits with each risk factor across the full range of predicted risk scores using strata of size 5 percentiles for visits with a prior PHQ9 item 9 response in the last year

# **Disclaimer**

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complete suicide event data in the 90-da	ays following the vis	it.		In dia al Cananda
<b>A</b>	Mental He	ealth Sample	General N	Nedical Sample
Characteristic	N	%	N	%
Sex				
Female	68782	61	42648	57
Male	43638	39	32134	43
Other	1	0.001	5	0.007
Unknown	0	0	103	0.138
Race				
Asian	5272	5	2735	4
Black	11256	10	5760	8
Hawaiian / Pacific Islander	668	0.594	464	0.620
Native American	500	0.445	508	0.678
White	60343	54	47308	63
More than one or Other	3493	3	2625	4
Unknown	30889	27	15490	21
Ethnicity				
Hispanic	28077	25	12343	16
Insurance Type				
Commercial	56228	50	25878	35
Medicaid	4293	4	3667	5
Medicare	4539	4	9890	13
Other	47361	42	35455	47
Age				
11-17	8811	8	3066	4
18-29	32702	29	15662	21
30-44	35020	31	17996	24
45-64	29744	26	22511	30
65 or older	6144	5	15655	21
Prior Enrollment				
3 Months or More	78570	70	42584	57
1 Year or More	60053	53	32943	44
5 Years or More	10951	10	7742	10
PHQ-9 item 9 at				
Index Visit	76339	68	63666	85
Any Visit in Prior 3 Months	55159	49	8988	12
Any Visit in Prior Year	43577	39	15998	21
Visits Followed by a		1		
Suicide Attempt w/in 90 Davs	103	0.092	77	0.103
Suicide Death w/in 90 Days	0	0	0	0
Similar percentages of patient character	istics to Table 1 wit	h slight difference	es for unknown	race, commercial and Medicare

Supplementary Table 2. Count and percentage of mental health specialty visits with history of traditional risk factors in lower strata.												
	Attempt											
	Last 3		Last 12		Last 5 yea	ars	Last 3		Last 12		Last 5 yea	ars
	months		months		-		months		months			
	Ν	%	Ν	%	Ν	%	Ν	%	Ν	%	Ν	%
Risk Score Less than the 25th Per	rcentile											
Diagnosis of probable self-harm	0	0	0	0	8	0	4826	0	11872	0	59061	2
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	38257	1	148571	4	529761	14	94698	3	284538	8	755245	22
Hospitalization with MH <sup>b</sup> diagnosis	12245	0	51633	1	314180	8	41563	1	125228	4	336346	10
Any of the above diagnoses	48301	1	183699	5	682546	18	126818	4	355947	10	874960	25
Risk Score between the 25th and	50th Perce	entile										
Diagnosis of probable self-harm	2	0	40	0	1298	0	8802	0	20276	1	67455	2
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	147692	4	398002	10	934838	25	150179	4	375253	11	868861	25
Hospitalization with MH <sup>b</sup> diagnosis	50733	1	167316	4	530314	14	70301	2	193203	6	527541	15
Any of the above diagnoses	181406	5	489804	13	1136072	30	190075	5	469287	13	1052040	30
Risk Score between the 50th and	75th Perce	entile										
Diagnosis of probable self-harm	224	0	1910	0	19069	1	16132	0	35723	1	102262	3
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	358138	9	759654	20	1361381	36	264781	8	617751	18	1144295	33
Hospitalization with MH <sup>b</sup> diagnosis	160337	4	393060	10	826680	22	151679	4	379721	11	806952	23
Any of the above diagnoses	442413	12	932316	24	1604704	42	348543	10	780458	22	1380641	40
Risk Score between the 75th and	90th Perce	entile										
Diagnosis of probable self-harm	3258	0	14518	1	87173	4	24970	1	51633	2	106129	5
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	434230	19	790574	35	1184448	52	366540	17	680290	32	973538	46
Hospitalization with MH <sup>b</sup> diagnosis	261978	11	509180	22	832028	36	225796	11	458191	22	765747	37
Any of the above diagnoses	539381	24	955914	42	1355270	59	462127	22	828774	40	1150454	55
<sup>a</sup> Emergency Department	<sup>a</sup> Emergency Department											
Mental Health												

Supplementary Table 3. Count and percentage of general medical visits with history of traditional risk factors in lower percentile strata.												
	Attempt						Death					
	Last 3		Last 12		Last 5 yea	ars	Last 3		Last 12		Last 5 ye	ears
	months		months		_		months		months		_	
	Ν	%	Ν	%	Ν	%	Ν	%	Ν	%	Ν	%
Risk Score Less than the 25th Pere	centile											
Diagnosis of probable self-harm	0	0	0	0	0	0	393	0	1629	0	6013	0
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	20523	1	79651	3	355637	13	60474	3	201485	9	502494	21
Hospitalization with MH <sup>b</sup> diagnosis	6963	0	25367	1	170281	6	23746	1	81585	3	276413	12
Any of the above diagnoses	27014	1	99214	4	440485	17	76992	3	239370	10	600648	25
Risk Score between the 25th and 5	0th Percer	ntile										
Diagnosis of probable self-harm	0	0	0	0	1	0	945	0	2725	0	8751	0
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	83352	3	221954	8	560340	21	87918	4	251919	10	581320	23
Hospitalization with MH <sup>b</sup> diagnosis	36421	1	107152	4	351688	13	43682	2	124552	5	382448	15
Any of the above diagnoses	111333	4	289242	11	716655	27	113583	5	312442	12	726381	29
Risk Score between the 50th and 7	5th Percer	ntile										
Diagnosis of probable self-harm	0	0	0	0	642	0	2406	0	7471	0	21784	1
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	214635	8	451150	17	832577	32	169846	7	389255	16	725287	30
Hospitalization with MH <sup>b</sup> diagnosis	109960	4	257427	10	567681	22	98552	4	248158	10	517134	21
Any of the above diagnoses	277345	11	575416	22	1033136	39	235407	10	510797	21	902408	37
Risk Score between the 75th and 9	0th Percer	ntile										
Diagnosis of probable self-harm	3	0	294	0	15409	1	4527	0	12006	1	33888	2
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	258833	16	475405	30	734687	46	212068	15	356386	24	552423	38
Hospitalization with MH <sup>b</sup> diagnosis	146318	9	294909	19	523971	33	122384	8	241689	17	414334	28
Any of the above diagnoses	324427	20	581892	37	868330	55	267589	18	445079	31	667995	46

## <sup>a</sup> Emergency Department

#### <sup>b</sup> Mental Health

Supplementary Table 4. Count and percentage of mental health specialty with a prior history of traditional risk factors in all risk strata for patients with sex listed as female.

	Attempt						Death					
	Last 3		Last 12		Last 5 yea	ars	Last 3		Last 12		Last 5 ye	ears
	months		months				months		months			
	Ν	%	Ν	%	Ν	%	Ν	%	Ν	%	Ν	%
Risk Score Less than the 25th F	Percentile											
Diagnosis of probable self-harm	0	0	0	0	7	0	3336	0	8208	0	42305	2
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	25327	1	100654	4	362931	15	60691	3	191261	9	506983	23
Hospitalization with MH <sup>b</sup>	6888	0	32101	1	209335	9	26626	1	83737	4	235733	11
diagnosis												
Any of the above diagnoses	30945	1	122782	5	465897	19	80842	4	241008	11	593055	27
Risk Score between the 25th an	d 50th Per	centil	e	-		-				-		
Diagnosis of probable self-harm	0	0	37	0	802	0	5487	0	12372	1	39380	2
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	95492	4	263690	11	631987	26	89657	4	219004	10	527392	24
Hospitalization with MH <sup>b</sup>	29182	1	105521	4	357594	15	39581	2	107447	5	280346	13
diagnosis												
Any of the above diagnoses	115369	5	323541	13	772712	32	115473	5	271727	12	623315	28
Risk Score between the 50th an	d 75th Per	centil	е	-					T	-	1	-
Diagnosis of probable self-harm	144	0	1004	0	12131	0	10291	0	22861	1	66227	3
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	222774	9	486707	20	888640	37	143815	6	357044	16	718113	32
Hospitalization with MH <sup>b</sup>	94331	4	248255	10	546820	22	79740	4	215217	10	522520	24
diagnosis												
Any of the above diagnoses	274730	11	601661	25	1054632	43	186600	8	457549	21	890081	40
Risk Score between the 75th an	d 90th Per	centil	е	-		1			T	-		_
Diagnosis of probable self-harm	2020	0	9337	1	60790	4	16651	1	34387	3	77543	6
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	259003	18	482034	33	732833	50	229987	17	458058	34	670328	50
Hospitalization with MH <sup>b</sup>	152049	10	308477	21	516696	35	133798	10	300924	23	533795	40
diagnosis												
Any of the above diagnoses	322104	22	585566	40	838639	57	294584	22	566031	42	799311	60
Risk Score between the 90th an	d 95th Per	centil	е		1	r	1		1		•	
Diagnosis of probable self-harm	7949	2	27702	6	84983	17	14391	3	29337	7	47041	11
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	142182	29	250346	51	334939	69	155055	35	241943	54	282941	64
Hospitalization with MH <sup>b</sup>	103617	21	192401	40	273952	56	102451	23	176710	40	234644	53
diagnosis												
Any of the above diagnoses	180025	37	305861	63	380819	78	187620	42	280622	63	319479	72
Risk Score between the 95th an	d 98th Per	centil	е		1		1	1	1		1	
Diagnosis of probable self-harm	31894	11	76186	26	131014	45	19040	7	41716	16	50518	19
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	126472	43	213265	73	250323	86	126127	47	174396	65	191226	72
Hospitalization with MH <sup>b</sup>	108630	37	191692	66	231058	79	97175	36	143770	54	166406	62
diagnosis												
Any of the above diagnoses	161991	56	255620	88	279802	96	146919	55	195676	73	210867	79
Risk Score greater than or equa	al to the 98	th Pe	rcentile		1		1	r	1		1	
Diagnosis of probable self-harm	89128	46	137976	71	163201	84	52149	29	81667	46	84471	48
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	131364	68	176975	91	185323	95	112241	63	142367	80	148886	84
Hospitalization with MH <sup>b</sup>	123125	63	171826	88	180387	93	101129	57	131488	74	141424	80
diagnosis			1010-0			4.5.5	40					
Any of the above diagnoses	153431	79	191879	99	194155	100	127243	72	154889	87	160065	90
<sup>a</sup> Emergency Department												
<sup>o</sup> Mental Health												

Supplementary Table 5. Count and percentage of mental health specialty with a prior history of traditional risk factors in all risk strata for patients with sex listed as male.

	Attempt						Death					
	Last 3		Last 12		Last 5 ve	ars	Last 3		Last 12		Last 5 ve	ars
	months		months			aio	months		months			
	N	%	N	%	N	%	N	%	N	%	N	%
Risk Score Less than the 25th P	ercentile											
Diagnosis of probable self-harm	0	0	0	0	1	0	749	0	1828	0	14112	1
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	12801	1	47841	3	167333	12	28667	2	86797	7	229617	18
Hospitalization with MHb	5206	0	19518	1	105025	8	12130	1	36066	3	103253	8
diagnosis		-								-		-
Any of the above diagnoses	17128	1	60869	4	217367	16	37054	3	106759	8	265130	21
Risk Score between the 25th and	d 50th Perc	centile										
Diagnosis of probable self-harm	2	0	10	0	503	0	1722	0	4252	0	16547	1
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	52437	4	135011	10	303848	22	46890	4	117715	9	279753	22
Hospitalization with MH <sup>b</sup>	21434	2	61878	4	174088	13	25396	2	62871	5	143665	11
diagnosis												
Any of the above diagnoses	66301	5	167276	12	365360	26	63596	5	145684	11	325261	26
Risk Score between the 50th and	d 75th Pero	centile	)					-				
Diagnosis of probable self-harm	76	0	836	0	7132	1	3072	0	6890	1	26166	2
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	134330	10	272615	20	473287	34	86056	7	199488	16	385807	30
Hospitalization with MH <sup>b</sup>	65279	5	144688	10	280818	20	50582	4	119018	9	275101	22
diagnosis												
Any of the above diagnoses	166624	12	330495	24	550439	40	110711	9	250493	20	467566	37
Risk Score between the 75th and	d 90th Pero	centile	)			1	T	-	T		T	_
Diagnosis of probable self-harm	1155	0	4982	1	26935	3	5904	1	12908	2	30987	4
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	169673	20	299464	36	441550	53	154130	20	287795	38	392457	51
Hospitalization with MH <sup>b</sup>	105821	13	193144	23	305354	37	93840	12	196367	26	310215	41
diagnosis		_										
Any of the above diagnoses	210746	25	359173	43	503782	61	199549	26	356438	47	467952	61
Risk Score between the 90th and	d 95th Pero	centile	) 				I		L	-		
Diagnosis of probable self-harm	3371	1	11465	4	33973	12	5614	2	12561	5	19528	8
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	105433	38	169634	61	213699	77	108059	42	157384	62	177175	70
Hospitalization with MH <sup>b</sup>	78998	29	134356	49	176817	64	75642	30	118963	47	147198	58
diagnosis	400000	4-	000447	=0	0.400.50	07	400000	= 1	101017		400700	
Any of the above diagnoses	129923	4/	202147	73	240858	87	130389	51	181817	/1	199738	78
Risk Score between the 95th and	d 98th Perc	centile	00570	1.0	47404		0.507		10000	10	00407	45
Diagnosis of probable self-harm	10602	6	26572	16	4/134	28	8527	6	18699	12	22487	15
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	85195	51	130227	79	148112	89	92638	61	119095	/8	125453	82
Hospitalization with MH <sup>o</sup>	74249	45	119017	72	136709	83	76037	50	103648	68	114733	75
	400070	60	450400	04	400050	07	400440	<u> </u>	400077	00	407405	00
Any of the above diagnoses	103879	63	150102	91	160953	97	106112	69	132077	86	13/195	90
Risk Score greater than or equa	1 to the 98t	n Pere	Centile	50	76246	60	20000	20	42440	40	11E1E	4.4
Diagnosis of probable self-narm	40968	3/	03507	58	105042	69	28090	28	43449	43	44545	44
ED <sup>a</sup> VISIt With MH <sup>b</sup> diagnosis	79000	12	102311	93	105943	90	70093	73	91354	90	93033	91
	10021	ΟŌ	99121	90	104144	94	/ 1930		0/000	00	91000	09
Any of the above discresses	00600	ຊາ	100004	00	110000	10	85600	Q <i>1</i>	07965	06	08880	07
Any of the above diagnoses	90090	02	109094	99	110003	0	00020	04	91000	90	90000	91
a Emergency Department				I	1	U	1	I	1		1	1
b Mental Health												

Supplementary Table 6. Count and percentage of general medical visits with a prior history of traditional risk factors in all risk strata for patients with sex listed as female.

	Attempt						Death					
	Last 3		Last 12		Last 5 ye	ears	Last 3 months		Last 12		Last 5 ye	ears
	N	%	N	%	N	%	N	%	N	%	N	%
Risk Score Less than the 25th	Percentile						1		1			1
Diagnosis of probable self-harm	0	0	0	0	0	0	240	0	1056	0	4036	0
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	12933	1	51279	3	235258	14	41329	3	143439	9	356073	23
Hospitalization with MH <sup>b</sup> diagnosis	4211	0	15650	1	108330	7	14793	1	54942	4	190668	13
Any of the above diagnoses	16879	1	63440	4	289203	17	51927	3	168748	11	421334	28
Risk Score between the 25th ar	nd 50th Pe	rcent	ile		•						•	
Diagnosis of probable self-harm	0	0	0	0	1	0	449	0	1486	0	5072	0
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	53810	3	145348	9	374478	23	51954	3	132503	9	310625	20
Hospitalization with MH <sup>b</sup> diagnosis	22220	1	67166	4	230273	14	25112	2	64122	4	206941	14
Any of the above diagnoses	70897	4	187668	11	477324	29	67692	4	164514	11	393349	26
Risk Score between the 50th a	nd 75th Pe	rcent	ile									
Diagnosis of probable self-harm	0	0	0	0	428	0	752	0	2205	0	6986	0
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	133723	8	288721	17	545054	33	56171	4	175791	12	394337	26
Hospitalization with MH <sup>b</sup> diagnosis	65670	4	160250	10	367377	22	32469	2	101976	7	269238	18
Any of the above diagnoses	171603	10	367083	22	675801	41	75031	5	226828	15	496231	33
Risk Score between the 75th ar	nd 90th Pe	rcent	ile									
Diagnosis of probable self-harm	2	0	197	0	9893	1	1706	0	5487	1	14826	2
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	150553	15	284603	29	449698	45	108910	12	230612	25	398991	44
Hospitalization with MH <sup>b</sup> diagnosis	83051	8	173944	17	320647	32	63410	7	153177	17	291812	32
Any of the above diagnoses	189274	19	350382	35	535274	54	153093	17	306249	34	493170	54
Risk Score between the 90th a	nd 95th Pe	rcent	ile							-		<u> </u>
Diagnosis of probable self-harm	100	0	1677	1	20180	6	2249	1	5834	2	17504	6
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	78932	24	139827	42	201892	61	105537	35	151884	50	199855	66
Hospitalization with MH <sup>b</sup>	45185	14	89928	27	154281	46	57802	19	106431	35	154666	51
diagnosis												
Any of the above diagnoses	96660	29	167294	50	231306	70	131180	43	188018	62	233075	77
Risk Score between the 95th ar	nd 98th Pe	rcent	ile									
Diagnosis of probable self-harm	1010	1	6735	3	29988	15	3252	2	8533	5	21877	12
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	60194	30	102730	52	136753	69	86671	47	108806	60	129951	71
Hospitalization with MHb	37017	19	71772	36	112829	57	53360	29	80619	44	105369	58
diagnosis												
Any of the above diagnoses	73395	37	121361	61	151816	76	100252	55	124159	68	143019	78
Risk Score greater than or equ	al to the 9	8th Pe	ercentile		•		•				•	
Diagnosis of probable self-harm	22271	17	44663	34	65407	49	13701	11	25422	21	45430	37
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	68360	51	102495	77	114319	86	71455	59	85850	71	97691	80
Hospitalization with MHb	50943	38	85231	64	103532	78	53969	44	74196	61	88425	73
diagnosis												
Any of the above diagnoses	82130	62	116071	87	123864	93	79936	66	94928	78	104494	86
a Emergency Department		-		•		-		-		-	•	·
b Mental Health												

Supplementary Table 7. Count and percentage of general medical visits with a prior history of traditional risk factors in all risk strata for patients with sex listed as male.

patients with sex listed as male.	Attomnt			Death								
	Last 3		Last 12		Last 5 v	are	Last 3		Last 12		Last 5 v	aare
	months		months		Lasi J y	5015	months		months		Lasi J ye	5015
	N	%	N	%	N	%	N	%	N	%	N	%
Risk Score Less than the 25th F	Percentile	70		70		70		70		70		70
Diagnosis of probable self-harm	0	0	0	0	0	0	210	0	574	0	1971	0
Emerg dept visit with MH	6811	1	25682	3	113155	12	24838	3	79258	g	186283	21
diagnosis	0011		20002	Ŭ	110100	12	24000	Ŭ	10200	5	100200	21
Hospitalization with MH	2493	0	8540	1	57878	6	11169	1	34440	4	106152	12
diagnosis	2100	Ŭ	0010	l .	01010	Ŭ			01110	1.	100102	
Any of the above diagnoses	9143	1	32223	3	141871	15	32029	4	94405	10	221490	24
Risk Score between the 25th an	d 50th Per	centile			1			I				<u></u>
Diagnosis of probable self-harm	0	0	0	0	0	0	235	0	646	0	2206	0
Emera, dept. visit with MH	28256	3	73791	8	180661	18	29002	3	70840	8	150361	17
diagnosis								-				
Hospitalization with MH	13716	1	38924	4	118265	12	15179	2	37434	4	101426	11
diagnosis												
Any of the above diagnoses	38761	4	98234	10	233685	24	38303	4	88726	10	190418	21
Risk Score between the 50th an	d 75th Per	centile	)				•					
Diagnosis of probable self-harm	0	0	0	0	112	0	625	0	1701	0	4591	0
Emerg. dept. visit with MH	84908	9	169973	17	302346	31	47940	5	120626	13	237053	26
diagnosis												
Hospitalization with MH	46315	5	101104	10	208823	21	29232	3	74538	8	168327	18
diagnosis												
Any of the above diagnoses	110871	11	217670	22	374671	38	64717	7	155563	17	298833	32
Risk Score between the 75th an	d 90th Per	centile	)									
Diagnosis of probable self-harm	0	0	69	0	5023	1	1259	0	3521	1	10045	2
Emerg. dept. visit with MH	106689	18	188421	32	280924	48	82095	15	152477	28	243752	45
diagnosis												
Hospitalization with MH	62912	11	120072	20	200864	34	51983	10	107917	20	186514	34
diagnosis												<u> </u>
Any of the above diagnoses	133445	23	228800	39	328815	56	11277	21	200355	37	301078	55
							8					
Risk Score between the 90th an	d 95th Per	centile	4070		44000		4500		4450		40000	
Diagnosis of probable self-harm	26	0	1070	1	11820	6	1508	1	4159	2	10338	6
Emerg. dept. visit with MH	53986	28	89558	46	123811	63	68851	38	97424	54	122650	68
diagnosis	24074	10	C1010	20	00000	40	44040	05	70400	40	00014	54
	34071	10	01912	32	90399	49	44810	20	13103	40	96214	54
Any of the above diagnoses	66215	34	106604	55	1/3113	73	97391	18	110100	66	1/2001	78
Bick Score botwcon the 95th an	00215	04 contile	100004	55	143113	13	07301	40	119100	00	142001	10
Diagnosis of probable solf harm	742		/337	1	1707/	15	2627	2	6452	6	12220	12
	142	30	70862	4	01676	78	57065	Z 53	70520	65	80333	7/
diagnosis	40141	39	12003	02	91070	10	57905	55	10520	05	00332	/4
Hospitalization with MH	33027	28	54884	47	77174	66	40505	37	56092	52	67854	62
diagnosis	55021	20	5-00-	1	11114	00	+0000	51	30032	52	0/034	02
Any of the above diagnoses	56784	48	85563	73	102481	87	67529	62	79788	73	88193	81
Risk Score greater than or equa	al to the 98	th Peri	centile	15	102401	07	01025	02	15100	15	00100	01
Diagnosis of probable self-harm	13876	18	26857	34	37425	48	8193	11	14540	20	24043	33
Emerg dept visit with MH	48219	62	66452	85	71325	91	48476	67	55069	76	60502	83
diagnosis	10210	02	00102	00	11020	01	10110	01	00000	10	00002	00
Hospitalization with MH	38094	49	57658	74	65976	84	38683	53	49059	68	55319	76
diagnosis				' '								.
Any of the above diagnoses	56917	73	73582	94	76168	97	52967	73	59313	82	63659	88
a Emergency Department		. <u> </u>										<u> </u>
b Mental Health												

Supplementary Table 8. Count and percentage of mental health specialty visits with a prior history of traditional risk factors in all strata. Restricted to visits with a PHQ-9 item 9 response in the prior 12 months.

Mental Health Sample	Attempt					Death						
	Last 3		Last 12		Last 5 ve	ears	Last 3		Last 12		Last 5 ve	ears
	months		months		Luot o y	curo	months		months		Luot o y	<i>,</i> ui 0
	N	%	N	%	Ν	%	N	%	N	%	Ν	%
Risk Score Less than the 25th Per	centile											
Diagnosis of probable self-harm	0	0	0	0	8	0	1490	0	3869	1	18196	2
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	14239	1	55084	5	171933	17	25841	3	77449	10	196271	26
Hospitalization with MH <sup>b</sup> diagnosis	3686	0	17748	2	101951	10	8679	1	29992	4	84728	11
Any of the above diagnoses	17550	2	69007	7	228335	22	32674	4	95950	12	229467	30
PHQ9 <sup>c</sup> item 9 response 2 or 3	15903	2	34085	3			72614	9	120040	16		
Any of the above	33256	3	101075	10	228335	22	98940	13	192221	25	229467	30
Risk Score between the 25th and	50th Perce	ntile										
Diagnosis of probable self-harm	0	0	27	0	790	0	2106	0	5351	1	19565	3
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	50912	5	135877	13	288744	28	34918	5	97175	13	212099	28
Hospitalization with MH <sup>b</sup> diagnosis	15394	1	54061	5	162217	16	14683	2	49467	6	136891	18
Any of the above diagnoses	62467	6	169265	16	356322	35	44436	6	124631	16	266965	35
PHQ9 <sup>c</sup> item 9 response 2 or 3	60404	6	109487	11			70141	9	117589	15		-
Any of the above	120442	12	264671	26	356322	35	105888	14	212255	28	266965	35
Risk Score between the 50th and	75th Perce	ntile										т.
Diagnosis of probable self-harm	149	0	882	0	9522	1	4159	1	9153	1	27897	4
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	114050	11	247520	24	422696	41	68309	9	160178	21	274670	36
Hospitalization with MH <sup>b</sup> diagnosis	49152	5	124398	12	254810	25	35446	5	94527	12	198685	26
Any of the above diagnoses	140498	14	303777	29	499948	48	89174	12	203382	26	338113	44
PHQ9 <sup>c</sup> item 9 response 2 or 3	144081	14	234699	23	4000.40	40	93745	12	150220	20	000440	
Any of the above	269147	26	482583	47	499948	48	165404	21	300714	39	338113	44
Risk Score between the 75th and	Juth Perce	ntile	7074	4	07400		7404	0	47404	4	24520	7
Diagnosis of probable self-narm	1004	0	7674	1	3/182	6	7421	2	17124	4	31530	1
ED <sup>a</sup> VISIT WITH MH <sup>b</sup> diagnosis	130847	12	252692	41	364162	59	95213	21	1/3819	38	232108	50
Hospitalization with MH <sup>o</sup> diagnosis	10/22	13	158351	20	253988	41	55978	12	11/698	25	183596	40
Any of the above diagnoses	165294	27	302090	49	413/84	67	07651	20	212040	40	277000	60
Any of the above	100304	21	24/00/	40	412704	67	170796	19	132015	29	077000	60
Bick Score between the 90th and 9	293942	4/ ntilo	447400	12	413/04	07	1/9/00	29	2/91/4	60	277000	00
Diagnosis of probable self-barm	5222	2	1782/	٥	12807	21	6661	1	1/700	10	10525	13
EDa visit with MHb diagnosis	73308	36	12/53/	60	157582	76	5300/	35	83072	55	087/15	64
Hospitalization with MH <sup>b</sup> diagnosis	52254	25	960/18	17	120257	63	37555	2/	6/210	12	83827	5/
Any of the above diagnoses	80/72	/3	1/7370	71	17/1026	85	656/5	/3	04210	6/	11//13	7/
PHO9 <sup>c</sup> item 9 response 2 or 3	74047	36	108076	52	174320	00	40338	26	57560	37	117710	17
Any of the above	133645	65	187036	91	174926	85	88849	58	120326	78	114413	74
Risk Score between the 95th and 9	98th Perce	ntile	10/000	01	11 1020	00	00010	00	120020	10		
Diagnosis of probable self-harm	16412	13	37201	30	59740	48	9853	11	18109	20	20193	22
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	57984	47	94255	76	108967	88	45806	50	63377	69	70161	76
Hospitalization with MH <sup>b</sup> diagnosis	46765	38	82014	66	98508	80	36108	39	53597	58	63047	68
Any of the above diagnoses	71871	58	109828	89	119085	96	53892	58	72467	78	78642	85
PHQ9 <sup>c</sup> item 9 response 2 or 3	49193	40	72676	59			29839	32	40789	44		
Any of the above	92735	75	121278	98	119085	96	67019	73	82493	89	78642	85
Risk Score greater than or equal t	o the 98th	Percer	ntile						1			
Diagnosis of probable self-harm	38110	46	58625	71	69708	84	17078	28	26608	43	27343	44
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	55388	67	74606	90	78776	95	41041	67	51354	83	53508	87
Hospitalization with MH <sup>b</sup> diagnosis	49803	60	71103	86	75766	92	36510	59	47914	78	51930	84
Any of the above diagnoses	64965	79	81319	98	82413	10 0	46922	76	56625	92	58237	95
PHQ9 <sup>c</sup> item 9 response 2 or 3	42757	52	58173	70	İ	1	24719	40	31673	51	İ	1
Any of the above	74506	90	82509	10 0	82413	10 0	53258	86	59859	97	58237	95
<sup>a</sup> Emergency Department <sup>b</sup> Mental Health	<u>ı</u>	1	1		ı	1 -	1	1	1	1	1	<u>.                                    </u>

° Patient Health Questionnaire

Supplementary Table 9. Count and percentage of general medical visits with a prior history of traditional risk factors in all strata. Restricted to visits with a PHQ-9 item 9 response in the prior 12 months.

General Medical Sample												
	Attempt		-		-		Death				-	
	Last 3		Last 12		Last 5 ye	ars	Last 3		Last 12		Last 5 ye	ears
	N	%	N	%	N	%	N	%	N	%	N	%
Risk Score Less than the 25th Per	centile						1		1			
Diagnosis of probable self-harm	0	0	0	0	0	0	99	0	416	0	1158	0
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	4140	1	16317	5	55458	17	7110	3	29255	11	65134	24
Hospitalization with MH <sup>b</sup> diagnosis	2446	1	7969	2	34075	10	3165	1	11321	4	41568	15
Any of the above diagnoses	6443	2	22933	7	76251	23	9462	3	35580	13	83172	30
PHQ9 <sup>c</sup> item 9 response 2 or 3	3253	1	9681	3			9490	3	25001	9		
Any of the above	9660	3	32213	10	76251	23	18296	7	55987	20	83172	30
Risk Score between the 25th and	50th Perce	ntile										
Diagnosis of probable self-harm	0	0	0	0	16	0	215	0	848	0	2272	1
ED <sup>a</sup> visit with MH <sup>b</sup> diagnosis	15885	5	42517	13	92604	28	8672	3	36914	13	79066	29
Hospitalization with MH <sup>b</sup> diagnosis	9027	3	24577	7	64199	19	7448	3	24100	9	57984	21
Any of the above diagnoses	23337	7	59946	18	123789	37	15191	6	52317	19	104235	38
PHQ9 <sup>c</sup> item 9 response 2 or 3	9975	3	24967	7			13696	5	30475	11		
Any of the above	32886	10	81611	25	123789	37	27902	10	75225	28	104235	38
Risk Score between the 50th and	75th Perce	ntile	••••			•.						
Diagnosis of probable self-harm	0	0	24	0	1284	0	916	0	2748	1	7107	3
FD <sup>a</sup> visit with MH <sup>b</sup> diagnosis	37969	11	80921	24	136336	41	34316	13	68127	25	109798	40
Hospitalization with MH <sup>b</sup> diagnosis	20438	6	47017	14	94752	28	18319	7	43646	16	82240	30
Any of the above diagnoses	51249	15	104813	31	168374	51	47172	17	89658	33	137456	50
PHQ9 <sup>c</sup> item 9 response 2 or 3	21291	6	47619	14	100011		18329	7	38676	14	101 100	
Any of the above	70051	21	139808	42	168374	51	61232	22	112625	41	137456	50
Risk Score between the 75th and 9	Oth Perce	ntile	100000		100011	0.	01202		112020		101 100	
Diagnosis of probable self-harm	44	0	874	0	8665	4	1415	1	3867	2	8331	5
EDa visit with MH <sup>b</sup> diagnosis	44533	22	83286	42	119142	60	28743	18	49892	30	74370	45
Hospitalization with MH <sup>b</sup> diagnosis	24135	12	51129	26	87002	44	17902	11	35343	22	56923	35
Any of the above diagnoses	55933	28	101041	51	137720	69	37355	23	63285	39	89729	55
PHO9° item 9 response 2 or 3	23297	12	46144	23	10/1/20	00	14346	9	27897	17	00120	00
Any of the above	73633	37	126780	63	137720	69	47299	29	78009	48	89729	55
Risk Score between the 90th and 9	15th Perce	ntile	120700	00	10/120	00	47200	25	10005	40	00120	00
Diagnosis of probable self-harm	302	0	2203	3	9079	14	1359	2	3397	6	6426	12
EDa visit with MH <sup>b</sup> diagnosis	21693	33	37205	56	48405	73	17408	32	26846	49	34729	63
Hospitalization with MH <sup>b</sup> diagnosis	12051	10	25061	38	383/13	58	1108/	20	20040	37	28308	52
Any of the above diagnoses	26675	10	/373/	66	53836	81	222/18	11	33/07	61	/0715	7/
PHOQC item Q response 2 or 3	11103	17	20622	31	00000	01	6212	11	11765	22	40715	/4
Any of the above	33756	51	526/1	70	53836	81	25853	17	37865	60	10715	7/
Risk Score between the 95th and 9	8th Perce	ntile	JZ041	13	33030	01	23033	47	57005	03	40715	/4
Diagnosis of probable self-barm	1306	3	5881	15	12/153	31	1851	6	3015	12	6670	20
EDa visit with MHb diagnosis	16780	12	28075	70	320/5	82	15876	18	206/8	63	24056	73
Hospitalization with MH <sup>b</sup> diagnosis	11167	28	21621	54	28721	72	0778	30	15650	/18	10080	61
Any of the above diagnoses	20600	52	32600	82	36131	00	10005	58	2/081	73	26061	82
PHO0: item 0 response 2 or 3	20003	22	16050	0Z 40	30131	90	5055	15	24001	26	20901	02
Any of the above	25100	62	26702	40	26121	00	21105	65	0400	20	26061	00
Bick Secre greater then or equal t	20190	Doroor	30703	92	30131	90	21100	00	20470	01	20901	02
Diagnosis of probable solf harm	9 1110 9011 9720	22	15/76	58	18550	70	2067	1/	5350	24	8370	38
EDa visit with MHb diagnosis	17165	64	23106	97 97	24420	02	12012	64	16327	24 75	180/0	20
Hospitalization with MUb diagnosis	12112	/0	20100	76	24420	9Z Q/	10267	//7	1/175	65	16224	75
	20222	49	20109	10	22040	04	10307	4/	141/0	00	10324	00
	20223 9501	20	20000	50	20040	90	10070	01	7150	0Z 22	19410	09
Any of the above	0004	ა∠ 02	14310	00	26049	00	4030	21	10254	00 00	10/10	90
Any of the above	22194	03	203/1	99	20040	90	1/010	١Ŏ	19354	0Ö	19410	09
<ul> <li>Mental Health</li> </ul>												

<sup>c</sup> Patient Health Questionnaire

Supplementary Table 10. Count and percentage of mental health specialty visits with a recorded PHQ9 total score at that visit that had a total score greater than or equal to 20.						
Total PHQ9 Score of 20 or more	Attempt		Death			
Risk Score	N	%	N	%		
Less than the 25th Percentile	309151	56	210101	51		
Between the 25th and 50th Percentile	301173	55	229206	56		
Between the 50th and 75th Percentile	323387	59	247057	60		
Between the 75th and 90th Percentile	221380	67	158514	64		
Between the 90th and 95th Percentile	82197	74	56105	68		
Between the 95th and 98th Percentile	52158	79	34883	70		
Greater than or equal to the 98th Percentile	37525	85	24395	74		

Supplementary Table 11. Count and percentage of general medical visits with a recorded PHQ9 total score at that visit that had a total score greater than or equal to 20.						
Total PHQ9 Score of 20 or more	Attempt		Death			
Risk Score	N	%	N	%		
Less than the 25th Percentile	21895	10	12978	7		
Between the 25th and 50th Percentile	32932	15	39831	21		
Between the 50th and 75th Percentile	47486	21	40510	21		
Between the 75th and 90th Percentile	37483	28	29176	26		
Between the 90th and 95th Percentile	15433	34	10953	29		
Between the 95th and 98th Percentile	10713	39	7021	31		
Greater than or equal to the 98th Percentile	9356	52	5364	36		

Supplementary Table 12. Distribution of absolute predicted risk by sample.								
Predicted Risk Score distribution								
	Mental Health Sample		General Medical Sample					
Percentile	Attempt	Death	Attempt	Death				
0	0.0001	0	0.00007	0				
25 <sup>th</sup>	0.00127	0.00003	0.00065	0.00003				
50 <sup>th</sup>	0.00244	0.00008	0.00115	0.00007				
75 <sup>th</sup>	0.00548	0.0002	0.0024	0.00015				
90 <sup>th</sup>	0.01349	0.00049	0.00584	0.00035				
95 <sup>th</sup>	0.0256	0.00088	0.01097	0.0006				
98 <sup>th</sup>	0.05644	0.00178	0.02345	0.00121				
100 <sup>th</sup>	0.70428	0.10513	0.74041	0.13301				

Supplementary Figure 1. Percentage of mental health specialty visits with each risk factor across the full range of predicted risk scores using strata of size 5 percentiles for visits with a prior PHQ9 item 9 response in the last year.



Supplementary Figure 2. Percentage of general medical visits with each risk factor across the full range of predicted risk scores using strata of size 5 percentiles for visits with a prior PHQ9 item 9 response in the last year

