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Declaration of competing interest

None

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## Abstract

**Introduction:** Suicidality, including suicidal ideation (SI), attempt (SA), and death (SD), represents complex and partially overlapping phenotypes that are moderately heritable. Suicidality definition heterogeneity impedes data replication and consolidation efforts by research consortia needed to address the sample size requirements of genetic research. The standardization of suicidality definitions would improve comparability of data across groups but has been insufficiently addressed in existing literature. Here, the Suicide Workgroup of the Psychiatric Genomics Consortium (PGC) provides International Classification of Disease (ICD) definitions and validation in real-world data for SA and SI.

**Methods:** The PGC Suicide Workgroup used published definitions coupled with expert consensus to develop ICD lists to serve as suicidality phenotype definitions. One SI and two SA lists were produced and evaluated for performance, including via sex stratification, against patient screening responses in multiple independent cohorts (total  $N = 21,772$ ) with differing ascertainment strategies.

**Results:** ICD code lists for suicidality component definitions were produced. SA ICD lists versus patient responses showed sensitivity of 15.4 % to 71.1 %, specificity of 67.6 % to 96.3 %, and positive predictive values of 0.57–0.92. SI ICD code performance versus patient report also varied in sensitivity (29.4 %–86.1 %), specificity (64.2 % to 90.6 %), and positive predictive values (0.67 to 0.98).

**Conclusions:** Lists of applicable ICD codes for SI and SA were developed that complied with C-SSRS definitions. Real-world application of ICD codes can vary substantially, perhaps dependent on clinician training and on cohort characteristics. Consistent training in use of ICD codes between sites may improve comparability of data sets.

## Keywords

Suicidality; Suicide attempt; Suicidal ideation; Phenotype; International classification of disease; Psychiatric genetics

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## 1. Introduction

Suicidality represents partially overlapping phenotypes spanning thoughts and behaviors. Suicidality includes suicidal ideation (SI), suicide attempt (SA), and death by suicide (SD), with differing patterns of associated psychopathology, neurobiology, and intent (Mieczkowski et al., 1993; Oquendo et al., 2021).

Phenotypic complexity of suicidality arises from shared and independent risk factors from genetic and environmental sources. Risk sources include underlying genetic vulnerabilities and lifetime exposures to adversity. SD, SA, and SI have estimated heritability in the range of 30–50 % based on family and twin studies (Brent and Mann, 2005; Mann et al., 2009). However, SI may have less estimated independent heritability than SA and SD (Docherty et al., 2023; Dutta et al., 2017).

Like most psychiatric phenotypes, suicidality is polygenic, arising from numerous genetic variants, each with small effect. As such, suicidality requires hundreds of thousands of samples to conduct well-powered genome-wide association studies (GWAS). The required sample size necessitates the formation of consortia, such as the Psychiatric Genomics Consortium (PGC) (Docherty et al., 2023; Mullins et al., 2022). Consortia analyses are sensitive to heterogeneity among combined samples, potentially reducing statistical power to identify meaningful and specific genetic variation associated with disease (Cai et al., 2020).

The complexity of suicidality, however, has also contributed to a wide array of definitions that hamper comparison and reproducibility across studies and sites. Table 1 displays current international standard suicidality definitions along with aggregated phenotype names (Cipriano et al., 2017; Crosby et al., 2011). Consistent phenotype definitions, arising from both patient responses to instruments and real-world electronic health record coding data, are required to reduce heterogeneity and increase power.

Patient-reported screening and research questionnaires are the ideal source for defining suicidality phenotypes. However, many real-world datasets, including registries and biobanks, often lack such instrument data. For many data sets, International Classification

of Disease (ICD) codes may be the only source of phenotype data. Studies are needed to test how well ICD codes can match suicidality phenotype definitions. Agreement is also needed on applicable ICD codes and would support clinician training on the utilization of appropriate ICD codes. Optimally, suicidality definitions need to be agreed upon and clinician training should follow for implementation within real-world data sources, including biobanks and large-scale health registries. These steps will enhance comparability of data sets from different research teams.

Effectively incorporating and harmonizing datasets with phenotypes defined partly or entirely from ICD codes became a priority for the PGC Suicide Workgroup. Our recent meta-analysis of previously published GWAS (Kimbrel et al., 2022; Mullins et al., 2022) included two cohorts with ICD-based phenotype definitions (Docherty et al., 2023). To date, we have harmonized phenotype definitions across questionnaires, scales, and interviews by requiring the use of specific language to disentangle suicide phenotypes and related self-harm phenotypes. Now, in anticipation of incorporating additional large population and healthcare datasets, which often rely on ICD data for phenotypes, we aim to develop consistent ICD-based definitions to improve consistency within the PGC Suicide Workgroup and across the field.

Here, the PGC Suicide Workgroup presents a flexible set of guidelines to represent best practices in the utilization of ICD coding lists to define SA and SI phenotypes to be implemented within the field in genetic studies. The performance of these ICD codes is compared to patient interviews. Implementing such ICD-based phenotype definitions is proposed to result in more homogeneous study populations and more reliable findings from large scale genetic studies. These codes could also serve as a template for guiding training for clinician suicidality coding.

## 2. Methods

### 2.1. SA and SI ICD code list construction

The ICD codes V62.84 (ICD-9) and R45.851 (ICD-10) serve as the only ICD definition matches for SI. For SA, ICD code lists were generated by evaluation and modification of a previously published SA definition list from the National Center for Health Statistics (NCHS) (Hedegaard et al., 2018). This list included all intentional self-harm codes from both ICD version 9 and 10. An international team of expert clinicians (Mann, Monson, Serretti, Smoller, Sokolowski, Stein) reviewed ICD codes, considering the potential for misclassification and acceptable error rate. All members of the clinician team were given the opportunity to review the complete list of ICD codes independently, and multiple live team discussions were held. These discussions included utilization of supporting phenomenological literature to resolve intent in cases of undetermined and accidental code assignments, as described above, to develop the final consensus ICD lists. Disagreements regarding the inclusion or exclusion of specific codes or injury categories were formally discussed by the group, with consideration of literature evidence and clinical experience. Final lists required approval from all team members.

Two lists for SA classification were generated to address the inherent complexity of intent determination. The first ICD list was focused on behaviors considered more specific to SA, serving as the primary phenotype definition for SA (SA Narrow). SA Narrow contains most intentional self-harm ICD codes and a selection of undetermined intent codes. In determining codes for the SA Narrow ICD definition, careful consideration was given to potential overlap between SA and nonsuicidal self-injury (NSSI) when selecting codes. This was particularly challenging considering that terms like self-harm and suicidality may be used interchangeably in different settings throughout the world. Because of this complexity, determination of suicidal intent must rely upon phenomenological characteristics to help separate NSSI from SA. For example, NSSI typically involves repetitive cutaneous/shallow injuries like cutting, burning, or banging the head or part of the body against something hard (Carroll et al., 2016; Fernando et al., 2022; Kimbrel et al., 2018; Lloyd-Richardson et al., 2007). Such injuries are more likely to be NSSI and not SAs and were intentionally excluded from the SA Narrow definition. Conversely, some codes/injuries tend to be more clearly associated with SAs and not NSSI, even when intent is undetermined. This includes certain types of poisoning (using hormones, especially insulin, antiepileptics, analgesics, psychotropics, hydrochloric acid, and carbon monoxide), drowning, stabbing instead of smaller repetitive parallel cuts, jumping from a height or in front of a train/vehicle, hanging, and self-inflicted gunshot wounds (Austin et al., 2017; Hsieh et al., 2018; Johansen and Christensen, 2018; Lohner and Konrad, 2006; Nada-Raja et al., 2004; von Mach et al., 2004). Undetermined intent codes related to these injury types were added to SA Narrow. Therefore, SA Narrow ICD codes were selected, by group consensus, with the intent of optimizing the potential sensitivity and specificity tradeoff (Randall et al., 2017).

The second ICD code list was generated to serve as a broader (SA Broad), more sensitive, but less specific, definition of SA. To be more inclusive, codes indicative of both SA and NSSI were included. Specifically, the SA Broad list includes all intentional and undetermined self-harm ICD codes, including those excluded from SA Narrow. In addition, accidental codes that correspond with undetermined intent codes included in the SA narrow list, for the reasons explained above, were also included in the SA Broad list.

Codes for generating ICD SA lists were obtained from separate sources for ICD-9 and ICD-10 codes, including international and United States versions of these lists. ICD-10 and ICD-10-CM (United States) code lists were obtained from <https://icd.who.int/browse10/2019/en/#/> and <https://www.cdc.gov/nchs/icd/Comprehensive-Listing-of-ICD-10-CM-Files.htm>, respectively. ICD-9 and ICD-9-CM code lists were obtained from <https://apps.who.int/iris/handle/10,665/39,473> and <https://www.cdc.gov/nchs/icd/icd9cm.htm>, respectively.

## 2.2. SI and SA ICD list validation cohorts

The codes in a total of four ICD lists, including SI, SA Narrow, SA Broad, and published SA NCHS (Hedegaard et al., 2018) lists, were validated in multiple United States-based datasets. Datasets were selected that contained both ICD and Columbia Suicide Severity Rating Scale (C-SSRS) (Posner et al., 2011) screening, or equivalent data. Data sharing agreements required that each dataset be analyzed within institutions

of data origin, with only summary data produced from analyses being shared with us. These data restrictions limited individual level analyses, including individual level ICD and demographic analyses, except for stratification by sex. Each of the validation cohorts have been previously described in detail, as referenced, with brief descriptions of available shared data summarized in Table 2.

The first validation cohort is derived from the Cooperative Studies Program #572 (**CSP572**), formally entitled “Genetics of Functional Disability in Schizophrenia and Bipolar Illness Validation.” This cohort was collected to evaluate genetic and other characteristics of veterans with severe chronic psychiatric illness (Bigdeli et al., 2024, 2021). Two timepoints were available for evaluation in this cohort: records available before (**CSP572-BE**) and after (**CSP572-AE**) formal enrollment in the CSP572 study. All participants in CSP572 received C-SSRS screening. Both timepoints were assessed to identify impact on ICD code performance, with CSP572-BE serving as proxy for “care as usual” versus a systematically screened psychiatric population (CSP572-AE).

The remaining validation cohorts arose from Vanderbilt University Medical Center (**VUMC**) via two independently ascertained populations. First, through de-identified VUMC medical record data from a research-oriented data repository, Synthetic Derivative (Roden et al., 2008). Synthetic Derivative (**VUMC-SD**) represents a general clinical population seen in all care settings within the VUMC system. Records from the VUMC-SD were screened via a natural language processing (**NLP**) protocol to identify patients with a history of SI or SA within narrative clinical records. Records identified by NLP were reviewed through manual validation for evidence of SI/SA (Bejan et al., 2022). The second VUMC cohort represents individuals seen at a psychiatric assessment service (**VUMC-Psych**) who completed self-reported screening for SI and/or SA (Bejan et al., 2022). Together, these two populations provide data within population/general clinic obtained (VUMC-SD) and acute psychiatric (VUMC-Psych) populations.

All data were handled in accordance with oversight and ethical approval from the Veterans Affairs Central Institutional Review Boards and Vanderbilt University Medical Center, as previously described.

### 2.3. Validation analytical method

After defining code lists and validation samples, criteria were selected for defining positive SI and SA cases. Requiring two or more positive ICD definition codes per case individual has been observed to increase accuracy in some phenotypes (Wei et al., 2016). However, this “rule of two” requirement is suspected to be less helpful for rare, acute, and time-limited conditions (Bastarache, 2021), all of which apply to suicidality. Therefore, a single code was elected to denote a positive SI or SA case for this evaluation. Questionnaire results were the gold standard against which ICD performance was measured. Positive ICD results were categorized as true positives if the individual had a positive instrument/screening/NLP response for prior SI/SA and as false positives if the individual had a negative questionnaire response. Negative ICD results were categorized as true and false negatives based on whether the instrument data for each corresponding individual were negative or positive for prior SI or SA, respectively. Sensitivity, specificity, and positive predictive values, along

with associated confidence intervals, were calculated for each of the four evaluated ICD lists in each population. In addition, EHR-defined sex-stratification analyses were performed for all groups.

### 3. Results

#### 3.1. SA ICD code lists

The SA Narrow and Broad ICD lists are summarized in Table 3, with complete lists of individual ICD codes for all lists available in Supplemental Tables S1 and S2. A single occurrence of any of the listed codes in a patient's EHR is considered a positive result because of infrequent SI/SA ICD coding in clinical records that results in under ascertainment of SI/SA even for use of single ICD coding. Choice of the Broad or Narrow list for defining suicidality phenotypes should be based on the composition of a given study population and aims of the study. Results in the assessed samples are representative of the varied performance of ICD codes that researchers may encounter in different study populations. Performance across the datasets and phenotypes is demonstrated within Table 4.

#### 3.2. SI ICD performance

A single SI list, composed of two ICD codes, was used to evaluate ICD performance versus instrument and NLP methods across the cohorts. SI ICD performance is visualized in Fig. 1. ICD sensitivity for SI had a range of 29.4 % to 86.1 % across the validation cohorts. Specificity and positive predictive value ranges were more consistent: 64.2 % to 90.6 % and 0.67 to 0.98, respectively.

#### 3.3. SA ICD performance

Three SA lists were evaluated across the cohorts, including the previously published NCHS list and the SA Narrow and Broad lists. Performance of each list across evaluated cohorts is visualized in Fig. 2. Sensitivity values ranged from 15.2 % to 71.1 % across the cohorts, with more consistent specificity and positive prediction values ranges from 67.6 % to 96.7 % and 0.68 to 0.92, respectively. Importantly, these values tended to vary more by cohort than by the ICD list used, as explored below. However, list-specific patterns emerged that were consistent with predictions, with the SA Narrow and NCHS lists having higher specificity and PPV, and the SA Broad list having greater sensitivity.

#### 3.4. Comparative performance among validation cohorts

Sensitivity performance showed wide variation across the cohorts. In general, the CSP572 cohorts, selected for chronic mental health issues, showed low sensitivity for detection of prior SA (15.2 % to 25.6 %) and SI (29.4 % to 48.9 %). In both SI and SA, all lists were more sensitive after study enrollment (CSP572-AE) as compared with general medical record coding available before formal study enrollment (CSP572-BE). VUMC populations, selected for prior suicidality (VUMC-SD) or acute psychiatric evaluations (VUMC-Psych) generally showed higher ICD sensitivity performance for SA (30.7 % to 71.1 %) and SI (56.8 % to 86.1 %).

Conversely, specificity and PPV tended to be generally lower in the VUMC populations. This was especially the case for SA Broad list specificity, which had a range of 67.6 % to 73.9 % in the VUMC samples versus 90.6 % to 95.1 % in the CSP572 samples. PPV showed best ICD performance in the VUMC-SD group for both SA and SI (ranging from 0.81 to 0.98) perhaps because this group was specifically selected for individuals having evidence of either SA or SI, and clinicians would have been more likely to use such ICD codes for this group.

### 3.5. Sex stratification results

Stratification by sex was also examined for all datasets and is reported in supplemental Table S3. It is noted that, across all populations, screening for SI in males showed consistently higher sensitivity and frequently higher specificity compared with females (range of an absolute difference of 1.7–11.6 % in sensitivity, and 2.1–3.3 % in specificity). SI and SA positive predictive values were similar within each sample between males and females. No clear/consistent differences by sex were observed for sensitivity or specificity within SA.

## 4. Discussion

The results of this study represent a systematic effort by the PGC Suicide Working Group to improve guidance for using ICD codes to define suicidality phenotypes and to establish consistent definitions that will be utilized by this workgroup, and the field more broadly, for evaluating ICD datasets. Our results are consistent with other studies in finding that ICD codes are generally much less sensitive at detecting suicidality than instruments or NLP algorithms (Bejan et al., 2022; Bigdeli et al., 2024; Lepow et al., 2024). This has important implications for any study using ICD coding to detect suicidality, as prevalence of suicidality will be underestimated and undetected suicidality will be present within comparison populations. This may contribute to more conservative and/or missed genetic and other findings that rely on ICD codes.

### 4.1. Population characteristics and coding practices impact performance of ICD codes

We find variability of performance in ICD codes across data sets ascertained from different sources. Such results indicate that ICD coding is impacted by several known factors. These factors include 1) lack of uniform standards for clinician coding training; 2) variable clarity, accuracy, described intent, and completeness of patient history; 3) insurance and administrative billing requirements driving ICD coding practice; 4) differences in how region and institutional culture regard SI/SA; and 5) potential liability or legal implications of assigning a suicidality code (O'Malley et al., 2005). It is reasonable to assume that SI/SA may not be coded unless they are the primary reason for evaluation.

We found codes captured, at best, 86 % of SI cases and 71 % of SA cases identified via instruments or NLP/manual review but more frequently found <50 % of cases. However, when codes were present, they demonstrated good specificity and positive predictive values across all the samples. Thus, as expected, level of ascertainment affected sensitivity and not specificity. Additionally, the proposed ICD definitions showed performance metrics that fell

within the range of other published studies (Sveticic et al., 2020; Swain et al., 2019; Walkup et al., 2012).

Importantly, the proposed definitions were least effective at identifying suicidality in the general psychiatric samples (CSP572-BE and AE). This finding points to a potential area for improvement in coding practices. In particular, emphasizing the importance of coding for SI and SA as a strategy for detecting/increasing visibility of patients at higher risk of suicidal behavior. In addition, such findings emphasize the need for applying methods, such as NLP, for more effectively identifying risk and implementing prevention (Walsh et al., 2017). Finally, to avoid risk of further reducing sensitivity, it is recommended that a single positive suicidality ICD code be sufficient to define a positive case in suicidality studies due to the acute and time-limited nature of the events captured in these codes (Bastarache, 2021).

Low sensitivity in the CSP572 cohort may also point to differences in clinical culture or routine. For example, it has been noted that psychiatric emergency rooms routinely evaluate suicidality cases (Grudnikoff et al., 2015). As such, providers in these settings may be more likely to code suicidal events via ICD, leading to improved capture and ICD sensitivity, as seen in the VUMC-Psych sample. Populations routinely assessed for other, non-acute reasons, however, may be less likely to receive specific ICD coding for prior suicidal events. This may be the case within the CSP572 cohort, which represents a population assessed and managed for significant and chronic psychiatric illness. It is worth noting that following instrument screening of the CSP572 cohort, the sensitivity of ICD coding did increase substantially. This suggests that incorporation of systematic screening may also lead to increased suicidality ICD coding.

Importantly, clinical familiarity with specific populations may also change ICD performance and coding patterns. Specifically, within the VA system CSP572 cohorts (where the majority of patients are male) specificity and sensitivity were higher in males than in females in most analyses. An opposite pattern, where females tended to have higher sensitivity and specificity, was observed within the VUMC populations, which had a more even male/female distribution. It is not clear whether these sex-specific differences are representations of actual clinical differences within males and females in these populations, or whether this is the result of coding practices and potential bias within specific settings. It is noted, however, that the majority of these differences were not significant as denoted by overlapping confidence intervals in Supplemental Table S3. It is also worth noting that the evaluation of lifetime suicidality and correspond EHR codes in CSP572 predated the VA's implementation of universal suicide risk screening in routine care settings (Gujral et al., 2023). These observations, however, may also underscore other systematic differences in the way suicidality is screened and reported in men and women. The ability to explore this issue within the presented data is limited by access to only summary results. However, future work examining the types and settings of coding in male and female patients may help to clarify some of these systematic differences.

Finally, regardless of the cause of the variations in sensitivity and specificity, it is critical to appreciate the potential impact of using ICD coding as a primary phenotype definition in suicidality. Because sensitivity may be lower within studies relying only on ICD definitions,

caution should be used in the interpretation of results. Specifically, low sensitivity may miss true cases and lead to retention of more individuals with a history of suicidality within control/comparison populations, both of which would contribute to attenuation of results and require larger sample sizes to identify significant findings. However, this limitation may be offset by the larger size of real-world population and healthcare system datasets, providing more statistical power. Therefore, inclusion of ICD datasets should be carefully considered based on these tradeoffs, and their limitations should be clearly described in studies relying on these definitions.

#### 4.2. Implementing proposed ICD definitions

The SA Narrow list should be used as a highly specific but less sensitive definition to improve homogeneity of analyses. For large-scale GWAS, the SA Narrow definition could reduce heterogeneity and contribute to better estimates of explained variance and more consistent/reproducible findings. In such cases, the SA Broad list could be used to screen control/comparison populations. However, the SA Broad list also showed consistently higher sensitivity with only modest decrease in specificity and PPV in most of the assessed samples. In smaller clinical and genetic studies, utilizing the SA Broad list as a definition may more realistically capture the population most at risk for future suicidal behavior. This is an important consideration as the two lists were designed with an emphasis on distinguishing SA from NSSI, but both increase risk for future suicidal behavior and suicide death.

Ultimately, the optimal strategy to define a given suicidality phenotype and control populations may vary based on available information, sample size, and the study question. Regardless of the strategy employed, a clear explanation of the rationale and design of the sample is recommended to aid future replication and meta-analysis efforts.

#### 4.3. Study limitations

The proposed ICD lists are designed to be simple, portable, and widely implementable. Alternative and potentially superior strategies that make use of rating scales, multi-ICD code inclusion/exclusion algorithms, AI-assisted coding, and natural language processing were not evaluated in this study. In particular, models that use multiple codes or EHR elements may more effectively distinguish suicidal behaviors from NSSI (Huang et al., 2020). However, methods listed are also not yet standardized and require more extensive access to individual records or resources than many studies may have. Future iterations of this protocol may include consideration of these strategies as they mature.

In addition, because the ICD code validation was also performed only within United States cohorts, further work to establish generalizability to international settings is warranted. Even other US samples may vary in clinical documentation practices and systemic biases, including racial bias, in psychiatric diagnoses (van der Ven et al., 2024). Therefore, future work on additional large datasets that include international and more diverse ascertainment strategies would be beneficial.

#### 4.4. Conclusion

The proposed SI and SA Narrow/Broad definition ICD lists from this workgroup have been designed to improve the consistency and comparability of suicide genetics study populations. However, there is still a problem with under ascertainment when relying solely on ICD codes. More consistent training in the use of ICD codes, using definitions like those presented here, would improve comparability of results across sites.

It is recommended that any suicidality research effort provide clear description of selection criteria and rationale for the design in terms of choosing between the Narrow and Broad ICD SA lists of codes. It will also be critical for authors to clearly define limitations in the use of ICD definitions, including consideration of how different clinical sites and international datasets may impact the accuracy of ICD coding definitions. Use of these lists and better sample description will improve results of individual studies and enhance comparison of results across studies.

#### Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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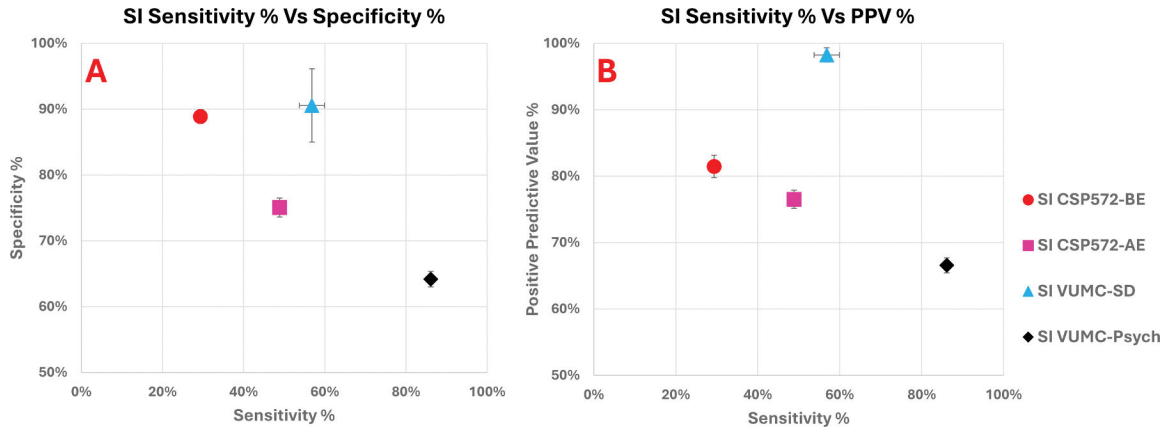
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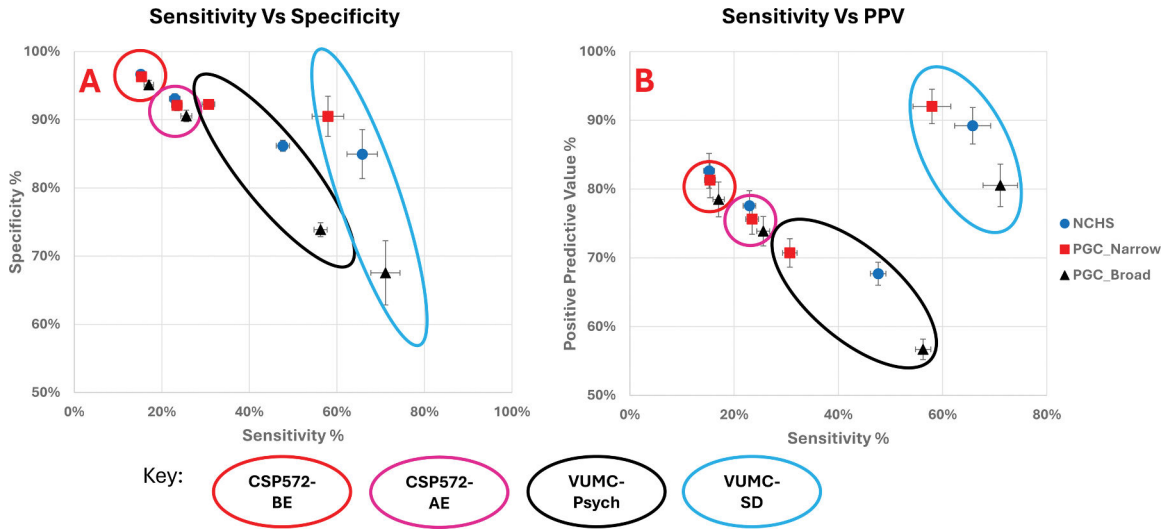
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**Fig. 1. SI Sensitivity, Specificity, and PPV plots.**

Scatter plots representing performance metrics for suicidal ideation codes within the evaluated samples. Panel A demonstrates plotted sensitivity vs specificity and Panel B demonstrates plotted sensitivity vs positive predictive value (PPV). 95 % confidence intervals for each plotted metric are represented by whiskers. Marker colors and shapes represent the four assessed populations/timepoints, with red circles = CSP572-BE, magenta squares = CSP572-AE, blue triangles = VUMC-SD, and black diamonds = VUMC-Psych.



**Fig. 2. SA sensitivity, specificity, and PPV plots.** Scatter plots representing performance metrics for suicide attempt (SA) code lists, including the published NCHS, PGC Narrow, and PGC Broad lists. Panel A demonstrates plotted sensitivity vs specificity and Panel B demonstrates plotted sensitivity vs positive predictive value (PPV). 95 % confidence intervals for each plotted metric are represented by whiskers. Marker colors and shapes represent the three assessed lists, with blue circles = NCHS published list, red squares = PGC–Narrow list, and black triangle = PGC-Broad list. Colored outlines represent the four assessed populations/timepoints, with red = CSP572-BE, magenta = CSP572-AE, blue = VUMC-SD, and black = VUMC-Psych.

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**Table 1**

Definitions of suicide and self-harm phenotypes.

Phenotype (Abbreviation)	Phenotype Definition	Aggregated Phenotype (Abbreviation)	
Suicidal ideation (SI) <sup>a</sup>	Thoughts of engaging in suicide-related behavior (Crosby et al., 2011).		
Suicide attempt (SA) <sup>b</sup>	A non-fatal self-directed potentially injurious behavior with any intent to die as a result of the behavior. A suicide attempt may or may not result in injury (Crosby et al., 2011).	Suicidality/ Suicidal thoughts and behaviors (STBs)	Suicidal behavior (SB)
Suicide death (SD) <sup>b</sup>	Death caused by self-directed injurious behavior with any intent to die as a result of the behavior (Crosby et al., 2011).	Deliberate self-harm (DSH)	
Non-suicidal self-injury (NSSI) <sup>b</sup>	The intentional self-inflicted destruction of body tissue without suicidal intention and for purposes not socially sanctioned (Cipriano et al., 2017)		

<sup>a</sup>Thoughts.

<sup>b</sup>Behaviors.

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**Table 2**

Summary of validation cohorts.

<b>Cohort</b>	<b>N</b>	<b>% Female</b>	<b>Sample Characteristics</b>
CSP572-BE	9151	13.8 %	Military veteran population with severe chronic mental health diagnoses (bipolar disorder and schizophrenia) ascertained before and after study enrollment and systematic screening.
CSP572-AE	9151	13.8 %	
VUMC-SD	1095	56.8 %	Individuals with SI/SA selected from a general clinical population.
VUMC-Psych	11,526	52.5 %	Individuals seen in an acute psychiatric treatment setting.

Key: CSP = Cooperative Studies Program, BE = Before enrollment; AE = After enrollment; VUMC = Vanderbilt University Medical Center; SD = Synthetic Derivative; Psych = Psychiatry.

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**Table 3**

Suicide attempt (SA) broad and narrow ICD code list.

ICD Version	Code_Group_Description	Codes
9_CM	Attempt via poison or toxic ingestion	E950.0-E950.9
9_CM	Attempt via poison or toxic Inhalation	E951.0-E951.8; E952.0-952.9
9_CM	Attempt via asphyxiation or drowning	E953.0-E953.9;E954
9_CM	Attempt via firearm	E955.0-E955.9
9_CM	Attempt via jumping, crashing, or exposure	E957.0-E957.9;E958.0; E958.1;E958.3-E958.9
9_CM	Late effects of self-inflicted injuries	E959
9_CM	Undetermined intent, asphyxiation/drowning	E983.0-E983.9;E984
9_CM	Undetermined intent, firearm injury	E985.0-E985.7
9_CM	Undetermined intent, fall, jumping, crash, exposure	E987.0-E987.9;E988.0- E988.1;E988.3-E988.7
9_CM	<b>Accidental fall from building</b>	<b>E882</b>
9_CM	<b>Accidental injury from firearm</b>	<b>E922.0-E922.9</b>
9_CM	<b>Self-inflicted injury via cutting/piercing instrument</b>	<b>E956</b>
9_CM	<b>Self-inflicted injury via scald</b>	<b>E958.2</b>
9_CM	<b>Undetermined intent, poisoning</b>	<b>E980.0-E980.9; E981.0-E981.8; E982.1-E982.9</b>
9_CM	<b>Undetermined intent, cutting</b>	<b>E986</b>
9_CM	<b>Undetermined intent, scald</b>	<b>E988.2</b>
9_CM	<b>Undetermined intent, other or undefined method</b>	<b>E988.8-E988.9</b>
9_CM	<b>Undetermined intent, late effects of injury</b>	<b>E989</b>
10_CM	<b>Nonsuicidal self-harm</b>	<b>R45.88</b>
10_CM	Suicide attempt	T14.91;*A,*D,*S
10_CM	Intentional or <b>undetermined</b> poisoning via medications, elements, compounds, venom, and other ingested or applied agents	T36-T65;**2,**2A, **2D,**2S,**4A,**4D,**4S
10_CM	Intentional or <b>undetermined</b> asphyxiation	T71:**2,**2A,**2D, **2S,**4A,**4D,**4S
10_CM	Undetermined and <b>accidental</b> intent, injury by hanging	T71.16;4A, 4D, 4S, 1A,1D,1S
10_CM	<b>Accidental fall from building</b>	<b>W13.4, W13.8, W13.9;4**A, 4**D, 4**S</b>
10_CM	<b>Accidental discharge of firearm</b>	<b>W32.0, W33.0, W34.0; **A, **D, **S</b>
10	Intentional poisoning	X60-X69
10	Intentional asphyxiation	X70
10_CM	Intentional drowning	X71;**XA,**XD,**XS
10_CM	Intentional firearm injury	X72-X74;**XA,**XD,**XS
10_CM	Intentional explosive or fire injury	X75-X76;**XA,**XD,**XS
10_CM	<b>Intentional injury by hot object/substance</b>	<b>X77;**XA,**XD,**XS</b>
10_CM	<b>Intentional injury by any sharp object</b>	<b>X78;*XA,*XD,*XS</b>
10_CM	<b>Intentional injury by blunt object</b>	<b>X79;**XA,**XD,**XS</b>
10_CM	Intentional injury by jumping, crashing, electrocution, or exposure	X80-X83;**XA,**XD,**XS
10	<b>Intentional harm by unspecified means</b>	<b>X84</b>

ICD Version	Code_Group_Description	Codes
10	<b>Poisoning, various ingested/inhaled agents</b>	<b>Y10-Y21</b>
10_CM	Undetermined intent, drowning	Y21;**XA,**XD,**XS
10	Undetermined intent, firearm injury	Y22-Y24
10_CM	Undetermined intent, firearm injury	Y22-Y24;**XA,**XD,**XS
10	Undetermined intent, explosives or fire injury	Y25-26
10_CM	Undetermined intent, explosives or fire injury	Y25-Y26;**XA,**XD,**XS
10_CM	Undetermined intent, falling, jumping, or crashing	Y30-Y32;**XA,**XD,**XS
10	Sequelae of intentional self-harm	Y87
10	<b>Undetermined intent, injury by hot object/substance</b>	<b>Y27</b>
10_CM	<b>Undetermined intent, injury by hot object/substance</b>	<b>Y27;**XA,**XD,**XS</b>
10	<b>Undetermined intent, injury by sharp object</b>	<b>Y28</b>
10_CM	<b>Undetermined intent, injury by sharp object</b>	<b>Y28;**XA,**XD,**XS</b>
10	<b>Undetermined intent, injury by blunt object</b>	<b>Y29</b>
10_CM	<b>Undetermined intent, injury by blunt object</b>	<b>Y29;**XA,**XD,**XS</b>
10	Undetermined intent, falling, jumping, or crashing	Y30-Y32
10_CM	<b>Suicide attempt, alleged or ruled out</b>	<b>Z03.89</b>
10_CM	<b>Personal history of self-harm</b>	<b>Z91.5</b>
10_CM	Personal history of suicidal behavior (attempt)	Z91.51
10_CM	<b>Personal history of nonsuicidal self-harm</b>	<b>Z91.52</b>

Key: \* = wildcard placeholder for alphanumeric values used in all ICD-10 code specifiers, inclusive; all ICD-10 codes presume inclusion of the base code prior to the semi-colon (without specifiers). Bolded codes are those present only in the SA Broad list and unbolded codes are included in both the Broad and Narrow ICD lists.

**Table 4**  
Suicidal ideation and attempt list validation results versus instrument responses in evaluated populations.

ICD List	Cohort	TP N	FP N	TN N	FN N	SN (95 % CI)	SP (95 % CI)	PPV (95 % CI)
<b>SI</b>								
SI Codes	CSP572-BE	1678	382	3054	4037	29.4 % (28.2 %, 30.5 %)	88.9 % (87.8 %, 89.9 %)	0.814 (0.798, 0.831)
SI Codes	CSP572-AE	2793	857	2579	2922	48.9 % (47.6 %, 50.2 %)	75.1 % (73.6 %, 76.5 %)	0.765 (0.751, 0.779)
SI Codes	VUMC-SD	562	10	96	427	56.8 % (53.7 %, 59.9 %)	90.6 % (85.0 %, 96.1 %)	0.983 (0.972, 0.993)
SI Codes	VUMC-Psych	4497	2258	4046	725	86.1 % (85.2 %, 87.1 %)	64.2 % (63.0 %, 65.4 %)	0.666 (0.654, 0.677)
<b>SA</b>								
NCHS List	CSP572-BE	710	149	4330	3962	15.2 % (14.2 %, 16.2 %)	96.7 % (96.1 %, 97.2 %)	0.827 (0.801, 0.852)
SA Narrow	CSP572-BE	718	165	4314	3954	15.4 % (14.3 %, 16.4 %)	96.3 % (95.8 %, 96.9 %)	0.813 (0.787, 0.839)
SA Broad	CSP572-BE	796	218	4261	3876	17.0 % (16.0 %, 18.1 %)	95.1 % (94.5 %, 95.8 %)	0.785 (0.760, 0.810)
NCHS List	CSP572-AE	1072	310	4169	3600	23.0 % (21.7 %, 24.2 %)	93.1 % (92.3 %, 93.8 %)	0.776 (0.754, 0.798)
SA Narrow	CSP572-AE	1096	353	4126	3576	23.5 % (22.2 %, 24.7 %)	92.1 % (91.3 %, 92.9 %)	0.756 (0.734, 0.778)
SA Broad	CSP572-AE	1196	423	4056	3476	25.6 % (24.3 %, 26.9 %)	90.6 % (89.7 %, 91.4 %)	0.739 (0.717, 0.760)
NCHS List	VUMC-SD	471	57	322	245	65.8 % (62.3 %, 69.3 %)	85.0 % (81.4 %, 88.6 %)	0.892 (0.866, 0.919)
SA Narrow	VUMC-SD	415	36	343	301	58.0 % (54.3 %, 61.6 %)	90.5 % (87.5 %, 93.5 %)	0.920 (0.895, 0.945)
SA Broad	VUMC-SD	509	123	256	207	71.1 % (67.8 %, 74.4 %)	67.6 % (62.8 %, 72.3 %)	0.805 (0.775, 0.836)
NCHS List	VUMC-Psych	2035	971	6057	2236	47.7 % (46.1 %, 49.1 %)	86.2 % (85.4 %, 87.0 %)	0.677 (0.660, 0.694)
SA Narrow	VUMC-Psych	1311	543	6485	2960	30.7 % (29.3 %, 32.1 %)	92.3 % (91.6 %, 92.9 %)	0.707 (0.686, 0.728)
SA Broad	VUMC-Psych	2403	1836	5192	1868	56.3 % (54.8 %, 57.8 %)	73.9 % (72.8 %, 74.9 %)	0.567 (0.552, 0.582)

Key: TP = true positive; FP = false positive; TN = True negative; FN = False negative; SN = Sensitivity; N = counted total number of individuals; SP = Specificity; PPV = Positive Predictive Value; SA = Suicide attempt; NCHS List = National Center for Health Statistics published ICD list; BE = ICD records collected before study enrollment; AE = ICD records obtained after study enrollment; VUMC = Vanderbilt University Medical Center; SD = Synthetic Derivative general clinical sample with identified suicidality; Psych = psychiatric urgent clinic samples; CI = confidence interval.