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Research paper

Network modeling of anxiety and psychological characteristics on suicidal behavior: Cross-sectional study

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ABSTRACT

Background: Suicide is influenced by complex interactions among various psychopathological features. We aimed to examine the relationship between suicide risk and psychological risk factors such as defense mechanisms, personality, and anxiety.
Methods: We established a psychiatric database by utilizing the Observational Medical Outcomes Partnership Common Data Model. We conducted a 1:1 propensity score matching with age, sex, and depression severity, and identified a sample (n = 258) with two groups: those with suicidal behavior and those with non-suicidal behavior. Using principal component analysis, we extracted nine psychological scales and applied network analysis to compare relationships among psychological factors between the two groups.
Results: Patients with non-suicidal behaviors showed associations between trait anxiety and defense mechanisms, while those with suicidal behaviors did not. For patients with suicidal ideation there was an association between somatization and trait anxiety. Patients with suicide attempts showed associations between paranoia and dissociation connected to trait anxiety.
Limitations: Longitudinal research is required to fully observe transitions from suicidal ideation to attempts and recurrent suicidal events. In addition, these networks may not generalize suicidal behaviors because the group participants are not homogeneous. Lastly, data from self-report questionnaires limits the reliability of responses.
Conclusions: We presented important new insights on suicidal behavior by estimating psychological networks. Patients with non-suicidal behavior may exhibit discrete relationships between defense mechanisms and anxiety, compared to those with suicidal behavior. Patients with suicidal ideation and suicide attempts may show distinct associations between anxiety and psychopathological features.

1. Introduction

Suicide has classically been associated with depression, but there is mounting evidence that it may also be associated with anxiety (Placidi et al., 2000; Bentley et al., 2016). Although anxiety is highly correlated to depression and often comorbid, its role in suicide is not clearly understood (Kanwar et al., 2013). Studies that have addressed this association have focused on state anxiety as a risk factor of suicide, but this research could greatly benefit by considering state anxiety and trait anxiety separately (Ohring et al., 1996; Goldston et al., 2006). State

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anxiety describes a critical, cross-sectional evaluation of anxious symptoms, while trait anxiety describes a more prevalent aspect of anxiety symptoms. Consequently, trait anxiety is often associated with personality features. State and trait anxiety can respond to different situations separately; hence this variation between state and trait anxiety is an important conceptualization in anxiety assessment (Leal et al., 2017).

Suicide is an outcome influenced by complex interactions of different psychopathologies (De Berardis et al., 2018). Evaluating an individual's characteristics, such as depression, anxiety, and personality, is crucial for understanding suicidal behaviors (Conwell et al., 1996; Lee et al., 2017; Packman et al., 2004). Defense mechanisms help reduce anxiety and protect the self against harmful thoughts or feelings. Therefore, individuals with impaired defense mechanisms are at a significantly increased risk for such harmful behaviors (Waqas et al., 2015). Moreover, the defense mechanism adopted by an individual may explain how their personality functions (Granieri et al., 2017). As a single domain of psychopathology does not fully explain complex suicidal behaviors, a network of psychopathologies might depict accurately the complex relationships between personality features and suicidal behavior. Therefore, investigating measures of personality and defense mechanisms along with anxiety may improve the assessment of suicide risk by untangling this complicated relationship and finding the most influential psychopathologic features.

Network analysis can explore complex patterns of relationships among various and diverse psychopathologies and reveal the core features of that network (Hevey, 2018). Graph theory (Harary and Norman, 1953) can provide new insights into the overall formulation of suicide risk. Therefore, we applied network analysis to investigate hidden relationships among psychological factors and anxiety in the context of suicidal behavior. A network perspective on suicide may help us identify which components are central (i.e., hubs) and which factors are related.

Through network analysis, we aimed to examine the relationship between the risk of suicide and incorporating influences of psychological risk factors, defense mechanisms, and personality along with anxiety. The network attributes are used to identify characteristics that differentiate patients with suicidal ideation from suicide attempts.

2. Method

We described all research procedures, including the database, measures, and analyses in Fig. 1, which are detailed below.

2.1. Database

Data were sourced from the Department of Psychiatry and Mental Health Center at Ajou University Medical Center from 2010 to 2018 and converted into the Observational Medical Outcomes Partnership Common Data Model (OMOP) Common Data Model (CDM) 6.0 (available at https://ohdsi.github.io/CommonDataModel/cdm60.html) in combination with a de-identification procedure (Voss et al., 2015). This 9-year database includes data of 32,491 psychiatric patients, including psychological reports, drug treatment plans, past medication, present illness, history of psychiatric disorder, admission notes, emergency room notes, evaluations and plans, and psychiatric referral notes. OMOP CDM is a standardization protocol with the same format and contents, requiring the same vocabulary and concepts. This standardized database enables us to participate in a distributed research network and conduct a multi-centered study (Yoon et al., 2016; Makadia and Ryan, 2014).

2.2. Measures

We considered three psychological test batteries to assess various psychological and psychopathological features: Ewha Defense Mechanisms (EDMT), Minnesota Multiphasic Personality Inventory-2 (MMPI-2), and Spielberger's State-Trait Anxiety Inventory (STAI). All scores of subscales are composite scores calculated by taking the sum of the items for each scale.

2.2.1. Ewha defense mechanisms test (EDMT)

EDMT (Kim et al., 1991) was developed to measure participants' defense mechanisms reflecting cultural characteristics and contexts by traditional Korean proverbs. It consists of 20 measurement subscales of defense mechanism: *show-off, reaction formation, identification, passive-aggressive behavior, projection, displacement, denial, controlling, suppression, distortion, anticipation, rationalization, dissociation, somatization, sublimation, acting out, altruism, regression, humor,* and *evasion.* Each subscale has ten questionnaires using a 5-point Likert scale. Raw scores are converted into standardized scores from 0 to 10 for each subscale. Further detailed subscales of the EDMT are provided in the Additional file 1.

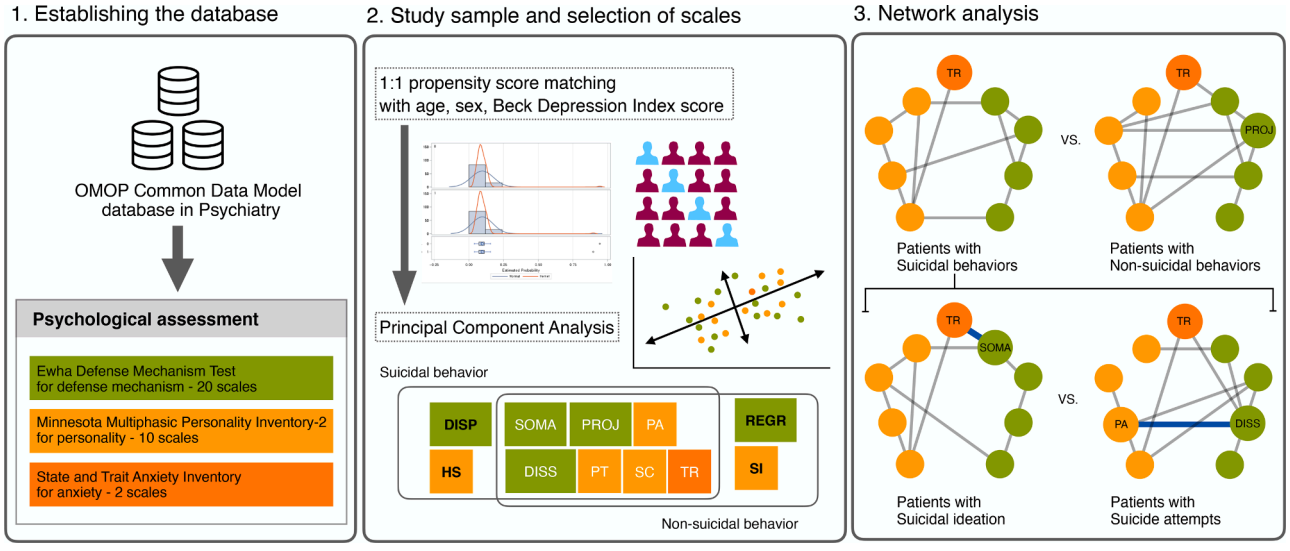

Fig. 1. Conceptualization of study flow. Abbreviation: SOMA: somatization; PROJ: projection; DISS: dissociation; DISP: displacement; REGR: regression; SC: schizophrenia; PT: Psychasthenia; PA: paranoia; HS: Hypochondriasis; SI: social introversion; TR: trait-anxiety.

2.2.2. Minnesota multiphasic personality inventory-2 (MMPI-2)

MMPI-2 (Butcher et al., 1989) was designed to assess adult psychopathology structure and personality traits using 567 true or false questions. The Korean version of MMPI-2 (Kim et al., 2005) was used in this study, and its reliability and validity were tested and found robust compared to the original MMPI-2. As a comprehensive result, four validity scores and ten clinical scores were drawn. Validity scores may assess the test taker's attitude and manner, so we used only ten clinical subscales: *hypochondriasis, depression, hysteria, psychopathic deviate, masculinity-femininity, paranoia, psychasthenia, schizophrenia, hypomania,* and *social introversion.*

2.2.3. Spielberger's state-trait anxiety inventory (STAI)

STAI (Spielberger et al., 1983) was designed to measure two types of anxiety, namely trait anxiety (T-anxiety) and state anxiety (S-anxiety). T-anxiety evaluates the proneness of stable and long-standing anxiety, while S-anxiety reflects current and temporal anxiety. It consists of 20 items for each anxiety. Total scores ranged from 20 to 80, with higher scores suggesting a higher level of anxiety. All scores in this analysis were t-standardized.

2.3. Participants

Observational records from patients (n= 8777) who visited the Department of Psychiatry and took at least one psychological assessment test were extracted from the Ajou OMOP CDM database. Fourteen psychological assessment tests and 812 scales were available in the database. Subjects with valid results for the STAI, EDMT, and MMPI-2 tests were included in this study. Data were retrospectively reviewed to identify patients with suicidal behavior (suicidal ideation and suicide attempts). Patients with suicidal ideation and suicide attempts were identified if patients ever visited the Emergency Department, and one of the patients' chief complaints during that visit was recorded as suicidal ideation or suicide attempts. The psychological test results of patients with suicidal behavior nearest to the date of suicidal behavior and patients with non-suicidal behavior at the latest available date were selected in the analysis. Patients with suicidal behavior took the test no later than two days, on average, after the date of suicidal behavior. Demographics, such as sex and age, were obtained from questionnaires.

Individual informed consent was waived because of fully anonymized and de-identified data. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. All procedures involving human subjects/patients were approved by the Institute Review Board of Ajou University and the ethics committee (AJIRB-MED-20–059).

2.4. Statistical analysis

2.4.1. Selection of sample

We explored basic demographics and employed propensity score matching (PSM) to match patients with suicidal and non-suicidal behavior. A 1:1 ratio was selected to increase statistical power and remove confounding factors when an imbalance existed. Propensity scores were calculated using a logistic regression model to predict suicidal behavior. The matching covariates in the logistic regression model were age, sex, and Beck Depression Index (BDI) to adjust for demographic factors and depression severity. We tested the differences between two groups on all scores for each test using the Wilcoxon rank-sum test or Chi-square test, as appropriate.

2.4.2. Estimation of networks

In this study, many more psychological scales were compared to study samples. To allow reasonable interpretation, we performed principal component analysis (PCA) to identify the most influential scales among all 32 test scales, which were t-standardized. PCA loadings quantify the contribution of each original variable to the component, and the first component explains the highest total variance. We selected a set of scales with a high loading (cutoff value = 0.65) with the first principal component. We conducted this analysis separately according to suicidal or non-suicidal behaviors, and anxiety was exclusively explored through two aspects (trait and state) to examine which aspect of anxiety was related to suicidal behavior.

Once we selected psychological scales according to the PCA loading, we estimated network structures separately for groups with suicidal and non-suicidal behavior. We listed node labels (variables and the abbreviations) in Table 1. Edges (or links) represented a statistical dependency between nodes. Blue and red edges indicate a positive and negative relationship, respectively. Thicker edges represent relatively large absolute weight and scale. The Gaussian graphical network model with the graphical lasso (Friedman et al., 2008) was selected to compute a sparse network. The EBIC glasso model created the network and visualized it using the R-package qgraph (v.1.6.5) (Epskamp et al., 2012). The tuning parameter for optimal model selection was chosen using the Extended Bayesian Information criterium (EBIC). The hyperparameter γ in EBIC was manually set as 0.25. For patients with suicidal behavior, networks were re-computed to identify characteristics in distinguishing patients with suicidal ideation and suicide attempts and compared two networks to investigate which edges differed significantly after Bonferroni correction using a two-tailed permutation test. The permutation test in edge difference between the two groups was repeatedly calculated 10,000 times to build sample distribution by resampling the observed data (Borkulo et al., 2017).

2.4.3. Network accuracy and stability

One of the concerns for network analysis raised in the literature is its replicability (Forbes et al., 2017; Steinley et al., 2017). Therefore, we addressed this issue and closely examined the accuracy of edge-weights and stability of node centrality indices, such as nodal strength, closeness, and betweenness of a network by data-driven non-parametric bootstrap methods (Epskamp et al., 2018). We computed a bootstrapped sampling distribution based on 10,000 bootstrap samples. We plotted bootstrapped 95% confidence intervals (CIs) of estimated edge-weights for edge-weight accuracy and a case-dropping subset bootstrap result for the stability of node centrality. The case-dropping subset bootstrap was used to see how stable the centrality order is retained after removing a subset of the data and justifying which centrality index is the most reliable. We assessed the stability and accuracy of the network using the R-package *bootnet* (v.1.4.3).

3. Results

3.1. Sample characteristics

We identified 1595 patients who took all three psychological tests. Among them, 129 (8%) indicated suicidal behaviors, 64 patients with suicidal ideation and 65 patients with suicide attempts. Of the 1595 patients, 129 patients with non-suicidal behaviors were propensity score matched with 129 patients with suicidal behaviors; these 258 patients comprise the overall sample. Following PSM, there were no significant differences in age, sex, and BDI between the two groups. BDI was high in both groups (Table 1). Concerning anxiety, T- and S-anxiety were not significantly different between the two groups. Compared to the non-suicidal behavior group, the suicidal behavior group had greater *Humor*, but lower *Psychasthenia, Schizophrenia*, and *Social introversion*. The sample characteristics of patients with suicidal ideation compared to those with suicide attempts are also summarized in Table 2. Compared to the group with suicidal ideation, those with suicide attempts had greater *Rationalization* but did not differ in any other way including *T- or S-anxiety*.

Table 1
Characteristic of the patients of suicidal and non-suicidal behavior.

Variable (abbreviation)	Overall (*n*= 258)	Non-suicidal behavior (*n*= 129)	Suicidal behavior (*n*= 129)	*P* value
Age	29.8 ± 13.3	29.1 ± 12.0	30.5 ± 14.4	0.78
Sex, Female, n (%)	140 (54%)	69 (53%)	71 (55%)	0.34
Beck Depression Index (BDI)	31.0 ± 31.5	30.9 ± 33.8	31.1 ± 29.1	0.85
Ewha Defense Mechanism Test (EDMT)				
Show-off (SHOW)	6.0 ± 2.0	5.7 ± 2.1	6.2 ± 2.0	0.14
Reaction formation (REAC)	5.2 ± 2.5	5.2 ± 2.5	5.1 ± 2.5	0.72
Identification (IDEN)	5.3 ± 2.6	5.2 ± 2.5	5.4 ± 2.7	0.50
Passive-aggressive behavior (PASS)	5.4 ± 2.5	5.3 ± 2.5	5.5 ± 2.5	0.51
Projection (PROJ)	6.6 ± 2.6	6.8 ± 2.6	6.5 ± 2.6	0.36
Displacement (DISP)	5.9 ± 2.5	6.1 ± 2.6	5.8 ± 2.5	0.26
Denial (DENI)	4.7 ± 2.3	4.7 ± 2.4	4.7 ± 2.3	0.73
Controlling (CONT)	4.3 ± 2.4	4.1 ± 2.5	4.6 ± 2.4	0.08
Suppression (SUPP)	4.5 ± 2.4	4.4 ± 2.4	4.6 ± 2.4	0.71
Distortion (DIST)	4.2 ± 2.4	4.1 ± 2.5	4.2 ± 2.3	0.54
Anticipation (ANTI)	4.4 ± 2.8	4.2 ± 2.5	4.6 ± 3.1	0.38
Rationalization (RAPT)	5.0 ± 2.2	4.9 ± 2.3	5.0 ± 2.1	0.91
Dissociation (DISS)	6.5 ± 2.5	6.6 ± 2.5	6.5 ± 2.6	0.77
Somatization (SOMA)	6.8 ± 2.5	6.8 ± 2.6	6.7 ± 2.5	0.67
Sublimation (SUBL)	4.5 ± 2.5	4.2 ± 2.5	4.8 ± 2.4	0.05
Acting out (ACTI)	6.6 ± 2.4	6.6 ± 2.5	6.7 ± 2.3	0.80
Altruism (ALTR)	4.7 ± 2.7	4.4 ± 2.5	5.0 ± 2.8	0.13
Regression (REGR)	6.7 ± 2.6	6.7 ± 2.7	6.7 ± 2.5	0.60
Humor (HUMO)	3.9 ± 2.4	3.6 ± 2.3	4.3 ± 2.5	0.02*
Evasion (EVAS)	6.6 ± 2.4	6.6 ± 2.6	6.7 ± 2.2	0.95
Minnesota Multiphasic Personality Inventory-2 (MMPI-2)				
Hypochondriasis (HS)	57.7 ± 11.4	58.4 ± 10.6	56.9 ± 12.1	0.13
Depression (D)	64.2 ± 14.2	65.3 ± 14.4	63.1 ± 13.9	0.20
Hysteria (HY)	58.3 ± 11.1	58.4 ± 11.3	58.2 ± 11.0	0.97
Psychopathic deviate (PD)	60.3 ± 12.1	60.9 ± 12.6	59.6 ± 11.6	0.35
Masculinity-Femininity (MF)	50.6 ± 10.9	49.8 ± 10.6	51.4 ± 11.3	0.30
Paranoia (PA)	66.6 ± 16.6	68.4 ± 16.8	64.8 ± 16.1	0.07
Psychasthenia (PT)	66.4 ± 14.3	68.3 ± 14.7	64.4 ± 13.6	0.03*
Schizophrenia (SC)	64.8 ± 14.4	67.1 ± 14.6	62.5 ± 13.9	0.01*
Hypomania (MA)	53.8 ± 11.1	53.2 ± 10.4	54.4 ± 11.7	0.56
Social Introversion (SI)	62.1 ± 14.3	64.4 ± 14.3	59.8 ± 13.9	0.01**
State-Trait Anxiety Inventory (STAI)				
State-anxiety (ST)	60.3 ± 12.4	61.0 ± 13.0	59.5 ± 11.7	0.16
Trait-anxiety (TR)	63.9 ± 12.9	64.7 ± 13.5	63.2 ± 12.2	0.29

Values were expressed as n (%), mean ± std unless otherwise noted. All scores of subscales are composite scores calculated by taking the sum of the items for each scale.
P values are based on the Chi-squared test for categorical variables and the Wilcoxon rank-sum test for continuous variables.
*$P < 0.05$.
**$P < 0.01$.
*** $P < 0.001$.

Table 2
Characteristic of the patients of suicidal ideation and attempts.

Variable (abbreviation)	Overall (*n*= 129)	Suicide attempts (*n*= 65)	Suicidal ideation (*n*= 64)	*P* value
Age	30.5 ± 14.4	30.5 ± 12.4	30.4 ± 16.3	0.23
Sex, Female, n (%)	71 (55%)	36 (55%)	35 (55%)	0.45
Beck Depression Index (BDI)	31.1 ± 29.1	28.7 ± 13.7	33.5 ± 38.9	0.72
Ewha Defense Mechanism Test (EDMT)				
Show-off (SHOW)	6.2 ± 2.0	6.1 ± 1.9	6.3 ± 2.1	0.76
Reaction formation (REAC)	5.1 ± 2.5	5.1 ± 2.3	5.1 ± 2.6	0.88
Identification (IDEN)	5.4 ± 2.7	5.5 ± 2.7	5.3 ± 2.7	0.53
Passive-aggressive behavior (PASS)	5.5 ± 2.5	5.2 ± 2.4	5.9 ± 2.5	0.10
Projection (PROJ)	6.5 ± 2.6	6.4 ± 2.7	6.6 ± 2.5	0.74
Displacement (DISP)	5.8 ± 2.5	5.8 ± 2.5	5.7 ± 2.4	0.65
Denial (DENI)	4.7 ± 2.3	4.7 ± 2.2	4.8 ± 2.3	0.75
Controlling (CONT)	4.6 ± 2.4	4.6 ± 2.4	4.5 ± 2.4	0.78
Suppression (SUPP)	4.6 ± 2.4	4.8 ± 2.4	4.5 ± 2.4	0.53
Distortion (DIST)	4.2 ± 2.3	4.2 ± 2.3	4.2 ± 2.3	0.95
Anticipation (ANTI)	4.6 ± 3.1	4.6 ± 3.7	4.6 ± 2.4	0.61
Rationalization (RAPT)	5.0 ± 2.1	5.4 ± 2.1	4.6 ± 2.1	0.03*
Dissociation (DISS)	6.5 ± 2.6	6.6 ± 2.6	6.4 ± 2.6	0.74
Somatization (SOMA)	6.7 ± 2.5	6.8 ± 2.4	6.7 ± 2.6	0.89
Sublimation (SUBL)	4.8 ± 2.4	4.6 ± 2.2	5.0 ± 2.6	0.49
Acting out (ACTI)	6.7 ± 2.3	6.9 ± 2.1	6.4 ± 2.5	0.32
Altruism (ALTR)	5.0 ± 2.8	5.4 ± 2.8	4.6 ± 2.8	0.13
Regression (REGR)	6.7 ± 2.5	6.8 ± 2.4	6.5 ± 2.6	0.59
Humor (HUMO)	4.3 ± 2.5	4.2 ± 2.5	4.4 ± 2.5	0.61
Evasion (EVAS)	6.7 ± 2.2	7.0 ± 2.2	6.4 ± 2.1	0.14
Minnesota Multiphasic Personality Inventory-2 (MMPI-2)				
Hypochondriasis (HS)	56.9 ± 12.1	55.3 ± 11.3	58.5 ± 12.8	0.16
Depression (D)	63.1 ± 13.9	61.2 ± 14.0	65.1 ± 13.6	0.12
Hysteria (HY)	58.2 ± 11.0	56.8 ± 11.3	59.6 ± 10.7	0.26
Psychopathic deviate (PD)	59.6 ± 11.6	59.7 ± 12.1	59.5 ± 11.2	0.98
Masculinity-Femininity (MF)	51.4 ± 11.3	50.9 ± 11.4	52.0 ± 11.2	0.69
Paranoia (PA)	64.8 ± 16.1	63.8 ± 14.9	65.9 ± 17.4	0.57
Psychasthenia (PT)	64.4 ± 13.6	63.2 ± 13.6	65.7 ± 13.5	0.28
Schizophrenia (SC)	62.5 ± 13.9	60.5 ± 13.1	64.4 ± 14.5	0.22
Hypomania (MA)	54.4 ± 11.7	53.9 ± 11.2	55.0 ± 12.3	0.66
Social Introversion (SI)	59.8 ± 13.9	58.9 ± 13.6	60.8 ± 14.3	0.56
State-Trait Anxiety Inventory (STAI)				
State-anxiety (ST)	59.5 ± 11.7	59.2 ± 11.2	59.8 ± 12.2	0.69
Trait-anxiety (TR)	63.2 ± 12.2	62.5 ± 12.7	63.9 ± 11.8	0.60

Values were expressed as n (%), mean ± std unless otherwise noted. All scores of subscales are composite scores calculated by taking the sum of the items for each scale.
P values are based on the chi-squared test for categorical variables and the Wilcoxon rank-sum test for continuous variables.
*$P < 0.05$.
**$P < 0.01$.
***$P < 0.001$.

3.1.1. Selection of scales

We identified a few substantial scales among the 32 psychological scales through PCA, separately, with each group of suicidal and non-suicidal behaviors. This analysis for scale selection was conducted with T-anxiety, then subsequently with S-anxiety, separately. (Fig. 2, Supplementary Fig. 1). The threshold for a high loading was greater than 0.65 because of the low sample size (Hair et al., 2009).

For suicidal behaviors, the selected scales according to the highest

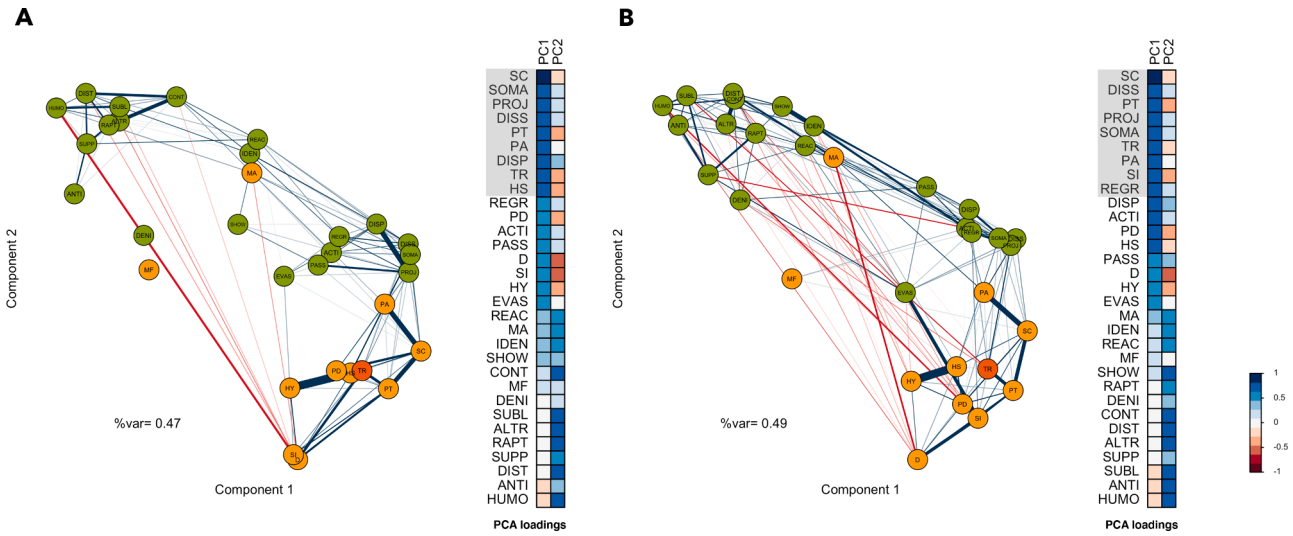

Fig. 2. Principal component analysis configuration of network with patients with (A) suicidal behavior and (B) non-suicidal behavior with T-anxiety. Blue edges indicate positive loadings, and red edges indicate negative loadings. The color saturation and the width of the lines correspond to the absolute loadings. Scales with a high loading were selected. Selected scales were shaded light gray. The threshold for a high loading was greater than 0.65 because of the low sample size. Refer to Table 1 for the definition of abbreviations.

rank in loadings were *Schizophrenia, Somatization, Projection, Dissociation, Psychasthenia, Paranoia, Displacement, T-anxiety, and Hypochondriasis;* while for non-suicidal behaviors, it was *Schizophrenia, Dissociation, Psychasthenia, Projection, Somatization, T-anxiety, Paranoia, Social introversion, and Regression.* The difference in selected scales was *Displacement* and *Hypochondriasis* in suicidal behaviors and *Social introversion* and *Regression* in non-suicidal behaviors. The *Depression* scale was not selected among the featured scales. The selected scales in the MMPI-2 can be briefly interpreted as follows. *Hypochondriasis* relates to neurotic concern over bodily function. *Paranoia* was meant to identify the level of trust, suspiciousness, and sensitivity. *Psychasthenia* was intended to measure doubt, fear, worry, tension, obsessiveness, and compulsions. *Schizophrenia* reflects a wide range of areas, including abnormal thinking and social alienation. Notably, individuals with high scores on this scale do not necessarily have schizophrenia. *Social introversion* measures the social introversion and extroversion of a person. When we included the two types of anxiety separately, T-anxiety had a high loading, while S-anxiety did not. Therefore, we conducted network

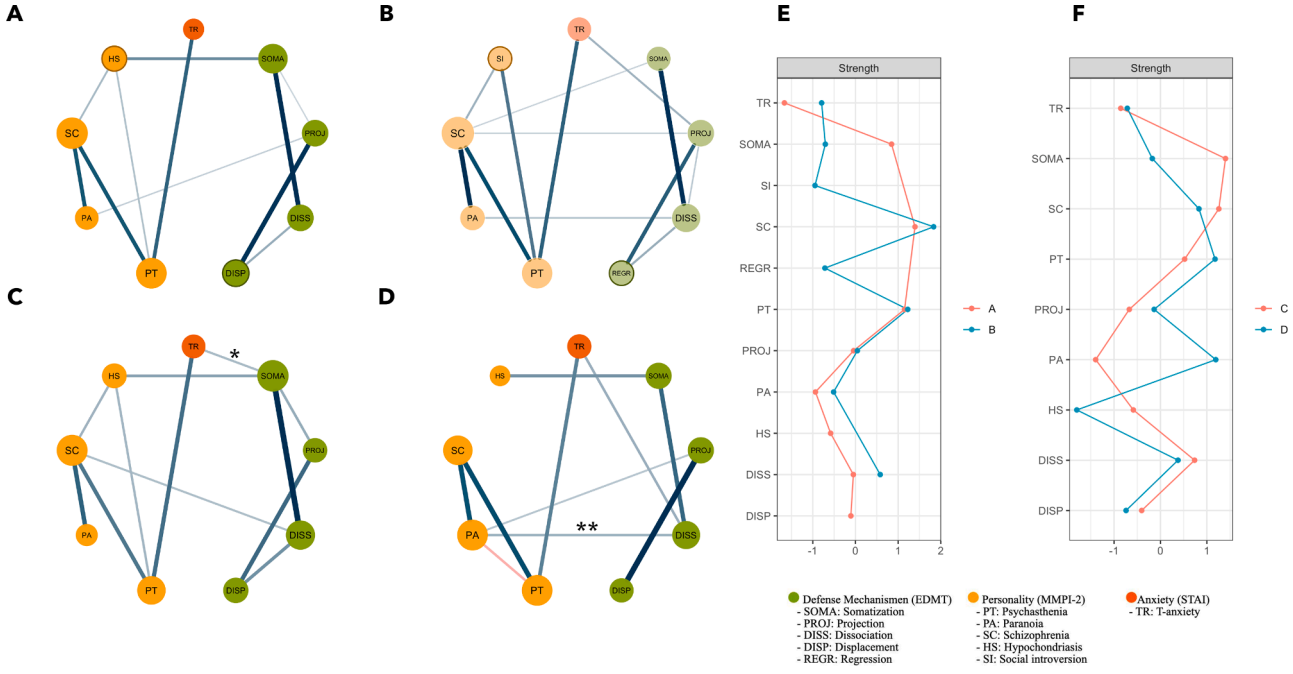

Fig. 3. Estimated network of patients with (A) suicidal behavior, (B) non-suicidal behaviors, (C) suicidal ideation, and (D) suicide attempts. Blue edges indicate positive weights, and red edges indicate negative weights. The color saturation and the width of the edges correspond to the absolute weight and scale relative to the strongest weight in the graph. Green nodes indicate components from the defense mechanism (Ewah Defense Mechanism Test), yellow nodes indicate components from personality (MMPI-II), and orange nodes indicate trait anxiety from anxiety (State and Trait Anxiety Index). Node size is proportional to its centrality in strength. The permutation test in edge difference between the two groups was repeatedly calculated 10,000 times to build sample distribution by resampling the observed data. Node centrality indices of strength from the network of patients with (E) A-suicidal behaviors, B-non-suicidal behaviors, (F) C-suicidal ideation, and D-suicide attempts. The indices are presented as standardized Z-score and ordered by strength. *: uncorrected $P< 0.05$, **: uncorrected $P< 0.01$.

analysis only on T-anxiety.

3.1.2. Suicidal behavior vs. non-suicidal behavior

We estimated inter-variable networks with suicidal behavior (Fig. 3A) and non-suicidal behavior groups (Fig. 3B). There were strong positive relationships in both networks between *Dissociation-Somatization* and *Psychasthenia-Trait anxiety*, and *Psychasthenia-Schizophrenia-Paranoia* was positively interrelated. The *Projection* was positively related to *Displacement* in the suicidal behavior network, whereas it was positively related to *Regression* in the non-suicidal behavior network. A relationship between *Trait anxiety-Projection* was indicated in subjects with non-suicidal behavior, while *T-anxiety* was not connected with any defense mechanism in patients with suicidal behavior. The edge of the resulting bootstrapped CIs around the estimated edge-weight was provided to assess edge-weight accuracy in Supplementary Fig. 2A and B Most bootstrapped CIs for edge-weights were overlapping.

We calculated node centrality indices such as strength, betweenness, and closeness for each network (Fig. 3E, Supplementary Fig. 3). The case-dropping subset was used to estimate the stability of all centrality indices. Based on the bootstrap result (Supplementary Fig. 4A and B), the strength is the most reliable. In both networks, *Schizophrenia*, followed by *Psychasthenia* had the highest centrality of strength. Except for those high scales, *Somatization* and *Dissociation* in the suicidal behaviors and non-suicidal behaviors, respectively, had a high score in strength. *T-anxiety* had a low value in all the centrality indices.

3.1.3. Suicidal ideation vs. suicide attempts

We split the subjects with suicidal behavior into two groups, suicidal ideation and suicide attempts, to characterize the difference between them. The networks of subjects with suicidal ideation (Fig. 3C) and suicide attempts (Fig. 3D) were estimated again with the previously used method using the same psychological components of suicidal behavior. Networks were constructed with the same nodes and structures, which enabled us to compare these two networks and examine the difference of each edge weight.

We identified that both networks shared many common relationships among psychological scales, and *T-anxiety* was positively related to *Somatization* in the suicidal ideation network. In the suicide attempts network, *T-anxiety* was positively related to *Dissociation*, and *Dissociation* was related to *Paranoia*, which was negatively related to *Psychasthenia*. The result of the permutation test for edge weight difference ($\Delta\rho$) indicated the association between *T-anxiety-Somatization* ($\Delta\rho = 0.1810$, $P = 0.0345$, uncorrected; $P = 0.0574$, Bonferroni correction) for suicidal ideators was stronger than for suicide attempters, and the association of *Dissociation-Paranoia* ($\Delta\rho = 0.2437$, $P = 0.004$, uncorrected; $P = 0.005$, Bonferroni correction) for suicide attempters was more substantial than for suicidal ideators.

We computed the centrality indices of nodes with both networks (Fig. 3F, Supplementary Fig. 3). *Somatization* scored high in strength in the suicidal ideation network as it indicated discriminant centrality in the network of suicidal behaviors, while *Paranoia* did in suicide attempts. T-anxiety scored relatively low in both networks. We also assessed the edge-weights accuracy (Supplementary Fig. 2C and D) and stability of the node (Supplementary Fig. 4C and D). The most stable centrality index was strength, as indicated before.

4. Discussion

To our knowledge, this study was the first to apply network analysis to determine and better understand complex relationships between defense mechanisms, personality, and anxiety in individuals with suicidal behaviors compared to those with non-suicidal behaviors by utilizing the OMOP CDM database in Psychiatry. Focusing on anxiety and its connectivities, the analysis revealed that patients with non-suicidal behaviors have relationships from *T-anxiety* to *Projection,* which is associated with *Regression* and other defense mechanisms. Furthermore, there is no direct connection between *T-anxiety* and any defense mechanism and interconnections within defense mechanisms in suicidal patients despite similar levels of anxiety in both groups. Further analysis demonstrated that the relationship of *Somatization-T-anxiety* and that of *Dissociation-Paranoia* connected to *T-anxiety* played a role in their psychological networks in suicide ideators and attempters, respectively.

Depression is strongly related to suicide and is a key risk factor (Handley et al., 2012), but anxiety is another main psychological factor related to suicidal behavior. However, few studies have assessed the impact of anxiety and its influence on suicidal behavior. Anxiety and depression can occur concurrently, but their psychological features and symptoms are different. Clark and Watson (Clark and Watson, 1991) proposed the tripartite model of anxiety and depression to explain the link between anxiety and depression. This tripartite model posits that both anxiety and depression have a negative effect in individuals, but can be differentiated by the physiological hyperarousal as a unique feature of anxiety and the low levels of positive affect characterizing depression. Therefore, this study focused on the anxiety measured from the state and trait aspects after controlling for depression. We conducted a network analysis to investigate these complicated relationships between defense mechanisms, personality, and anxiety.

The network analysis results revealed that anxiety is not merely related to suicidal behaviors; it influences suicidal behaviors by interacting with defense mechanisms and personality. We observed that there might be non-linear associations or interactions between two or more variables that affect the third variable in a non-additive manner; they were not examined in this analysis and should be explored in future studies. Anxiety is expected to have high centrality in *Schizophrenia* and *Psychasthenia* for both groups because we extracted the study sample from the psychiatric database, including those who already had psychiatric disorders (as shown in Supplementary Tables 1 and 2). *Somatization* and *Dissociation* featured the most strongly in the suicidal behaviors and non-suicidal behaviors networks, respectively. Patients with non-suicidal behaviors easily reached *Dissociation*, the most central node, via the connection between *Projection* and *T-anxiety* and all defense mechanisms were interrelated. However, patients with suicidal behaviors have no direct relationships between *T-anxiety* and any defense mechanism, especially the most influential node, *Somatization,* in this complex network. It may suggest that defense mechanisms and characteristics of suicidal patients do not work to alleviate anxiety and discomfort properly. Moreover, these missing connections between anxiety and defense mechanisms may posit a close link between anxiety and suicidal behaviors.

Klonsky and May proposed the ideation–to–action framework in suicide, which views ideation's development and the progression from ideation to attempts as distinct processes (Klonsky and May 2014). From this perspective, each has distinct predictors, hence it is crucial to identify them to distinguish suicide attempters among ideators. Many studies have been conducted to identify differentiable factors such as psychological (e.g., depression, hopelessness), biological (e.g., pain sensitivity), or neurocognitive factors (e.g., planning and decision-making, impulsivity) (Klonsky et al., 2017). In light of previous efforts, we suggested the psychological factors of differentiating suicide attempts from suicidal ideation by estimating separate networks for suicidal ideation and suicide attempts.

We observed a strong association between *T-anxiety* and *Somatization* in the network of suicidal ideation compared to the network of suicide attempt. Severe anxiety has both emotional and physical components. The repetitive physical symptoms of anxiety may cause great distress. Thoughts of suicide might occur during this period of stress or anxiety. These findings are in line with a theory suggesting that prolonged exposure to physiological distress results in suicidal thoughts because of a desire to escape from the pain or an intolerable situation (Crawford et al., 2018).

Meanwhile, we discovered the significant relationship between *Paranoia* and *Dissociation*, and *Dissociation* was connected to *T-anxiety* in

patients with suicidal attempts. *Paranoia* is a measure of interpersonal sensitivity in the aspect of personality, not referring to clinical meanings. Interpersonal sensitivity was a personal risk factor for suicidal behavior and influences mental health symptoms (Rossetti et al., 2017). During a stressful, anxiety-inducing event, patients with suicide attempts might disconnect from the real world, which is a way of dealing with negative thoughts or feelings and decreasing their fear and anxiety.

Electronic medical records (EMRs) have been increasingly implemented but are slowly being adopted in psychiatry. One possible explanation of this difficulty is the lack of proper format due to psychiatric data, primarily narrative, and high confidentiality entailing privacy issues (Kokkonen et al., 2013). Currently, patients' treatment requires more than one expert because of the nature of the mental illness (Hashemi et al., 2019). Moreover, the data containing accurate patient information is directly related to healthcare quality and treatment results. Connecting data by comprehensive and appropriate forms across psychiatry and other related specialties are essential. Hence, we established OMOP CDM in psychiatry and utilized it in this study for the first time, giving us the collaborative potential to incorporate studies with other institutions in or out of the country.

Studies with real-world data in psychiatry have been infrequent even though they could bring complementary evidence for a greater understanding of treatments, drugs, and therapies in real-world settings (Joshi et al., 2018; Vanasse et al., 2016). Thus, the common data model can be an optimal solution. The common data model focuses on data standardization, resulting in a global research infrastructure to facilitate studies in large-scale data networks (Garza et al., 2016). Consequently, our group has established the common data model in the psychiatric domain and utilized it in this study. Additionally, network analysis with psychological assessment tests was useful in understanding patients' characteristics with a high risk of suicide. A suicide attempt is a dangerous act that increases the likelihood of death from suicide. Clinicians should be aware of which psychological factors are related to reducing ideation and identifying attempters among ideators. Identifying those with tendencies toward suicide and understanding the characteristics of suicide will be an important clinical clue to advance our understanding and prevent suicides, and in turn, will contribute to the development of mental health policies.

These results indicate that the associative characteristics between defense mechanism, personality profile, and trait anxiety might be distinct according to the suicidal behavior risk. Many parts of the patient's defense mechanisms and personality characteristics are already considered through each psychological test in the clinical field. However, we investigated defense mechanisms and personality characteristics from an integrated perspective in a unique way, focusing on anxiety symptoms, which differed depending on the suicide attempt. For our research to be used more widely in the clinical field, it seems necessary to develop a method that can be intuitively used by clinicians in the clinical setting and confirm its validity through longitudinal research. The results of this study support the need for an integrated and intuitive way to examine anxiety symptoms, defense mechanisms, and personality characteristics in evaluating suicide attempts.

Our findings should be interpreted with caution because of several study limitations. This study is a single-center study with a low sample size. Longitudinal research is required to fully observe transitions from suicidal ideation to suicide attempts and recurrent suicidal events. Even though we established the 9-year database, including 32,491 psychiatric patients, solely 5% ($n = 1595$) of them took three psychological tests, and patients with suicidal behaviors ($n = 129$) were relatively low than other research on suicide. This scarcity of available data could hinder the generalizability of the findings. In this sense, we can benefit from the established CDM database, which can expand our study to a multicentered study with distributed research network or a longitudinal one and safely keep the data in the standardized format in the long run. A diagnosis of mental disorders and previous psychiatric history as previous suicide attempts were not considered in the analysis. Even though there was a distinction between suicidal behavior and non-suicidal behavior, these networks may not represent suicidal behaviors as long as the group subjects are not homogeneous. Besides, we used PCA to select a subset of variables to include most of the influential information according to loadings. The cutoff value of high loading was chosen when considering the literature review and network parsimony. Thus, under other circumstances, it may give us another set of variables and impact the network results. Therefore, the result cannot be warranted on a generalization of suicidal behaviors. However, we controlled for age, the severity of depression, and sex, one of the most significant risk factors for suicide (Qin et al., 2000), preventing them from influencing the analysis. Apart from controlling factors, the analysis result differentiated between suicidal behaviors and non-suicidal behaviors. Lastly, we obtained data from self-report questionnaires, limiting the reliability of responses. Moreover, we used composite scores by combining all related items. Thus, each subscale should be interpreted by how it can be utilized in the clinical setting and is associated with other subscales rather than the original meaning of the scale or its profile. This can restrain the scope of this study despite psychological test scales being utilized throughout.

5. Conclusion

We presented important new insights on suicidal behavior by estimating psychological networks and improving our understanding of the difference between suicide attempts and suicidal ideation. Compared to non-suicide cases, defense mechanisms and psychological properties might not efficiently reduce anxiety symptoms in suicidal behavior cases. Patients with suicidal ideation and ones with suicide attempts might have a different way of interconnecting psychological scales with anxiety.

CRediT authorship contribution statement

Eunyoung Lee: Conceptualization, Software, Formal analysis, Writing – original draft, Writing – review & editing. **Helmet Karim:** Methodology, Writing – original draft, Writing – review & editing. **Carmen Andreescu:** Methodology, Writing – original draft, Writing – review & editing. **Akiko Mizuno:** Writing – original draft, Writing – review & editing. **Howard Aizenstein:** Writing – original draft, Writing – review & editing. **Heirim Lee:** Writing – original draft, Writing – review & editing. **Dongyun Lee:** Writing – original draft, Writing – review & editing. **Kyungmin Lee:** Writing – original draft, Writing – review & editing. **Sun-Mi Cho:** Writing – original draft, Writing – review & editing. **Doyeop Kim:** Data curation, Visualization, Writing – original draft, Writing – review & editing. **Rae Woong Park:** Conceptualization, Writing – original draft, Writing – review & editing. **Sang Joon Son:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Bumhee Park:** Conceptualization, Software, Formal analysis, Methodology, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no competing interests.

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Supplementary materials

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