Original Article

Predicting the Risk of Psychological Distress among Lung Cancer Patients: Development and Validation of a Predictive Algorithm Based on Sociodemographic and Clinical Factors

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ABSTRACT

Objective: Lung cancer patients reported the highest incidence of psychological distress. It is extremely important to identify which patients at high risk for psychological distress. The study aims to develop and validate a predictive algorithm to identify lung cancer patients at high risk for psychological distress. **Methods:** This cross-sectional study identified the risk factors of psychological distress in lung cancer patients. Data on sociodemographic and clinical variables were collected from September 2018 to August 2019. Structural equation model (SEM) was conducted to determine the associations between all factors and psychological distress, and then construct a predictive algorithm. Coincidence rate was also calculated to validate this predictive algorithm. **Results:** Total 441 participants sent back validated questionnaires. After performing SEM analysis, educational level (β = 0.151, P = 0.004), residence (β = 0.146, P = 0.016), metastasis (β = 0.136, P = 0.023), pain degree (β = 0.133, P = 0.005), family history (β = −0.107, P = 0.021), and tumor, node, and metastasis stage (β = −0.236, P < 0.001) were independent predictors for psychological distress. The model built with these predictors showed an area under the curve of 0.693. A cutoff of 66 predicted clinically significant psychological distress with a sensitivity, specificity, positive predictive value, and negative predictive value of 65.41%, 66.90%, 28.33%, and 89.67%, respectively. The coincidence rate between predictive algorithm and distress thermometer was 64.63%. **Conclusions:** A validated, easy-to-use predictive algorithm was developed in this study, which can be used to identify patients at high risk of psychological distress with moderate accuracy.

Key words: Lung neoplasm, prediction model, psychological distress, structural equation model

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Introduction

According to the data released by the International Agency for Research on Cancer, lung cancer accounts for around 11.4% of new cancer cases and 18.0% of cancer-related deaths in 2020.[1] Patients who were identified with lung cancer report significantly high detection rate of psychological distress mainly because of poor 5-year survival rate.[2] Previous studies indicated that approximate 17.0%–73.0% lung cancer patients experienced clinically significant psychological distress worldwide.[3-6] More importantly, compared to other types of cancers, lung cancer patients reported the highest incidence of psychological distress.[7,8]

As a negative emotional state, psychological distress has been established to be associated with poor treatment adherence and physical symptoms.[9] Meanwhile, there are some studies which found that psychological distress may enhance tumor growth and diminish effective treatment response, as well as decrease therapeutic effectiveness.[10,11] As a result, lung cancer patients with clinically significant psychological distress reported poor quality of life[5] and even higher mortality.[12] Therefore, it is critical to early detect patients at high risk of psychological distress from overall lung cancer patients with a validated prediction tool.[13]

Background

Accurately understanding risk factors of causing psychological distress and clarifying the correlations between psychological distress and various predictive factors is crucial for developing a reliable and robust prediction tool for early and accurately predicting the risk of psychological distress among lung cancer patients.[6] To date, a great deal of studies have performed to investigate the predictive factors of developing psychological distress among cancer patients.[14] Meanwhile, many studies have also been conducted in order to understand the predictive factors of psychological distress in lung cancer patients.[14]

In 1999, Keller and Henrich investigated gender difference of psychological distress and found that female patients suffer from more serious psychological distress compared to male patients,[15] which was supported by the study performed by Morrison *et al*. in 2017[16] and performed by Lv *et al*. in 2020.[6] However, the gender difference of psychological distress in lung cancer patients has not yet been detected.[3] Moreover, Lv *et al*. also found that educational level, medical insurance, residence, and occupational status were associated with psychological distress,[6] which was partially consistent with the findings from another study in terms of educational level and occupational status.[3] Meanwhile, Chambers *et al*.[5] and Morrison *et al*.[16] found an age difference of psychological distress, which was also detected in a study by Tian *et al*.[3] Moreover, household income was also noted to be related to the occurrence of psychological distress.[3]

Previous studies also investigated the associations between various clinical variables and psychological distress except for sociodemographic characteristics. Carlson *et al*. found that advanced cancer patients with metastasis suffer from more serious psychological distress,[17] which was also consistent with results found by Morrison *et al*.[16] However, the role of metastasis in causing psychological distress was not determined in Lv *et al*.'s study.[6] Family history, drinking history, and tumor stage were also found to be associated with psychological distress.[3] Moreover, there are some studies[18-21] which suggested that surgery, pain degree, and comorbidity were also the predictors of psychological distress.

Although various predictive factors of psychological distress among lung cancer patients have been examined, several conflicting conclusions were generated due to the inclusion of a limited number of potential predictors. Meanwhile, no study has investigated the predictive effect of combining established predictive factors on psychological distress. As a result, <10% of patients at high risk of psychological distress can been early detected.[13] We therefore performed this study to first identify those predictive factors of psychological distress in lung cancer patients. Then, we set out to develop a predictive algorithm that may assist the clinical practitioners in identifying patients at high risk for psychological distress.

Methods

Study design

A cross-sectional descriptive study was performed to identify the risk factors of psychological distress and further develop a validated predictive algorithm of high-risk psychological distress in lung cancer patients based on optimal predictors. All results were presented in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[22]

Participants

We developed the following criteria to recruit eligible participants according to previous studies:[3,6] (a) adult patients with definitive lung cancer diagnosis and (b) having ability to independently complete questionnaires. We excluded those patients who were identified to have the psychiatric disorder and were therefore unable to cooperate with questionnaire survey or other types of cancer. We first estimated sample size based on the algorithm for cross-sectional survey design:[6]

$$N=\left(\mu_{\alpha/2}^{2}\pi[1-\pi]\right)/\delta^{2}$$

In this algorithm, π and δ indicate the incidence and allowed error, respectively. We calculated an anticipated sample size of 384 after setting α of 0.05, π of 0.5, and δ of 0.5. Meanwhile, we also calculated a sample size of 190 according to the principle of minimum numbers needed to modeling the relationship between all variables and psychological distress with structural equation model (SEM).[23] Theoretical sample size of 384 was determined eventually.

Procedure

This study is strictly in accordance with the provisions of the Declaration of Helsinki. Moreover, the protocol of this study has been approved by the institute review board of all participated hospitals. All lung cancer patients who were admitted to the medical oncology and respiratory department of two tertiary hospitals and five secondary hospitals in Chongqing of China for further treatment were checked for eligibility between September 2018 and August 2019 with convenience sampling method, and all eligible patients were enrolled for questionnaire survey within 48 h of admission to ward. All participants fully understood aims and procedure of this study and patients' rights before participating in the survey. Meanwhile, participants were further informed that all questionnaires in this study will be completed anonymously, and collected data were just used to academic dissemination. We obtained oral or written informed consent from all participants before performing formal survey. Moreover, a pilot study suggested a feasibility of conducting the questionnaire survey, and then, all questionnaires were completed by patients in the formal survey. Data were collected by face to face in wards.

Study variables

In this study, we mainly aimed to determine the optimal predictors of psychological distress in lung cancer patients from sociodemographic and clinical aspects. Therefore, after comprehensively reviewed published studies which investigated impact factors of psychological distress among cancer patients, especially lung cancer patients, the following sociodemographic variables were collected including gender, age, nationality, educational level, occupational status, marital status, payment method, residence, the quantity of children, household income, family history, smoking history, and drinking history. Meanwhile, we also collected the clinical variables as following: diagnosis duration, surgical history, metastasis, comorbidity, pain degree, and tumor, node, and metastasis (TNM) stage. All sociodemographic and clinical variables were collected used the standard sheet.

As the main outcome variable, psychological distress was measured with distress thermometer (DT), which was designed to have a 11-point scale (0 indicates no distress and 10 suggests extreme distress) in a thermometer format.[24] The psychometric properties of DT have been extensively validated in various settings,[25,26] and several studies consistently indicated 4 or above scores as the criteria of defining patients with clinically significant psychological distress.[27,28] Certainly, this criterion of DT ≥4 was also demonstrated to be applicable to Chinese cancer patients, with an area under the receiver operating characteristic curve of 0.885 in an empirical study.[26]

Statistical analysis

We used descriptive statistics including frequency and percentage to summarize participants' sociodemographic and clinical variables. Mean rank was calculated to express the score of psychological distress because of Kolmogorov–Smirnov test indicated a skew distribution. The mean rank of psychological distress between variables was first tested using univariate analysis prior to constructing the prediction model. However, we did not determine independent variables according to the results of univariate analysis, and all sociodemographic and clinical variables were included to modeling prediction structure. We calculated the following indices to evaluate the fitness of the overall model including the ratio of Chi-square (χ^2) to degrees of freedom (df), goodness-of-fit index (GFI), adjusted GFI (AGFI), comparative fit index (CFI), and root mean square error of approximation (RMSEA). According to Kline,[29] model fit was regarded as good when a ratio of χ^2/df was ≤3. For GFI and AGFI, a value of more than indicates a good model fit.[30] Moreover, CFI of ≥0.90[31] and RMSEA of <0.05[32] were also suggesting a good model fit. $P < 0.05$ indicated significance for all analyses. Data were analyzed with the Statistical Package for the Social Sciences (Chicago, IL, USA) and IBM AMOS 21.0 (Chicago, IL, USA).

Results

Sample characteristics

We distributed 450 questionnaires during survey, and 441 valid questionnaires were received finally, with a validated response rate of 98.0%. The participants had a median age of 60.0 (interquartile range: 52.0–67.0) and most were male (71.4%) and Han nationality (98.6%). Most participants did not get adequate education (68.0%), and a significant number of participants were jobless (44.9%). Most participants got married (99.3%) and had medical insurance (97.3%), and more than half of them had no drinking history (53.7%) and diagnosis duration

of <6 months (53.1%). In addition, most participants lived in urban (69.4%), had one or two children (99.4%), but no family history (87.8%) and no comorbidity (74.1%). However, most of these participants were at the advanced stage (85.7%) and most experienced metastasis (62.6%). Moreover, a minority of these participants experienced moderate-to-severe pain (19.0%), but most participants did not receive surgery (61.9%). The details of participants' characteristics are shown in Table 1.

Influencing factors for psychological distress

Univariate analysis suggested that eight variables including age, educational level, occupational status, household income, drinking history, diagnosis duration, family history, and TNM stage were substantially related to psychological distress. Younger participants experienced a higher level of psychological distress (P = 0.046), and participants having work also experienced significant psychological distress (P = 0.038). Participants who were from middle-income family had lower level psychological distress (P < 0.001), and participants who were newly diagnosed with lung cancer had the highest level of psychological distress (P = 0.001). Moreover, participants who were at the early stage reported a higher level of psychological distress (P < 0.001). Those participants with drinking history (P = 0.031) and without family history (P = 0.029) had a higher level of psychological distress. Meanwhile, higher educational level also caused the increasing of the level of psychological distress (P = 0.031). The details are shown in Table 1.

Structural equation modeling of the factors predicting psychological distress

We used SEM technique to further inveterate the association between sociodemographic and clinical variables and psychological distress in order to identify the independent predictive factors of psychological distress. We coded all variables to meet the requirement of performing structural equation modeling, and the coded information is summarized in Table 2. We used maximum likelihood to perform SEM for determining the predictive effect of each variable on psychological distress. The structural model of variables and psychological distress is displayed in Figure 1, and the regression weights of psychological distress and various variables are summarized in Table 3. Meanwhile, the correlations of all error variables are documented in Table 4. The results revealed that the structural model adequately fitted the data (χ^2/df = 0.412, GFI = 1.000, AGFI = 0.980, CFI = 1.000, and RMSEA = 0.000 [90% confidence interval, 0.000–0.073]).

Among those 19 paths, 13 paths did not achieve statistical significance, and the remaining 6 paths were statistically significant with all critical ratios of more than 2.0. Specifically, educational level (β = 0.151, P = 0.004), residence (β = 0.146, P = 0.016), metastasis (β = 0.136, P = 0.023), and pain degree (β = 0.133, P = 0.005) positively predicted psychological distress, however, family history (β = −0.107, P = 0.021) and TNM stage (β = −0.236, P < 0.001) negatively predicted psychological distress.

Psychological distress predictive algorithm

Based on the results from SEM analysis, we developed the following predictive algorithm of psychological distress: risk score = (0.151 × educational level + 0.146 × residence + 0.136 × metastasis + 0.133 × pain degree − 0.107 × family history − 0.236 × TNM stage) × 100, with an overall risk score distribution of −75–120. We calculated the risk score of each surveyed participant with the above predictive algorithm, and obtained an overall risk score distribution of −65–78. Then, we also calculated an area under the curve (AUC) of 0.693 for our predictive algorithm, which is depicted in Figure 2. Meanwhile, we also determined a cutoff value of −9, which was corresponding to a sensitivity of 65.4%, a specificity of 66.9%, a positive predictive value of 28.33%, and a negative predictive value of 89.66% when Youden's index got a maximum value of 0.323. Furthermore, in order to improve the feasibility of the predictive algorithm in clinical practice, we inserted a constant of 75 into the algorithm to eliminate negative risk score, and the user needed to do decimals to round up and round down numbers. Therefore, an updated predictive algorithm was constructed as following: risk score = 75 + (0.151 × educational level + 0.146 × residence + 0.136 × metastasis + 0.133 × pain degree − 0.107 × family history − 0.236 × TNM stage) × 100. As a result, the overall distribution of risk score was ranging from 0 to 195. Certainly, the cutoff value was also changed to be 66 eventually.

Next, we applied this predictive algorithm to our surveyed participants for further validating its predictive performance, and detected 51 participants at high risk from those 78 participants who were identified with clinically significant psychological distress with DT and 234 participants at low risk from 363 participants who were identified without clinically significant psychological distress with DT. Finally, a coincidence rate of 64.63% was achieved. Finally, 40.82% of participants were identified to get clinically significant psychological distress using our predictive algorithm.

Discussion

Psychological distress has been recognized as an important consequence of cancer diagnosis and treatment because

Table 1: Comparison of psychological distress among 441 participants according to demographic and clinical variables

Variable	Frequency	Proportion (%)	Mean rank of PS	Z or χ^2	P
Gender					
Male	315	71.4	219.51	−0.479	0.632
Female	126	28.6	224.71		
Age (years)					
18-39	12	2.7	266.00	8.005	0.046
40-49	57	12.9	249.26		
50-59	141	32.0	218.64		
≥60	231	52.4	213.13		
Nationality					
Han	435	98.6	220.44	−0.976	0.329
Minority	6	1.4	261.75		
Educational level					
Primary	120	27.2	215.34	8.891	0.031
Junior high	180	40.8	208.43		
Senior high	84	19.1	243.55		
University	57	12.9	228.42		
Occupational status					
Not working	198	44.9	217.48	6.560	0.038
Working	54	12.2	254.50		
Retired	189	42.9	215.12		
Marital status					
Married	438	99.3	220.21	3.798	0.051
Divorced/widowed	3	0.7	336.50		
Payment method					
Medical insurance	429	97.3	221.58	−0.703	0.482
Private payment	12	2.7	200.38		
Residence					
Urban	306	69.4	216.96	−1.24	0.214
Rural	135	30.6	230.17		
Quantity of children					
0	3	0.6	155.00	2.531	0.282
1	234	53.1	216.23		
≥2	204	46.3	227.44		
Household income (rmb)					
<20,000	39	8.8	259.77	22.224	<0.001
20,000-50,000	123	27.9	204.87		
50,000-100,000	192	43.5	207.38		
>100,000	87	19.8	256.48		
Diagnosis duration (month)					
<1	51	11.6	269.09	16.492	0.001
1-6	183	41.5	211.85		
7-12	84	19.0	233.80		
>12	123	27.9	205.93		
Family history					
No	387	87.8	224.99	−2.177	0.029
Yes	54	12.2	192.42		
Smoking history					
No	159	36.1	218.00	−0.459	0.646
Yes	282	63.9	222.69		
Drinking history					
No	237	53.7	211.18	−2.157	0.031
Yes	204	46.3	232.40		
Surgery					
No	273	61.9	216.76	−1.102	0.270
Yes	168	38.1	227.89		

Contd...

Table 1: Contd...

Variable	Frequency	Proportion (%)	Mean rank of PS	Z or χ^2	P
Metastasis					
No	165	37.4	229.43	−1.328	0.184
Yes	276	62.6	215.96		
Comorbidity					
No	327	74.1	225.78	−1.649	0.099
Yes	114	25.9	207.30		
Pain					
No pain	183	41.5	207.33	7.323	0.062
Mild	174	39.5	233.41		
Moderate	81	18.4	227.67		
Severe	3	0.06	155.00		
TNM stage					
I	42	9.5	247.79	62.803	<0.001
II	21	4.8	387.07		
III	48	10.9	212.38		
IV	330	74.8	208.28		

PS: Psychological distress; TNM: Tumor, node, and metastasis

Table 2: Coding of categorical variables

Variable	Coding
Gender	1=male, 2=female
Age	1=18-39, 2=40-49, 3=50-59, 4=≥60
Nationality	1=Han nationality, 2=minority
Educational level	1=primary, 2=junior high, 3=senior high, 4=university
Occupational status	0=not working, 1=working, 2=retired
Marital status	1=married, 2=divorced/widowed
Payment method	1=medical insurance, 2=private payment
Residence	1=urban, 2=rural
Quantity of children	0=childness, 1=1 child, 2=≥children
Household income	1=<20,000; 2=20,000-50,000; 3=50,000-100,000; 4=>100,000
Diagnosis duration	1=<1, 2=1-6, 3=7-12; 4=>12
Family history	0=no, 1=yes
Smoking history	0=no, 1=yes
Drinking history	0=no, 1=yes
Surgery	0=no, 1=yes
Metastasis	0=no, 1=yes
Comorbidity	0=no, 1=yes
Pain degree	0=no pain, 1=mild, 2=moderate, 3=severe
TNM stage	1=I, 2=II, 3=III, 4=IV

TNM: Tumor, node, and metastasis

it was negatively associated with decreased therapeutic effectiveness, increased risk of morbidity and mortality, and poor quality of life.[24] Patients with lung cancer reported to have the highest incidence of psychological distress compared to other types of cancer.[8,17] Unfortunately, no validated screening tool specifically focused on lung cancer has been developed for early detection of patients at high risk of psychological distress although several studies have identified some risk factors of psychological distress.[3,6,16] In this study, a predictive algorithm with a moderate predictive accuracy (AUC = 0.693) was first developed and validated. Noteworthy, a cutoff value of 66 identified that 40.82% of lung cancer patients were at high risk of psychological distress, which was supported by results from several previous studies.[8,17,33]

In this study, total 19 risk factors were included for the final investigation, and younger age, higher educational level, working, extremely low or high household income, shorter diagnosis duration, no family history, drinking history, and advanced cancer stage were first identified as the risk factors of psychological distress. Furthermore, educational level, residence, family history, TNM stage, metastasis, and pain degree were included to develop predictive algorithm eventually, which were all reported previously to have predictive effects on psychological distress in lung cancer patients. However, the predictive role of other important risk factors, especially age and gender which have been identified previously to be the independent risk factor of psychological distress,[5,15,16,34] was not demonstrated. We therefore suggested performing more studies with larger sample size to further assess their association.

To our knowledge, several screening tools have been applied in practice for assessing the level of psychological distress in cancer patients.[24] Of these tools, DT and Hospital Anxiety and Depression Scale (HADS) were used most extensively. As an easy-to-use tool, DT has been recommended by the National Comprehensive Cancer Network to identify the level of psychological distress.[24] However, the cutoff value must be calculated again when DT was used for different types of cancer, in diverse cultural settings, and for different aims,[18,28,35-38] which may significantly increase the inaccuracy of psychological distress. Moreover, the accuracy of assessing psychological distress will be impaired because DT is marked subjectively

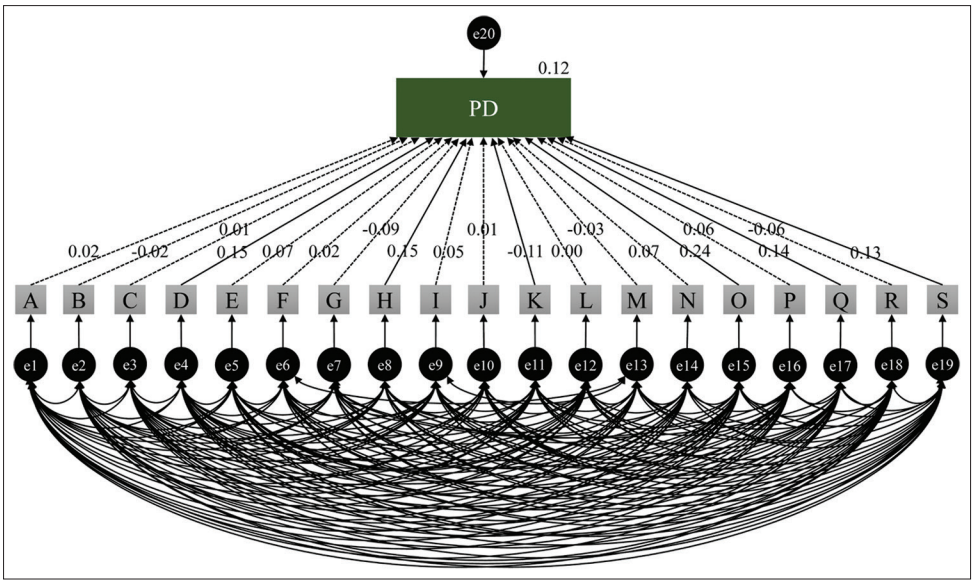

Figure 1: Path diagram of psychological distress and different demographic and clinical variables. Solid arrow indicates significant difference. A to S presents gender, age, nationality, educational level, occupational status, marital status, payment method, residence, quantity of children, household income, diagnosis duration, family history, smoking history, drinking history, surgery, metastasis, comorbidity, pain, and tumor, node, and metastasis stage, respectively

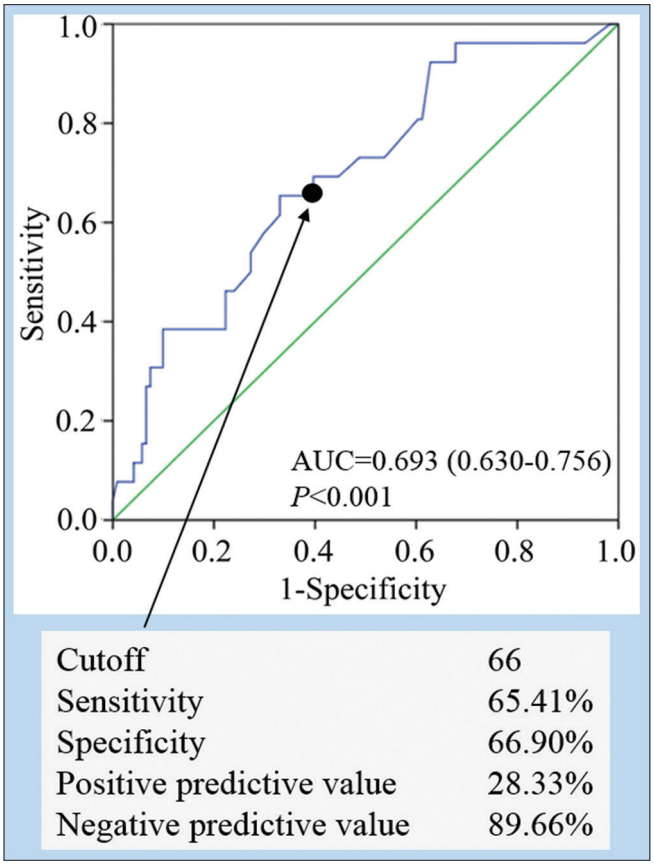

Figure 2: Receiver operating characteristic curve of the predictive algorithm. Black dot indicates cutoff value of 66

Table 3: Regression weights of psychological distress and different demographic and clinical variables

Pathway	Standard estimate	SE	CR	*P*
PD				
Gender	0.022	0.178	0.312	0.755
Age	−0.016	0.007	−0.280	0.779
Nationality	0.009	0.439	0.194	0.846
Educational level	0.151	0.060	2.885	0.004
Occupational status	0.068	0.072	1.126	0.260
Marital status	0.021	0.631	0.459	0.646
Payment method	−0.088	0.331	−1.837	0.066
Residence	0.146	0.148	2.411	0.016
Quantity of children	0.050	0.110	0.992	0.321
Household income	0.010	0.071	0.178	0.859
Family history	−0.107	0.158	−2.310	0.021
Diagnosis duration	0.001	0.058	0.019	0.985
Smoking history	−0.028	0.174	−0.379	0.705
Drinking history	0.065	0.106	1.379	0.168
TNM stage	−0.236	0.070	−3.973	<0.001
Surgery	0.059	0.105	1.288	0.198
Metastasis	0.136	0.139	2.270	0.023
Comorbidity	−0.060	0.126	−1.214	0.225
Pain degree	0.133	0.070	2.783	0.005

PS: Psychological distress; SE: Standard error; CR: Critical ratio; TNM: Tumor, node, and metastasis

by participants.[24] For the HADS, it was actually developed to measure the level of anxiety and depression in the hospital setting.[39] The HADS was extensively utilized in identifying psychological distress because anxiety and depression were considered to be manifestations of psychological distress. However, it is a mistake to simply equate anxiety and depression with psychological distress, which was defined as a negative emotional state characterized by physical and/or emotional discomfort, pain, or anguish.[24] Therefore, the HADS cannot adequately

Table 4: The correlations of all error variables

Correlation			Estimate	Correlation			Estimate	Correlation			Estimate	Correlation			Estimate	Correlation			Estimate
e18	<-->	e19	−0.015	e12	<-->	e18	0.107	e2	<-->	e16	0.066	e9	<-->	e12	−0.071	e2	<-->	e8	−0.147
e17	<-->	e18	0.039	e11	<-->	e18	0.015	e1	<-->	e16	−0.031	e8	<-->	e12	−0.152	e1	<-->	e8	0.004
e16	<-->	e17	0.060	e10	<-->	e18	0.014	e13	<-->	e15	−0.102	e7	<-->	e12	−0.104	e5	<-->	e7	−0.130
e15	<-->	e16	0.042	e9	<-->	e18	0.021	e12	<-->	e15	0.221	e6	<-->	e12	−0.052	e4	<-->	e7	−0.030
e14	<-->	e15	−0.078	e8	<-->	e18	−0.223	e10	<-->	e15	−0.317	e5	<-->	e12	−0.030	e3	<-->	e7	−0.020
e13	<-->	e14	−0.015	e7	<-->	e18	−0.099	e9	<-->	e15	0.082	e4	<-->	e12	0.086	e2	<-->	e7	−0.121
e12	<-->	e13	0.119	e6	<-->	e18	−0.049	e8	<-->	e15	0.067	e3	<-->	e12	0.004	e1	<-->	e7	−0.106
e11	<-->	e12	0.024	e5	<-->	e18	0.195	e7	<-->	e15	−0.087	e2	<-->	e12	0.116	e4	<-->	e6	−0.015
e10	<-->	e11	0.076	e4	<-->	e18	0.004	e6	<-->	e15	0.044	e1	<-->	e12	0.052	e3	<-->	e6	−0.010
e10	<-->	e9	−0.088	e3	<-->	e18	0.020	e5	<-->	e15	0.033	e9	<-->	e11	−0.012	e2	<-->	e6	−0.095
e8	<-->	e9	0.188	e2	<-->	e18	0.316	e4	<-->	e15	−0.204	e8	<-->	e11	−0.116	e1	<-->	e6	−0.052
e7	<-->	e8	0.161	e1	<-->	e18	−0.167	e3	<-->	e15	0.000	e7	<-->	e11	−0.059	e3	<-->	e5	0.066
e6	<-->	e7	−0.014	e15	<-->	e17	0.572	e2	<-->	e15	0.308	e6	<-->	e11	−0.033	e2	<-->	e5	0.328
e5	<-->	e6	−0.087	e14	<-->	e17	−0.042	e1	<-->	e15	−0.068	e5	<-->	e11	0.029	e1	<-->	e5	−0.034
e4	<-->	e5	0.265	e13	<-->	e17	−0.062	e12	<-->	e14	−0.121	e4	<-->	e11	0.132	e2	<-->	e4	−0.161
e3	<-->	e4	0.059	e11	<-->	e17	0.052	e11	<-->	e14	−0.094	e3	<-->	e11	−0.044	e1	<-->	e4	0.024
e17	<-->	e19	−0.002	e10	<-->	e17	−0.150	e10	<-->	e14	0.118	e2	<-->	e11	−0.011	e1	<-->	e3	0.012
e16	<-->	e19	−0.071	e9	<-->	e17	0.140	e9	<-->	e14	−0.080	e1	<-->	e11	−0.050	e12	<-->	e17	0.358
e15	<-->	e19	0.045	e8	<-->	e17	−0.094	e8	<-->	e14	0.064	e8	<-->	e10	−0.413	e2	<-->	e13	−0.197
e14	<-->	e19	−0.057	e7	<-->	e17	−0.129	e7	<-->	e14	0.012	e7	<-->	e10	−0.094	e1	<-->	e2	−0.115
e13	<-->	e19	−0.194	e6	<-->	e17	0.065	e6	<-->	e14	0.089	e6	<-->	e10	−0.071	e2	<-->	e3	0.016
e12	<-->	e19	−0.096	e5	<-->	e17	0.117	e5	<-->	e14	−0.023	e5	<-->	e10	0.359				
e11	<-->	e19	0.105	e4	<-->	e17	−0.065	e4	<-->	e14	0.042	e4	<-->	e10	0.359				
e10	<-->	e19	0.020	e3	<-->	e17	0.011	e3	<-->	e14	0.009	e3	<-->	e10	0.058				
e9	<-->	e19	−0.025	e2	<-->	e17	0.206	e2	<-->	e14	−0.053	e2	<-->	e10	−0.090				
e8	<-->	e19	−0.024	e1	<-->	e17	−0.070	e1	<-->	e14	0.077	e1	<-->	e10	0.015				
e7	<-->	e19	0.103	e14	<-->	e16	−0.065	e11	<-->	e13	−0.060	e7	<-->	e9	0.015				
e6	<-->	e19	−0.085	e13	<-->	e16	−0.035	e10	<-->	e13	−0.005	e6	<-->	e9	−0.074				
e5	<-->	e19	0.032	e12	<-->	e16	−0.001	e9	<-->	e13	0.079	e5	<-->	e9	−0.066				
e4	<-->	e19	−.011	e11	<-->	e16	−0.025	e8	<-->	e13	−0.007	e4	<-->	e9	−0.135				
e3	<-->	e19	−0.018	e9	<-->	e16	0.088	e7	<-->	e13	0.048	e3	<-->	e9	0.087				
e2	<-->	e19	0.062	e8	<-->	e16	0.003	e6	<-->	e13	−0.062	e2	<-->	e9	0.246				
e1	<-->	e19	−0.056	e7	<-->	e16	−0.043	e5	<-->	e13	−0.074	e1	<-->	e9	0.055				
e16	<-->	e18	0.038	e6	<-->	e16	−0.007	e4	<-->	e13	−0.005	e6	<-->	e8	0.125				
e15	<-->	e18	0.042	e5	<-->	e16	−0.009	e3	<-->	e13	−0.007	e5	<-->	e8	−0.537				
e14	<-->	e18	−0.049	e4	<-->	e16	−0.005	e1	<-->	e13	0.748	e4	<-->	e8	−0.364				
e13	<-->	e18	−0.152	e3	<-->	e16	−0.053	e10	<-->	e12	−0.008	e3	<-->	e8	−0.036				

identify patients at high risk of psychological distress. According to the updated definition, we developed the initial predictive algorithm of psychological distress through including sociodemographic and clinical variables based on participants from seven different hospitals with different levels. Meanwhile, this predictive algorithm will objectively calculate the corresponding risk score after entering the value of each predictive factor. Therefore, compared to reported tools, our predictive algorithm has potential of objectively and accurately identifying participants at high risk of psychological distress.

Two main limitations in this study must be further interpreted. First, psychosocial factors were not included despite the fact that 19 sociodemographic and clinical factors have been considered. However, it remains an issue that inclusion of psychological factors may greatly decrease the feasibility of predictive algorithm because psychological states will be assessed with various complex questionnaires. Second, external validation was not performed after developing the predictive algorithm. However, we further evaluated the accuracy of our predictive algorithm through calculating the coincidence rate.

Conclusions

In this study, some important independent sociodemographic and clinical predictive factors for clinically significant psychological distress in lung cancer patients were identified, and a validated, easy-to-use predictive algorithm with fair predictive yield was developed.

Implications for practice

By applying this predictive algorithm, a considerable number of subjects at the clinically significant level for psychological distress who will benefit more from psychological intervention programs can be early and precisely identified. Therefore, the predictive algorithm has great potential as a validated screening measure for use in research, evaluating the effects of intervention programs designed to decrease the level of psychological distress among lung cancer patients through measuring accumulation of psychological distress.

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Conflicts of interest

There are no conflicts of interest.

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