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Prevalence and predictive nomogram of depression among hypertensive patients in primary care

A cross-sectional study in less developed Northwest China

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Abstract

Hypertensive patients commonly co-exist persistent depressive symptoms. However, these issues are not always identified, especially in primary health care, which may worsen the prognosis of hypertension. Therefore, the aim of this study was to determine the prevalence and risk factor of depression, and to develop risk nomogram of depression in hypertensive patients from primary health care Northwest China.

We used a stratified multistage random sampling method to obtain 1856 hypertensives subjects aged ≥18 years in Xinjiang between April and October 2019. The subjects were randomly divided into a training set (n = 1299) and a validation set (n = 557). Depression was evaluated by Hospital Anxiety and Depression Scale (HADS), with a cut-off score ≥8. Using the least absolute shrinkage and selection operator (LASSO) regression model, we identified optimized risk factors of depression in the training set, followed by the establishment of prediction nomogram. The discriminative ability, calibration, and clinical usefulness of nomogram were assessed. The results were verified by internal validation in validation set.

13.7% hypertensive subjects displayed depression. Seven independent risk factors of depression were identified and entered into the nomogram including age, region, ethnicity, marital status, physical activity, sleep quality, and control of hypertension. The nomogram displayed robust discrimination with an AUC of 0.760 [95% confidence interval (CI): 0.724–0.797)] and 0.761 (95%CI: 0.702–0.819), and good calibration in training set and validation set, respectively. The decision curve analysis and clinical impact curve demonstrated clinical usefulness of predictive nomogram.

There is a considerable prevalence of depression in patients with hypertension from primary care of Xinjiang, Northwest China. Our nomogram may help primary care providers assess the risk of depression in patients with hypertension.

Abbreviations: BMI = body mass index, BP = blood pressure, CI = confidence interval, CVD = cardiovascular diseases, DBP = diastolic blood pressure, DCA = decision curve analysis, FPG = fasting plasma glucose, GPAQ = Global Physical Activity Questionnaire, HADS = Hospital Anxiety and Depression Scale, HDL-C = high-density lipoprotein cholesterol, LASSO = least absolute shrinkage and selection operator, LDL-C = low-density lipoprotein cholesterol, OR = odds ratio, PSQI = Pittsburgh sleep quality index, SBP = systolic blood pressure, TC = total cholesterol, TG = triglycerides.

Keywords: depression, hypertension, less-developed regions, nomogram, prevalence, risk factors

1. Introduction

Globally, one third of adults exhibits hypertension, of whom 75% are distributed in low and middle income countries (LMICs),[1] where people have low awareness and treatment rates, limited medical resources, and consequently poor blood pressure control.[2] Therefore, the burden of cardiovascular diseases (CVD) is enormous there as well.[3–5] Previous studies indicate that depression is common in patients with hypertension,[6,7] which increases the risk of cardiovascular mortality and morbidity, if untreated.[8,9]

Accumulating hospital-based surveys indicate that the prevalence of depression in hypertension ranges from 4.8% to 62.8% in China,[10] and 20% to 30% in the Netherlands.[11,12] Nonetheless, the prevalence of depression in hypertensives is less reported in primary care settings, especially in less developed regions. In addition, depression remains largely under-recognized and under-treated at primary health care,[13] where >70% of hypertensive patients are managed in less developed region.

The co-existence of depression not only affects the quality of life, but also interferes with the treatment and prognosis of hypertension.[9,14] In fact, the United States Preventive Services Task Forces recommends screening patients with chronic diseases for depression in clinical practices that have systems in place to assure accurate diagnosis, treatment and follow-up.[15] However, it is difficult to identify depression in hypertensive patients at primary health care facilities due to lack of recognition. Furthermore, even if physicians do attempt to screen for mental disorders in hypertensive patients, primary health care facilities are faced with barriers such as overburdened work, insufficient human and material resources, and communication difficulties since physicians sometimes have to read aloud the self-reported depression scales to illiterate patients, which may lead to misunderstandings, misdiagnosis and/or inappropriate treatment.[16] Currently, the management of depression comorbid medical conditions in primary care settings has been developed and shown positive effects in developed countries.[17–19] Therefore, the availability of appropriate tools at primary health care could contribute to the quality of detection and management of depressive disorders in LIMCs, particularly in less developed regions.

Thus, we aimed to evaluate the prevalence of depression and identify the associated risk factors in hypertensive population from primary health care of Northwest China, and to develop a predictive nomogram to estimate the probability of depression in a given visit, according to 4 dimensions related to the demographic factors, socioeconomic status, health-related behaviors, and anthropometric value, in order to identify possible targets for population-based preventive interventions.

2. Methods

2.1. Site

The study was conducted at primary health care centers including the urban, agricultural and stock-raising settings in Emin County Northern Xinjiang, an underdeveloped region in China, with a total population of over 160,000. Previous survey showed local residents have higher prevalence of hypertension, and low awareness, treatment and control rates.[20] Thus, it is an ideal setting for the study about the status of depression in hypertensive population from the less-developed region.

2.2. Study population

This cross-sectional study was conducted between April to October 2019. We used a stratified-cluster sampling method (district/township-community/village-resident) to collect 6294 subjects aged ≥18 years with a response rate of 96.8% (6294/6500). The current analysis included the 1856 hypertensive patients, as in Figure 1.

Subjects were eligible if:

1. Local inhabitants aged ≥18 years;
2. they agree to participate and sign an informed consent form.

Patients with confirmed dementia/Alzheimer's disease and physical disabilities were excluded because they could not answer questions. The Ethics Committee at the People's Hospital of Xinjiang Uygur Autonomous Region approved the current study.
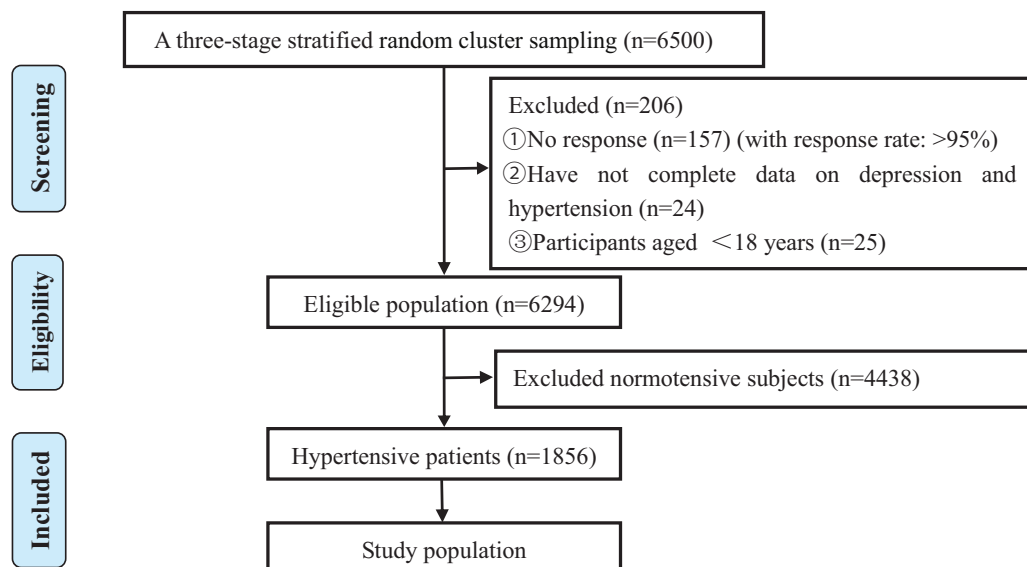
Figure 1. The flow chart of recruiting the surveyed subjects including screening, eligibility and Included.

2.3. Data collection and measurement

Trained study staff collected data on demographic characteristics (such as age, sex, and ethnicity), socioeconomic status (occupation, education level, marital status, and family income per member), health-related behaviors (alcohol consumption, cigarette smoking, physical activity, and sleep quality), and hypertensive status (whether they had a previously diagnosed by a doctor? whether they were receiving anti-hypertensive drugs treated in the past 2 weeks?) using standardized questionnaires. Other information of comorbidities such as dyslipidemia, diabetes, cardiovascular disease (including stroke and coronary heart disease) were collected by staff as well.

2.4. Blood pressure (BP) and anthropometric variables

Each participant's BP records were measured using with the automatic sphygmomanometer OMRON HBP-1300 Professional Portable Blood Pressure Monitor (OMRON, Kyoto, Japan). All participants were measured 3 times for BP with a 30 seconds interval between each measurement. The mean value of the 3 measurements was used for analysis. Height, weight and waist circumference were also measured by trained investigators. Body mass index (BMI) was calculated as weight divided by the square of height (kg/m^2).

2.5. Plasma glucose and lipid measurements

All subjects were fasting for ≥8 hours, and a 5-ml fasting blood sample was collected. Then, fasting plasma glucose (FPG), triglycerides (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) were tested at local primary care center using standard methods.

2.6. Hypertension

Hypertension is defined as systolic BP (SBP) ≥140 mm Hg, and/or diastolic BP (DBP) ≥90 mm Hg, and/or use of antihypertensive agents within 2 weeks.[21] Control of hypertension was defined as SBP <140 mm Hg and DBP<90 mm Hg.

2.7. Evaluation and definition of depression

Depression was evaluated by the Hospital Anxiety and Depression Scale (HADS). The HADS is a 14 items scale and is divided into 2 subscales directed at either depression (HADS-D) or anxiety (HADS-A). Each subject completed the Chinese version of the HADS questionnaire.[22] Depression was identified as a score of ≥8 in the HADS-D, yielding a sensitivity and specificity of approximately 80%.

2.8. Other variables and definitions

Living regions were divided into agricultural, stock-raising, and urban setting based upon subjects' self report. Education level was categorized into: primary and lower, junior high, and senior high and higher. Occupation was defined as manual and intelligent. Family income per member was divided into 5 groups as ≤¥500/month, ¥501–1000/month, ¥1001–2000/month, ¥2001–3000/month, and >¥3000/month. Marital status was classified as single, married, or separated (divorced or widowed). Cigarette consumption was coded as yes/no. Alcohol intake was

defined as yes/no. Physical activity was assessed by Global Physical Activity Questionnaire (GPAQ), which was divided into 3 categories: low physical activity, moderate, and high physical activity based on the WHO's (2010) physical activity recommendations.[23,24] Sleep quality was inquired using Pittsburgh sleep quality index (PSQI), which was classified into very good, fair good, fair bad, and very bad if PSQI score of 0–4, 5–9, 10–14 and ≥15, respectively.[25,26] The Body mass index (BMI) was further classified into normal, overweight and obesity if BMI is below 24.0 kg/m^2, between 24.0 and 27.9 kg/m^2, and ≥28.0 kg/m^2, respectively.[27] Abdominal obesity was defined as WC ≥ 90 cm in men, and WC ≥85 cm in women. Comorbidity was defined as a combination of 2 or more diseases: dyslipidemia, diabetes, and CVD.

2.9. Statistical analysis

Descriptive analyses were conducted for all subjects between training set and validation set using SPSS 20.0 for Windows (SPSS Inc., Chicago, IL). All continuous variables were summarized as means ± standard deviations (M ± SD), and categorical variables were expressed as frequency (n) and proportions (%), and the results were compared using Student t test and the Chi-Squared test to detect the statistical significances, respectively.

The formulation and the assessment of nomogram is divided into 6 steps: First, we developed the nomogram by randomly selecting 70% of our subjects (n = 1299) to construct the model. We reserved the remaining 30% (n = 557) for validation. Second, we identified independent predictive features in the training set by nonzero coefficients in the least absolute shrinkage and selection operator (LASSO) regression model.[28,29] Third, multivariable logistic regression model of the training set was applied to construct a predicting nomogram based on the selected feature from the LASSO regression model,[30] with results presented as numbers (N), odds ratio (OR) with associated 95% confidence interval (95%CI), and corresponding P value. Fourth, we assessed performance of nomogram by the discrimination and calibration. The discrimination of nomogram was evaluated by the area under the receiver operating characteristic curve (AUC). The calibration was assessed by comparing the nomogram-predicted probability with the actual probability, which was visualized by calibration curves plot using 1000 bootstrap resamples procedures and tested by Hosmer-Lemeshow test.[31] Fifth, we conducted internal validation of the nomogram in the validation set. The AUC, and calibration curves and Hosmer-Lemeshow test of nomogram were assessed in the validation set. Finally, the decision curve analysis and clinical impact curve were conducted to determine the clinical usefulness of the nomogram in the validation set, which quantified the net benefits at different threshold probabilities in the study.[32] The nomogram and the bootstrap analysis were performed using the package of "rms" in R version 3.5.1. A P value <.05 was considered to indicate significance.

3. Results

3.1. Subject characteristics

The baseline characteristics of the subjects in the training and validation sets are summarized in Table 1 and Supplementary Table S1, http://links.lww.com/MD/F609. Totally, subjects with depression accounted for 13.7% (254/1856), with 13.8% (179/1299) and 13.5% (75/557) in the training and validation

Table 1

Characteristics of the subjects in training and validation sets.

	Training set (N=1299)	Validation set (N=557)	Total (N=1856)	P value
Depression (n, %)				
No	1120 (86.2)	482 (86.5)	1602 (86.3)	.883
Yes	179 (13.8)	75 (13.5)	254 (13.7)	
Age (years)	53.42±12.46	54.45±12.45	53.7±12.5	.105
18–44	285 (21.9)	114 (20.5)	399 (21.5)	.335
45–59	627 (48.3)	258 (46.3)	885 (47.7)	
≥60	387 (29.8)	185 (33.2)	572 (30.8)	
Gender (n, %)				
Women	556 (42.8)	247 (44.3)	803 (43.3)	.540
Men	743 (57.2)	310 (55.7)	1053 (56.7)	
Regions (n, %)				
Agriculture	756 (58.2)	320 (57.5)	1076 (58.0)	.800
Stock-raising	172 (13.2)	70 (12.6)	242 (13.0)	
Urban	371 (28.6)	167 (30.0)	538 (29.0)	
Education attainment status (n, %)				
Primary and lower	562 (43.3)	251 (45.1)	813 (43.8)	.232
Junior high	461 (35.5)	207 (37.2)	668 (36.0)	
Senior high and higher	276 (21.2)	99 (17.8)	375 (20.2)	
Occupation (n, %)				
Manual	975 (75.1)	428 (76.8)	1403 (75.6)	.443
Intelligent	324 (24.9)	129 (23.2)	453 (24.4)	
Ethnicity (n, %)				
Han	635 (48.9)	297 (53.3)	932 (50.2)	.158
Kazakh	455 (35.0)	171 (30.7)	626 (33.7)	
Others	209 (16.1)	89 (16.0)	298 (16.1)	
Family income per member				
≤¥500/month	316 (24.3)	129 (23.2)	445 (24.0)	.770
¥501–1000/month	343 (26.4)	150 (26.9)	493 (26.6)	
¥1001–2000/month	340 (26.2)	159 (28.5)	499 (26.9)	
¥2001–3000/month	141 (10.9)	59 (10.6)	200 (10.8)	
>¥3000/month	159 (12.2)	60 (10.8)	219 (11.8)	
Marital status (n, %)				
Single	60 (4.6)	18 (3.2)	78 (4.2)	.090
Married	1058 (81.4)	443 (79.5)	1501 (80.9)	
Separated	181 (13.9)	96 (17.2)	277 (14.9)	
Cigarette consumption (n, %)				
No	777 (68.9)	350 (62.8)	1127 (60.7)	.233
Yes	522 (40.2)	207 (37.2)	729 (39.3)	
Alcohol intake (n, %)				
No	1109 (85.4)	494 (88.7)	1603 (86.4)	.065
Yes	190 (14.6)	63 (11.3)	253 (13.6)	
Physical activity (n, %)				
Low	225 (17.3)	102 (18.3)	327 (17.6)	.576
Median	727 (56.0)	297 (53.3)	1024 (55.2)	
High	347 (26.7)	158 (28.4)	505 (27.2)	
PSQI score	4.78±3.78	5.02±3.88	4.8±3.8	.216
sleep quality (n, %)				
Very good	867 (66.7)	351 (63.0)	1218 (65.6)	.458
Fair good	305 (23.5)	142 (25.5)	447 (24.1)	
Fair bad	113 (8.7)	57 (10.2)	170 (9.2)	
Very bad	14 (1.1)	7 (1.3)	21 (1.1)	
Body mass index (kg/m^2)	27.37±4.51	27.34±4.35	27.4±4.5	.889
BMI: <23.9 kg/m^2	285 (21.9)	126 (22.6)	411 (22.1)	.704
BMI: 24.0–27.9 kg/m^2	486 (37.4)	197 (35.4)	683 (36.8)	
BMI: ≥28.0 kg/m^2	528 (40.6)	234 (42.0)	762 (41.1)	
waist circumference (cm)	91.96±11.88	92.21±11.75	92.0±11.8	.683
Abdominal obesity (n, %)	818 (63.0)	364 (65.4)	1182 (63.7)	.343
Comorbidity (n, %)	129 (9.9)	55 (9.9)	184 (9.9)	1.000
Blood pressure (mm Hg)				
Systolic blood pressure	150.78±19.18	150.58±20.45	150.7±19.6	.837
Diastolic blood pressure	91.17±12.97	90.70±13.81	91.0±13.2	.475

(continued)

Table 1

(continued).

	Training set (N=1299)	Validation set (N=557)	Total (N=1856)	P value
FPG (mmol/L)	5.92±2.42	5.82±2.28	5.89±2.38	.423
TC (mmol/L)	5.00±1.06	5.01±1.10	5.00±1.07	.850
TG (mmol/L)	1.69±1.44	1.66±1.18	1.68±1.36	.650
LDL-c (mmol/L)	2.33±0.32	2.35±0.45	2.33±0.36	.220
HDL-c (mmol/L)	1.56±0.20	1.55±0.14	1.56±0.18	.157

FPG = fasting plasma glucose, TC = total cholesterol, TG = triglycerides, LDL-C = low density lipoprotein cholesterol, HDL-C = high-density lipoprotein cholesterol, PSQI = Pittsburgh sleep quality index.

sets, respectively, with no significant difference ($P = .883$). In addition, the significant differences were unobserved in the baseline characteristics of the subjects between the training set and the validation set (P value range from .065 to 1.000).

### 3.2. Independent risk factors for depression in hypertensive subjects

We used the LASSO regression model to screen independent risk factors of depression in the training set. Of demographic variables, socioeconomic status, health-related behaviors, and anthropometric measurments, 7 potential predictors were screened out of 38 factors in the study (~5:1 ratio; Fig. 2 A and B) and were with nonzero coefficients in the LASSO regression model. These factors included age, living setting, ethnicity, marital status, physical activity, sleep quality, and control of hypertension (Table 2).

3.3. Development of a predictive nomogram

Based on the results of multivariable logistic regression analysis, which included the above independent predictors (Table 2), the model was built and presented as the nomogram (Fig. 3). We observed very bad sleep quality corresponded to the highest risk score of 100 points, second was separated and single marital status (75 points and 67 points, respectively), and followed by Kazakh (68 points), low physical activity (58 points), living in agricultural setting (46 points) and controlled hypertension (43 points).

3.4. Performance and internal validation of the nomogram

The AUC for the predictive nomogram was 0.760 (95% CI: 0.724–0.797) in the training set, and was confirmed to be 0.761 (95% CI: 0.702–0.819) through internal validation in the validation set (Fig. 4), which indicated the model's good
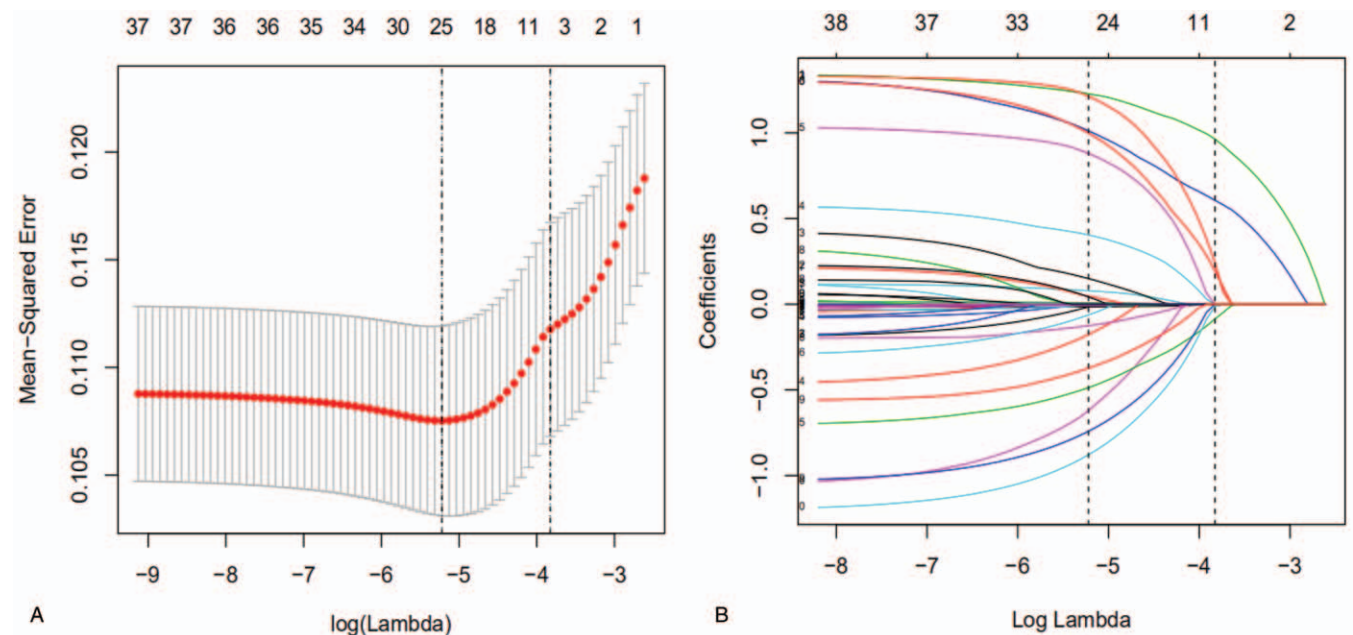
Figure 2. Predictor selection from demographic variables, socioeconomic status, health-related behaviors, and anthropometric measurements using the LASSO binary logistic regression model. Notes: (A) Optimal parameter (lambda) selection in the LASSO model used fivefold cross-validation via minimum criteria. The partial likelihood deviance (binomial deviance) curve was plotted versus log (lambda). Dotted vertical lines were drawn at the optimal values by using the minimum criteria and the 1 SE of the minimum criteria (the 1-SE criteria). (B)LASSO coefficient profiles of the 38 features. A coefficient profile plot was produced against the log (lambda) sequence. Vertical line was drawn at the value selected using fivefold cross-validation, where optimal lambda resulted in seven features with nonzero coefficients. Abbreviations: LASSO, least absolute shrinkage and selection operator; SE, standard error.

Table 2

**Factors associated with depression from study population by multiple logistic regression.**

Stratification	N	Prevalence (95%CI)	Adjusted OR (95%CI)	P value
Age (count)	–	–	1.02 (1.01–1.03)	.033
18–44	36/285	12.6 (9.0–17.1)	1 (Reference)	
45–59	71/627	11.3 (8.9–14.1)	1.18 (0.74–1.88)	.490
≥60	72/387	18.6 (14.8–22.8)	1.57 (1.03–2.65)	.043
Regions (vs Urban)	26/31	7.0 (4.6–10.1)	1 (Reference)	
Stock-raising	29/172	16.8 (11.6–23.3)	1.55 (0.84–2.87)	.160
Agriculture	14/756	16.4 (13.8–19.2)	2.25 (1.42–3.56)	.001
Ethnicity (vs Han)	60/635	9.4 (7.2–12.0)	1 (Reference)	
Kazakh	93/455	20.4 (16.8–24.4)	3.25 (2.15–4.92)	<.001
Others	26/209	12.4 (8.3–17.7)	1.62 (0.97–2.70)	.066
Marital status (vs Married)	107/1058	10.1 (8.4–12.1)	1 (Reference)	
Single	14/60	23.3 (13.4–36.0)	3.21 (1.57–6.58)	.001
Separated	58/181	32.0 (25.3–39.4)	3.82 (2.54–5.75)	<.001
Physical activity (vs High)	35/347	10.1 (7.1–13.7)	1 (Reference)	
Median	88/727	12.1 (9.8–14.6)	1.30 (0.85–1.98)	.225
Low	56/225	24.9 (19.4–31.1)	2.85 (1.75–4.65)	<.001
Sleep quality (vs Very good)	104/867	12.0 (9.9–14.3)	1 (Reference)	
Fairly good	44/305	14.4 (10.7–18.9)	1.02 (0.68–1.54)	.911
Fairly bad	24/113	21.2 (14.1–29.9)	1.44 (0.83–2.51)	.195
Very bad	7/14	50.0 (23.0–76.9)	5.83 (1.78–19.12)	.004
Control of hypertension (vs Yes)	12/149	8.0 (4.2–13.6)	1 (Reference)	
No	167/1150	14.5 (12.5–16.7)	2.19 (1.15–4.18)	.018

The above variables were identified by LOSSO regression; Multiple logistic regression adjusted the variables including: Age (count), region, ethnicity, marital status, physical activity, sleep quality, control of HT. HT = hypertension; OR = odd ratio; CI = confidence interval.

discrimination. The calibration of depressive nomogram demonstrated good agreement when performing the calibration curve plot in training set and validation set, respectively (Fig. 5A and B). The nomogram-predicted probability and actual probability are highly consistent by using Hosmer-Lemeshow test (training set, $P=.960$; validation set, $P=.368$).

3.5. Clinical use
The DCA for the depressive nomogram showed that when the threshold probabilities of depression in hypertensive patients ranged from 8% to 82%, the use of this nomogram to predict the depressive risk yielded more net benefit than the scheme, which indicated the nomogram to be clinically useful (Fig. 6).
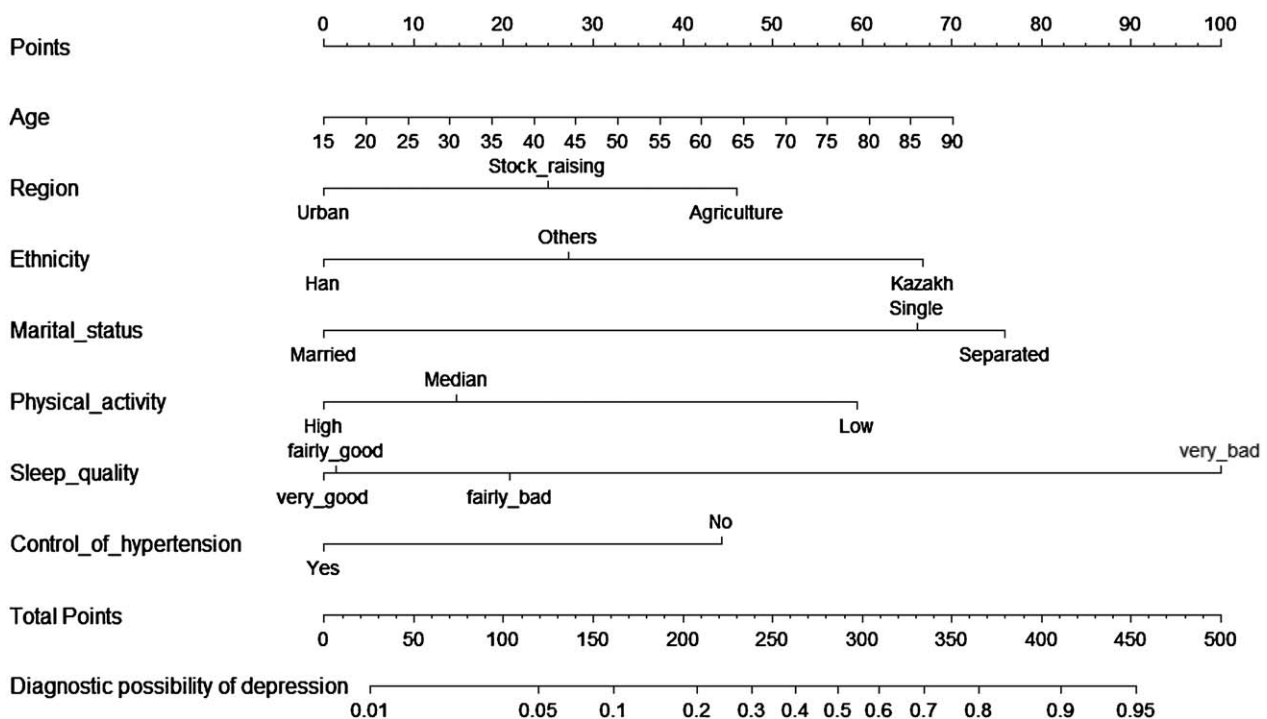
Figure 3. Proposed nomogram for depression in patients with hypertension. Nomogram predicting depression risk in hypertensive patients.
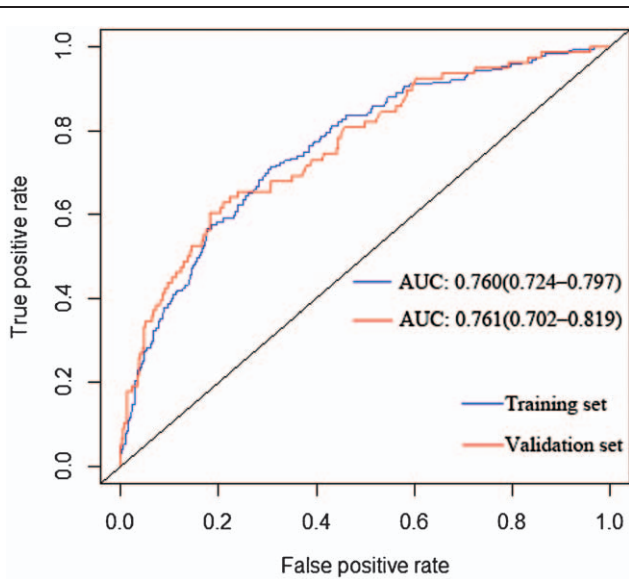
Figure 4. ROC curve of the nomogram. AUC: area under the curve.

3.6. Clinical impact curve

The clinical effectiveness of the nomogram was demonstrated by the clinical impact curve, which predicted the probability stratification of 1000 subjects with the bootstrap technique. The clinical impact curve displayed the number of high-risk subjects (the number of positive cases predicted by the nomogram) and the number of high-risk subjects with events (the number of true-positive cases) under each threshold probability. The cost benefit ratios of the depressive nomogram was determined in clinical impact curve, as shown in Figure 7. For

example, the dotted vertical line illustrates a tentative cut-off point (20% risk of depression) at which 340 of 1000 subjects (34%) would be filtered by the nomogram, with about 140 of these (41.2%) being true depression cases.

4. Discussion

In this study, the prevalence of depression among hypertensive patients in an economically less developed region of Northwest China is 13.7%. Moreover, the presence of depression in hypertensive patients is associated with age, living setting, ethnicity, marital status, physical activity, sleep quality and uncontrolled hypertension. A nomogram was generated based on 7 variables to predict depression in hypertensive patients. Furthermore, the nomogram showed good discrimination, excellent calibration, and satisfactory validity and clinical utility, indicating good performance.

The current study reports that the prevalence of depression in patients with hypertension in primary care setting is 2 times greater than in a study in the Norwegian population, of whom 6.5% of hypertensives have depression using the same cut-off ≥8.[33] However, this is not consistent with the result of a recent meta-analysis of 41 studies.[10] Divergent results may partly be explained by study subjects from different regions, and various assessment tools and cut-off scores for depression. Additionally, previous studies show that the depression complicates the management of hypertension and is closely related to adverse health outcomes.[34–36] Therefore, primary health care physicians should be aware of the importance of early and regular assessment for depression among patients with hypertension.[37]

Results of the current study show that the presence of depression in hypertensive patients is higher in those aged ≥60 years, living in agricultural areas, Kazakh, with single and separated marital status, with low physical activity, with poor sleep quality, and in those who experience uncontrolled
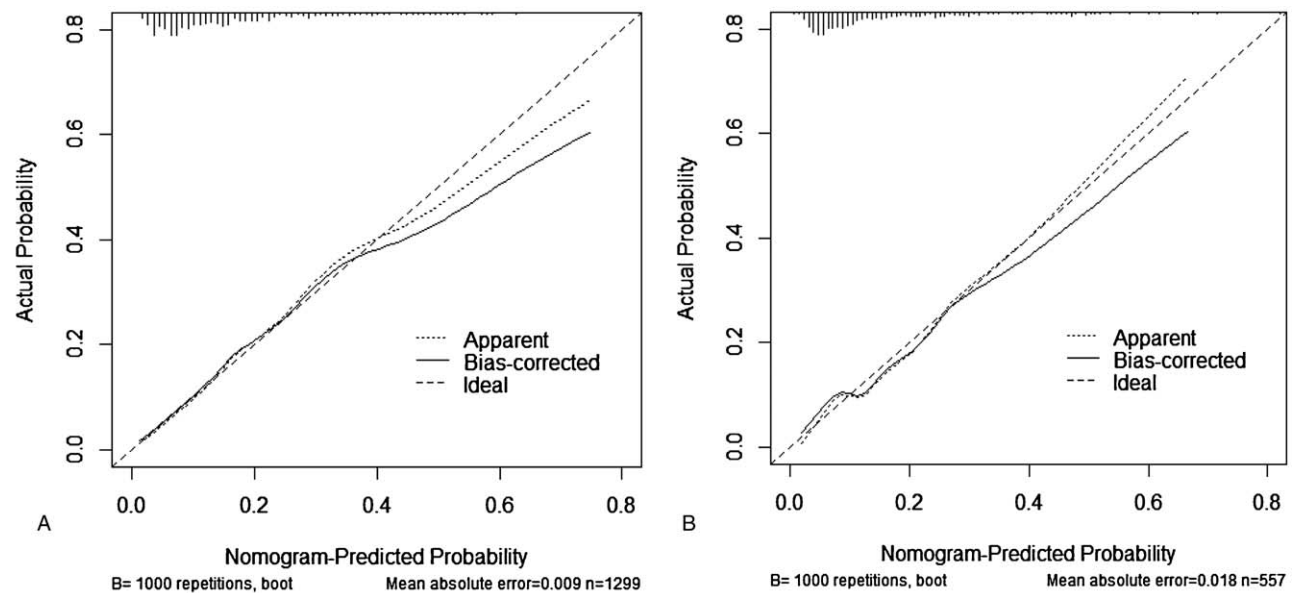

Figure 5. Calibration curves of the depressive nomogram prediction in the study. Notes: (A) Calibration curve of the depressive nomogram prediction in the training set. (B) Calibration curve of the depressive nomogram prediction in the validation set. The x-axis represents the predicted depressive risk. The y-axis represents the actual identified patients with depression. The diagonal dotted line represents a perfect prediction by an ideal model. The solid line represents the performance of the nomogram, of which a closer fit to the diagonal dotted line represents a better prediction.
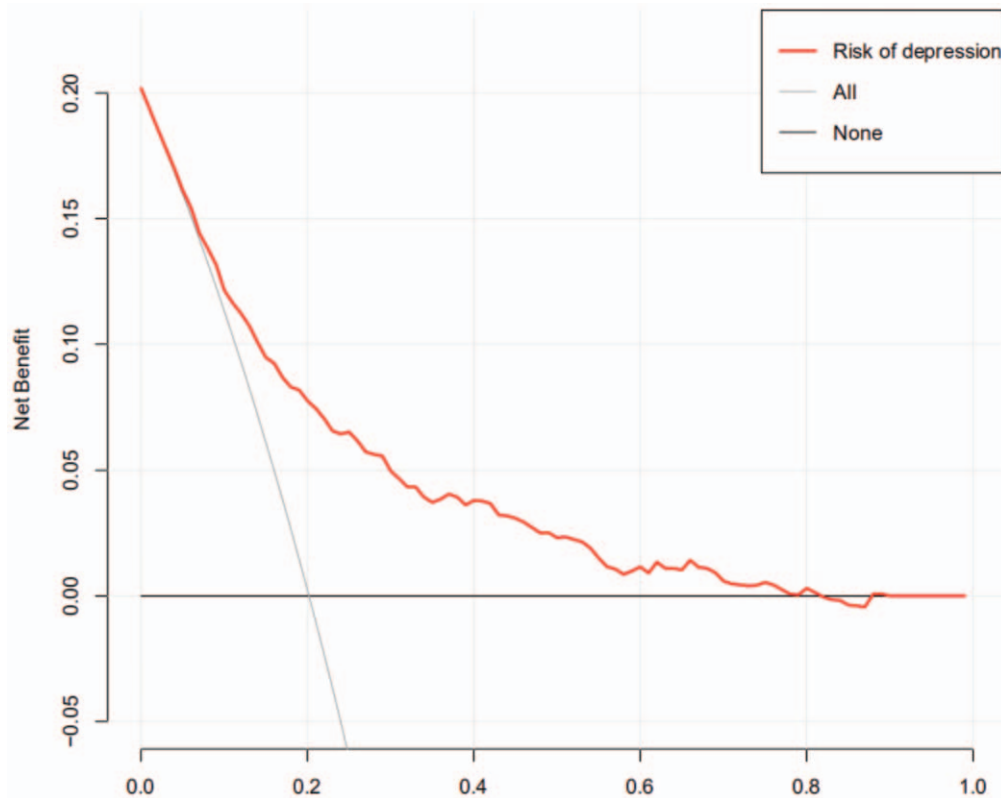
Figure 6. Decision curve analysis for the nomogram for predict depression. Notes: The y-axis measures the net benefit. The red line represents the depressive risk nomogram. The thin solid line represents the assumption that all patients are non-depression. Thin thick solid line represents the assumption that no patients are non-depression to medication. The decision curve showed that if the threshold probability of a patient and a doctor is ranged from 8% to 82%, using this nomogram for depression in the current study to predict depression risk adds more benefit than the intervention-all-patients scheme or the intervention-none scheme.

hypertension status, which are consistent with the previous study results.[38–41] The persons living in agricultural setting are mostly peasants, with poor medical access, little education and low income, especially in the elderly, compared with those living in urban region.[42] Therefore, they cannot receive a prompt diagnosis and treatment when suffering from hypertension. Poor health and mental status make them more prone to depression. Furthermore, hypertensive patients who are single and divorced/widowed often feel isolated and are less willing to communicate with other people, exacerbating the likelihood of depression.[41] Unfortunately, low physical activity and poor sleep quality also lead to depression, which corresponds to previous reports of low physical activity and poor sleep quality in hypertensive patients with depressive symptoms.[38,39] Moreover, depression can influence the efficacy of anti-hypertensive pharmaceutical treatment. A previous study found that depression can cause the dysfunction of the autonomic nervous systems hypothalamic-pituitary-adrenal axis, which can increase vascular tone and resistance to the control of blood pressure.[43] In turn, uncontrolled hypertension can aggravate the depressive symptoms of patients with hypertension.

Some studies have found the non-adherence to medication (contributing to untreated and uncontrolled hypertension) plays a significant role in the increased morbidity and mortality in hypertension and comorbid depression.[44] Therefore, it is very imperative to identify, detect and treat depression in hypertension. Our study is the first to develop and validate a nomogram for depression among hypertensive patients using 7 readily

available variables, which might be useful in improving the patient outcomes with individualized risk prediction and interventions. This prediction tool has relatively accurate discrimination and calibration power, which can be widely and accurately used in primary health care among less developed region with similar populations and economies. And it may assist primary care providers in early identification of hypertensive patients at high risk for depression. Previous studies indicate that interventions such as health education, regular symptom monitoring, support of society and families, and regular follow-up could improve the treatment and prognosis of patients co-existed hypertension and depression.[18]

Current study harbors several strengths. First, we established a nomogram of predicting depression for hypertensive patients to make individualized screening possible for the first time. Second, our study contains relatively larger sample, comprehensive variables and strict data collection procedure, and wider age range, which may merit the data quality and generalizability. It makes the report one of the valuable information for public health sectors and clinical setting. Inevitably, this study has some limitations. First, the study sample is selected from one site of Xinjiang, China, which may hamper the representativeness of study results. Second, although the robustness of our nomogram was examined extensively with internal validation, we failed to conduct external validation. Therefore, the further study of the generalizability to hypertensive populations in other regions and countries is warranted. Finally, the control rate of hypertension in our sample population is 11%, significantly lower than that in
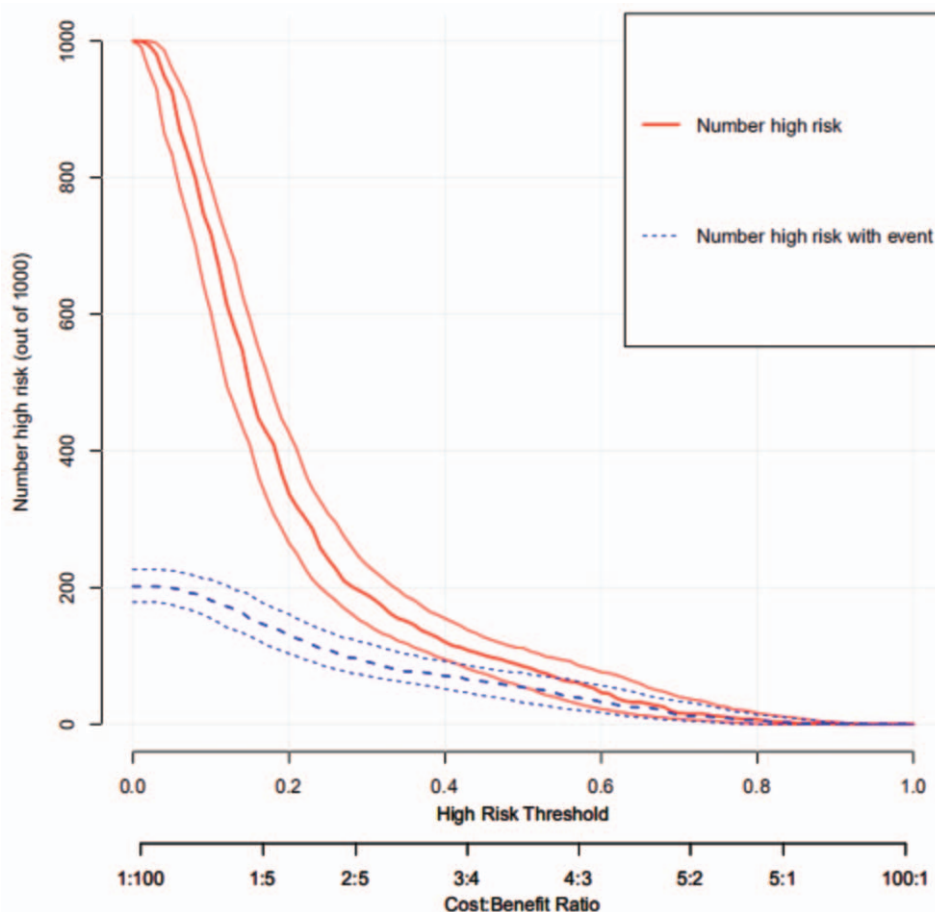
Figure 7. The clinical impact curves of the nomogram predicting risk stratification of 1,000 people and showing the loss-benefit ratio. The red line, number high risk: under each threshold probability, the number of people classified by the nomogram as positive (high risk). The blue line, number high risk with outcome: the number of people with true positive under each threshold probability. The x-axis represents the net benefit; the y-axis represents the high risk (out of 1000) of depression in hypertensive patients. For example, the dotted vertical line illustrates a tentative cut-off point (20% risk of depression) at which 340 of 1000 subjects (34%) would be filtered by the nomogram, with about 140 of these (41.2%) being true depression cases.

high-income countries,[1] and accordingly, the extrapolation of this nomogram was limited to some extent.

5. Conclusions

There is considerable prevalence of depression in patients with hypertension at primary health care, Northwest China. Seven risk factors are associated depression in patients with hypertension. The nomogram developed may help primary care provider assess the risk of depression in hypertensives, and its external evaluation in wider hypertensive populations are warranted.

Author contributions

NL was involved in the study design. NL, LW, MH, ML, FP, ZY, ZW, and RA paticipated in the data collection. LW and MH designed the survey and performed the statistical analysis. LW drafted the manuscript. MH critically revised the manuscript. NL, ML, FP, ZY, ZW, and RA gave important suggestions and did significant changes. All authors reviewed and approved the final version of the paper. We also thank all the participants of the survey including the population.

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