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ARTICLE

Clinical and Carotid Plaque Features in Symptomatic and Asymptomatic Ischemic Stroke

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Abstract

Aims/Background Ischemic stroke (IS), a cerebrovascular condition, is commonly detected by evaluating carotid intima-media (CIA) stenosis. Symptomatic CIA stenosis carries a high risk (up to 32%) of another ischemic event within 12 weeks, while asymptomatic CIA stenosis has an annual risk ranging from 1% to 2%. Therefore, this study aims to explore the diagnostic value of clinical features and carotid plaque characteristics in both symptomatic and asymptomatic IS.

Methods This study enrolled 543 consecutive patients with internal carotid artery stenosis confirmed by carotid ultrasonography. Participants were categorized into the symptomatic group (n = 356) and the asymptomatic group (n = 187) by clinical symptoms and computed tomography (CT)/magnetic resonance imaging (MRI) of the brain. Demographic data, clinical features, and ultrasonographic characteristics of the carotid plaque were collected, and logistics regression analysis was carried out to explore the predictive risk factors of IS.

Results According to the differences in clinical and carotid plaque characteristics between the two groups, coronary heart disease (CHD), stenosis degree, plaque diameter, plaque length, plaque vulnerability, and plaque echo type were included. The results of the multivariate logistics regression analysis showed that plaque vulnerability, CHD, and plaque hypoechogenicity were independent predictors of symptomatic stroke. The clinical-ultrasonographic prediction model showed an area under the curve (AUC) of 0.85 [95% confidence interval (CI): 0.82–0.88], a sensitivity of 0.74 (95% CI: 0.69–0.78), and a specificity of 0.81 (95% CI: 0.76–0.87), with a good performance in the model prediction.

Conclusion Plaque vulnerability, CHD, and plaque hypoechogenicity are meaningful predictors of symptomatic ischemic stroke and deserve attention in the future.

Key words: ischemic stroke; symptoms; clinical features; ultrasonographic detection; influencing factors; prognosis

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Introduction

Ischemic stroke (IS) is a cerebrovascular condition that often arises due to the development of blood clots or embolisms in the blood vessels of the brain. When a blockage occurs in a cerebral artery, the surrounding region experiences substantial ischemia, which disrupts cellular energy metabolism and leads to cellular necrosis within minutes (Shi et al, 2023). The ischemic zone surrounding the core of the infarction will give rise to an ischemic penumbra, which is characterized by a semi-dark band. Neurons within this region may undergo apoptosis within hours. Ultrasonography is commonly used for detecting IS by assessing carotid intima-media (CIA) stenosis. Ruka et al (2022) identified several risk predictors, such as the degree of CIA stenosis and a history of ischemic events in the carotid area. Symptomatic CIA stenosis carries a high risk (up to 32%) of another ischemic event within 12 weeks, while asymptomatic CIA stenosis has an annual risk ranging from 1% to 2% (Kim et al, 2023). High-risk stenosis is characterized by a thin fibrous cap, a large necrotic core, intraplaque hemorrhage, and a significant number of infiltrating inflammatory cells (Giannopoulos et al, 2018). Timely treatment with intravenous thrombolytic medications and cerebral endovascular recanalization techniques is effective in improving the prognosis of approximately 80% of stroke patients. However, the mortality rate (about 33%) and the disability rate (about 33%) are still high (Vilela and Rowley, 2017). Therefore, improving the accuracy of predicting the onset of IS symptoms is crucial. Factors associated with the development of IS include smoking, diabetes, and atrial fibrillation (Fukuoka et al, 2018). Despite extensive research on stroke, little has been done to investigate the combined clinical features of CIA stenosis and plaque status as diagnostic indicators of IS symptom onset and prognosis. Understanding these aspects is essential due to the variations in clinical features and IS pathology among different patients. In this study, we examined the influencing factors and risk factors for symptomatic and asymptomatic IS and developed a suitable mathematical model for prognostic assessment. These findings will serve as a reference for future clinical diagnosis and treatment of IS.

Methods

Patient Selection

This study enrolled 543 consecutive patients with internal carotid artery stenosis confirmed by carotid ultrasonography who attended the stroke center of The First Affiliated Hospital of Soochow University, regardless of whether they had symptoms. This is a retrospective study that used existing medical records or data. It does not involve the identity or privacy of the participants, nor does it cause any risk or harm to the participants, and the participants' informed consent was exempted. This study was approved by the Ethics Committee of The First Affiliated Hospital of Soochow University (No. 2024381), and it was conducted in accordance with the Helsinki Declaration.

Inclusion and Exclusion Criteria

The inclusion criteria were: (1) age 45–80 years old, regardless of gender; (2) imaging examination showing the presence of carotid plaque with resulting luminal stenosis; (3) carotid stenosis of $\geq$30%; and (4) complete clinical data.

The exclusion criteria were: (1) history of carotid endarterectomy and carotid stenting; (2) history of myocardial infarction, cerebral infarction, or neck chemotherapy; (3) cerebrovascular diseases such as neural demyelinating disease, cerebral vasculitis, or amyloidosis; or (4) malignant neoplasms; cardiopulmonary, hepatic, and renal diseases, immune system diseases, or hematological diseases.

Grouping Method

Patients who had a recent (<30 days) noncardiac ischemic cerebrovascular event and confirmed ischemic lesions by head computed tomography (CT)/magnetic resonance imaging (MRI) were included in the stroke group (Li et al, 2019a). The asymptomatic group was defined as patients with no history of a cerebrovascular event.

Clinical Data Collection

Clinical Characteristics

Clinical characteristics included age, gender, hypertension (blood pressure $\geq$ 140/90 mmHg on at least two occasions or taking antihypertensive medications), dyslipidemia, diabetes, history of smoking (smoking more than 1 cigarette per day for 6 consecutive or cumulative months), history of alcohol (daily ethanol equivalent to 40 g/day for men $\geq$ and 20 g/day for women $\geq$ for more than 5 years), cerebrovascular disease, coronary heart disease, atrial fibrillation, and peripheral vascular disease.

Measurement of Peripheral Blood Serological Parameters

Fasting blood glucose (FBG), total cholesterol (TC), high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglyceride (TG), C-reactive protein (CRP), and uric acid (UA) were measured in the peripheral blood of all the patients upon hospitalization.

Carotid Ultrasonography

The method described by Ben et al (2022) was used with slight modifications. Ultrasonography of the carotid arteries was performed using a color-coded duplex machine (CX50, Philips Healthcare, Amsterdam, Netherlands) equipped with a compound imaging 12-3 MHz linear-array transducer and a 5-1 MHz transducer. For conventional ultrasonography, the patient lies flat with their head tilted to the opposite side of the examiner, exposing the neck fully. The examination begins at the origin of the common carotid artery and progresses proximally to the bifurcation of the common carotid artery. The color-coded duplex machine is used to observe blood flow within the arterial lumen, and narrow sections are measured using Doppler ultrasound to assess blood flow velocity. According to the North American Symptomatic Carotid Endarterectomy Trial (NASCET), the residual diameter (R) of the stenosed lumen and the diameter of the distal internal carotid artery close to the normal segment (D1) are measured. The stenosis rate is calculated using the formula: Stenosis rate = $(1 - R/D1) \times 100\%$. Additionally, plaque echoes, along with the surface morphology, thickness, length, resistance, number of plaques, location and morphology of calcification, peak systolic velocity (PSV), end diastolic velocity (EDV), and resistive index (RI) are recorded.

Statistical Analyses

Data were analyzed using R (version 4.31, R Foundation for Statistical Computing, Vienna, Austria) and SPSS 20.0 software packages (version 29, IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used to assess the normality of the measurement data. For data conforming to a normal distribution, results are presented as mean with standard deviation (SD), and analyses were performed using the two-independent samples *t*-test. Data not conforming to a normal distribution are expressed as median (interquartile range) [Median (IQR)], and the paired samples were analyzed using the Wilcoxon sign rank test. Count data were expressed using the number of cases (percentage) [n (%)] and compared between groups using χ^2 test.

Univariate and multivariate stepwise forward logistic regression was used to screen independent predictors for the construction of clinical models of logistic regression. The receiver operating characteristic (ROC) curve was plotted, and the area under the curve (AUC) was calculated to evaluate its efficacy in predicting the occurrence of IS in patients with carotid artery stenosis. $p < 0.05$ indicated that differences were statistically significant.

Results

Distribution of IS Patients with/without Symptoms and Differences in Their Clinical Characteristics

Among the 543 enrollments, 356 asymptomatic stroke patients were in the asymptomatic group and 187 were in the symptomatic group. The differences in systolic blood pressure (SBP), diastolic blood pressure (DBP), CRP, UA, and coronary heart disease (CHD) history between the asymptomatic group and the symptomatic group were significant ($p < 0.05$). The baseline clinical data are shown in Table 1.

A comparison of the ultrasonographic characteristics of carotid plaques between the two groups revealed that there were significant differences in the degree of stenosis, RI, plaque length, peak systolic velocity (PSV), end diastolic velocity (EDV), plaque vulnerability, plaque location, plaque echogenicity, calcification location, and calcification shape between the two groups. The ultrasonographic features of carotid plaques are shown in Table 2.

Logistics Regression Analysis to Screen Risk Factors Affecting IS Patients with/without Symptoms

Based on the differences in clinical and ultrasonographic characteristics between the two groups, several factors were considered, including SBP, DBP, CRP, UA, CHD, PSV, EDV, RI, plaque length, plaque thickness, degree of stenosis, plaque vulnerability, plaque location, plaque echogenicity, calcification location, and calcification shape.

Predominantly hyperechoic

Multivariate logistic regression analysis was conducted, and the results revealed that predominantly hypoechoic, vulnerable plaques, superficial calcifications, and CHD were independent predictors of symptomatic stroke. The results of the multivariate logistic regression analysis are presented in Table 3.

Table 1. Baseline clinical data.

Variable	Asymptomatic	Symptomatic	Statistic	p
n	356	187		
Age (years old)	70.73 ± 8.63	69.48 ± 9.70	t = 1.54	0.125
Gender (male)	275 (77.25)	149 (79.68)	χ^2 = 0.42	0.515
SBP (mmHg)	136.19 ± 20.42	143.49 ± 21.15	t = –3.91	**<0.001**
DBP (mmHg)	76.48 ± 11.38	79.05 ± 11.75	t = –2.473	**0.014**
FBG (mmol/L)	5.51 (4.69, 6.69)	5.50 (4.99, 6.69)	Z = –1.40	0.162
TC (mmol/L)	4.07 (3.31, 4.90)	4.04 (3.31, 4.86)	Z = –0.40	0.690
HDL (mmol/L)	1.04 (0.85, 1.19)	0.97 (0.80, 1.15)	Z = 0.208	0.855
LDL (mmol/L)	2.39 (1.68, 3.22)	2.44 (1.80, 3.15)	Z = –0.51	0.607
TG (mmol/L)	1.27 (0.97, 1.71)	1.25 (1.03, 1.73)	Z = –0.32	0.749
CRP (mmol/L)	2.63 (1.00, 7.60)	5.16 (1.71, 9.52)	Z = –3.39	**0.001**
UA (µmol/L)	348.4 (288.5, 416.4)	323.5 (274.6, 393.3)	Z = –2.59	**0.010**
LVH (yes)	22 (6.18)	13 (6.95)	χ^2 = 0.12	0.728
Hypertension (yes)	278 (78.09)	154 (82.35)	χ^2 = 1.37	0.242
Diabetes history (yes)	161 (45.22)	76 (40.64)	χ^2 = 1.05	0.306
Smoking history (yes)	95 (26.69)	43 (22.99)	χ^2 = 0.88	0.348
Alcohol history (yes)	64 (17.98)	31 (16.58)	χ^2 = 0.17	0.683
Cerebrovascular disease	48 (13.48)	28 (14.97)	χ^2 = 0.23	0.634
CHD (yes)	122 (34.27)	14 (7.49)	χ^2 = 46.85	**<0.001**
Atrial fibrillation (yes)	19 (5.34)	10 (5.35)	χ^2 = 0.00	0.996

SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TC, total cholesterol; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglyceride; CRP, C-reactive protein; UA, uric acid; CHD, coronary heart disease; LVH, left ventricular hypertrophy. The bold font indicates that the differences are statistically significant.

ROC Assessment of Risk Factors

The clinical-ultrasonographic prediction model was established by integrating the above four independent clinical characteristics (Fig. 1), with an AUC of 0.85 (95% CI: 0.82–0.88), a sensitivity of 0.74 (95% CI: 0.69–0.78), and a specificity of 0.81 (95% CI: 0.76–0.87), which showed a good performance in the model prediction.

Column-Line Diagram

Using the established model, a column-line diagram (Fig. 2) was created to represent the relationship between the clinical and ultrasonographic information of the screened patients and the corresponding points assigned to each factor. The total score corresponded to the risk of poor regression.

Discussion

In this study, a comprehensive dataset consisting of general clinical data, peripheral blood serological parameters, and ultrasonographic parameters was used to identify risk factors associated with the development of IS symptoms. Logis-

Table 2. Ultrasonographic features of carotid plaques.

Variable	Asymptomatic	Symptomatic	Statistic	*p*
n	356	187		
RI	0.68 ± 0.11	0.65 ± 0.12	$t = 2.926$	**0.004**
Plaque length (mm)	22.90 (18.45, 29.00)	25.80 (20.30, 31.60)	Z = –3.03	**0.002**
Plaque thickness (mm)	3.80 (3.10, 4.50)	4.10 (3.30, 5.10)	Z = –2.95	**0.003**
Degree of stenosis (%)	60.35 (47.99, 77.40)	72.70 (49.65, 86.20)	Z = –4.56	**<0.001**
PSV	159.00 (112.75, 253.00)	179.00 (116.00, 381.50)	Z = –2.21	**0.027**
EDV	46.00 (31.75, 78.00)	54.00 (32.00, 148.00)	Z = –2.43	**0.015**
Calcification number			$\chi^2 = 1.81$	0.404
None	115 (32.30)	53 (28.34)		
Multiple	154 (43.26)	79 (42.25)		
Solitary	87 (24.44)	55 (29.41)		
Vulnerability (yes)	222 (62.35)	174 (93.05)	$\chi^2 = 58.76$	**<0.001**
Location of plaque			$\chi^2 = 8.11$	**0.017**
Internal carotid artery	269 (75.56)	159 (85.03)		
Carotid bulb	44 (12.36)	10 (5.35)		
Common carotid artery	43 (12.08)	18 (9.63)		
Multiple plaques (yes)	337 (94.66)	183 (97.86)	$\chi^2 = 3.09$	0.079
Plaque echogenicity			–	**<0.001**
Hypoechogenicity	3 (0.84)	15 (8.02)		
Predominantly hypoechoic	125 (35.11)	137 (73.26)		
Predominantly hyperechoic	223 (62.64)	35 (18.72)		
Hyperechogenicity	5 (1.40)	0 (0.00)		
Plaque calcification (yes)	241 (67.70)	134 (71.66)	$\chi^2 = 0.90$	0.343
Calcification location			$\chi^2 = 74.46$	**<0.001**
None	115 (32.30)	53 (28.34)		
Superficial calcification	34 (9.55)	74 (39.57)		
Basal calcification	174 (48.88)	46 (24.60)		
Mixed calcification	33 (9.27)	14 (7.49)		
Calcification shape			$\chi^2 = 21.34$	**<0.001**
None calcification	115 (32.30)	53 (28.34)		
Focal calcification	33 (9.30)	42 (22.46)		
Linear calcification	181 (50.84)	72 (38.50)		
Mixed calcification	27 (7.58)	20 (10.70)		

RI, resistive index; PSV, peak systolic velocity; EDV, end diastolic velocity. The bold font indicates that the differences are statistically significant.

tic regression analysis, based on analysis of variance, was employed to investigate these risk factors and incorporate them into a predictive model for prognostic assessment. Additionally, a column chart was developed based on the "clinical–ultrasonographic" characteristics to aid in the detection of IS symptoms.

Studies have shown that clinical interventions may not be effective in all cases of IS. Wang and Xiong (2023) reported that endovascular treatment of patients with acute IS often results in ineffective reperfusion, which can be attributed to patient

Table 3. Multivariate logistics regression.

Variable	β	SE	Z	p	OR (95% CI)	Wald chi-square
Intercept	–2.289	1.852	–1.236	0.216	0.101	30.624
Plaque echogenicity						
Hypo echogenicity					1.00 (Reference)	
Predominantly hypoechoic	–1.788	0.764	–2.340	**0.019**	0.17 (0.04~0.75)	5.468
Predominantly hyperechoic	–3.123	0.8	–3.904	<**0.001**	0.04 (0.01~0.21)	15.254
Hyperechogenicity	–22.812	16,406.138	–0.001	0.999	0.00 (0.00~Inf)	0.000
Vulnerability						
No					1.00 (Reference)	
Yes	1.332	0.376	3.543	<**0.001**	3.79 (1.81~7.91)	12.567
Location of plaque						
Internal carotid artery					1.00 (Reference)	
Carotid bulb	–0.515	0.482	–1.068	0.286	0.6 (0.23~1.54)	1.140
Common carotid artery	0.416	0.471	0.883	0.377	1.52 (0.6~3.81)	0.781
Calcification location						
None					1.00 (Reference)	
Superficial calcification	1.392	0.339	4.106	<**0.001**	4.02 (2.07~7.81)	16.889
Basal calcification	–0.45	0.298	–1.510	0.13	0.64 (0.36~1.14)	2.288
Mixed calcification	0.452	0.469	0.964	0.335	1.57 (0.63~3.94)	0.928
SBP	0.014	0.007	2.000	0.039	1.01 (1~1.03)	4.281
DBP	0.007	0.012	0.583	0.533	1.01 (0.99~1.03)	0.388
CRP	0.041	0.022	1.864	0.07	1.04 (1~1.09)	3.284
UA	–0.002	0.001	–2.000	0.079	1 (1~1)	3.095
PSV	–0.001	0.003	–0.333	0.65	1 (0.99~1)	0.206
EDV	0.002	0.005	0.400	0.669	1 (0.99~1.01)	0.183
RI	0.403	1.761	0.229	0.819	1.5 (0.05~47.22)	0.052
Plaques length	0.011	0.016	0.688	0.487	1.01 (0.98~1.04)	0.482
Plaque thickness	0.001	0.110	0.009	0.993	1 (0.81~1.24)	0.000
Degree of stenosis	0.007	0.012	0.583	0.559	1.01 (0.98~1.03)	0.342
CHD						
No					1.00 (Reference)	
Yes	–1.571	0.346	–4.540	<**0.001**	0.21 (0.11~0.41)	20.634

OR, odds ratio; CI, confidence interval; SE, standard error. The bold font indicates that the differences are statistically significant.

variability. They suggested several potential mechanisms such as the “no-reflow” phenomenon, collateral dysfunction, venous dysfunction, and inflammation. However, there is currently a lack of clarity on the factors influencing these symptoms. Therefore, individualized treatments for IS are crucial. Accurate and timely risk prediction assessment plays a vital role in providing rapid diagnosis and optimal treatment for patients with IS, as well as implementing intensive treatment and rehabilitation programs for those with a poor prognosis (Sennfält et al, 2021). By predicting the prognosis of IS patients, we expect that those with a favorable outlook

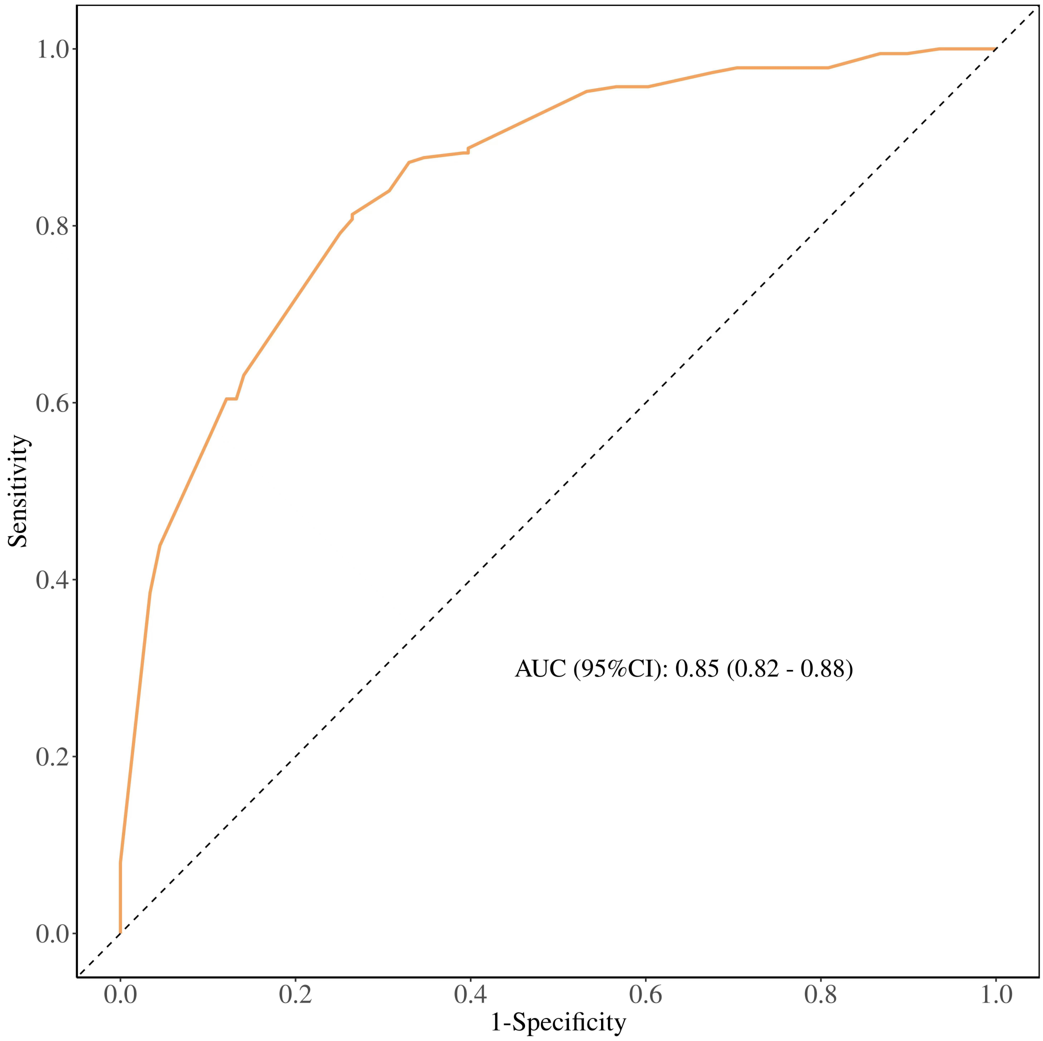

Fig. 1. Results of receiver operating characteristic (ROC) assessment for combined multiple single-factors. AUC, area under the curve.

will actively engage in their treatment, thereby avoiding unnecessary interventions and optimizing available medical resources.

Imaging techniques are widely used in the prognosis of patients with stroke. Among them, ultrafast ultrasonography incorporates parameters for the characterization of carotid plaques by shear wave elastography and ultrafast Doppler. Goudot et al (2020) used ultrasonography to characterise three different ultrasound biomarkers: plaque stiffness heterogeneity, wall shear stress, and intra-plaque microfluidics and correlated these biomarkers with computed tomography angiography (CTA) results and pathological findings. Cao et al (2020) investigated the role of escitalopram in neurological prognosis and endothelial dysfunction after acute IS using ultrasonography. This study suggests that early treatment with escitalopram after ischemic stroke can enhance neural functional outcomes and address endothelial dysfunction, with fewer side effects, making it a promising option for clinical prophylaxis. Tramonte et al (2022) assessed the determinants of severe dysfunctional outcomes and in-hospital mortality rates in patients discharged from hospitals with

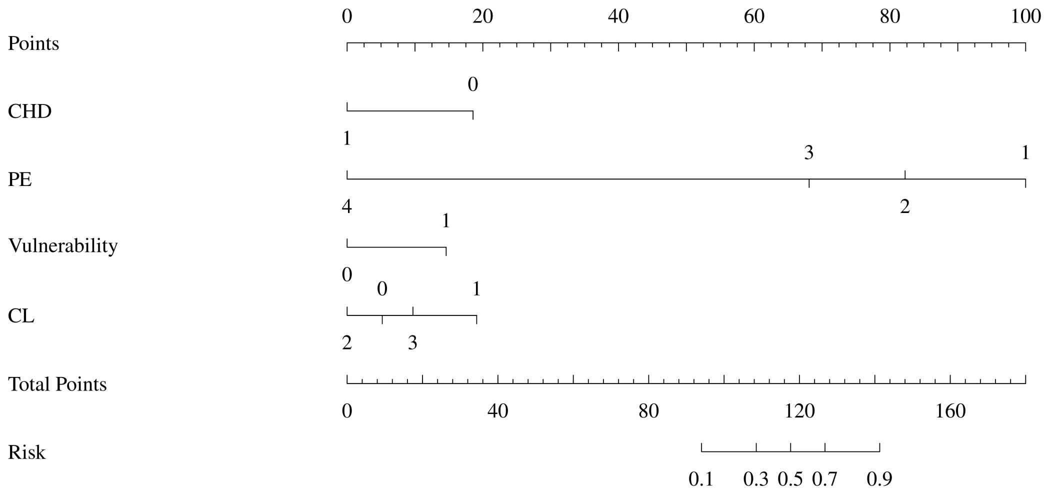

Fig. 2. Results of nomogram analysis of risk factors. CHD, coronary heart disease; PE, plaque echogenicity (1 = hypoechogenicity; 2 = predominantly hypoechoic; 3 = predominantly hyperechoic; 4 = hyperechogenicity); CL, calcification location (0 = none; 1 = superficially; 2 = basally; 3 = mixed).

acute IS based on the early implementation of primary palliative care and found that a National Institutes of Health Stroke Scale score of $\geq$16 results in a 15.5-fold increase in the incidence of fatal outcomes. Goh et al (2022) conducted a retrospective study of 552 patients with echocardiographically-identified left ventricular thrombus performed at a tertiary centre between March 2011 and January 2021 and found that ischemic left ventricular thrombus is associated with older age (60.4–55.3 years), male gender (86.8–65.0%), smoking (49.2–25.0%), and hyperlipidaemia (54.3–28.3%), and a greater risk of having IS. Zhao et al (2023) retrospectively enrolled 336 patients with IS and used ultrasonography to detect non-traditional lipid parameters (lipoprotein cholesterol, non-high-density lipoprotein cholesterol (HDL-C)/HDL-C, non-HDL-C, cardiac risk index-I, and cardiac risk index-II) which were treated as an automated identification system for potential predictors of carotid plaque vulnerability. For the clinical factors in our study, multivariate logistic regression analysis screened the risk factors impacting the occurrence of IS symptoms. Li et al (2019b) showed by multivariate logistic regression analysis that carotid plaque characteristics, such as linear enhancement or diffuse enhancement, were independent risk factors for IS or recurrent transient ischemic attack. Similar to the results of our study, carotid plaque characteristics, as analysed by logistics regression, showed that three of the four risk factors were associated with arterial plaque characteristics: plaque vulnerability, plaque echogenicity, and plaque calcifications location. However, coronary heart disease history was also somewhat associated with arterial plaque characteristics. Another study confirmed that there is a correlation between stroke symptoms and coronary heart disease (Colantonio et al, 2016). Furthermore, as in the retrospective analysis of IS patients carried out by Zhou et al (2022), age, sex, stroke history, diabetes, baseline modified Rankin Scale (mRS), baseline National Institutes of Health Stroke Scale score, and radiomics score were independent predictors of IS outcomes. However, unlike using imaging data as an independent predictor, our study focused on carotid plaque status and location as key indicators. These factors were analysed and evaluated as risk factors with favorable prognostic implications. In contrast to imaging data alone, our approach is more clinically sound, and as a predictor, carotid plaque characteristics offer more reference value for clinical diagnosis.

Our study also revealed results that differed from earlier studies. Li et al (2022) found that patients with hypertension have a higher risk of stroke. Follow-up data showed that 78.9% of patients with hypertension were at risk of stroke, 91.0% of whom were men and 70.7% of whom were women. Furthermore, stroke risk continues to increase disproportionately during hypertension, with four distinct peaks of incidence. Thus, as hypertension persists, the probability of stroke risk continues to increase. Another study has shown that arterial stenosis is also a symptomatic finding affecting IS (Wang and Wei, 2022). In this paper, however, the examination of hypertension and arterial stenosis revealed that these two factors are not risk factors for IS. The more controversial factor in the study of which factors affect stroke is depression, which has been studied in different stages of stroke, while it has been rarely reported in the study of stroke symptom onset, which needs to be further explored (Wu et al, 2019).

Nevertheless, the lack of model validation is a key limitation that must be addressed. Moving forward, we intend to implement a comprehensive validation strategy to thoroughly evaluate the diagnostic performance of the developed model.

Conclusion

The developed model, integrating clinical features and ultrasonographic test index scores, can accurately predict the onset of symptoms in patients with IS, providing valuable insights for clinical practice. This study has the potential to assist clinicians in formulating appropriate treatment plans during the early stages of symptom onset, ultimately leading to improved outcomes for stroke patients.

Key Points

- Ischemic stroke (IS) is often detected by evaluating carotid intima-media (CIA) stenosis.
- Symptomatic CIA stenosis has a high short-term risk of another ischemic event, while asymptomatic stenosis carries a lower annual risk.
- A study of 543 patients found that plaque vulnerability, coronary heart disease (CHD), and plaque hypoechogenicity are independent predictors of symptomatic stroke.
- The clinical-ultrasound prediction model showed good performance with an AUC of 0.85, a sensitivity of 0.74, and a specificity of 0.81.

Availability of Data and Materials

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

We declare that all the listed authors have participated actively in the study and all meet the requirements of the authorship. SZ, YY and PH made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; SZ and PH were involved in drafting the manuscript. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors gave final approval of the version to be published. All authors participated fully in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics Approval and Consent to Participate

This study is approved by the Ethics Committee of The First Affiliated Hospital of Soochow University (No. 2024381). This study is a retrospective study that uses existing medical records or data. It does not involve the identity or privacy of the participants, nor does it cause any risk or harm to the participants. The Ethics Committee of The First Affiliated Hospital of Soochow University approved the study and waived the requirement for written informed consent.

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Conflict of Interest

The authors declare no conflict of interest.

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