Submitted: 30 June, 2023 Accepted: 22 November, 2023 Published: 08 January, 2024 DOI:10.22514/sv.2024.004

Open Access
Signa Vitae

ORIGINAL RESEARCH

Predictive value of right heart contrast echocardiography combined with STAF in cardioembolism

Junjie Wen[1], Dingming Liu[1], Hua Chen[1], Zhan Su[2,*]

[1]Department of Cardiovascular, Guang'an People's Hospital, 638000 Guang'an, Sichuan, China
[2]Ultrasonic Medical Center, Guang'an People's Hospital, 638000 Guang'an, Sichuan, China

***Correspondence**
Suzhan_666@163.com
(Zhan Su)

Abstract

Cardioembolism (CE) is a prevalent cerebrovascular disease in clinical practice. This study aims to assess the predictive efficacy of right heart contrast echocardiography combined with the Score for Targeting Atrial Fibrillation (STAF) for diagnosing CE. A total of 149 patients with CE and 93 patients with non-CE (NCE) were classified into the study group and control group, respectively, and their data were retrospectively analyzed. All patients underwent right heart contrast echocardiography and STAF assessment, and comparative analyses between the groups were performed. In addition, the predictive potential of combining right heart contrast echocardiography with STAF for CE was evaluated, and the CE patients underwent a one-year follow-up to assess survival and prognostic factors. The results of this study showed that patients in the CE group had higher incidences of grade 1 + 2 + 3 right-to-left shunt, patent foramen ovale (PFO) positivity, greater foramen ovale length, larger shunt inner diameter, and higher STAF score compared to the NCE group ($p < 0.05$). Receiver operating characteristic curve analysis revealed that the predictive values for CE, in terms of right-to-left shunt grade, PFO positivity, foramen ovale length, shunt inner diameter, and area under the curve (AUC) for STAF, were 0.582, 0.570, 0.679, 0.808 and 0.750, respectively. The combined AUC value for all these parameters was 0.905. Univariate and multiple logistic regression analysis indicated that atrial fibrillation, total cholesterol and fibrinogen were not prognostic factors in CE patients ($p > 0.05$), whereas National Institute of Health stroke scale (NIHSS) score, PFO positivity, foramen ovale length and STAF at admission were prognostic factors ($p < 0.05$). Therefore, combining right heart contrast echocardiography with STAF may enhance the predictive efficacy for CE.

Keywords

Right heart contrast echocardiography; Score for the targeting of atrial fibrillation; Cardioembolism; Predictive value

1. Introduction

Cardioembolism (CE) is a common cerebrovascular disease encountered in clinical practice. It accounts for approximately 20% to 30% of ischemic cerebral infarctions. CE patients often present with extensive cerebral infarcts, heightened susceptibility to hemorrhagic transformation, and recurrent infarctions post-onset, all contributing to a comparatively unfavorable prognosis. Therefore, timely and accurate diagnosis and categorization of CE hold significant importance for the subsequent management, treatment and prognosis assessment of affected individuals [1–3]. One of the principal underlying mechanisms of CE is the presence of a patent foramen ovale, which induces a right-to-left shunt. This shunt enables emboli to retrogradely enter the systemic circulation from either the venous system or the right heart system through the patent foramen ovale and remains a pivotal pathological explanation for CE. It has been demonstrated that patent foramen ovale is a prevalent form of structural cardiac anomaly and represents an important risk factor for developing CE [4]. Right heart contrast echocardiography allows the visualization of unique high-reflectance microbubbles in the left heart following the intravenous administration of a specialized contrast agent, which facilitates the detection of patent foramen ovale and is therefore a valuable tool for assessing cerebral infarction, particularly in CE patients [5, 6]. In parallel, the Score for Targeting Atrial Fibrillation (STAF) has demonstrated promising utility as a straightforward and convenient diagnostic instrument. It has been validated for the identification of atrial fibrillation in patients with cerebral infarction and aids in monitoring changes in their conditions. Initially designed for atrial fibrillation screening, STAF incorporates various risk factors associated with atrial fibrillation-related stroke, including age, left atrial diameter, National Institutes of Health Stroke Scale (NIHSS) score, and vascular etiology. Ongoing research has also affirmed its applicability in the diagnosis of cerebral

infarction in addition to screening atrial fibrillation [7–9]. Based on this, we designed this present study to investigate the predictive value of right heart contrast echocardiography combined with STAF for CE in diagnosing CE.

2. Materials and methods

2.1 General data

In this retrospective analysis, data from 149 patients diagnosed with CE and 93 patients without CE (NCE) treated at our hospital between August 2017 and August 2021 were retrieved and classified into a CE and NCE group. Study inclusion criteria comprised adherence to the Chinese guidelines for acute ischemic stroke diagnosis and treatment, patient age between 20 and 79 years, National Institutes of Health Stroke Scale (NIHSS) scores ranging from 4 to 25 points, a disease duration between 0.5 and 4.5 hours, and complete patient data for study analysis. The exclusion criteria were NIHSS scores exceeding 25 points, a history of stroke or sequelae within the last 3 months, a history of bleeding within the previous 6 months, central nervous system injury, intracranial hemorrhage, severe liver or kidney function abnormalities, and incomplete data (Fig. 1).

2.2 Method

2.2.1 Right heart contrast echocardiography

Patients were examined using the iE33 color Doppler ultrasound diagnostic apparatus (Philips, EPIQ CVx, Amsterdam, Netherlands). Prior to the examination, venous access was established in the patient's left cubital vein, followed by the connection of a three-way tube to facilitate the collection of autologous blood (1 mL), air (1 mL) and normal saline (8 mL), which were rapidly injected more than 20 times after thorough mixing within the three-way tube. The contrast agent was administered *via* a bolus injection, and sequential observation was conducted in both the patient's resting state and during a Valsalva maneuver, selecting the apical four-chamber view. The evaluation of microbubble development within the left heart started when the right atrium was visible for 3 to 5 cardiac cycles, which necessitated a minimum of 2 repetitions and up to 4 to 6 repetitions for cases with inadequate results. A senior radiologist measured the long diameter of the foramen ovale and the inner diameter of the shunt to facilitate the diagnosis of right-to-left shunt and patent foramen ovale. The semi-quantitative grading of the right-to-left shunt was as follows [10]: Grade 0 (no microbubbles in the left heart chamber), Grade 1 (1–10 microbubbles/frame), Grade 2 (11–30 microbubbles/frame), and Grade 3 (>30 microbubbles/frame). The diagnostic criteria for patent foramen ovale were based on the presence of a conspicuous aperture between the second septum and the valve of the foramen ovale, small atrial left-to-right shunting between the two, and shunting concentrated at the junction of the second septum and the valve of the foramen ovale, all of which were used to confirm the presence of patent foramen ovale [11].

2.2.2 STAF scale [12] evaluation

STAF assessment was performed based on patient age, left atrial diameter, NIHSS score and vascular etiology. Patients aged $\geq$62 years were assigned 2 points, while those $<$62 years received 0 points. Left atrial diameter measurements $>$35 mm were given 2 points, whereas measurements $\leq$35 mm received 0 points. An NIHSS score $\geq$8 indicated 1 point, while an NIHSS score $<$8 received 0 points. If no proximal vascular stenosis $\geq$50% and no evidence of image-clinical small vessel disease was evident, a score of 3 points was given; otherwise, 0 points were assigned.

2.2.3 Analysis of prognostic factors in CE patients

Baseline data, including gender, age, hypertension, drinking and smoking history, diabetes, disease duration, NIHSS score at admission, as well as laboratory parameters such as myocardial enzymes, blood lipids, blood biochemistry, coagulation function and homocysteine levels, were recorded and assessed. Additionally, results from right heart contrast echocardiography and STAF in CE patients were also documented. The 1-year survival of patients was assessed by reviewing their medical records from inpatient or outpatient visits. A poor prognosis was defined as recurrence or death due to various causes, while a good prognosis indicated the absence of such outcomes.

2.3 Statistical methods

Data analysis was conducted using the SPSS 20.0 software (IBM, Armonk, NY, USA). Measurement data are presented as (mean $\pm$ standard deviation) and compared using the *t*-test. Categorical data are expressed as percentages, and differences were assessed using the χ^2 test. The predictive value of CE was evaluated using the receiver operating characteristic (ROC) curve, while prognostic factors for CE patients were analyzed through multiple logistic regression analysis. Statistical significance was defined as $p < 0.05$.

3. Results

3.1 Comparison of general data between both groups

The general data of the two groups were compared, and the results are shown in Table 1, which indicates no significant difference between the two groups ($p > 0.05$).

3.2 Comparison of right heart contrast echocardiography results between both groups

Further analysis showed that patients in the CE group had significantly higher grade 1 + 2 + 3 right-to-left shunt, greater positivity of patent foramen ovale, larger diameter of foramen ovale and inner diameter of shunt compared to those in the NCE group ($p < 0.05$), as shown in Table 2.

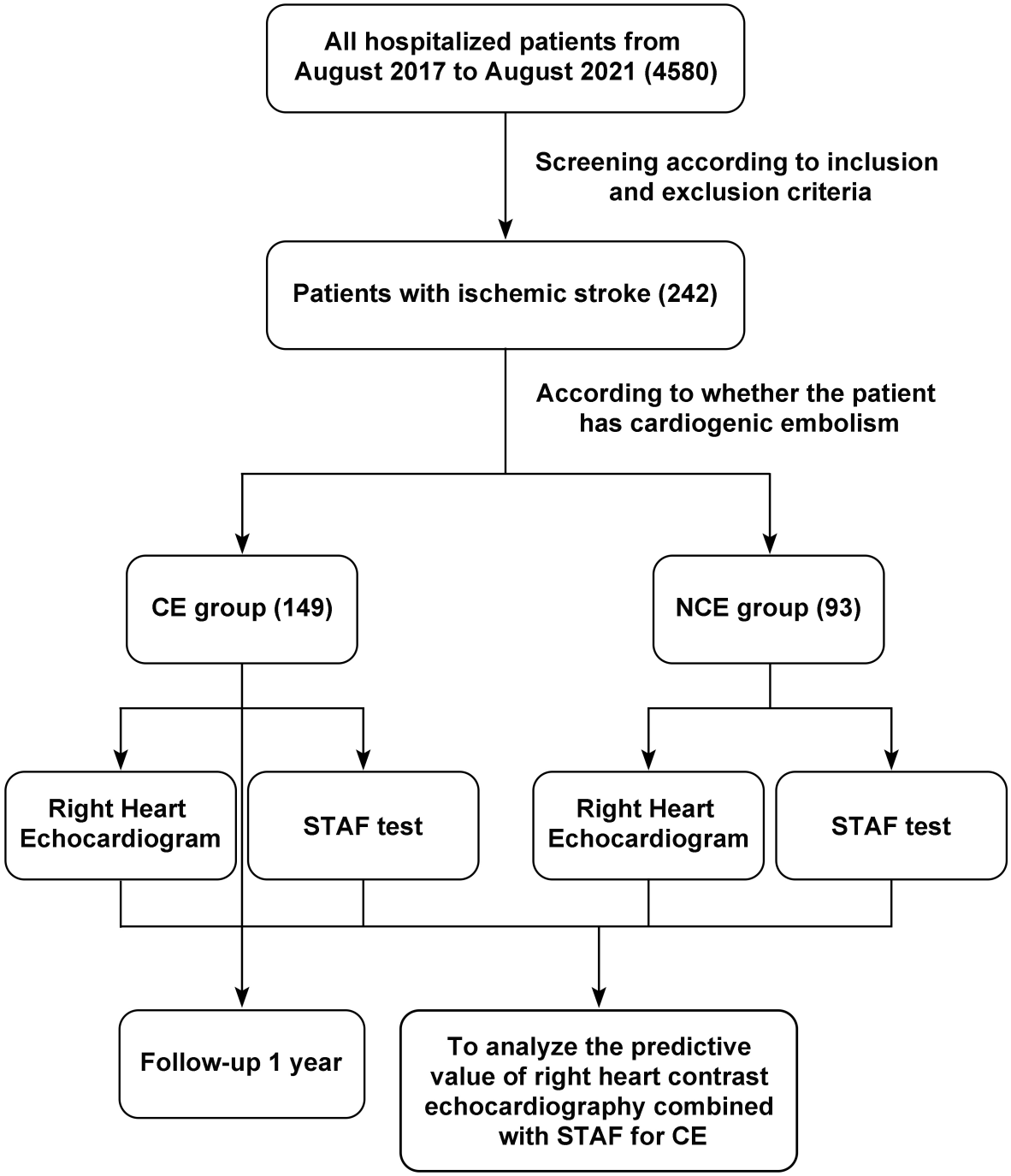

FIGURE 1. The flow chart of the study. CE: Cardioembolism; NCE: non-CE; STAF: Score for Targeting Atrial Fibrillation.

TABLE 1. Comparison of general data between the two groups.

Variables	No. of cases	Sex		Age (yr)	Disease duration (h)	NIHSS score (points)
		Male	Female			
CE group	149	84	65	58.64 ± 13.69	2.18 ± 0.41	10.75 ± 2.86
NCE group	93	45	48	60.13 ± 13.75	2.29 ± 0.57	10.94 ± 2.65
t/χ^2 value		1.468		0.822	1.742	0.517
p value		0.226		0.412	0.083	0.606

CE: Cardioembolism; NCE: non-CE; NIHSS: National Institutes of Health Stroke Scale.

TABLE 2. Comparison of right heart contrast echocardiography results between the two groups.

Variables	No. of cases	Right-to-left shunt grade					Positive rate of patent foramen ovale	Long diameter of foramen ovale (mm)	Inner diameter of shunt (mm)
		Grade 0	Grade 1	Grade 2	Grade 3	Grade 1 + Grade 2 + Grade 3			
CE Group	149	80 (53.69)	21 (14.09)	35 (23.49)	13 (8.72)	69 (46.31)	76 (51.01)	12.13 ± 2.89	1.44 ± 0.42
NCE Group	93	65 (69.89)	8 (8.60)	16 (17.20)	4 (4.30)	28 (30.11)	32 (34.41)	10.26 ± 1.97	1.03 ± 0.31
t/χ^2 value						6.258	6.384	5.492	8.130
p value						0.012	0.012	<0.001	<0.001

CE: Cardioembolism; NCE: non-CE.

3.3 STAF comparison between the two groups

We also observed that those in the CE group had higher STAF than those in the NCE group, and the difference was statistically significant ($p < 0.05$), as demonstrated in Table 3.

TABLE 3. Comparison of STAF between the two groups ($\bar{x} \pm s$/point).

Variables	No. of cases	STAF
CE group	149	2.12 ± 0.56
NCE group	93	1.49 ± 0.36
t value		9.670
p value		<0.001

CE: Cardioembolism; NCE: non-CE; STAF: Score for Targeting Atrial Fibrillation.

3.4 Predictive value of right heart contrast echocardiography combined with STAF for CE

The values for right-to-left shunt grade, positive rate of patent foramen ovale, long diameter of foramen ovale, shunt diameter, and area under the curve (AUC) of STAF in predicting CE were 0.582, 0.570, 0.679, 0.808 and 0.750, respectively (Table 4 and Fig. 2). Additionally, the combined AUC value of all these indices was 0.905.

3.5 Univariate analysis of the prognosis of CE patients

During the 1-year follow-up period, 26 patients experienced relapse, and 6 patients had died, resulting in 117 patients with favorable and 32 patients with unfavorable prognoses. Notably, there were no significant differences in gender, age, hypertension, drinking and smoking history, diabetes, disease duration, creatine kinase isoenzyme, high-density lipoprotein, triglyceride, low-density lipoprotein, systolic blood pressure, diastolic blood pressure, D-dimer, homocysteine levels, right-to-left shunt grade, shunt diameter or other indicators between CE patients with favorable and unfavorable prognoses ($p > 0.05$), while significant differences were observed in atrial fibrillation, NIHSS score at admission, total cholesterol, fibrinogen, positive rate of patent foramen ovale, long diameter of foramen ovale and STAF between CE patients with favorable and unfavorable prognoses ($p < 0.05$) (Table 5).

3.6 Multiple logistic regression analysis of prognosis in CE patients

Multiple logistic regression analysis showed that atrial fibrillation, total cholesterol and fibrinogen were not independent factors in CE patients ($p > 0.05$), while NIHSS score at admission, positive rate of patent foramen ovale, long diameter of foramen ovale, and STAF were independent factors associated with the survival of CE patients ($p < 0.05$) (Table 6).

3.7 Typical case analysis

Here, we present the case of a 53-year-old female patient diagnosed with CE. The results of right heart contrast echocardiography revealed a semi-quantitative classification of the right-to-left shunt, with a grade 2 observed at rest (Fig. 3) and a grade 3 during the Valsalva maneuver (Fig. 4).

A 62-year-old male patient with cardioembolism presented with semi-quantitative right-to-left shunt grade 0 (Fig. 5) and Valsalva grade 2 (Fig. 6) at rest on right heart contrast echocardiography.

4. Discussion

A significant portion (20% to 30%) of cerebral infarctions are classified as CE. However, epidemiological studies have revealed that CE patients make up only 7% to 10% of hospitalized cases of ischemic cerebral infarction in China, which may be largely attributable to insufficient attention to CE diagnosis, resulting in missed diagnoses. These oversights can have a substantial impact on the initiation of secondary anticoagulant therapy and, consequently, on patient prognosis [13]. Therefore, accurate CE diagnosis is essential to guide

TABLE 4. Predictive value of right heart contrast echocardiography combined with STAF for CE.

Indicators	Cut-off value	AUC	Sensitivity	Specificity	95% CI	*p* value
Right-to-left shunt grade	-	0.582	46.3	69.9	0.509–0.655	0.032
Positive rate of patent foramen ovale	-	0.570	37.6	76.3	0.496–0.643	0.068
Long diameter of foramen ovale	11.34 mm	0.679	64.4	66.7	0.612–0.745	<0.001
Inner diameter of shunt	1.15 mm	0.808	75.2	75.3	0.754–0.862	<0.001
STAF	2	0.750	87.2	50.6	0.689–0.812	<0.001
Combined indicators	-	0.905	77.2	91.4	0.868–0.942	<0.001

AUC: area under the curve; STAF: Score for Targeting Atrial Fibrillation; CI: Confidence Interval.

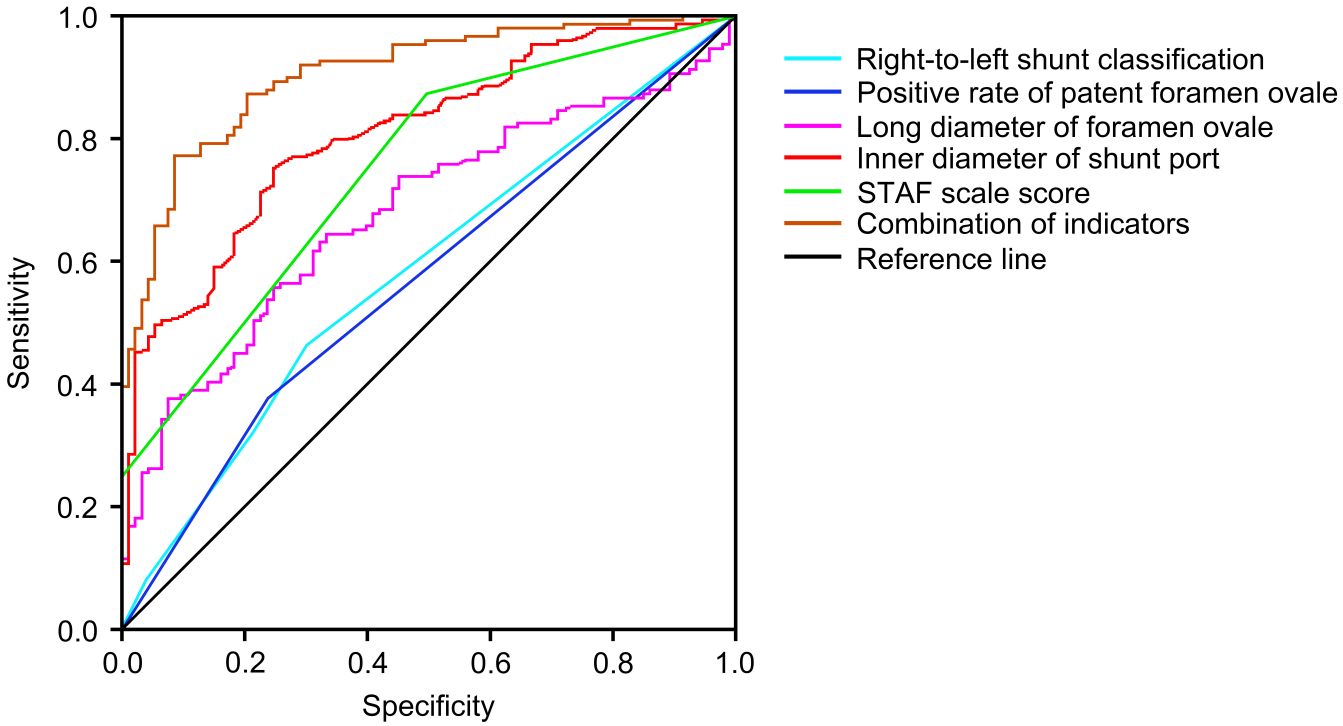

FIGURE 2. ROC curves of right heart contrast echocardiography results combined with STAF for predicting CE. STAF: Score for Targeting Atrial Fibrillation.

subsequent treatment and improve patient outcomes.

It has been established that individuals with patent foramen ovale exhibit elevated right heart pressure compared to the left heart [14]. Consequently, emboli originating from the venous system can directly access the left heart through the persistently open foramen ovale, bypassing the pulmonary circulation. Once these emboli reach intracranial arteries and branches [15], they can lead to cerebral ischemia. Thus, the right-to-left shunting induced by patent foramen ovale constitutes a critical pathological mechanism enabling emboli from the venous system or right heart to enter the systemic circulation, ultimately precipitating CE *in vivo*. The findings of this study show significantly higher positive rates of grade 1 + 2 + 3 right-to-left shunt, patent foramen ovale positivity, long diameter of foramen ovale and shunt diameter in the CE group compared to the NCE group. This highlights the utility of right heart contrast-enhanced ultrasound in the detection of patent foramen ovale and right-to-left shunting. In right heart contrast echocardiography, microbubble suspensions are introduced into the peripheral vein. These microbubble suspensions, being larger in diameter than red blood cells, scatter strongly in the bloodstream. Echocardiography then enables the enhanced visualization of the right atrium and right ventricle, enhancing image resolution and contrast. Normally, microbubble suspensions do not reach the left heart *via* the pulmonary circulation, resulting in a lack of contrast agent in the left heart chamber. However, in patients with patent foramen ovale, microbubble suspensions can traverse into the left chamber through a right-to-left shunt, allowing for their visualization within the left chamber. Some studies have even suggested that right heart contrast echocardiography can provide specific insights into the extent of right-to-left shunting in patients with patent foramen ovale [16], thereby offering valuable imaging support for patent foramen ovale closure.

STAF is a straightforward and convenient tool, encompassing multiple high-risk factors for cerebral infarction, including age, left atrial diameter, NIHSS score and vascular etiology. Furthermore, STAF is instrumental in monitoring changes in

TABLE 5. Univariate analysis of patients with CE.

Variables		Favorable prognosis group (n = 117)	Unfavorable prognosis group (n = 32)	t/χ^2	p
Sex					
Male	84	65	19	0.149	0.699
Female	65	52	13		
Age	58.64 ± 13.69	58.53 ± 13.19	59.04 ± 15.61	0.187	0.852
Atrial fibrillation	25	15	10	6.112	0.013
Alcohol history	36	28	8	0.016	0.900
Smoking history	47	39	8	0.808	0.369
Diabetes	38	28	10	0.708	0.400
Disease duration (h)		2.19 ± 0.39	2.14 ± 0.48	0.568	0.571
NIHSS score at admission (points)		10.31 ± 2.34	12.36 ± 3.89	3.750	<0.001
Creatine kinase isoenzyme (U/L)		4.26 ± 1.72	4.38 ± 1.53	0.358	0.721
High density lipoprotein (mmol/L)		1.09 ± 0.29	1.13 ± 0.31	0.681	0.497
Triglyceride (mmol/L)		1.89 ± 0.34	1.81 ± 0.36	1.165	0.246
Low density lipoprotein (mmol/L)		2.38 ± 0.62	2.49 ± 0.67	0.874	0.384
Total cholesterol (mmol/L)		4.29 ± 0.89	4.67 ± 0.84	2.165	0.032
Systolic blood pressure (mmHg)		149.65 ± 21.16	154.71 ± 19.62	1.217	0.226
Fasting blood glucose (mmol/L)		5.84 ± 1.29	6.15 ± 1.41	1.181	0.240
Diastolic (mmHg)		92.14 ± 10.47	91.53 ± 11.65	0.285	0.776
Fibrinogen (g/L)		3.07 ± 0.76	3.46 ± 0.71	2.608	0.010
D-dimer (mg/L)		0.58 ± 0.16	0.59 ± 0.15	0.317	0.751
Homocysteine (μmol/L)		10.12 ± 2.35	9.86 ± 2.54	0.545	0.587
Right-to-left shunt grade					
Grade 0	80	62	18		
Grade 1	21	16	5	1.093	0.779
Grade 2	35	28	7		
Grade 3	13	10	5		
Positive rate of patent foramen ovale	69	47	22	8.254	0.004
Long diameter of foramen ovale (mm)		11.58 ± 2.24	14.14 ± 3.97	4.755	<0.001
Inner diameter of shunt (mm)		1.41 ± 0.41	1.55 ± 0.44	1.677	0.096
STAF (Points)		2.03 ± 0.51	2.45 ± 0.62	3.930	<0.001

NIHSS: National Institutes of Health Stroke Scale; STAF: Score for Targeting Atrial Fibrillation.

TABLE 6. Multivariate logistic regression analysis of the prognosis of patients with CE.

Factors	β	SE	wald χ^2	OR	95% CI	p value
Atrial fibrillation	0.516	0.311	2.753	1.675	0.911–3.082	0.098
NIHSS score at admission	0.408	0.206	3.923	1.504	1.004–2.252	0.048
Total cholesterol	0.486	0.374	1.689	1.626	0.781–3.384	0.194
Fibrinogen	0.428	0.319	1.800	1.534	0.821–2.867	0.180
Positive rate of patent foramen ovale	0.626	0.245	6.529	1.870	1.157–3.023	0.011
Long diameter of foramen ovale	0.573	0.226	6.428	1.774	1.139–2.762	0.012
STAF	0.517	0.232	4.966	1.677	1.064–2.642	0.026

NIHSS: National Institutes of Health Stroke Scale; STAF: Score for Targeting Atrial Fibrillation; SE: Standard Error; OR: Odds Ratio; CI: Confidence Interval.

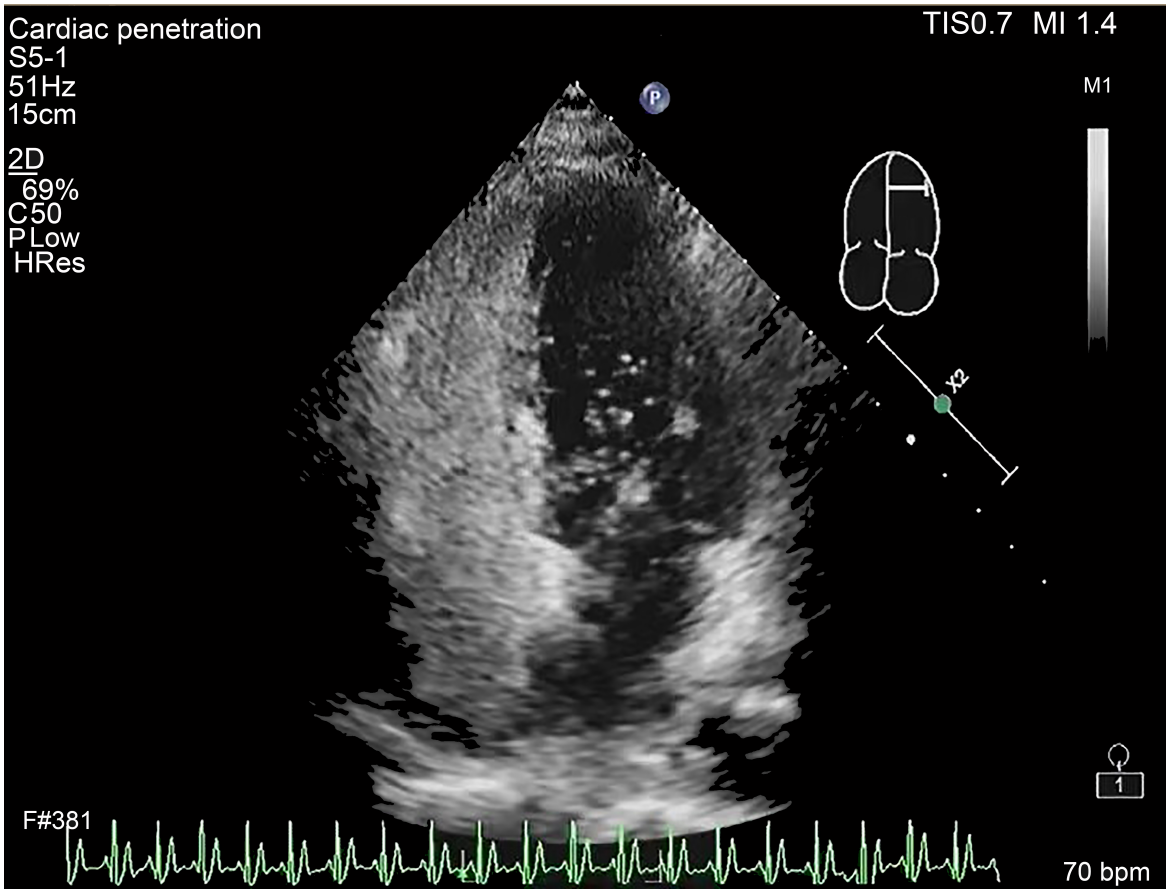

FIGURE 3. Right heart contrast echocardiography at rest.

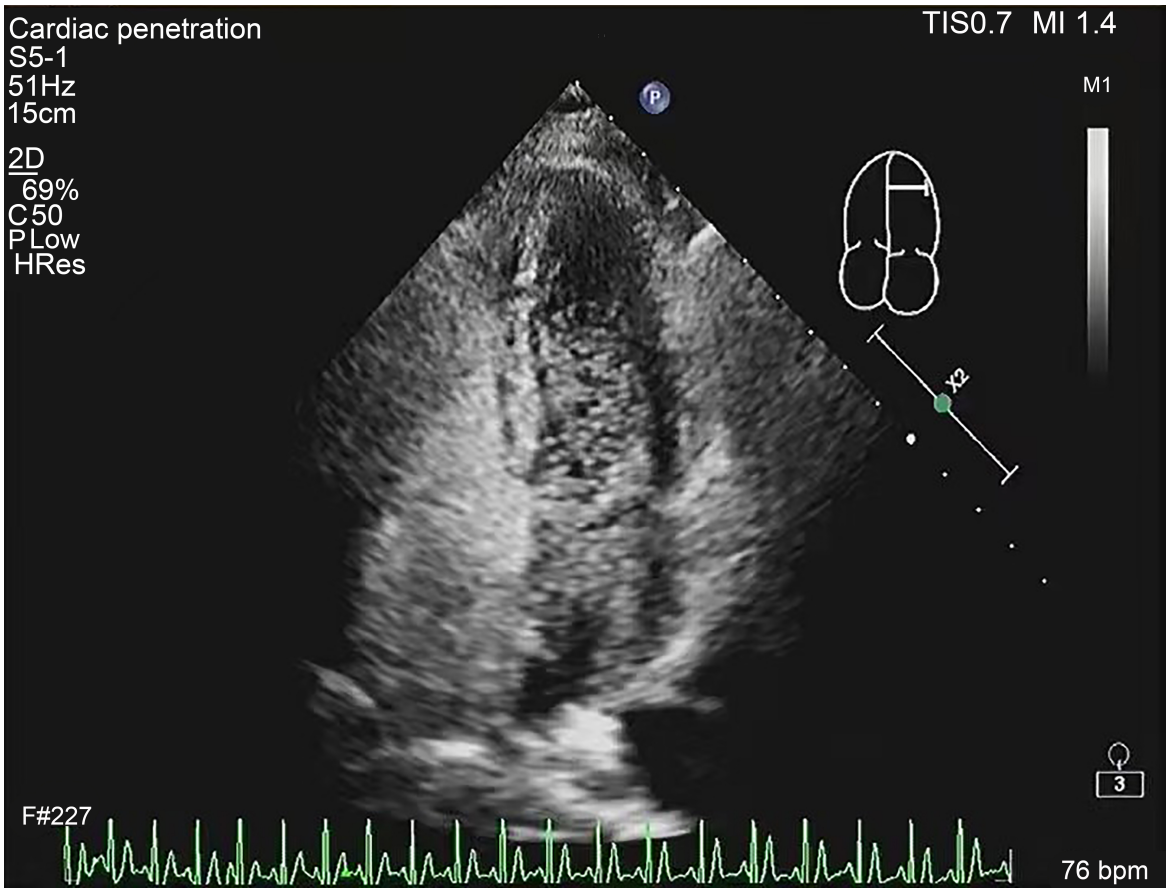

FIGURE 4. Right heart contrast echocardiography in Valsalva state.

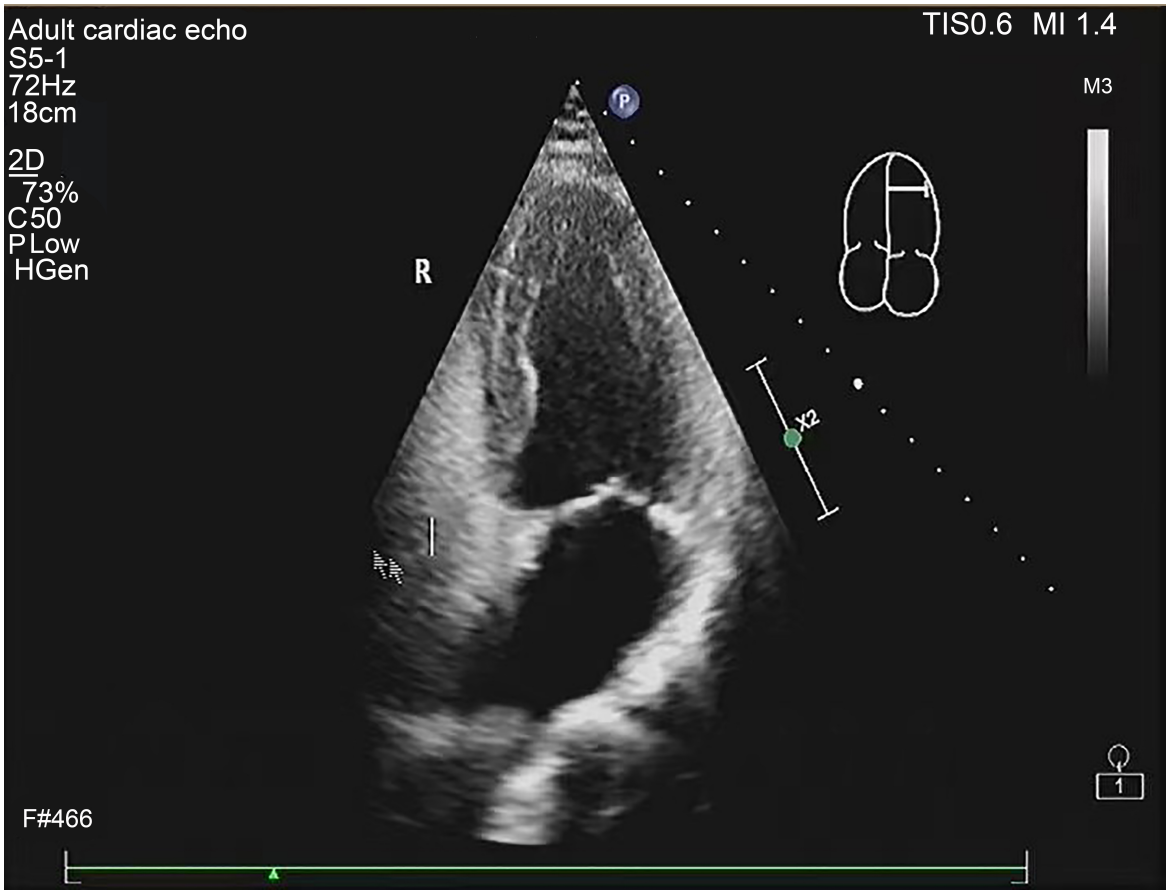

FIGURE 5. Right heart contrast echocardiography at rest.

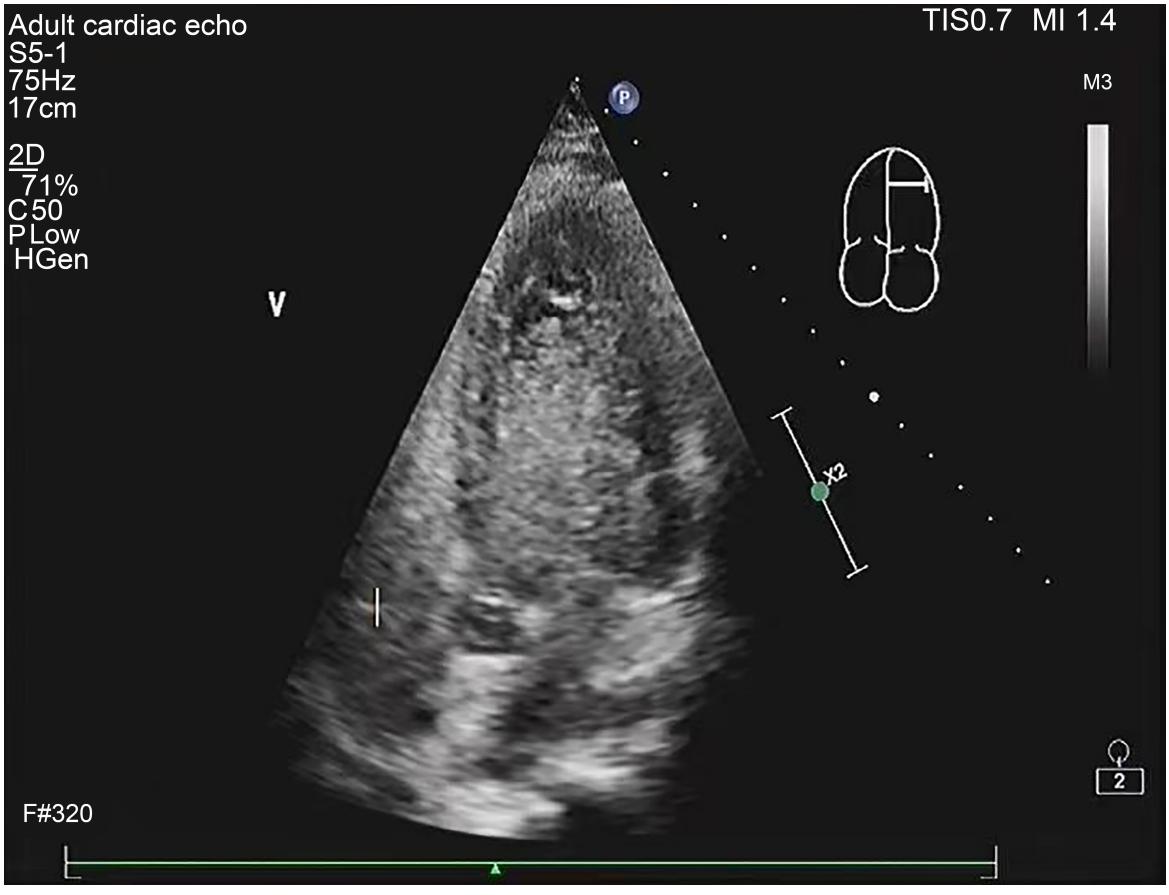

FIGURE 6. Right heart contrast echocardiography in Valsalva state.

cerebral infarction. It has been confirmed [7] that STAF can be used to effectively diagnose atrial fibrillation in cerebral infarction cases and aid in tracking patients' condition progression following cerebral infarction, and a separate study demonstrated that STAF scores were notably higher in CE patients compared to NCE patients. Furthermore, STAF's diagnostic utility for CE patients surpassed that of cardiac troponin I, underscoring its value as a reliable reference for predicting CE diagnoses [17]. In this study, STAF was higher in patients from the CE group compared to those in the NCE group, demonstrating a clear association between STAF and the occurrence of CE in patients. Notably, previous investigations into right heart contrast echocardiography parameters for predicting CE did not incorporate ROC analysis, which was introduced in this study. The findings revealed that the AUC values for right-to-left shunt grade, the positive rate of patent foramen ovale, the long diameter of foramen ovale, the inner diameter of the shunt, and STAF for CE prediction were 0.582, 0.570, 0.679, 0.808 and 0.750, respectively. The combined AUC values for all these indices amounted to 0.905. These results underscored the valuable contribution of right heart contrast echocardiography combined with STAF in enhancing the diagnostic accuracy of CE. Furthermore, the study used multiple logistic regression analysis to identify potential prognostic factors in CE patients, which showed that the positive rate of patent foramen ovale, long diameter of foramen ovale and STAF were significant prognostic factors in CE patients, emphasizing the close relationship between the assessment of foramen ovale and STAF *via* right heart contrast echocardiography and the clinical condition of CE patients. Additionally, the analysis revealed that the NIHSS score at admission was also a prognostic factor in CE patients. Lower NIHSS scores at admission were indicative of smaller infarct sizes, milder neurological impairment and a faster rate of recovery following symptomatic treatment, leading to more favorable prognoses. Previous studies have similarly demonstrated the impact of baseline NIHSS scores on patient prognoses, indicating that it is an important predictor of favorable 3-month prognosis (Odds Ratio (OR) = 0.604, 95% Confidence Interval (CI): 0.436–0.837, $p = 0.002$) [18, 19], which is consistent with the conclusions of our present study.

5. Conclusions

In conclusion, the use of both right heart contrast echocardiography and STAF provides valuable insights into the condition of CE patients as their synergistic use improves the overall diagnostic accuracy of CE. Moreover, the NIHSS score at admission, the positive rate of patent foramen ovale, the long diameter of foramen ovale and STAF were identified as significant prognostic factors in CE patients, indicating the importance of monitoring patients with these factors and promptly initiating targeted treatments to improve patient prognoses.

AVAILABILITY OF DATA AND MATERIALS

The authors declare that all data supporting the findings of this study are available within the paper and any raw data can be obtained from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

JJW and ZS—designed the study and carried them out; JJW, DML, HC—supervised the data collection, analyzed the data, interpreted the data, prepare the manuscript for publication and reviewed the draft of the manuscript. All authors have read and approved the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Ethics Committee of Guang'an People's Hospital (Approval no. 2022014). Written informed consent was obtained from a legally authorized representative(s) for anonymized patient information to be published in this article.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This work was supported by Sichuan government Transfer payment project (2021ZYZFSY01), Scientific and technological innovation guiding plan project of Guang'an (2021zdxjh13) and Guang'an People's Hospital High Quality Development Fund Project (21FZ009).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Suzuki ARCSY, Tsubakino S, Fujii H. Motor function and activities of daily living recovery after cardiogenic internal carotid artery infarction: a retrospective cohort study. Journal of Stroke and Cerebrovascular Diseases. 2021; 30: 105734.

[2] Terasawa Y, Miyamoto Y, Kohriyama T. Features of cerebral infarction due to left ventricular thrombus. Internal Medicine. 2022; 61: 2581–2585.

[3] Katano T, Suda S, Ohta T, Miyagami M, Kodaira Y, Konaka C, *et al.* Regular pulse checks for patients with non-cardioembolic stroke in rehabilitation hospitals to improve recognition and detection of atrial fibrillation (the ESCORT study): protocol for a prospective multicenter observational study. Frontiers in Neurology. 2023; 14: 1247020.

[4] Canali E, Serani M, Tarzia P, Ciampi P, Canestrelli S, Calò L. Echocardiography in cardioembolic stroke prevention. European Heart Journal Supplements. 2023; 25: C212–C217.

[5] Nakayama R, Takaya Y, Akagi T, Watanabe N, Ikeda M, Nakagawa K, *et al*. Identification of high-risk patent foramen ovale associated with cryptogenic stroke: development of a scoring system. Journal of the American Society of Echocardiography. 2019; 32: 811–816.

[6] Ji MH, Seoung YH. Right-to-left shunt evaluation in cardiac patent foramen ovale using bubble contrast transcranial color-coded doppler: a cryptogenic stroke case. Healthcare. 2023; 11: 2655.

[7] Chen X, Luo W, Li J, Li M, Wang L, Rao Y, *et al*. Diagnostic accuracy of STAF, LADS, and iPAB scores for predicting paroxysmal atrial fibrillation in patients with acute cerebral infarction. Clinical Cardiology. 2018; 41: 1507–1512.

[8] Ratajczak-Tretel B, Lambert AT, Al-Ani R, Arntzen K, Bakkejord G, Bekkeseth H, *et al.* Prediction of underlying atrial fibrillation in patients

with a cryptogenic stroke: results from the NOR-FIB Study. Journal of Neurology. 2023; 270: 4049–4059.

[9] Lin S, Long Y, Chen X, Lin P, Jiang H. STAF score is a new simple approach for diagnosing cardioembolic stroke. International Journal of Neuroscience. 2017; 127: 261–266.

[10] Feng C, Luo T, Luo Y, Zhao N, Huang K, Xiao C. Contrast-enhanced transthoracic echocardiography applied in evaluation of pulmonary right-to-left shunt: a preliminary study. Computerized Medical Imaging and Graphics. 2018; 68: 55–60.

[11] Ukponmwan EU, Banga S, Kim AG, Qintar M, Abela G. Cryptogenic stroke caused by a newly diagnosed patent foramen ovale in a healthy young adult. Cureus. 2023; 265: e46895.

[12] Göksu E, Yüksel B, Esin M, Küçükseymen E, Ünal A, Genç A, *et al.* The value of STAF (score for the targeting of atrial fibrillation) in patients with cryptogenic embolic stroke. Noro Psikiyatri Arsivi. 2019; 56: 119–122.

[13] Mead GE, Sposato LA, Sampaio Silva G, Yperzeele L, Wu S, Kutlubaev M, *et al*. A systematic review and synthesis of global stroke guidelines on behalf of the World Stroke Organization. International Journal of Stroke. 2023; 18: 499–531.

[14] Teshome MK, Najib K, Nwagbara CC, Akinseye OA, Ibebuogu UN. Patent foramen ovale: a comprehensive review. Current Problems in Cardiology. 2020; 45: 100392.

[15] Dia A, Cifu AS, Shah AP. Management of patients with a patent foramen ovale with history of stroke or TIA. JAMA. 2021; 325: 81–82.

[16] Fleissner F, Frank P, Haverich A, Ismail I. Echocardiographic guided, transatrial closure of a patent foramen ovale. Journal of Cardiothoracic Surgery. 2020; 15: 255.

[17] Liu LB, Guo YD, Xu AD, Zhong JX, Zhuo WY. Diagnostic value of STAF score in combination with D-dimer in cardioembolism. PLOS ONE. 2018; 13: e0204838.

[18] Zeng Y, Long C, Zhao W, Liu J. Predicting the severity of neurological impairment caused by ischemic stroke using deep learning based on diffusion-weighted images. Journal of Clinical Medicine. 2022; 11: 4008.

[19] Du J, Wang Y, Che B, Miao M, Bao A, Peng Y, *et al*. The relationship between neurological function trajectory, assessed by repeated NIHSS measurement, and long-term cardiovascular events, recurrent stroke, and mortality after ischemic stroke. International Journal of Stroke. 2023; 18: 1005–1014.

How to cite this article: Junjie Wen, Dingming Liu, Hua Chen, Zhan Su. Predictive value of right heart contrast echocardiography combined with STAF in cardioembolism. Signa Vitae. 2024; 20(1): 84-93. doi: 10.22514/sv.2024.004.