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Research Paper

Can Neurological Characteristics and Comorbidities Predict Early Mortality of Non-traumatic Sub-arachnoid Hemorrhage?

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ABSTRACT

Background: Non-traumatic subarachnoid hemorrhage (SAH) is a severe cerebrovascular emergency with a high early mortality rate due to risks of neurological deterioration, rebleeding, and elevated intracranial pressure. Prognosis largely depends on hemorrhage severity and level of consciousness at presentation. Identifying predictors of early mortality is crucial for timely intervention.

Objectives: This study evaluated the clinical and demographic predictors of 24-hour and in-hospital mortality in patients with non-traumatic SAH and identify high-risk profiles.

Materials & Methods: A retrospective study of 174 adults diagnosed with non-traumatic SAH between March 2020 and February 2024 was conducted. Data on demographics, comorbidities, presenting symptoms, imaging findings, and neurological scores (Glasgow coma scale [GCS], Hunt–Hess grade, modified Rankin scale [MRS]) were collected. Univariate and multivariate logistic regression analyses identified independent predictors of 24-hour and in-hospital mortality.

Results: Early (24-hour) mortality occurred in 3.4% of patients, and overall, in-hospital mortality was 35.6%. Higher SAH grades and lower GCS scores were strongly associated with mortality. Each additional GCS point reduced the odds of 24-hour death by 43% (OR=0.57, P<0.001), while higher SAH grade increased the risk of mortality. Age was inversely correlated with early mortality but increased overall in-hospital mortality risk. Hypertension independently raised the odds of in-hospital death (OR=3.3, P=0.021). Other comorbidities and demographics were not significant predictors after adjustment.

Conclusion: GCS and SAH grade at admission are the strongest predictors of early mortality in non-traumatic SAH. Comorbidities play a secondary role. Early identification of high-risk patients and prompt targeted management may reduce preventable deaths, particularly in resource-limited settings.

Keywords: Non-traumatic subarachnoid hemorrhage (SAH), Early mortality, Glasgow coma scale (GCS), Hunt–Hess grade, Hypertension, Prognosis

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Highlights

- Lower admission GCS predicted both 24-hour and in-hospital mortality of SAH.
- Higher SAH grades increased the risk of early and overall in-hospital mortality.
- Hypertension and older age raised in-hospital mortality risk for SAH.
- Early mortality occurred in 3.4%, while overall in-hospital mortality was 35.6%.
- The incidence of SAH in this cohort was lower than national and international rates.

Introduction

Subarachnoid hemorrhage (SAH) is a life-threatening neurological emergency characterized by bleeding into the subarachnoid space, leading to abrupt intracranial pressure elevation, cerebral perfusion impairment, and a broad spectrum of acute and long-term neurological deficits [1-3]. Non-traumatic SAH most commonly results from aneurysmal rupture, accounting for approximately 85% of cases, although a substantial proportion of patients demonstrate no identifiable vascular source on angiographic evaluation, referred to as angiogram-negative SAH [4-6]. Compared to other SAH subtypes, non-traumatic SAH disproportionately affects younger individuals and contributes to considerable morbidity, persistent functional and neurologic impairment, and reduced quality of life among survivors [2, 3].

Patients typically present with sudden severe headache, nausea, vomiting, neck stiffness, photophobia, seizures, or focal neurological deficits, such as hemiplegia or sensory loss [7]. The hemorrhage can precipitate life-threatening complications, including rebleeding, hydrocephalus, delayed cerebral ischemia secondary to vasospasm, cardiac dysfunction, and pulmonary edema, all of which significantly influence short- and long-term outcomes [8-11]. Prognosis is shaped by multiple interrelated factors, including patient-specific characteristics (age, hypertension, diabetes, smoking, and cardiovascular disease), the underlying vascular pathology, and the severity of neurological injury at presentation [12-15]. Modifiable lifestyle factors, particularly cigarette smoking and excessive alcohol consumption, remain important contributors to aneurysm formation and rupture risk [14, 15].

Timely neuroimaging, including computed tomography (CT), CT angiography, and digital subtraction angiography (DSA) is central for prognosis stratification, detection of secondary complications, and informing surgical or endovascular treatment decisions [16-20]. Outcome patterns also vary across populations due to demographic and health system factors [21].

In Guilan Province, vascular comorbidities are common, yet there is limited local data on predictors of early and in-hospital mortality in non-traumatic SAH. This study aimed to evaluate clinical, demographic, and neurological predictors of 24-hour and in-hospital mortality in patients with non-traumatic SAH admitted to Poursina Hospital, a tertiary referral center in Rasht, Guilan, Iran. By identifying high-risk profiles, the study aimed to inform early management strategies and improve patient outcomes in this high-risk population.

Materials and Methods

Study design and setting

This analytical retrospective cross-sectional study was conducted at Poursina Academic Hospital, a tertiary referral center for neurological disorders in Rasht, Guilan, Iran. The study was performed to identify demographic, clinical, and neurological predictors of short-term outcomes in adults with non-traumatic SAH. The study period extended from March 2020 to February 2024. The study protocol was approved by the Ethics Committee of Guilan University of Medical Sciences. All procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki (2013).

Patient selection

Eligible participants were adults aged ≥18 years with a diagnosis of non-traumatic SAH confirmed by CT, cerebral angiography, or lumbar puncture, based on standard diagnostic criteria. Patients were excluded if they had traumatic SAH, SAH secondary to coagulation disorders, or incomplete or invalid medical records.

Sampling method

Due to the low incidence of non-traumatic SAH, census sampling was employed. All eligible patients admitted consecutively during the study period were included.

Data collection

Data were extracted from electronic and paper-based medical records using a structured checklist. Two trained investigators independently reviewed all records to ensure accuracy and consistency. Missing data were addressed using multiple imputation methods.

Variables collected

• Demographic and lifestyle factors: Age, sex, marital status, occupation, smoking status, alcohol consumption, and substance use

• Comorbidities: Hypertension, diabetes mellitus, ischemic heart disease, hyperlipidemia, and prior intracerebral hemorrhage or SAH

• Clinical presentation: Sudden headache, nausea or vomiting, thunderclap headache, loss of consciousness, paresis, and vital signs at admission

• Neurological and functional scores: Glasgow coma scale (GCS) score at admission and hospitalization, Hunt–Hess grade, and modified Rankin scale (MRS) score at admission and discharge

• Imaging findings: CT scan and cerebral angiography results, including the presence of intracranial aneurysms

Perioperative variables and the modified Fisher grade were recorded but not included in the analysis due to the limited number of surgically treated patients.

Outcome measures

Primary outcomes included early mortality within the first 24 hours of hospitalization (24-hour mortality) and in-hospital mortality. Functional status at admission and discharge was assessed using the MRS, which ranged from 0 (no symptoms) to 6 (death).

SAH severity classification

SAH severity was classified using the Hunt–Hess grading system (grades I–V), with higher grades indicating greater neurological impairment and poorer early prognosis.

Statistical analysis

Continuous variables were expressed as Mean±SD, and categorical variables as frequencies and percentages. Normality was assessed using the Shapiro–Wilk test. Age showed a normal distribution, whereas other continuous variables were non-normally distributed.

Comparisons were performed using the independent-samples t-test for normally distributed variables, the Mann–Whitney U test for non-normally distributed variables, and Fisher's exact test for categorical variables.

Univariate binary logistic regression analysis was used to identify candidate predictors of 24-hour and in-hospital mortality ($P<0.10$). Multivariate logistic regression was subsequently performed using backward likelihood ratio selection. Odds ratios (ORs) with 95% confidence intervals (CIs) were reported. Statistical significance was defined as $P<0.05$. All analyses were conducted using SPSS software, version 25.

Results

Population and incidence: Over the five-year study period between March 2020 and February 2024, 174 patients were hospitalized with non-traumatic SAH at Poursina Academic Hospital, Rasht, serving a population of 2,675,000. Hospitalizations peaked in 2023 (56 patients, 32.2%) and were lowest in 2020 and 2021 (18 patients each, 10.3%). Six patients (3.4%) died within 24 hours of admission, half of whom were hospitalized in 2023. Overall, 62 patients (35.6%) died during hospitalization. The annual incidence of SAH ranged from 0.67 to 2.09 per 100,000 population, with the highest incidence observed in 2023.

Baseline characteristics

Baseline demographic, lifestyle, and clinical characteristics are summarized in Table 1. The mean age was 58.4±13.4 years, and 55.2% of patients were female. Hypertension was the most common comorbidity, present in nearly half of the cohort. Smoking and substance use were reported in approximately one-fifth of patients, while alcohol consumption was uncommon.

The most frequent presenting symptoms were headache, nausea or vomiting, and decreased level of consciousness. Intracranial aneurysms were identified in 27.6% of patients. None of the demographic characteristics, lifestyle factors, presenting symptoms, or admission blood pressure measurements were significantly

associated with 24-hour mortality. Patients who died within 24 hours were younger than survivors.

SAH severity, GCS, and mortality

Distributions of SAH grade and admission GCS scores, along with mortality outcomes, are presented in Tables 2 and 3 and illustrated in Figure 1. SAH severity was most frequently classified as grades 2 and 3. Increasing SAH grade was associated with progressively lower GCS scores and higher mortality rates.

In-hospital mortality increased markedly with increasing SAH grade, exceeding 60% among patients with grades 4 and 5 hemorrhage (Figure 1). Grade 5 SAH accounted for the majority of deaths occurring within the first 24 hours.

Admission GCS category demonstrated a strong inverse association with both early and in-hospital mortality (Figure 1A). Nearly all 24-hour deaths occurred among patients with low GCS scores (3–8), who also experienced the highest in-hospital mortality.

Functional status and outcomes

Functional status at admission, assessed by the MRS, is summarized in Table 4. More than half of patients (56.3%) presented with unfavorable functional status (MRS 3–6). Patients who died within 24 hours had significantly higher admission MRS scores compared with survivors; however, dichotomized favorable versus unfavorable MRS categories did not differ significantly between groups. Multivariate analysis of predictors of unfavorable functional outcome at discharge is shown in Table 5. Increasing age and higher SAH grade were independently associated with poor functional outcome, while hypertension showed a borderline association. These results highlight that baseline neurological function and stroke severity strongly determine functional outcomes at discharge, while age and comorbidities further modify recovery.

Table 1. Baseline demographic and clinical characteristics of patients with SAH (n=174)

Characteristic		Mean±SD/No. (%)
Age (y)		58.4±13.4
Female sex		96(55.2)
Married		164(94.3)
Occupation	Homemaker	98(56.3)
Lifestyle factors	Smoking	38(21.8)
	Substance use	31(17.8)
	Alcohol consumption	6(3.5)
	Any comorbidity present	101(58.1)
	Hypertension	86(49.4)
	Admission systolic BP (mm Hg)	142.1±30.1
	Admission diastolic BP (mm Hg)	83.6±17
	Intracranial aneurysm identified,	48(27.6)
Presenting symptoms	Headache	147(84.5)
	Nausea or vomiting	95(54.6)
	Decreased level of consciousness	91(52.3)

Table 2. SAH severity, the GCS, and mortality outcomes

Subarachnoid Hemorrhage (SAH) Grade	No. (%)	Mean±SD	No. (%)	
		GCS Score	24-hour Mortality	In-hospital Mortality
1	20(11.5)	15±0	0(0)	2(10)
2	75(43.1)	13±2.5	0(0)	15(20)
3	35(20.1)	11±3	1(2.9)	18(51.4)
4	24(13.8)	9±3.2	1(4.2)	15(62.5)
5	20(11.5)	5.5±2	5(25)	12(60)

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Note: Mortality increased progressively with higher SAH grades, while mean GCS scores decreased with increasing severity.

Table 3. Admission GCS categories and mortality

GCS Category	No. (%)	No. (%)	
		24-hour Mortality	In-hospital Mortality
3–8 (poor)	55(31.6)	5(9.1)	38(69.1)
9–12	63(36.2)	1(1.6)	17(27)
13–15	56(32.2)	0(0)	7(12.5)

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Note: Lower admission GCS was strongly associated with both early and in-hospital mortality; nearly all early deaths occurred in the poor GCS category.

Table 4. Functional status according to the MRS at admission

Measure	Mean±SD/ Median (IQR)/No. (%)		
	Total (n=174)	24-hour Survivors	24-hour Deaths
MRS	3.14±1.46	3.10±1.44	4.33±1.63
MRS	3 (2–5)	3 (2–4.5)	5 (5–5)
Favorable (0–2)	76 (43.7)	—	—
Unfavorable (3–6)	98 (56.3)	—	—

Mann-Whitney U test, P=0.039 (continuous MRS)

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Table 5. The MRS score at discharge: Multivariate predictors of unfavorable outcome (MRS 3–6)

Predictor	Odds Ratio (OR)	P
Age (per year increase)	1.08	0.002
Hypertension	3.06	0.056
SAH grade (per grade increase)	14.03	<0.001

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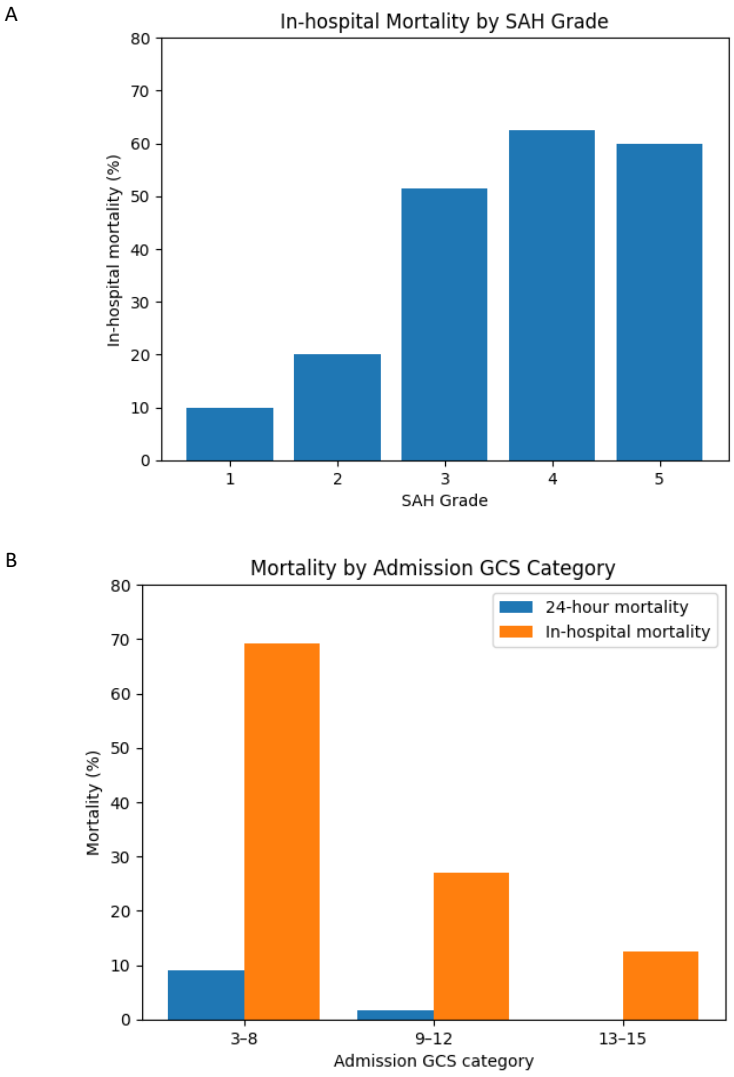

Figure 1. Association between admission neurological severity and mortality outcomes

A) In-hospital mortality rate based on SAH grade, B) Mortality rate based on admission GCS category

Predictors of mortality

Multivariate logistic regression analyses are presented in Table 6. Lower admission GCS score was the strongest independent predictor of both 24-hour and in-hospital mortality. Increasing age was inversely associated with 24-hour mortality but independently increased the risk of in-hospital death. Pre-existing hypertension and higher SAH grade were also independently associated with in-hospital mortality.

Key findings

The GCS and SAH grade were the strongest predictors of both early and overall in-hospital mortality. Age showed contrasting effects, appearing protective against 24-hour mortality but increasing the risk of in-hospital death. Hypertension and comorbidities significantly increased the risk of in-hospital mortality. The low number of early deaths limited the statistical power of the 24-hour mortality analyses.

Discussion

In this single center retrospective study of 174 patients with non-traumatic SAH, early 24-hour mortality was 3.4%, and overall, in-hospital mortality was 35.6%. These mortality rates are comparable to those reported in hospital-based and population-level studies, in which in-hospital mortality ranged from approximately 25% to 45%, depending on case mix, neurological severity, and healthcare setting [21-23]. Despite advances in aneu-

Table 6. Multivariate logistic regression analyses for mortality

Variables		Odds Ratio (OR)	P
Predictors of 24-hour mortality	Age (per year increase)	0.89	0.030
	GCS score (per point increase)	0.57	<0.001
Predictors of in-hospital mortality	Age (per year increase)	1.05	0.018
	Hypertension	3.3	0.021
	GCS score (per point increase)	0.69	0.003
	SAH grade (per grade increase)	2.02	0.058

rysm management and neurocritical care, SAH remains associated with substantial mortality and long-term disability [21].

Neurological severity at admission was the strongest determinant of both early and in-hospital mortality in our study. Patients who died within 24 hours had significantly lower admission GCS scores, and mortality increased progressively with worsening SAH grade. Notably, SAH grade 5 accounted for 83.3% of early deaths, compared with 7.1% among survivors. Similarly, in-hospital mortality increased from 10% in SAH grade 1 to 60% in SAH grade 5. Admission GCS score showed a strong inverse association with mortality: 24-hour mortality occurred almost exclusively in patients with low GCS scores [3-6], and in-hospital mortality reached 69.1% in this group, compared to 12.5% among patients with GCS scores of 13–15. These findings reinforce the dominant role of early neurological injury in determining prognosis and are consistent with prior studies showing that admission neurological status outperforms demographic variables in mortality prediction [24, 25]. Lashkarivand et al. similarly reported markedly elevated mortality among patients presenting with GCS scores of 3–5 [26], and comparable gradients across clinical severity grades have been described in high-grade SAH cohorts [27].

Age demonstrated contrasting associations with early versus in-hospital mortality. Patients who died within 24 hours were younger than survivors (mean age 49.3 vs 58.3 years), and multivariate analysis showed that each additional year of age was associated with an 11% reduction in the odds of early death (OR=0.89). In contrast, increasing age independently increased the risk of in-hospital mortality, with each additional year raising the odds of death by approximately 5% (OR=1.05). This divergence likely reflects differing mechanisms underlying early versus delayed mortality. Vergouwen et al. reported that early deaths are more often attributable to the initial hemorrhage, whereas later deaths are increasingly driven by systemic and medical complications that disproportionately affect older patients [28]. Population-based data from Finland similarly demonstrate higher in-hospital case fatality rates among elderly SAH patients [22], and Engström et al. identified advanced age and poorer premorbid health as independent predictors of mortality following aneurysmal SAH [24].

Hypertension was the most prevalent comorbidity in our cohort (49.4%) and emerged as an independent predictor of in-hospital mortality, increasing the odds of death more than threefold (OR=3.3). However, hypertension was not associated with 24-hour mortality, suggesting that while it contributes to overall disease burden and vulnerability to complications, it has limited influence on immediate post-rupture outcomes. Similar associations between hypertension and in-hospital mortality have been reported in hospitalized SAH cohorts [29]. Malinova et al. demonstrated that comorbidity burden, particularly hypertension, adds prognostic value beyond neurological severity scores [30]. In contrast, diabetes mellitus and ischemic heart disease were associated with mortality only in univariate analyses in our study and lost significance after multivariate adjustment, consistent with findings from other retrospective ICU- and hospital-based studies [23, 30].

Women accounted for 55.2% of patients in our study, consistent with prior epidemiological studies reporting a female predominance in SAH [31]. Smoking (21.8%) and diabetes mellitus (17.8%) were also common, reflecting known vascular risk factors in SAH populations. While these conditions contribute to long-term cerebrovascular vulnerability, their lack of independent association with early mortality in our analysis underscores the

overriding importance of acute neurological injury in determining short-term outcomes [32].

The most common presenting symptoms, sudden severe headache (84.5%), nausea or vomiting (54.6%), and decreased level of consciousness (52.3%), are characteristic of acute SAH and reflect abrupt increases in intracranial pressure following aneurysmal rupture [32]. Although higher admission MRS scores were observed among patients who died within 24 hours (mean 4.33 vs 3.10), MRS did not independently predict early mortality when dichotomized into favorable and unfavorable categories. This finding suggests that while MRS captures baseline functional impairment, GCS remains a more sensitive indicator of acute neurological deterioration and early mortality risk [30].

Functional outcome at discharge was strongly influenced by baseline neurological status and SAH severity. In multivariate analysis, each increase in SAH grade increased the odds of unfavorable functional outcome by more than 14-fold, while increasing age was associated with an 8% rise in the odds of poor outcome per year. Hypertension was associated with nearly a threefold increase in the odds of unfavorable MRS at discharge. These findings align with prior studies demonstrating that clinical severity grading systems strongly predict functional dependency following SAH [31, 33].

Long-term outcome studies further support the central role of early neurological injury. In the 10-year follow-up of the International Subarachnoid Aneurysm Trial cohort, Hua et al. reported persistent dependency and reduced quality of life among survivors, particularly those with poor initial clinical grades [34]. Daou et al. similarly emphasized that early neurological severity has lasting effects on survival and functional independence, even among patients who survive the acute hospitalization [35]. More recently, machine learning–based prognostic models have consistently identified admission GCS score, SAH grade, and comorbidity burden as the most influential predictors of outcome, reinforcing the robustness of traditional clinical predictors [33].

Overall, our results demonstrated that neurological severity at presentation was the principal determinant of both early and in-hospital mortality and functional outcome following non-traumatic SAH, while age and hypertension significantly influenced in-hospital prognosis. These findings support the importance of early risk stratification and targeted neurocritical care in the acute management of SAH.

Conclusion

In this cohort of 174 patients with non-traumatic SAH, initial neurological status and hemorrhage severity were the strongest predictors of early and in-hospital mortality. Each 1-point decrease in GCS score increased the odds of early death by 65.6%, and each 1-grade increase in SAH severity raised the odds by 102%. Older age and hypertension further elevated in-hospital mortality risk, while other comorbidities were not independent predictors.

These findings highlight the utility of simple, rapidly measurable indicators for bedside risk stratification, guiding ICU triage, neurosurgical evaluation, and timely clinical decision-making. Integrating clinical scores, hemorrhage severity, and patient characteristics allows accurate early risk estimation, supporting individualized care and optimized resource allocation, particularly in high-demand or resource-limited settings.

Future research

Future studies should explore:

The impact of additional comorbidities (renal failure, diabetes, coagulation disorders) on outcomes.

Effects of hospital presentation delays and time-to-treatment intervals on early mortality.

Predictive models combining multiple clinical indicators for improved prognostic accuracy.

Outcomes of early interventions, including blood pressure management and surgical treatments.

Multicenter studies to assess epidemiological and clinical variations.

Correlations between imaging findings (CT/MRI) and hemorrhage severity or prognosis.

Limitations

This retrospective, single-center study is limited by dependence on pre-existing documentation, potential data incompleteness, and variability in clinical recording, which may introduce information bias. Generalizability is constrained by the specific patient population and institutional practices. Certain clinical variables were unavailable, limiting interpretability. Despite procedures to address missing or inconsistent data, residual bias could

not be fully excluded. Prospective, multicenter studies are warranted to validate and expand these findings.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Research Ethics Committee of the Guilan University of Medical Sciences, Rasht, Iran (Code: IR.GUMS.REC.1403.540). All study procedures were in compliance with the ethical guidelines of the Declaration of Helsinki, 2013.

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This study was extracted from the General Medical Doctorate thesis of Armin Gharagozlou, approved by the School of Medicine, Guilan University of Medical Sciences, Rasht, Iran.

Authors contributions

Conceptualization: Yaser Moadabi; Methodology: Armin Gharagozlou, Mohammad Ali Yazdanipour, and Kimia Shameli; Investigation: Nastaran Mohseni, Yaser Moadabi, and Armin Gharagozlou; Writing: All authors; Resources: Armin Gharagozlou; Supervision: Yaser Moadabi.

Conflict of interest

The authors declared no conflict of interest.

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