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Impact of treatment management on the hospital stay in patients with acute coronary syndrome

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Abstract

Background The length of hospital stay in patients with acute coronary syndrome (ACS) is crucial for determining clinical outcomes, managing healthcare resources, controlling costs, and ensuring patient well-being. This study aimed to explore the impact of treatment approaches on the length of stay (LOS) for ACS patients.

Methods A total of 7109 ACS cases were retrospectively recruited from a hospital between 2018 and 2023. Demographical baseline data, laboratory examinations, and diagnostic and treatment information of the included subjects were extracted from electronic medical records to investigate the factors contributing to extended hospitalization and further explore the impact of treatment management on the LOS.

Results Advanced age, female sex, and elevated levels of B-type natriuretic peptide, C-reactive protein and higher low-density lipoprotein cholesterol were identified as risk factors for extended hospitalization. At the 0.2–0.9 quantile of LOS, compared with the non-invasive group, the percutaneous transluminal coronary angioplasty group and the stent implantation group exhibited decreases in LOS of 0.37–2.37 days and 0.12–2.28 days, respectively. Stratified analysis based on diagnosis showed that percutaneous coronary intervention decreased hospitalization time in the high quantile of LOS but conversely increased it in the low quantile.

Conclusion Percutaneous coronary intervention is important for reducing hospitalization duration, particularly for patients susceptible to prolonged stays. Early and assertive management intervention, incorporating elements such as lipid-lowering therapy, and anti-inflammatory agents, is essential for improving outcomes within high-risk groups.

Keywords Acute coronary syndrome, Percutaneous coronary intervention, The length of hospital stay, Retrospective study, Quantile regression

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Introduction

Acute coronary syndrome (ACS) encompasses a range of conditions resulting from the sudden reduction or cessation of blood flow to the heart muscle [1]. This reduction is typically caused by a clot blocking a coronary artery, leading to various manifestations based on severity and clinical impact [1, 2]. ACS includes unstable angina (UA) and myocardial infarction, which is further categorized into ST-elevation myocardial infarction (STEMI) and non-ST-elevation myocardial infarction (NSTEMI) based on electrocardiographic findings [1, 2]. The pathophysiology of ACS involves the rupture or erosion of atherosclerotic plaques within the coronary arteries, triggering platelet activation, thrombus formation, and subsequent ischemia or infarction of the myocardium [3–5]. Multiple risk factors contribute to the onset of ACS, including modifiable factors such as tobacco use, unhealthy diet, physical inactivity, and obesity, as well as non-modifiable factors like age, gender, and family history of cardiovascular diseases [6]. The intricate interplay among these risk factors and their underlying mechanisms highlights the complexity of ACS, posing a challenge for effective management.

The progression of diagnostic tools has brought a transformative shift in ACS management. High-sensitivity cardiac troponin assays now enable more precise detection of myocardial injury [7]. While the diagnosis of STEMI/NSTEMI is typically clear, artificial intelligence (AI) plays an important role in electrocardiography (ECG) by interpreting and detecting ST-segment changes, as well as monitoring ECG signals from cardiac implantable electronic devices and wearable devices in real time [8, 9]. A study conducted by Chen and coworkers [10] showed that AI-assisted detection of STEMI using prehospital 12-lead electrocardiograms facilitates patient triage for timely reperfusion therapy.

Shorter hospital stays improve cost-effectiveness and align with modern medical trends emphasizing early mobilization and reducing hospital-acquired complications. The cornerstone of ACS treatment is reperfusion therapy, with percutaneous coronary intervention (PCI) [11] being the primary modality. Percutaneous transluminal coronary angioplasty (PTCA) represents a more invasive yet commonly employed intervention, while stent implantation (SI) involves the placement of a small metal mesh tube to support the dilated artery and prevent re-restenosis. In the management of ACS, two main types of stents are utilized: bare-metal stents (BMS) and drug-eluting stents (DES) [12, 13]. BMS are effective in opening blocked arteries but carry a higher risk of restenosis. DES reduce this risk through a drug coating that inhibits cell proliferation, although they may necessitate prolonged dual antiplatelet therapy [12, 13]. DES is the preferred option for most patients requiring stenting due to its efficacy in minimizing restenosis. Nonetheless, in certain special cases—such as patients with comorbid conditions requiring urgent surgical intervention—BMS may still be a viable alternative [12, 13]. Despite numerous studies examining the efficacy, safety, cost-efficacy, and timing of various treatment methods [14, 15], there is a noticeable gap in the literature regarding their comparative impact on patient hospitalization time. Understanding the factors contributing to prolonged hospital stays following specific interventions is imperative for healthcare providers to make informed decisions and streamline patient care pathways. This study aimed to

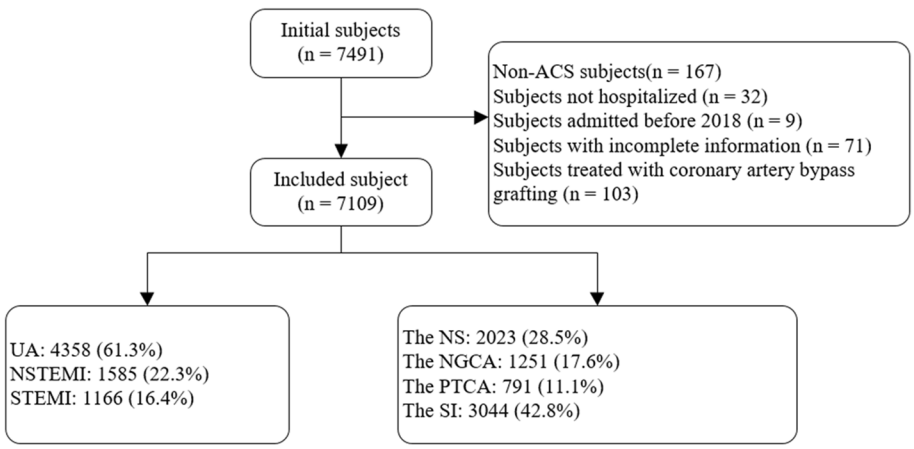

Fig. 1 Study inclusion flow. UA Unstable angina; NSEMI Non-ST-segment elevation myocardial infarction; STEMI ST-segment elevation myocardial infarction. ACS acute coronary syndrome. NS Non-invasive group; NGCA Negative group of coronary angiography; PTCA Percutaneous transluminal coronary angioplasty; SI Stent implantation

explore the risk factors for extended hospitalization and assess the impact of diverse treatment strategies on the length of stay (LOS) in ACS patients.

Methods

Participates

This study was a single-center, retrospective, observational cohort study. From January 2018 to December 2023, patients with ACS admitted to Shanghai Tongren Hospital were enrolled in this study, including 4838 males and 2271 females. The oldest was 104 years old, the youngest was 20 years old, and the average age was 68.97 ± 12.34 years. The inclusion criteria were as follows: (1) age ≥ 18 years; (2) diagnosed as UA, STEMI or NSTEMI according to ICD-10; (3) hospitalized for at least one day; and (4) patients treated without coronary artery bypass grafting. Patients were excluded from the study if they had significant missing data or were pregnant or lactating. Most importantly, the study was approved by the Ethical Committee of The Tongren Hospital of Shanghai Jiao Tong University School of Medicine and consecutive individuals who suffered from ACS were retrospectively enrolled. Additionally, written or oral informed consent was also obtained from all participants.

General information of the subjects

General information of the subjects was collected in the study, including age, gender, admission and discharge

Table 1 Characteristics of included study subjects

Variable	Level	Overall (*n* = 7109)	NS (*n* = 2023)	NGCA (*n* = 1251)	PTCA (*n* = 791)	SI (*n* = 3044)	*P*
Age		69.00 [62.00, 78.00]	67.00 [62.00, 74.00]	76.00 [66.00, 85.00]	68.00 [61.00, 75.00]	66.00 [59.00, 74.00]	< 0.001
Gender (%)	Female	2271 (31.95)	472 (37.73)	903 (44.64)	199 (25.16)	697 (22.90)	< 0.001
	Male	4838 (68.05)	779 (62.27)	1120 (55.36)	592 (74.84)	2347 (77.10)	
Admission Year (%)	2018	636 (8.95)	45 (3.60)	224 (11.07)	17 (2.15)	350 (11.50)	< 0.001
	2019	877 (12.34)	42 (3.36)	430 (21.26)	35 (4.42)	370 (12.16)	
	2020	1724 (24.25)	317 (25.34)	545 (26.94)	72 (9.10)	790 (25.95)	
	2021	1800 (25.32)	390 (31.18)	439 (21.70)	251 (31.73)	720 (23.65)	
	2022	1570 (22.08)	349 (27.90)	302 (14.93)	298 (37.67)	621 (20.40)	
	2023	502 (7.06)	108 (8.63)	83 (4.10)	118 (14.92)	193 (6.34)	
Admission Method (%)	Emergency	2399 (33.75)	262 (20.94)	575 (28.42)	280 (35.40)	1282 (42.12)	< 0.001
	Outpatient	4710 (66.25)	989 (79.06)	1448 (71.58)	511 (64.60)	1762 (57.88)	
hs-cTnI		0.31 [0.02, 4.61]	0.02 [0.01, 0.10]	0.02 [0.01, 0.19]	0.94 [0.13, 5.22]	3.22 [0.39, 7.84]	< 0.001
CK-MB		2.78 [1.27, 7.11]	1.49 [0.89, 2.76]	1.58 [0.86, 3.19]	3.61 [1.66, 8.26]	5.35 [2.48, 16.57]	< 0.001
BNP		77.88 [34.61, 281.62]	47.06 [22.03, 92.23]	92.11 [41.11, 384.92]	74.08 [32.10, 242.42]	87.69 [40.56, 350.36]	< 0.001
Scr		80.70 [67.60, 94.70]	75.10 [63.30, 89.20]	83.50 [67.23, 106.07]	81.00 [69.50, 93.90]	81.50 [69.10, 94.10]	< 0.001
CRP		3.58 [1.25, 8.92]	1.60 [0.70, 4.11]	3.63 [1.23, 9.23]	3.42 [1.18, 8.28]	4.74 [1.78, 10.38]	< 0.001
TG		1.28 [0.96, 1.79]	1.23 [0.92, 1.68]	1.18 [0.87, 1.68]	1.29 [0.98, 1.83]	1.35 [1.03, 1.90]	< 0.001
TC		3.90 [3.20, 4.70]	3.65 [3.05, 4.40]	3.79 [3.10, 4.57]	3.77 [3.14, 4.52]	4.11 [3.44, 4.92]	< 0.001
LDL-C		2.42 [1.75, 3.22]	2.11 [1.58, 2.84]	2.26 [1.62, 2.99]	2.33 [1.73, 3.18]	2.68 [1.96, 3.46]	< 0.001
HDL-C		0.97 [0.83, 1.17]	1.01 [0.85, 1.21]	1.01 [0.84, 1.23]	0.94 [0.81, 1.13]	0.95 [0.82, 1.13]	< 0.001
sd LDL-C		0.61 [0.42, 0.91]	0.59 [0.40, 0.84]	0.51 [0.36, 0.78]	0.62 [0.45, 0.92]	0.68 [0.47, 1.01]	< 0.001
Lp (a)		162.00 [92.00, 333.00]	148.00 [82.00, 294.75]	156.50 [87.25, 321.75]	162.00 [95.00, 363.25]	170.00 [97.00, 345.00]	< 0.001
Ne		4.63 [3.56, 6.47]	4.02 [3.22, 5.06]	4.16 [3.25, 5.44]	4.86 [3.72, 6.66]	5.45 [3.99, 7.96]	< 0.001
Lym		1.50 [1.10, 1.90]	1.60 [1.26, 2.00]	1.40 [1.08, 1.80]	1.50 [1.10, 1.90]	1.50 [1.10, 1.90]	< 0.001
Diagnosis	NSTEMI	1585 (22.30)	165 (13.19)	412 (20.37)	185 (23.39)	823 (27.04)	< 0.001
	STEMI	1166 (16.40)	37 (2.96)	63 (3.11)	129 (16.31)	937 (30.78)	
	UA	4358 (61.30)	1049 (83.85)	1548 (76.52)	477 (60.30)	1284 (42.18)	

NS Non-invasive group, *NGCA* Negative group of coronary angiography, *PTCA* Percutaneous transluminal coronary angioplasty, *SI* Stent implantation, *UA* Unstable angina, *NSEMI* Non-ST-segment elevation myocardial infarction, *STEMI* ST-segment elevation myocardial infarction, *hs-cTnI* High-sensitive cardiac troponin I, *CK-MB* Creatine kinase MB, *BNP* B-type natriuretic peptide, *Scr* Serum creatinine, *CRP* C-reactive protein, *Ne* Neutrophil, *Lym* Lymphocyte, *TC* Total cholesterol, *TG* triglycerides, *LDL-C* low-density lipoprotein cholesterol, *HDL-C* High-density lipoprotein cholesterol, *sd LDL-C* Small dense LDL cholesterol, *LP(a)* Lipoprotein a

times, diagnostics, and treatment details. Morning fasting venous blood samples were collected and analyzed for relevant laboratory indicators, including total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), small dense LDL cholesterol (sdLDL-C), and lipoprotein(a) [Lp(a)), high-sensitive cardiac troponin I (hs-cTnI), creatine kinase-MB (CK-MB), B-type natriuretic peptide (BNP), serum creatinine (Scr), C-reactive protein (CRP), neutrophil (Ne) and lymphocyte (Lym),. The length of stay (LOS, in day) was calculated by subtracting the time of admission from the time of discharge.

Treatment management

ACS patients were initially categorized based on whether they underwent coronary angiography, dividing them into invasive and non-invasive groups (NS). For those who undergo angiography, lesions with stenosis greater than 50% were assessed using the SYNTAX score, along with intracoronary imaging or functional assessments such as intravascular ultrasound, optical coherence tomography, and fractional flow reserve. This group was then further divided into the following categories: negative group of coronary angiography (NGCA), pure percutaneous transluminal coronary angioplasty (PTCA) group, and stent implantation (SI) group. Therefore, cases were categorized into the following four management groups: (1) Non-invasive group (NS): Cases exhibited symptoms consistent with a clinical diagnosis of ACS but did not undergo coronary angiography due to personal reasons, such as renal insufficiency, advanced age, or family refusal. These patients were typically managed with sustained medical interventions to address risk factors and prevent potential cardiovascular events, coupled with vigilant monitoring. (2) NGCA: Cases with coronary lesions showing stenosis $\geq 50\%$ and $< 75\%$, where the operator, after evaluation, determines that PTCA or stent implantation was not necessary, but was managed with aggressive medical therapy. (3) PTCA: Cases with coronary lesions showing stenosis $\geq 75\%$, involving small diameter vessels (≤ 2.5 mm), bifurcation lesions, in-stent restenosis, or cases deemed unsuitable for stent implantation due to high thrombus burden. (4) SI: Cases with coronary lesions showing stenosis $\geq 75\%$, involving major branch lesions, vessel diameters ≥ 2.25 mm, or cases with residual stenosis $\geq 30\%$ after PTCA, or situations where the target vessel exhibited flow-limiting dissection, intramural hematoma, or other complications.

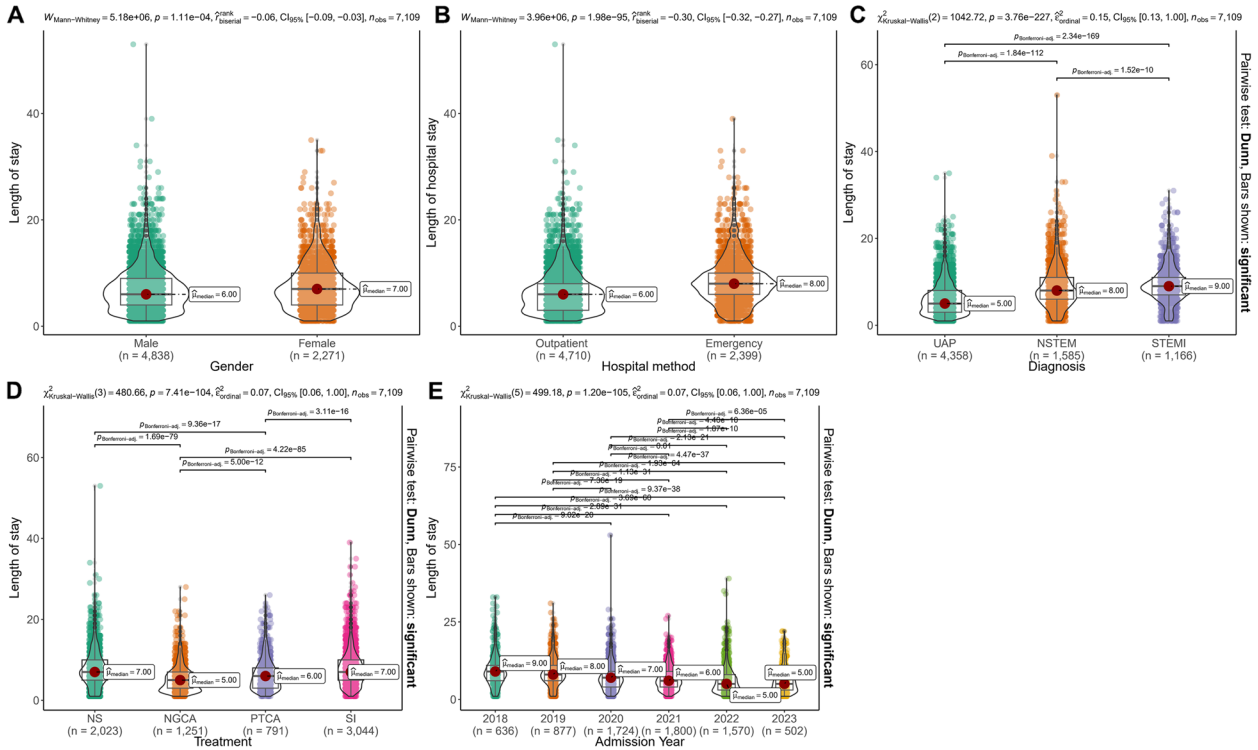

Fig. 2 Gender (**A**), Hospital method (**B**), Diagnosis (**C**), Treatment (**D**), and Admission year (**E**) univariate analysis with Length of hospital stay. NS Non-invasive group; NGCA Negative group of coronary angiography; PTCA Percutaneous transluminal coronary angioplasty; SI Stent implantation. UA Unstable angina; NSEMI Non-ST-segment elevation myocardial infarction; STEMI ST-segment elevation myocardial infarction

Statistical analysis

Categorical variables were presented using frequency and composition ratio, while normally distributed numerical variables were described by mean ± SD. Skewed distributed numerical variables were described by median (P_{25}, P_{75}). Mann–Whitney test and chi-square test were used for univariate analysis, and Bonferroni correction was used for group-wise comparisons.

To explore the potential non-linear relationship, restricted cubic spline (RCS) assessed the association between age and LOS while adjusting for relevant variables. The weighted least squares method analyzed the influencing factors of LOS. Quantile regression further estimated the distribution of the impact of treatments on the different quantiles of LOS. The quantile regression model formula is:

$$Y_{(\tau)i}|(X = X_I) = \beta_{0(\tau)} + \beta_{1(\tau)i}X_{1i} + \beta_{2(\tau)i}X_{2i} + \cdots + \beta_{m(\tau)i}X_{mi} + \varepsilon_{(\tau)i}$$

Among them, τ represented the τ quantile of hospital LOS Y, $0 < \tau < 1$; i represented the number of the study object, $i = 1,2,\ldots n$; 0 represented the constant term; m denoted the number of independent variables. A P value of less than 0.05 was statistically significant.

Results

Characteristics of the included subjects

Out of the 7109 cases included in the study (Fig. 1), 2023 belonged to the NS group, 1251 to the NGCA, 791 to the PTCA group, and 3044 to the SI group. The diagnoses comprised 4358 (61.3%) cases of UA, 1585 (22.3%) cases of NSTEMI, and 1166 (16.4%) cases of STEMI. Significant differences were observed in the

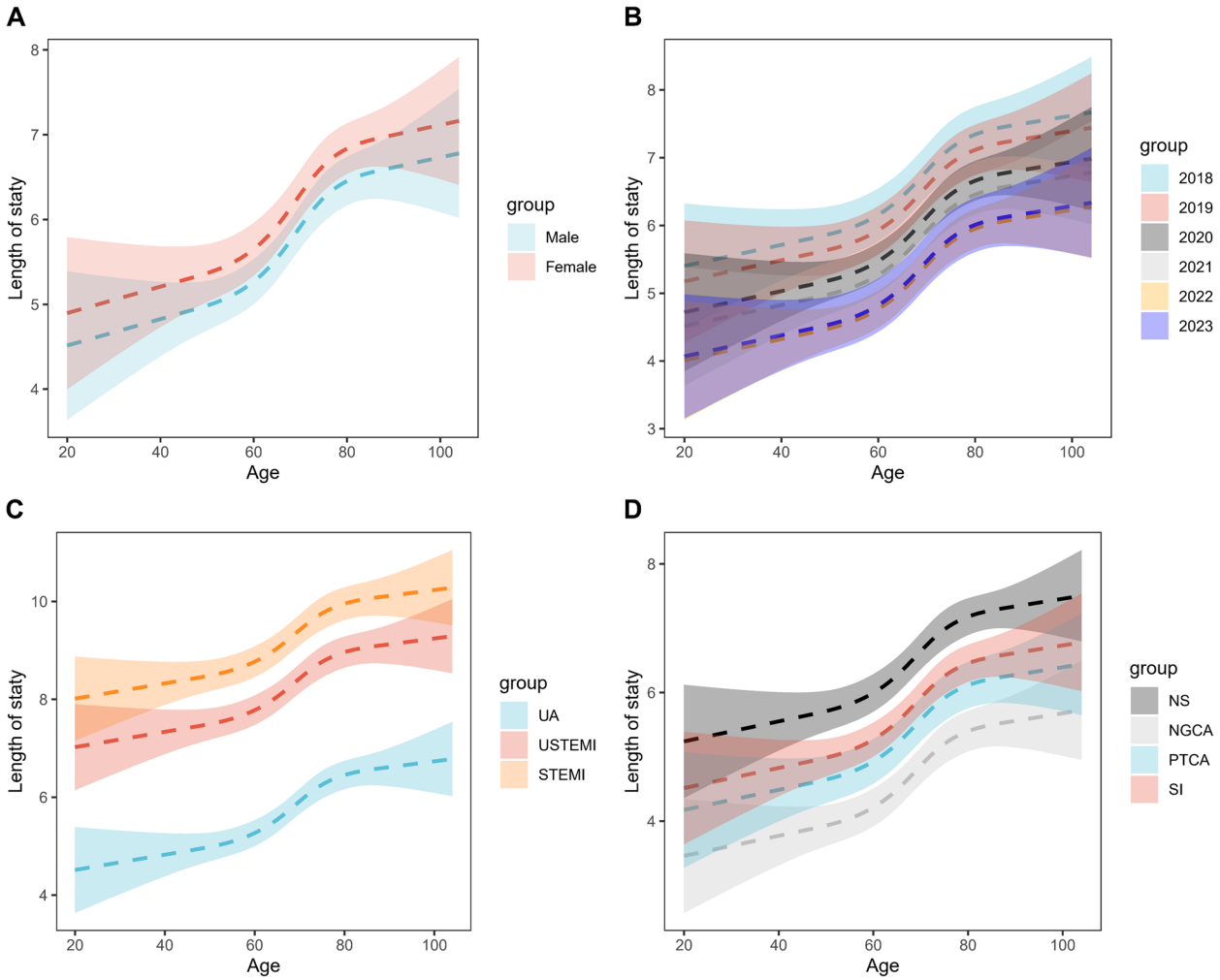

Fig. 3 Non-linear relationship between age and length of hospitalization. **A** Adjust admission times, tests, diagnoses, and treatment; **B** Adjust gender, tests, diagnoses, and treatment; **C** Adjust gender, admission times, tests, and treatment; **D** Adjust gender, admission times, tests, diagnoses. UA Unstable angina; NSEMI Non-ST-segment elevation myocardial infarction; STEMI ST-segment elevation myocardial infarction. NS Non-invasive group; NGCA Negative group of coronary angiography; PTCA Percutaneous transluminal coronary angioplasty; SI Stent implantation. LOS Length of stay

composition ratios of demographic characteristics, biochemical indicators, and diagnosis among the various treatment groups (NS, NGGA, PTCA, SI) ($P<0.001$) (Table 1).

The hospital LOS was longer for women (7 days) compared with men (6 days) ($P<0.05$) and for emergency admissions (8 days) compared to outpatient admissions (6 days) ($P<0.05$). There was a declining trend in hospitalization days over the years from 9 days in 2018 to 5 days in 2023 ($P<0.05$). STEMI had the longest LOS (9 days), followed by NSTEMI (8 days), and UA (5 days) ($P<0.05$). The average LOS was 7 days in the NS and SI groups, 5 days in the NGCA group, and 6 days in the PTCA group ($P<0.05$) (Fig. 2).

The impact of age on LOS

The variance inflation factors of TC and LDL-C exceeded 10, indicating the presence of multicollinearity (Table S1). Given the high variance inflation factor, TC was excluded, and the subsequent analysis proceeded with the remaining variables. After adjusting for relevant variables and stratified by gender, year of admission, diagnosis, and treatment, a nonlinear positive relationship was observed between age and LOS (Fig. 1). Distinct differences in the

Table 2 Weighted least squares model of hospitalization duration

Variable	*β*	2.50%	97.50%	Std. Error	t value	*P*
(Intercept)	3.8775	2.8876	4.8674	0.5050	7.68	< 0.001***
Age	0.0398	0.0304	0.0492	0.0048	8.3	< 0.001***
Gender (Ref = Male)						
Female	0.4622	0.2232	0.7013	0.1220	3.79	< 0.001***
Adm. year (Ref = 2018)						
2019	-0.1687	-0.6053	0.2678	0.2230	-0.76	0.4487
2020	-0.6787	-1.0779	-0.2795	0.2040	-3.33	< 0.001***
2021	-0.9301	-1.3333	-0.5270	0.2060	-4.52	< 0.001***
2022	-1.4380	-1.8545	-1.0215	0.2120	-6.77	< 0.001***
2023	-1.2542	-1.7640	-0.7443	0.2600	-4.82	< 0.001***
Adm. method (Ref = Ordinary)						
Emergency admission	0.5582	0.3211	0.7952	0.1210	4.62	< 0.001***
hs-cTnI	-0.0096	-0.0229	0.0037	0.0068	-1.41	0.1574
CK-MB	-0.0010	-0.0044	0.0024	0.0017	-0.56	0.5729
BNP	0.0004	0.0002	0.0006	0.0001	3.92	< 0.001***
Scr	0.0002	-0.0009	0.0013	0.0006	0.28	0.7786
CRP	0.0205	0.0167	0.0244	0.0020	10.39	< 0.001***
TG	0.0429	-0.0707	0.1566	0.0580	0.74	0.4587
LDL-C	0.2455	0.0862	0.4048	0.0812	3.02	< 0.01**
HDL-C	-0.0841	-0.4712	0.3029	0.1970	-0.43	0.6700
sd LDL-C	-0.2019	-0.6704	0.2666	0.2390	-0.85	0.3982
Lp (a)	-0.0001	-0.0005	0.0002	0.0002	-0.68	0.4980
Ne	0.0149	-0.0105	0.0404	0.0130	1.15	0.2502
Lym	-0.1503	-0.3054	0.0049	0.0791	-1.90	0.0576
Diagnosis (Ref = UA)						
NSTEM	2.0034	1.7155	2.2913	0.1470	13.64	< 0.001***
STEMI	2.7937	2.4208	3.1666	0.1900	14.69	< 0.001***
Treat (Ref = NGS)						
NGCA	-1.4440	-1.7760	-1.1121	0.1690	-8.53	< 0.001***
PTCA	-0.6675	-1.0487	-0.2864	0.1940	-3.43	< 0.001***
SI	-0.3478	-0.6353	-0.0604	0.1470	-2.37	< 0.05*

NGCA Negative group of coronary angiography, *PTCA* Percutaneous transluminal coronary angioplasty, *SI* Stent implantation, *UA* Unstable angina, *NSEMI* Non-ST-segment elevation myocardial infarction, *STEMI* ST-segment elevation myocardial infarction, *LOS* Length of stay, *hs-cTnI* High-sensitive cardiac troponin, *CK-MB* Creatine kinase MB, *BNP* B-type natriuretic peptide, *Scr* Serum creatinine, *CRP* C-reactive protein, *Ne* Neutrophil, *Lym* Lymphocyte, *TC* Total cholesterol, *TG* triglycerides, *LDL-C* low-density lipoprotein cholesterol, *HDL-C* High-density lipoprotein cholesterol, *sd LDL-C* Small dense LDL cholesterol, *LP(a)* Lipoprotein a

* < 0.05

** < 0.01

*** < 0.001

slopes of LOS and age were noted across different age brackets. Overall, the relationship between LOS and age for ACS patients aged 60–80 years was greater than that for patients aged 20–60 years, showing a steeper slope compared with patients aged 60–80 years (Fig. 3).

Risk factor of pronged LOS

Several factors including age, gender, year of admission, mode of admission, BNP, CRP, LDL-C, different diagnoses, and mode of treatment, demonstrated a significant impact on hospital LOS (Table 2). Older age was associated with longer hospitalization days (β: 0.0398; 95% CI: 0.0304, 0.0492). Female patients experienced a longer hospitalization by 0.4622 days (95% CI: 0.2232, 0.7013) compared with males. A progressive increase in the year of admission was associated with a longer LOS. Emergency admissions were associated with an additional 0.5582 days of LOS (95% CI: 0.3211, 0.7952) compared with outpatient admissions. Longer hospital LOS was also associated with elevated BNP (β: 0.0004; 95% CI: 0.0002, 0.0006), CRP (β: 0.0205; 95% CI: 0.0167, 0.0244), and LDL-C (β: 0.2455; 95% CI: 0.0862, 0.4048).

Compared with UA, hospitalization was 2.0034 days longer (95% CI: 1.7155, 2.2913) for NSTEMI and 2.7937 days longer (95% CI: 2.4208, 3.1666) for STEMIN. Post-admission treatment modalities significantly influenced hospital LOS, with NGCA reducing hospitalization by an average of -1.4440 days (95% CI: -1.7760, -1.1121) compared to the NS group, PTCA reducing hospitalization by an average of -0.6675 days (95% CI: -1.0487, -0.2864), and SI reducing hospitalization by an average of -0.3478 days (95% CI: -0.6353, -0.0604).

Effect of treatment management on LOS

Quantile regression (Table 3) showed that at quantiles lower than 0.1 of LOS, both PTCA and SI led to increased hospitalization time compared to the NS group. In the quantiles ranging from 0.2 to 0.9 of LOS, NGCA demonstrated a reduction in LOS by 0.7–2.96 days, PTCA by 0.37–2.37 days, and SI by 0.12–2.28 days compared with the NS group. As the quantile increased, the magnitude of reduction in hospitalization time for patients with NGCA, PTCA, and SI became more pronounced.

Stratified analyses showed that NGCA, PTCA, and SI all contributed to a reduction in hospital length of stay in the UA group, and this reduction of LOS intensified with increasing quantiles. However, starting from quantile 0.4, the reduction in hospitalization days plateaued for both PTCA and SI plateaued (Fig. 4). For NSTEMI patients, NGCA did not show a significant impact on hospitalization time in the 0.1–0.4 quantile of LOS but led to a decreased length of hospitalization in the 0.5–0.9 quantile. In the patients with STEMI, in the 0.1–0.3 quantile, PTCA and SI increased hospitalization time, whereas in the 0.6–0.9 quantile, both PTCA and SI contributed to a decrease in the length of hospitalization.

Discussion

This study showed that female and elderly patients with ACS experienced longer hospital stays, which aligns with previous studies showing that these populations face more adverse outcomes in ACS [16, 17]. As elderly patients age, declines in cardiovascular and immune function, along with increased chronic inflammation, can worsen their clinical condition and hinder recovery

Table 3 Quantile regression of treatment with LOS after adjusting for age, year of admission, testing, and diagnosis

Quantile	NGCA			PTCA			SI		
	Overall *β1*	Male*β2*	Female*β3*	Overall*β4*	Male*β5*	Female*β6*	Overall*β7*	Male*β8*	Female*β9*
0.1	0.15 (0.16)	-0.21 (0.23)	0.37* (0.16)	0.42* (0.16)	0.16 (0.23)	0.51 (0.31)	0.78*** (0.16)	0.33 (0.23)	1.16*** (0.17)
0.2	-0.70*** (0.13)	-0.95*** (0.16)	-0.29 (0.22)	-0.37*** (0.14)	-0.6*** (0.16)	0.01 (0.24)	-0.12 (0.13)	-0.33* (0.16)	0.33 (0.24)
0.3	-1.33*** (0.14)	-1.73*** (0.16)	-1.06*** (0.22)	-0.84*** (0.17)	-1.27*** (0.19)	-0.47 (0.35)	-0.53*** (0.14)	-0.96*** (0.16)	-0.05 (0.24)
0.4	-1.7*** (0.13)	-2.02*** (0.16)	-1.47*** (0.22)	-1.23*** (0.14)	-1.48*** (0.18)	-0.72* (0.33)	-0.92*** (0.13)	-1.23*** (0.15)	-0.47* (0.20)
0.5	-1.92*** (0.15)	-2.22*** (0.19)	-1.47*** (0.23)	-1.44*** (0.16)	-1.77*** (0.18)	-0.89* (0.36)	-1.12*** (0.13)	-1.37*** (0.15)	-0.63** (0.23)
0.6	-1.99*** (0.16)	-2.27*** (0.21)	-1.69*** (0.28)	-1.63*** (0.20)	-1.89*** (0.22)	-0.7 (0.58)	-1.32*** (0.14)	-1.6*** (0.17)	-0.81*** (0.25)
0.7	-2.15*** (0.16)	-2.41*** (0.19)	-1.75*** (0.29)	-1.59*** (0.19)	-2.04*** (0.23)	-0.53 (0.41)	-1.54*** (0.15)	-1.81*** (0.18)	-1.23*** (0.32)
0.8	-2.33*** (0.18)	-2.67*** (0.27)	-2.12*** (0.25)	-1.86*** (0.19)	-2.36*** (0.26)	-1.1** (0.35)	-1.76*** (0.17)	-2.16*** (0.24)	-1.36*** (0.27)
0.9	-2.96*** (0.30)	-4.34*** (0.36)	-1.76*** (0.41)	-2.37*** (0.38)	-3.84*** (0.43)	-1.18* (0.58)	-2.28*** (0.29)	-3.66*** (0.34)	-1.11** (0.38)

Values in parentheses are standard errors. *β*1, *β*2, and *β*3 represent the regression coefficients of hospitalization time for NGCA treatment in the overall, male, and female population compared with Non-invasive treatment; *β*4, *β*5, and *β*6 represent the PTCA treatment methods in the overall, male, and female population compared with Non-invasive treatment. Regression coefficients of hospitalization time; *β*7, *β*8, and *β*9 represent the regression coefficients of hospitalization time for SI treatment in the overall, male, and female population compared with Non-invasive treatment

NGCA Negative group of coronary angiography, *PTCA* Percutaneous transluminal coronary angioplasty, *SI* Stent implantation

* < 0.05

** < 0.01

*** < 0.001

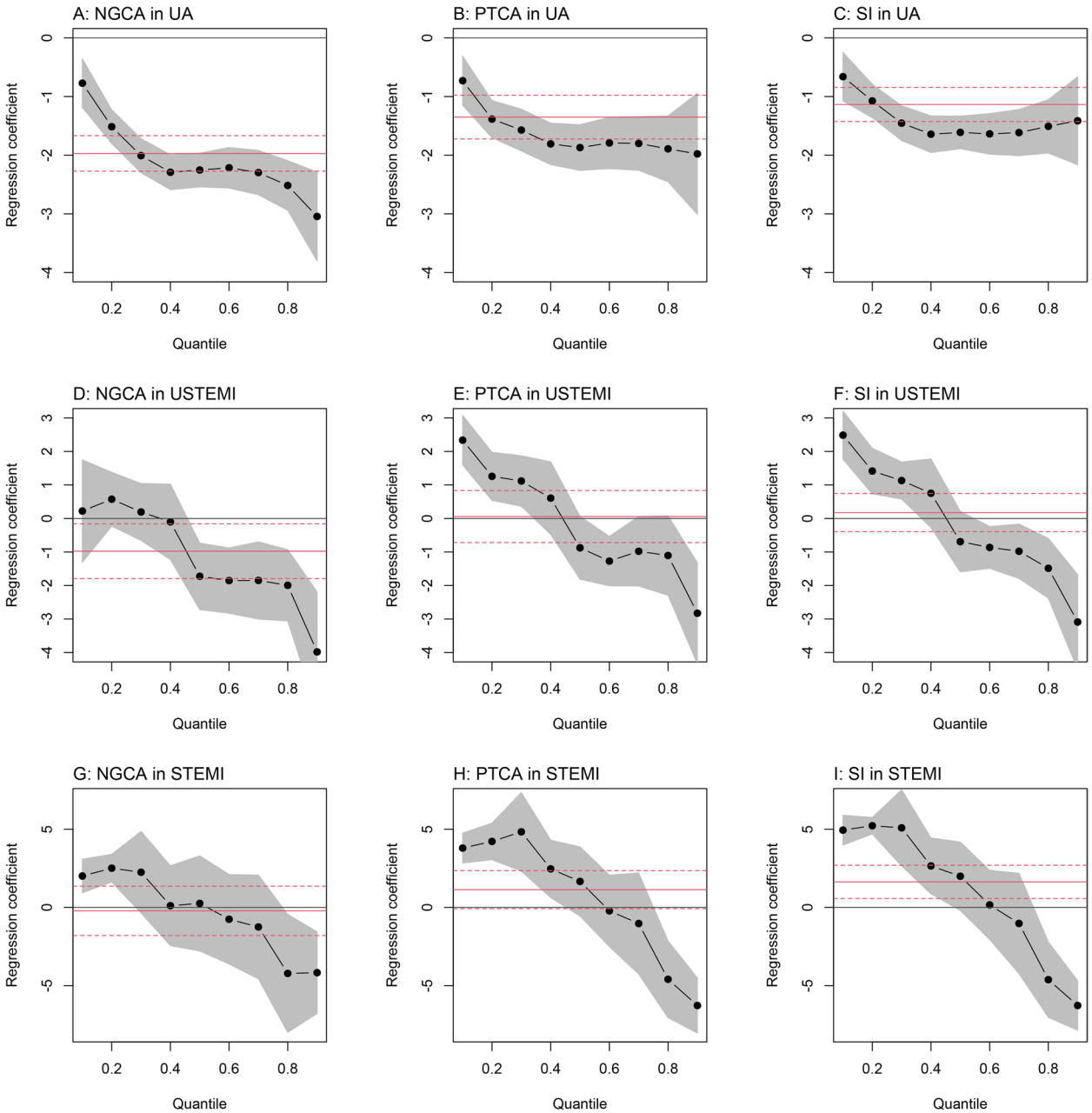

Fig. 4 Impact of different treatments on length of hospitalization in patients with UA (**A**-**C**), NSTEMI (**D**-**F**), and STEMI (**G**-**I**). NGCA Negative group of coronary angiography; PTCA Percutaneous transluminal coronary angioplasty; SI Stent implantation. UA Unstable angina; NSEMI Non-ST-segment elevation myocardial infarction; STEMI ST-segment elevation myocardial infarction

[16]. Women often present with multiple comorbidities and atypical symptoms like fatigue and upper abdominal discomfort, which can cause diagnostic delays and impact the effectiveness of treatment [17].

Recent studies have highlighted the prognostic value of simple and accessible markers, such as the neutrophil-to-lymphocyte ratio (NLR), fibrinogen-to-albumin ratio (FAR), and serum albumin levels (Table 4). NLR is a significant predictor of adverse outcomes in ACS patients, as elevated NLR levels correlate with increased inflammatory response [23]. A recent observational study demonstrated that higher FAR values are significantly correlated with greater coronary artery stenosis, as assessed by angiography, and poorer clinical outcomes in ACS patients [23]. Another study found that FAR served as an independent prognostic

Table 4 Risk factors and biomarkers for the outcome of acute coronary syndrome

Risk factors or biomarkers	Implications for ACS outcome
Aging	Aging can increase stiffness of the aorta and large central arteries; it increases susceptibility to an imbalance between myocardial oxygen demand and supply [16].
Sex difference	Women with ACS have a higher risk of thrombotic events and recurrent cardiovascular incidents, partly due to differences in vascular structure and inflammatory responses [17].
Obesity; Malnutrition	Severe obesity is associated with worse survival following ACS [18]. Malnutrition is a significant independent risk factor for prognosis in patients with ACS [19].
Neck circumference (NC)	NC is associated with MetS and its components, coronary calcification and lesion degree, and MACEs [20].
Anemia	Anemia reduces platelet inhibition to the loading dose of clopidogrel, contributing to a consequent increase in ischaemic and mortality risks [21].
Neutrophil-to-lymphocyte ratio (NLR)	NLR was associated with mortality during treatment and major adverse cardiac events after percutaneous coronary intervention [22].
Fibrinogen-to-albumin ratio (FAR)	FAR is independently associated with severe coronary stenosis and long-term prognosis [23, 24].
Serum albumin	Nutritional status and systemic inflammation, both of which can influence recovery and prognosis in ACS patients [25].
Triglyceride-glucose index (TyG)	A higher TyG index represents a higher coronary anatomical complexity and more extensive and complex coronary anatomical lesions, irrespective of diabetes mellitus status [26].
25-Hydroxyvitamin D	Low 25(OH)D represents high thrombus burden and compromised coronary reperfusion [27].
Monocyte-to-HDL Ratio (MHR)	MHR serves as a comprehensive marker of inflammation and lipid metabolism. Monocytes contribute to the formation and progression of atherosclerosis, while HDL plays a protective role through its anti-inflammatory and antioxidant properties [28].
Growth differentiation factor 15 (GDF-15)	Increased GDF-15 reflects cardiac stress and inflammatory responses and are associated with an increased risk of cardiovascular events in ACS patients, including myocardial infarction and mortality [29].
Stress hyperglycemia ratio (SHR)	High SHR indicates more severe stress responses and metabolic disturbances, suggesting increased systemic inflammation and oxidative stress, which can worsen cardiac damage and promote atherosclerosis development [30].

ACS acute coronary syndrome, *MetS* metabolic syndrome, *MACE* major adverse cardiovascular events

factor for major adverse cardiovascular events at 30 days, 6 months, and 1 year after drug-eluting stent implantation [24]. Additionally, serum albumin levels reflect nutritional status and systemic inflammation, both of which can influence recovery and prognosis in ACS patients [25].

This study found that elevated levels of BNP, CRP, and LDL-C, may be independent risk factors of prolonged hospital stays in patients with ACS. BNP levels significantly increase within the first 24 h after myocardial infarction in STEMI patients, reaching a relatively stable level, with a possible second peak around 5 days later, potentially indicating ongoing remodeling [31]. Although BNP has a short half-life, it is secreted alongside NT-proBNP, a peptide fragment with a longer half-life. A retrospective cohort study showed that Elevated NT-proBNP levels, particularly those above 1568 pg/ml, were significantly associated with increased risks of in-hospital and long-term all-cause mortality among non-ST-segment elevation acute coronary syndrome patients with multivessel coronary artery disease undergoing PCI [32]. CRP levels greater than 3 mg/L at discharge are a prognostic factor for future myocardial infarction and stroke, indicating an increased risk of readmission within one year due to recurrent cardiovascular instability or myocardial infarction [31]. Another cross-sectional study showed that higher LDL-C and hs-CRP were associated with a high risk of STEMI and its complications [33]. Collectively, these factors highlight the importance of early identification of these biomarkers for risk stratification and the development of more personalized treatment strategies.

This study discerned potential variations in the impact of PCI interventions among distinct subgroups of ACS patients, revealing nuanced effects that vary based on the specific diagnosis. The

observed reduction in the hospital stay subsequent to PCI treatment for patients with unstable angina aligns with the clinical rationale advocating for early intervention [34–36]. Unstable angina is characterized by transient and reversible myocardial ischemia, frequently trigged by the disruption of atherosclerotic plaques without complete occlusion of the coronary artery [37]. PCI seeks to promptly alleviate ischemia and forestall the progression to more severe forms of ACS [38]. The immediate relief of symptoms and prevention of additional ischemic events play crucial roles in expediting the recovery process, underscoring the advantages of surgical intervention in the unstable angina subgroup [36]. For NSTEMI and STEMI patients with shorter hospital stays, PCI might, in some instances, increase the duration of hospitalization. This paradoxical effect could be attributed to factors such as procedural complications, the need for additional monitoring, or the presence of comorbidities [39, 40]. Conversely, in patients with longer hospital stays, PCI interventions contribute to a more efficient recovery by addressing underlying coronary pathology, reducing the risk of recurrent events, and facilitating earlier discharge [41]. By mitigating the severity of myocardial injury and addressing complications, timely revascularization strategies facilitate a more efficient recovery process [42].

While the evidence supporting the efficacy of surgical interventions in reducing hospitalization time is robust, challenges persist. Variability in patient presentation, the intricacy of coronary anatomy, and the availability of resources may influence the feasibility and timing of PTCA or stent implantation. Additionally, considering individual risk profiles is crucial for optimizing outcomes [43]. Factors such as the timing of intervention, the selection of revascularization strategy, and the presence of multivessel disease are subjects of ongoing investigation, aiming to enhance our understanding of how to tailor interventions for optimal outcomes [44, 45].

The study presented several limitations that are important to consider. Firstly, the data were sourced exclusively from a single hospital, which may limit the generalizability of the findings. Secondly, retrospective studies often rely on existing records and data, which may not be as comprehensive or detailed as data collected prospectively. This can lead to potential biases in data collection and interpretation, as the data were not gathered with the specific intent of addressing the research questions posed by this study. Furthermore, this design limits the ability to establish causality, as it primarily identifies correlations from historical data.

Conclusions

The evidence strongly supports the pivotal role of percutaneous coronary intervention in reducing hospitalization time for ACS patients. The ability to shorten hospital stays, especially for those at risk of prolonged admissions, underscores the importance of the comprehensive management of ACS in improving clinical outcomes and enhancing cost-effectiveness.

Abbreviations

ACS	Acute coronary syndrome
UA	Unstable angina
NSTEMI	Non-ST-segment elevation myocardial infarction
STEMI	ST-segment elevation myocardial infarction
ECG	Electrocardiography
PCI	Percutaneous coronary intervention
PTCA	Percutaneous transluminal coronary angioplasty
SI	Stent implantation
BMS	Bare-metal stents
DES	Drug-eluting stent
LOS	Length of stay
RCS	Restricted cubic spline
hs-cTnI	High-sensitive cardiac troponin I
CK-MB	Creatine kinase-MB
BNP	B-type natriuretic peptide
CRP	C-reactive protein
Ne	Neutrophil
Lym	Lymphocyte
Scr	Serum creatinine
TC	Total cholesterol
TG	Triglycerides
LDL-C	Low-density lipoprotein cholesterol
HDL-C	High-density lipoprotein cholesterol
SdLDL-C	Small dense LDL cholesterol
Lp(a)	Lipoprotein(a)
NGCA	Negative group of coronary angiography
NLR	Neutrophil-to-lymphocyte ratio
FAR	Fibrinogen-to-albumin ratio

Supplementary Information

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Supplementary Material 1.

Clinical trial number

Not applicable.

Authors' contributions

Conception and design: Y Zhou, Y Gong, X Tang, Y Wang. Data collection: X Tang, Y Wang, Y Chen. Data analysis/interpretation: Y Gong, Y Zhou, Y Chen. Guarantee for data/analysis T Wang, Y Zhou, Y Chen, X Tang, Y Chen. Drafting of the manuscript: Y Gong, X Tang, Y Zhou, Y Chen. Critical revision of the manuscript: Y Chen. Final approval of the manuscript: all authors. All authors agree to be accountable for all aspects of this manuscript.

Data availability

Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate
The present analysis was followed and approved by the appropriate institutional committees at the Ethics Committee of the Tongren Hospital of Shanghai Jiao Tong University School of Medicine (Number: K2024-022–01). Informed consent was obtained from all individual participants included in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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