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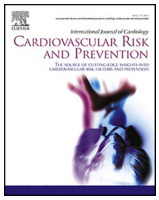

The prevalence and outcomes in STEMI patients aged ≥75 undergoing primary percutaneous coronary intervention in China

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ABSTRACT

Objective: To investigate the prevalence and outcomes of primary percutaneous coronary intervention (PCI) in Chinese patients with ST-segment elevation myocardial infarction (STEMI) aged ≥75 years.

Methods: We identified STEMI patients aged ≥75 years between 2013 and 2014 from a multicenter registry. The primary outcome was all-cause mortality. The secondary outcome was major adverse cardiac and cerebrovascular event (MACCE) including a composite of all-cause mortality, cardiac death, recurrent MI, stroke, revascularization, and major bleeding. Hazard ratios (HR) and associated 95% confidence interval (CI) were calculated.

Results: Approximately 32.9% (n = 999) patients received primary PCI. Primary PCI was associated with lower risks of two-year all-cause mortality (18.0% vs. 36.4%; adjusted HR: 0.54, 95% CI: 0.45 to 0.65, P < 0.0001), MACCE (28.7% vs. 43.5%; adjusted HR: 0.68, 95% CI: 0.59 to 0.80, P < 0.0001), and cardiac death (10.0% vs. 23.6%; adjusted HR: 0.49, 95% CI: 0.38 to 0.62, P < 0.0001) relative to no reperfusion (n = 2041) in patients aged ≥75 years. The better outcomes in two-year all-cause mortality, MACCE, and cardiac death were consistently observed in STEMI patients aged ≥85 years. No differences were observed in recurrent MI, stroke, revascularization, and major bleeding between the two groups. Additionally, in patients with relatively high-risk profiles such as cardiogenic shock or delaying hospital admission, primary PCI was also superior to no reperfusion.

Conclusion: Primary PCI may decrease two-year all-cause mortality, MACCE, and cardiac death in STEMI patients aged ≥75 years, even in these with age ≥85 years, cardiogenic shock, or delaying hospital admission. However, primary PCI was underutilized in Chinese clinical practice.

1. Introduction

Older patients aged ≥75 years constitute 14–28% of all patients with ST-segment elevation myocardial infarction (STEMI) [1,2], and is associated with high mortality since comorbidities increase with age [3]. Because of the rapid growth of the older population, the World Health Organization predicts that coronary heart disease deaths will increase by 120–137% during the next two decades [4]. Although previous studies indicated that primary percutaneous coronary intervention (PCI) in older patients was associated with improved survival compared with no reperfusion, and the recent guidelines also support invasive management regardless of age [5,6], yet these conclusions are mainly derived from observational studies or subgroup analyses of randomized trials [7–12]. No dedicated randomized trials are available for the management of STEMI patients with older age, thus limiting the generalizability and translation of these results to older patients. Additionally, these studies mainly involved patients aged more than 65 or 75 years, yet the clinical outcomes in patients with very old age (85 years or more) were less studied and need to be determined in later studies. According to data from the National Inpatient Sample database in the USA, in real-world scenarios, the rate of primary PCI declines with age, with only 38% of patients aged more than 80 years receiving primary

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PCI as compared with 78% of those aged less than 60 years [13], which may be related to the perceived higher risks of invasive procedures. Moreover, great gaps existed between developed and developing countries. The aforementioned studies are mainly conducted in developed countries whereas little information is known about the situation in developing countries such as China.

In this context, using the China Acute Myocardial Infarction (CAMI) Registry, the aims of the current study are to establish the prevalence of primary PCI use in Chinese clinical practice and to evaluate whether primary PCI is associated with better outcomes in STEMI patients aged ≥75 years, even in those aged ≥85 years.

2. Methods

2.1. Study population

The prospective, nationwide, multicenter CAMI Registry is an observational study enrolling acute myocardial infarction (AMI) patients between January 2013 and September 2014 [14]. 108 hospitals in total from 27 provinces and 4 municipalities in Mainland China participated, including 31 provincial hospitals (university-affiliated academic hospitals located in the capital city of each province), 45 municipal hospitals (hospitals in medium-sized cities), and 32 county hospitals (hospitals in the smallest cities, usually with surrounding rural areas). Eventually, 26,648 patients with AMI were included. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki and has been registered on www.clinicaltrials.gov (NCT01874691). Written informed consent was obtained from eligible patients before registration. Data were collected and submitted through a web-based electronic data capture system. Senior cardiologists who were responsible for the data quality control undertook periodic database checking. Trained physicians at each participating site conducted follow-up in a real-time manner to ensure data accuracy and reliability [14]. AMI is diagnosed following the third universal definition of myocardial infarction [15]. All-cause mortality was defined as any death during or after the procedure and was considered to be of cardiac origin unless obvious noncardiac causes could be established [16]. Major bleeding was defined according to the Thrombolysis in Myocardial Infarction (TIMI) classification [17]. In the present analysis, STEMI patients aged ≥75 years were included. Patients who underwent coronary artery bypass graft (CABG) or thrombolysis were excluded.

2.2. Clinical outcomes

The primary outcome was all-cause mortality. The secondary outcome was major adverse cardiac and cerebrovascular event (MACCE) including a composite of all-cause mortality, cardiac death, recurrent MI, stroke, revascularization (PCI/CABG), and major bleeding.

2.3. Statistics

Baseline characteristics were described by number and percentage for categorical data, mean ± SD for normally distributed continuous data, or median and interquartile range for non-normally distributed continuous data, respectively. Differences in baseline characteristics were assessed by chi-square tests, 2-sample Student t-tests, or Mann-Whitney *U* test, respectively. Kaplan-Meier curves were used to assess the cumulative incidences of clinical events, and differences between patients who received primary PCI and those who did not receive reperfusion were evaluated with the log-rank test. Multivariable Cox proportional-hazards models were used to assess the risk of primary PCI relative to no reperfusion therapy for the primary and secondary outcomes, expressed as hazard ratios (HR) and associated 95% confidence interval (CI). The HR was adjusted for important covariables that had significant effects ($P < 0.1$) in the univariate analysis or were deemed to be associated with clinical outcomes. Eventually, the adjusted variables included age, sex, hypertension, hyperlipemia, diabetes, prior MI, prior stroke, hospital level, symptoms onset to admission time, GRACE risk score, Killip class, angiotensin-converting enzyme inhibitor/angiotensin receptor blockers (ACEI/ARB), and beta-blockers. To mitigate the influence of "immortal time bias", patients who died within 48 h were excluded as a sensitivity analysis. For all analyses, statistical significance was defined as $P < 0.05$. Statistical evaluation was performed using SAS 9.4 software (SAS Institute, Cary, North Carolina).

3. Results

Of the 3168 STEMI patients aged ≥75 years, after excluding 127 patients receiving thrombolysis and one patient receiving CABG, eventually, 2041 patients not receiving reperfusion and 999 patients receiving primary PCI were included in the present analysis (Supplementary Fig. 1).

3.1. Baseline clinical and procedural characteristics in STEMI patients aged ≥75 years

Overall, compared with patients in the no reperfusion group, those in the primary PCI group were younger males and had higher prevalence of smoke and hyperlipemia, but lower prevalence of heart failure and stroke (Table 1). They were also more likely to be admitted to provincial hospitals at an early time from symptom onset to admission. Heart rate, the prevalence of atrial flutter/fibrillation, Killip II-IV, and cardiogenic shock were lower in the primary PCI group, yet ventricular flutter/fibrillation was higher. Although TIMI 0 and I (78.8%) were high in the primary PCI group before PCI procedure, 93.7% of patients achieved TIMI 3 after primary PCI. Moreover, patients in the primary PCI group were more likely to receive aspirin, clopidogrel/ticagrelor, GP IIb/IIIa receptor antagonist, statins, beta-blockers, and ACEI/ARB during or after admission, yet they were less likely to receive nitrate.

3.2. 30-Day and two-year clinical outcomes in STEMI patients aged ≥75 years

With regard to 30-day clinical outcomes, the primary PCI group had a significantly lower incidence of all-cause mortality (9.3% vs. 23.0%, unadjusted HR: 0.38, 95% CI: 0.30 to 0.47, $P < 0.0001$; adjusted HR: 0.49, 95% CI: 0.39 to 0.63, $P < 0.0001$, Table 2) compared with no reperfusion group (Table 2). The incidences of MACCE (14.8% vs. 27.9%, unadjusted HR: 0.50, 95% CI: 0.41 to 0.60, $P < 0.0001$; adjusted HR: 0.62, 95% CI: 0.50 to 0.76, $P < 0.0001$) and cardiac death (6.9% vs. 17.1%, unadjusted HR: 0.39, 95% CI: 0.30 to 0.51, $P < 0.0001$; adjusted HR: 0.49, 95% CI: 0.37 to 0.66, $P < 0.0001$) were also significantly lower in the primary PCI group than that in the no reperfusion group. Both groups had comparable incidences of recurrent MI, stroke, revascularization, and major bleeding. After two years of follow-up, patients in the primary PCI group consistently had a significantly lower incidence of all-cause mortality (18.0% vs. 36.4%, unadjusted HR: 0.44, 95% CI: 0.37 to 0.51, $P < 0.0001$; adjusted HR: 0.54, 95% CI: 0.45 to 0.65, $P < 0.0001$), MACCE (28.7% vs. 43.5%, unadjusted HR: 0.58, 95% CI: 0.51 to 0.67, $P < 0.0001$; adjusted HR: 0.68, 95% CI: 0.59 to 0.80, $P < 0.0001$), and cardiac death (10.0% vs. 23.6%, unadjusted HR: 0.40, 95% CI: 0.32 to 0.51, $P < 0.0001$; adjusted HR: 0.49, 95% CI: 0.38 to 0.62, $P < 0.0001$) relative to patients in the no reperfusion group. Although the rate of revascularization was lower in the primary PCI group, yet the difference disappeared after multivariable adjustment. As a sensitivity analysis, patients who died within 48 h were excluded to mitigate the influence of "immortal time bias". The results consistently revealed that primary PCI was superior to no reperfusion in reducing 30-day and two-year all-cause mortality, MACCE, and cardiac death (Supplementary Table 1).

Multivariable adjusted Kaplan-Meier curves of the clinical outcomes in Fig. 1 revealed that primary PCI was associated with lower incidences

Table 1
Baseline and procedural characteristics in STEMI patients aged ≥75 Years or ≥85 Years with different treatment modalities.

	Age ≥ 75 years				Age ≥ 85 years			
	Total (3040)	No reperfusion (n = 2041)	Primary PCI (n = 999)	P value	Total (448)	No reperfusion (n = 354)	Primary PCI (n = 94)	P value
Demographic characteristics								
Age, years	80.18 ± 4.01	80.50 ± 4.17	79.54 ± 3.58	<0.0001	87.60 ± 2.70	87.62 ± 2.79	87.54 ± 2.36	0.8117
Male, n (%)	1804 (59.3)	1157 (56.7)	647 (64.8)	<0.0001	241 (53.8)	183 (51.7)	58 (61.7)	0.0822
BMI, kg/m^2	23.29 ± 11.30	22.94 ± 3.29	23.99 ± 19.13	0.0865	22.53 ± 3.04	22.37 ± 2.92	23.13 ± 3.39	0.0314
Risk factors, n (%)								
Smoker	1085 (35.7)	695 (34.1)	390 (39.0)	0.0072	128 (28.6)	97 (27.4)	31 (33.0)	0.2923
Current smoker	639 (21.0)	400 (19.6)	239 (23.9)	0.0064	69 (15.4)	48 (13.6)	21 (22.3)	0.0434
Hypertension	1651 (54.3)	1105 (54.1)	546 (54.7)	0.7891	222 (49.6)	165 (46.6)	57 (60.6)	0.0153
Diabetes	513 (16.9)	342 (16.8)	171 (17.1)	0.8033	56 (12.5)	35 (9.9)	21 (22.3)	0.0023
Hyperlipemia	112 (3.7)	47 (2.3)	65 (6.5)	<0.0001	17 (3.8)	4 (1.1)	13 (13.8)	<0.0001
Prior MI	195 (6.4)	142 (7.0)	53 (5.3)	0.0762	30 (6.7)	25 (7.1)	5 (5.3)	0.5375
Prior PCI	103 (3.4)	62 (3.0)	41 (4.1)	0.1327	9 (2.0)	7 (2.0)	2 (2.1)	1.0000
Prior CABG	9 (0.3)	6 (0.3)	3 (0.3)	1.0000	0	0	0	NA
Prior heart failure	98 (3.2)	77 (3.8)	21 (2.1)	0.0111	16 (3.6)	15 (4.2)	1 (1.1)	0.2117
Prior stroke	370 (12.2)	272 (13.3)	98 (9.8)	0.0046	16 (3.6)	59 (16.7)	6 (6.4)	0.0065
Prior peripheral artery diseases	21 (0.7)	14 (0.7)	7 (0.7)	0.9632	16 (3.6)	5 (1.4)	2 (2.1)	0.6409
Prior renal failure	42 (1.4)	31 (1.5)	11 (1.1)	0.3446	6 (1.3)	5 (1.4)	1 (1.1)	1.0000
Prior COPD	139 (4.6)	95 (4.7)	44 (4.4)	0.7557	15 (3.3)	10 (2.8)	5 (5.3)	0.3283
Hospital level, n (%)				<0.0001				<0.0001
Provincial level	914 (30.1)	465 (22.8)	449 (44.9)		104 (23.2)	64 (18.1)	40 (42.6)	
Municipal level	1634 (53.8)	1126 (55.2)	508 (50.9)		242 (54.0)	195 (55.1)	47 (50.0)	
County level	492 (16.2)	450 (22.0)	42 (4.2)		102 (22.8)	95 (26.8)	7 (7.4)	
Symptoms onset to admission time ≥12h, n (%)	1249 (41.1)	1127 (55.2)	122 (12.2)	<0.0001	193 (43.1)	185 (52.3)	8 (8.5)	<0.0001
Admission status								
Heart rate, (beats/min)	78 (66, 90)	78.00 (67, 92)	74 (62, 85)	<0.0001	80 (68, 94)	82 (70, 98)	76 (60, 84)	<0.0001
Systolic pressure, (mmHg)	126 (110, 142)	126 (110, 143)	125 (110, 142)	0.5688	127 (109, 144)	129 (110, 145)	125 (108, 136)	0.4008
Malignant arrhythmia, n (%)	321 (10.6)	211 (10.3)	110 (11.0)	0.5718	54 (12.1)	44 (12.4)	10 (10.6)	0.6310
Atrial flutter/fibrillation	104 (3.4)	79 (3.9)	25 (2.5)	0.0453	25 (5.6)	21 (5.9)	4 (4.3)	0.5162
Atrial-ventricular block	113 (3.7)	72 (3.5)	41 (4.1)	0.4337	19 (4.2)	15 (4.2)	4 (4.3)	1.0000
Ventricular flutter/fibrillation	46 (1.5)	20 (1.0)	26 (2.6)	0.0009	5 (1.1)	4 (1.1)	1 (1.1)	1.0000
Killip II-IV, n (%)	1194 (39.3)	911 (44.6)	283 (28.3)	<0.0001	206 (46.0)	174 (49.2)	32 (34.0)	0.0084
Cardiogenic shock, n (%)	248 (8.2)	191 (9.4)	57 (5.7)	0.0004	48 (10.7)	40 (11.3)	8 (8.5)	0.4258
GRACE risk score ≥155, n (%)	2490 (81.9)	1680 (82.3)	810 (81.1)	0.4075	395 (88.2)	315 (89.0)	80 (85.1)	0.3128
Procedural characteristics, n (%)								
Radial access	–	861 (86.2)	–	–			78 (83.0)	
DES	–	938 (93.9)	–	–			81 (86.2)	
TIMI before PCI								
0	–	678 (67.9)	–	–			58 (61.7)	
I	–	109 (10.9)	–	–			14 (14.9)	
II	–	82 (8.2)	–	–			8 (8.5)	
III	–	130 (13.0)	–	–			14 (14.9)	
TIMI after PCI								
0	–	15 (1.5)	–	–			2 (2.1)	
I	–	22 (2.2)	–	–			3 (3.2)	
II	–	26 (2.6)	–	–			4 (4.3)	
III	–	936 (93.7)	–	–			85 (90.4)	
In-hospital medications, n (%)								
Aspirin	2831 (93.1)	1853 (90.8)	978 (97.9)	<0.0001	403 (90.0)	311 (87.9)	92 (97.9)	0.0009
Clopidogrel/ticagrelor	2790 (91.8)	1826 (89.5)	964 (96.5)	<0.0001	403 (90.0)	311 (87.9)	92 (97.9)	0.0009
GP inIIb/IIIa receptor antagonist	676 (22.2)	206 (10.1)	470 (47.0)	<0.0001	55 (12.3)	22 (6.2)	33 (35.1)	<0.0001
Heparin	2570 (84.5)	1708 (83.7)	862 (86.3)	0.0601	348 (77.7)	274 (77.4)	74 (78.7)	0.7835
Statins	2834 (93.2)	1878 (92.0)	956 (95.7)	0.0001	416 (92.9)	329 (92.9)	87 (92.6)	0.8981
Beta-blockers	1796 (59.1)	1139 (55.8)	657 (65.8)	<0.0001	247 (55.1)	189 (53.4)	58 (61.7)	0.1479
ACEI/ARB	1606 (52.8)	1035 (50.7)	571 (57.2)	0.0008	213 (47.5)	159 (44.9)	54 (57.4)	0.0305
Admission time, days								
CCU days	3 (1, 7)	3 (0, 7)	3 (2, 6)	0.1707	3 (1, 6)	3 (0, 6)	3 (2, 6)	0.1288

(*continued on next page*)

Table 1 (*continued*)

	Age ≥ 75 years				Age ≥ 85 years			
	Total (3040)	No reperfusion (n = 2041)	Primary PCI (n = 999)	P value	Total (448)	No reperfusion (n = 354)	Primary PCI (n = 94)	P value
In-hospital days	10 (6, 14)	10 (6, 14)	10 (7, 13)	0.1619	9 (4, 13)	9 (3, 13)	10 (6, 15)	0.2862
Discharge medications, n (%)								
Aspirin	2251 (74.0)	1424 (69.8)	827 (82.8)	<0.0001	282 (62.9)	211 (59.6)	71 (75.5)	0.0036
Clopidogrel/ticagrelor	2201 (72.4)	1382 (67.7)	819 (82.0)	<0.0001	287 (64.1)	214 (60.5)	73 (77.7)	0.0015
Statins	2280 (75.0)	1456 (71.3)	824 (82.5)	<0.0001	293 (65.4)	221 (62.4)	72 (76.6)	0.0085
Beta-blockers	1472 (48.4)	915 (44.8)	557 (55.8)	<0.0001	186 (41.5)	140 (39.5)	46 (48.9)	0.1022
ACEI/ARB	1279 (42.1)	811 (39.7)	468 (46.8)	0.0002	165 (36.8)	125 (35.3)	40 (42.6)	0.1987
Nitrate	1352 (44.5)	963 (47.2)	389 (38.9)	<0.0001	177 (39.5)	152 (42.9)	25 (26.6)	0.0033
Calcium channel blockers	204 (6.7)	139 (6.8)	65 (6.5)	0.7525	25 (5.6)	21 (5.9)	4 (4.3)	0.5162

ACEI/ARB: angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; BMI: body mass index; CABG: coronary artery bypass graft; CCU: intensive care unit; COPD: chronic obstructive pulmonary disease; DES: drug-eluting stent; MI: myocardial infarction; PCI: percutaneous coronary intervention; STEMI: ST-segment elevation myocardial infarction; TIMI: thrombolysis in myocardial infarction.

of two-year all-cause mortality (Fig. 1A), MACCE (Fig. 1B), and cardiac death (Fig. 1C), which is similar with the unadjusted Kaplan-Meier curves (Supplementary Fig. 2).

3.3. Subgroup analysis of all-cause mortality and MACCE in STEMI patients aged ≥75 years

To determine whether the outcomes observed in the overall population were consistent, we calculated the HR for all-cause mortality and MACCE in various complex subgroups. The better outcomes associated with primary PCI in terms of two-year all-cause mortality were consistent across various subgroups including patients with relatively high-risk profiles such as age ≥85 years, hypertension, diabetes, heart failure, smoke, symptom onset to admission time ≥12 h, Killip II-IV, Grace score ≥155**,** cardiogenic shock, or left ventricular ejection fraction ≤40%. Even for patients admitted in county hospitals with limited medical resources, primary PCI was superior to no reperfusion (Fig. 2A). Similar results were obtained for 30-day all-cause mortality (Supplementary Fig. 3), 30-day MACCE (Supplementary Fig. 4), and two-year MACCE (Supplementary Fig. 5).

3.4. Independent predictors of all-cause mortality and MACCE in STEMI patients aged ≥75 years

Primary PCI, male, provincial hospitals, municipal hospitals, aspirin, statins, beta-blockers, and ACEI/ARB were associated with decreased risks of both 30-day all-cause mortality and MACCE, while age, diabetes, GRACE risk score, and cardiogenic shock were associated with increased risks of both 30-day all-cause mortality and MACCE (Supplementary Table 2). Similar results were observed with two-year all-cause mortality and MACCE (Supplementary Table 3).

3.5. Baseline clinical and procedural characteristics in STEMI patients aged ≥85 years

For STEMI patients aged ≥85 years receiving primary PCI, they had higher BMI (body mass index) and were more likely to be current smokers and have comorbidities such as hypertension, diabetes, and hyperlipemia. They were also more likely to be admitted in provincial hospitals in an early time. Additionally, aspirin, clopidogrel/ticagrelor, GP IIb/IIIa receptor antagonist, statins, and ACEI/ARB were more common in the primary PCI group. However, prior stroke, Killip II-IV, and nitrate were less common in the primary PCI group. The heart rate was also lower in the primary PCI group. 76.6% patients had TIMI 0 or 1 before PCI in the primary PCI group, yet after performing primary PCI, 90.4% patients achieved TIMI 3.

3.6. 30-Day and two-year clinical outcomes in STEMI patients aged ≥85 years

Similar with STEMI patients aged ≥75 years, those aged ≥85 years receiving primary PCI also had lower risks of both 30-day and two-year all-cause mortality, MACCE, and cardiac death (Table 2). After excluding patients who died within 48 h after admission, primary PCI was still superior to no reperfusion (Supplementary Table 1).

Multivariable adjusted Kaplan-Meier curves in Fig. 3 revealed that primary PCI could decrease two-year all-cause mortality (Fig. 3A), MACCE (Fig. 3B), and cardiac death (Fig. 3C), which was similar with the unadjusted Kaplan-Meier curves in Supplementary Fig. 6.

3.7. Subgroup analysis of all-cause mortality and MACCE in STEMI patients aged ≥85 years

Similarly, the better outcomes associated with primary PCI in terms of two-year all-cause mortality were consistent across various subgroups including those with hypertension, Grace score ≥155, or cardiogenic shock (Fig. 2B). Similar results were observed for 30-day all-cause mortality (Supplementary Fig. 7), 30-day MACCE (Supplementary Fig. 8), and two-year MACCE (Supplementary Fig. 9).

3.8. Independent predictors of all-cause mortality and MACCE in STEMI patients aged ≥85 years

Primary PCI, provincial hospitals, municipal hospitals, and statin were independent predictors to decrease both 30-day all-cause mortality and MACCE, whereas age and cardiogenic shock were independent predictors to increase both 30-day all-cause mortality and MACCE (Supplementary Table 2). Similar results were obtained for two-year all-cause mortality and MACCE (Supplementary Table 3).

4. Discussion

The main findings of our analysis are that primary PCI was related to a substantial reduction in both short- and long-term all-cause mortality, MACCE, and cardiac death in STEMI patients aged ≥75 years, even in these aged ≥85 years. No significant differences were observed in recurrent MI, stroke, revascularization, or major bleeding between the two groups. Additionally, in patients with relatively high-risk profiles

Table 2
Comparison of 30-day and two-year outcomes in STEMI patients aged ≥75 Years or ≥85 Years with different treatment modalities.

	Age ≥75 years						Age ≥85 years					
	No reperfusion (n = 2041)	Primary PCI (n = 999)	Unadjusted		Multivariable adjusted		No reperfusion (n = 354)	Primary PCI (n = 94)	Unadjusted		Multivariable adjusted	
			HR (95% CI)	P value	HR (95% CI)	P value			HR (95% CI)	P value	HR (95% CI)	P value
30-day outcomes												
All-cause mortality	461 (23.0)	91 (9.3)	0.38 (0.30, 0.47)	<0.0001	0.49 (0.39, 0.63)	<0.0001	120 (34.7)	15 (16.7)	0.42 (0.25, 0.72)	0.0017	0.35 (0.19, 0.65)	0.0009
MACCE	548 (27.9)	143 (14.8)	0.50 (0.41, 0.60)	<0.0001	0.62 (0.50, 0.76)	<0.0001	135 (39.6)	21 (23.6)	0.53 (0.33, 0.84)	0.0064	0.45 (0.27, 0.77)	0.0036
Cardiac death	327 (17.1)	66 (6.9)	0.39 (0.30, 0.51)	<0.0001	0.49 (0.37, 0.66)	<0.0001	88 (27.5)	10 (11.8)	0.39 (0.20, 0.75)	0.0048	0.31 (0.14, 0.66)	0.0026
Recurrent MI	23 (1.4)	8 (0.9)	0.65 (0.29, 1.45)	0.2937	0.61 (0.25, 1.49)	0.2775	3 (1.2)	2 (2.5)	2.15 (0.36, 12.91)	0.4007	0.06 (0.00, 7.97)	0.2592
Stroke	28 (1.7)	18 (2.0)	1.25 (0.69, 2.26)	0.4620	1.79 (0.87, 3.69)	0.1127	5 (1.9)	3 (3.7)	2.12 (0.51, 8.89)	0.3033	0.74 (0.05, 10.94)	0.8298
Revascularization	28 (1.7)	18 (2.0)	1.19 (0.66, 2.16)	0.5593	1.18 (0.59, 2.36)	0.6310	3 (1.2)	2 (2.5)	2.33 (0.39, 13.94)	0.3558	1.65 (0.07, 37.67)	0.7535
Major bleeding	64 (3.9)	35 (3.8)	1.01 (0.67, 1.53)	0.9587	1.01 (0.62, 1.64)	0.9800	15 (5.8)	4 (5.0)	0.86 (0.29, 2.59)	0.7870	0.98 (0.27, 3.61)	0.9803
two-year outcomes												
All-cause mortality	711 (36.4)	171 (18.0)	0.44 (0.37, 0.51)	<0.0001	0.54 (0.45, 0.65)	<0.0001	181 (53.7)	29 (33.0)	0.51 (0.34, 0.75)	0.0007	0.49 (0.31, 0.77)	0.0019
MACCE	852 (43.5)	273 (28.7)	0.58 (0.51, 0.67)	<0.0001	0.68 (0.59, 0.80)	<0.0001	201 (58.9)	37 (42.0)	0.59 (0.42, 0.84)	0.0033	0.56 (0.37, 0.84)	0.0049
Cardiac death	418 (23.6)	90 (10.0)	0.40 (0.32, 0.51)	<0.0001	0.49 (0.38, 0.62)	<0.0001	110 (38.3)	15 (19.5)	0.45 (0.26, 0.77)	0.0038	0.41 (0.22, 0.76)	0.0047
Recurrent MI	59 (4.0)	22 (2.6)	0.65 (0.40, 1.06)	0.0852	0.68 (0.39, 1.19)	0.1725	13 (6.0)	3 (4.1)	0.68 (0.19, 2.39)	0.5488	0.17 (0.03, 1.08)	0.0601
Stroke	44 (3.0)	34 (3.9)	1.47 (0.94, 2.32)	0.0931	1.36 (0.80, 2.32)	0.2589	7 (3.3)	5 (6.7)	2.35 (0.74, 7.42)	0.1453	1.32 (0.24, 7.20)	0.7454
Revascularization	62 (4.2)	52 (6.1)	1.48 (1.02, 2.14)	0.0381	1.22 (0.79, 1.87)	0.3697	4 (1.9)	3 (4.1)	2.47 (0.55, 11.08)	0.2364	0.92 (0.12, 7.23)	0.9368
Major bleeding	78 (5.3)	45 (5.2)	1.05 (0.73, 1.51)	0.7968	0.94 (0.61, 1.45)	0.7849	16 (7.4)	5 (6.9)	1.00 (0.37, 2.72)	0.9958	0.91 (0.26, 3.26)	0.8902

MACCE: major adverse cardiac and cerebrovascular event; MI: myocardial infarction.
[a]Age, sex, hypertension, hyperlipemia, diabetes, prior myocardial infarction, prior stroke, hospital level, symptoms onset to admission time, GRACE risk score, Killip class, angiotensin-converting enzyme inhibitor/angiotensin receptor blockers, and beta-blockers were included in the adjustment model.

such as cardiogenic shock or delaying hospital admission, primary PCI was also superior to no reperfusion in reducing both short- and long-term all-cause mortality and MACCE. However, primary PCI was underutilized in Chinese clinical practice.

The 2018 European Society of Cardiology (ESC) guideline recommend reperfusion therapy in all STEMI patients with time from symptom onset <12 h duration (Class I, Level A). Routine primary PCI should be considered in patients presenting late (12–48 h) after symptom onset (Class IIa, Level B) [18]. Similarly, the American College of Cardiology Foundation (ACCF)/American Heart Association (AHA) guideline also recommend primary PCI in patients with STEMI and ischemic symptoms of <12 h' duration (Class I, Level A) [19]. However, older patients often do not receive primary PCI for reasons including atypical presentation, reduced reporting of chest pain, residual ST-segment elevation from old infarcts, increased incidence of heart failure on presentation, or possibly limited life expectancy [20]. Moreover, confusion may be the presenting feature in up to 20% of patients aged ≥85 years, which complicates diagnosis and management [21]. Additionally, worse complications associated with primary PCI may hinder the application of it due to extensive coronary artery disease and more complex comorbidities [22, 23]. For example, older patients are more susceptible to contrast-induced nephropathy after primary PCI as a result of worse renal function at baseline [24] and more complex lesions, which may mandate increased contrast use [25]. Therefore, it is common to see that the prevalence of primary PCI was low in STEMI patients with older age. A study enrolling patients between 2001 and 2006 reported that in patients aged more than 80 years, just 20% of patients with non-ST-segment elevation myocardial infarction (NSTEMI) and 30% with STEMI were treated by invasive treatment [26]. However, in the Hungarian Myocardial Infarction Registry (HUMIR) begins in 2014, the proportions of PCI for NSTEMI and STEMI patients increased to 61.0% and 83.8%, respectively [11]. The London Heart Attack Group cohort also demonstrated that the proportion of primary PCI procedures for octogenarians increased over time, which may be related to increasing

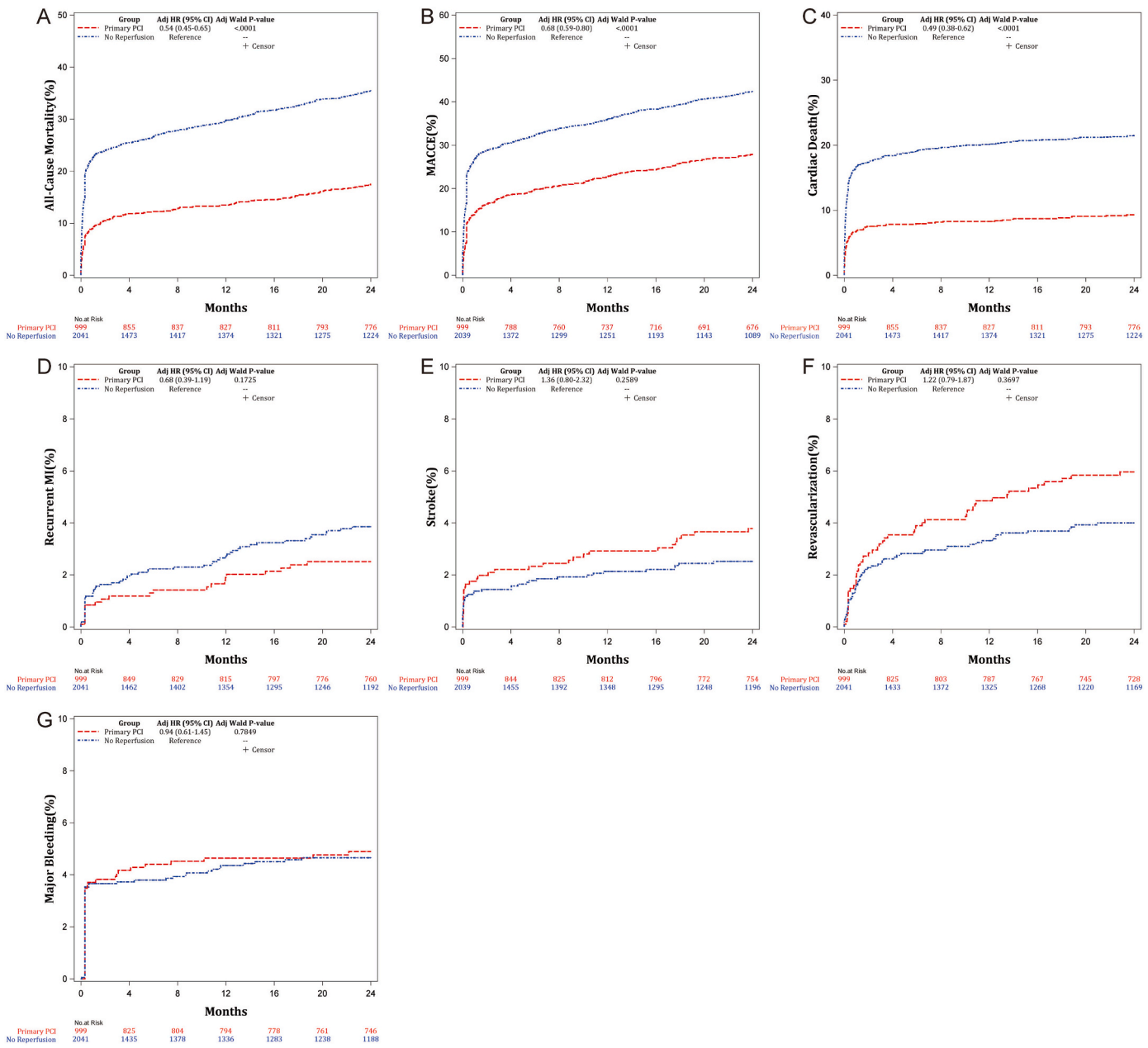

Fig. 1. Multivariable Adjusted Kaplan-Meier Estimates of the Cumulative Incidence of Outcomes After Two-Year Follow-Up in Patients Aged ≥75 Years. MACCE: major adverse cardiac and cerebrovascular event; MI: myocardial infarction; PCI: percutaneous coronary intervention. * Age, sex, hypertension, hyperlipemia, diabetes, prior myocardial infarction, prior stroke, hospital level, symptoms onset to admission time, GRACE risk score, Killip class, angiotensin-converting enzyme inhibitor/angiotensin receptor blockers, and beta blockers were included in the adjustment model.

experience and improved techniques of primary PCI [10].

In the present analysis, we found that in STEMI patients aged ≥75 or 85 years, the proportions of primary PCI were just 32.9% and 21.0%, respectively. Primary PCI could decrease both short- and long-term all-cause mortality, MACCE, and cardiac death in STEMI patients aged ≥75 years, even for those ≥85 years or with relatively high-risk profiles such as cardiogenic shock or delaying hospital admission. Consistent with our findings, Di Bari et al. revealed that the application of primary PCI for the acute coronary syndrome was associated with a lower risk of all-cause mortality in patients aged ≥75 years, although these patients receiving primary PCI were complicated with higher background risks [27]. In the ISACS-TC registry, primary PCI causes a remarkable reduction in 30-day mortality in both the older (75–79 years) and very-old patients (≥80 years) [28]. In the study conducted by Yudi et al. [29], they consistently suggested that in STEMI patients aged ≥85 years, primary PCI was associated with lower in-hospital, 12-month, and long-term all-cause mortality as compared with no reperfusion. Sappa et al. [30], also revealed that primary PCI in patients aged ≥85 years was relatively safe. Even for STEMI patients aged ≥90 years, a steady decrease in hospitalizations from 4 per 1000 in 2010 to 2 per 1000 in 2017 was also observed [31]. All of the abovementioned observational studies suggested that primary PCI was superior to no reperfusion regardless of age or risk profiles. In the randomized After Eighty study [32], 457 NSTEMI patients aged ≥80 years were randomly assigned to revascularization strategy (n = 229) or no reperfusion strategy (n = 228). During a median follow-up of 1.53 years, the primary outcome defined as a composite of MI, need for urgent revascularization, stroke, and death occurred less frequently in the revascularization group as compared with the no reperfusion group (40.6% vs 61.4%; HR: 0.53; 95% CI: 0.41 to 0.69; P = 0.0001), which was mainly due to the reduced

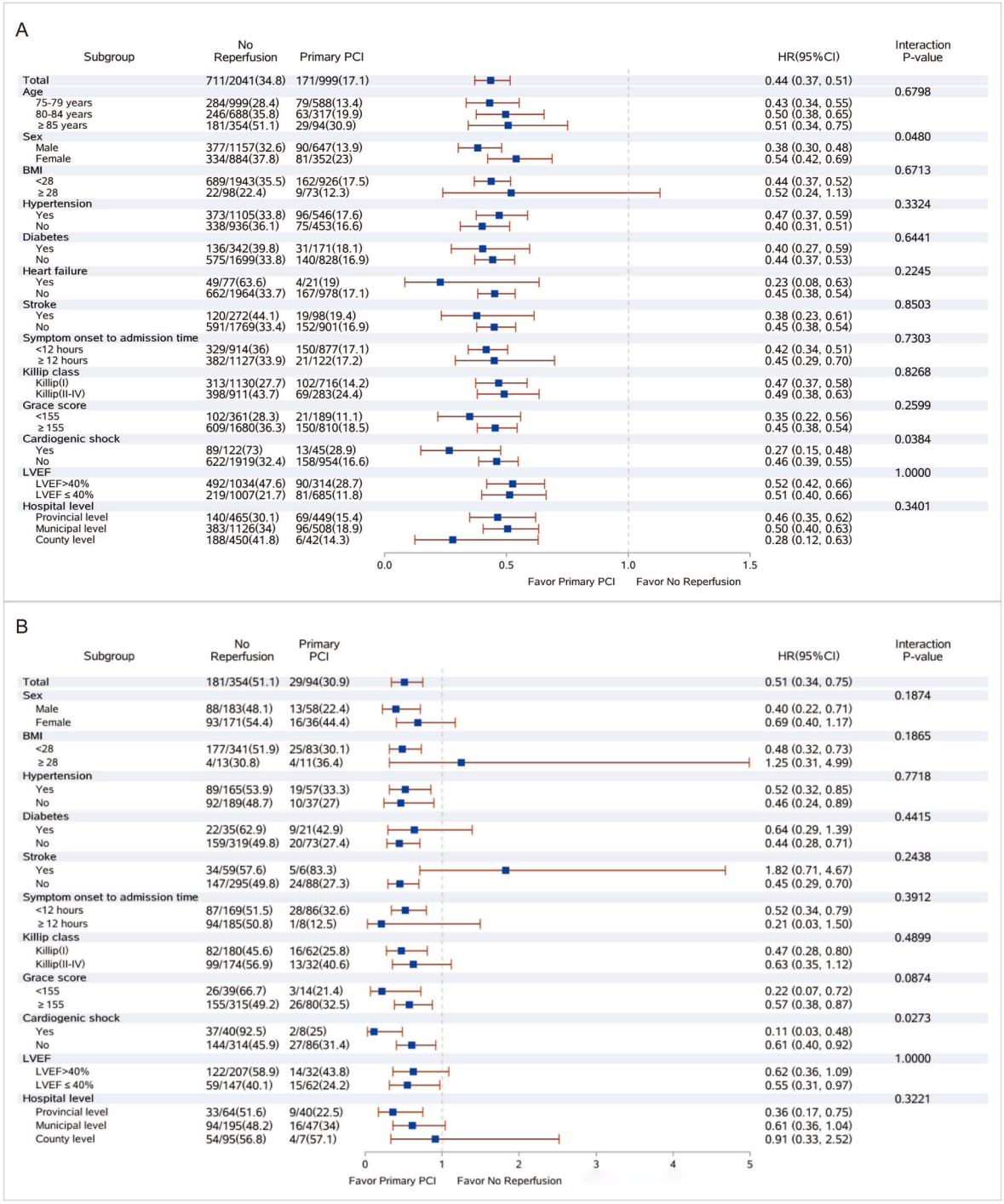

Fig. 2. Subgroup Analysis of Two-Year All-Cause Mortality in Patients Aged ≥75 Years (A) or ≥85 Years (B). BMI: body mass index; LVEF: left ventricular ejection fraction.

risks of MI (HR: 0.52; 95% CI: 0.35 to 0.76; P = 0.0001) and urgent revascularization (HR: 0.19; 95% CI: 0.07 to 0.52; P = 0.0001). Moreover, a more obvious benefit in patients aged ≥90 years was observed. The results suggest that the highest-risk patients may derive the most absolute benefit from invasive management. Moreover, age alone may not preclude patients presenting with STEMI from invasive revascularization. Although increasing age is associated with increased all-cause mortality, the deleterious impact of increasing age may be offset by improved outcomes of primary PCI. After all, prompt restoration of blood flow to the culprit vessel and consequent reduction in infarct size, and decreased incidence of cardiogenic shock and subsequent cardiac death may be helpful for the recovery of cardiac function [33].

In the present study, the rate of major bleeding was not different between the two groups, which might be explained by the wide use of antithrombotic treatment and the introduction of radial access in the catheterization laboratory [34]. Moreover, in STEMI patients with cardiogenic shock primary PCI was also superior to no reperfusion in reducing both short- and long-term all-cause mortality and MACCE, which is similar with the results from a large publicly available all-payer inpatient health care database, where PCI was also associated with a lower risk of in-hospital all-cause mortality [35]. It is reported that patients admitted to PCI-capable centers were more commonly to

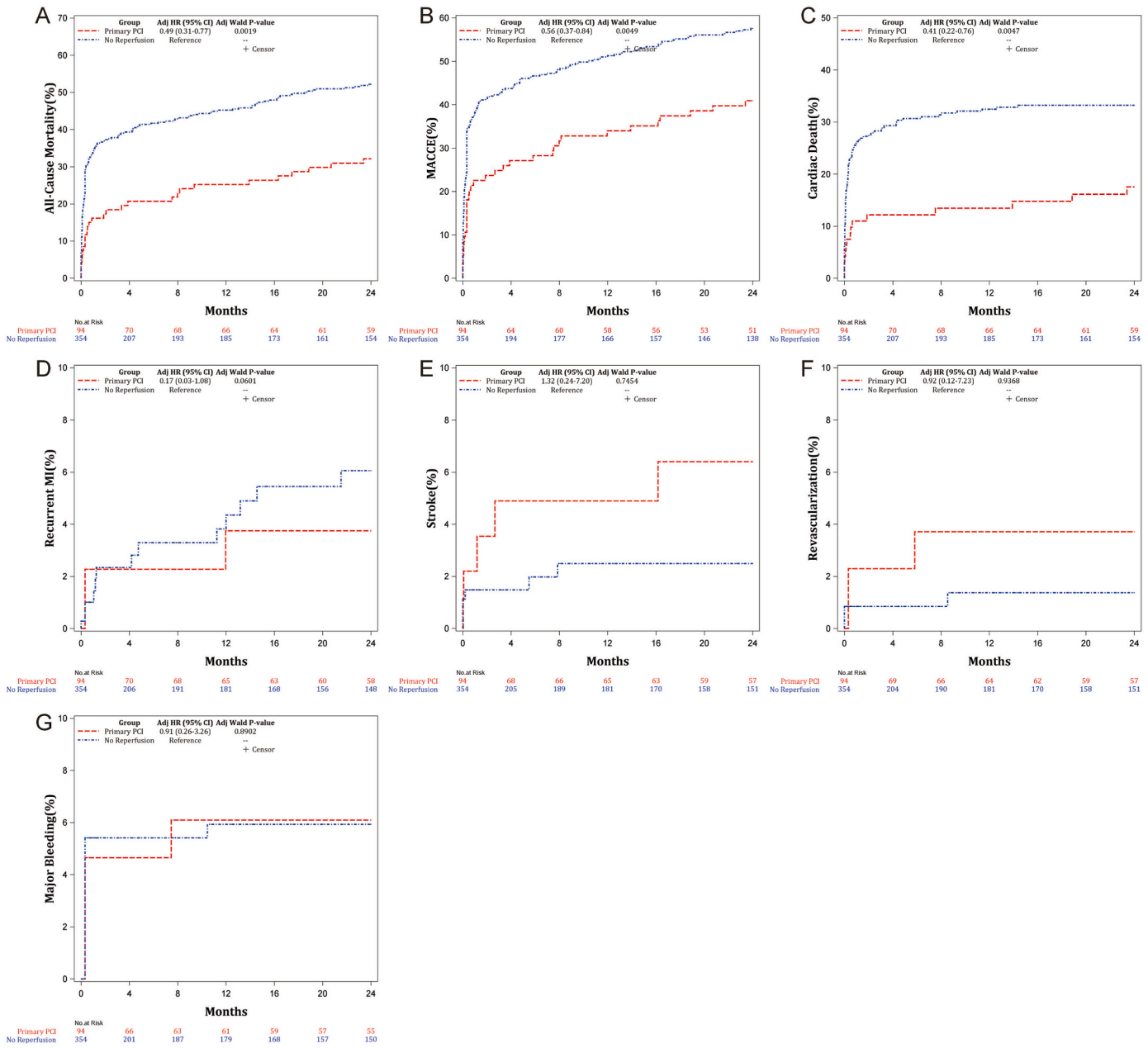

Fig. 3. Multivariable Adjusted Kaplan-Meier Estimates of the Cumulative Incidence of Outcomes After Two-Year Follow-Up in Patients Aged ≥85 Years. MACCE: major adverse cardiac and cerebrovascular event; MI: myocardial infarction; PCI: percutaneous coronary intervention. * Age, sex, hypertension, hyperlipemia, diabetes, prior myocardial infarction, prior stroke, hospital level, symptoms onset to admission time, GRACE risk score, Killip class, angiotensin-converting enzyme inhibitor/angiotensin receptor blockers, and beta blockers were included in the adjustment model.

receive an invasive strategy [31,36]. Similarly, primary PCI was also more likely to be performed in provincial and municipal hospitals compared with county hospitals in our study. However, even for patients admitted in county hospitals with limited medical resources, primary PCI was also superior to no reperfusion. Also, it is in a dilemma whether to revascularize the culprit vessel after symptom onset more than 12 h [37,38]. The problem is even troublesome in patients with older age as a result of atypical presentation and late admission. Our results also indicated that primary PCI was superior to no reperfusion even for patients with delaying hospital admission.

Existing guidelines emphasize early invasive treatment, particularly for those with high-risk profiles [5,6], yet practice patterns show lower use of invasive management in older individuals who are likely to benefit [39]. In our study, the prevalence of primary PCI was also lower as compared with no reperfusion. Treatment is often hindered by complex multivessel coronary calcification, tortuous vascular anatomy, impaired ventricular function, higher-risk profiles, and substantial comorbidity [40]. Phan et al. [41] pointed out two most common reasons for not performing primary PCI: 1. poor candidacy for reperfusion as a result of suboptimal coronary anatomy, comorbidities, frailty, or other reasons (38.9%); 2. significant obstructive coronary artery disease but high risk-benefit ratio favoring no reperfusion (36.3%) first with the option for invasive management “as needed” if fails. However, with the advancement in PCI techniques and accumulating experience in the treatment of older patients, it is promising that the prevalence of primary PCI and consequent clinical outcomes will be improved in patients age ≥75 years, even in these aged ≥85 years.

5. Limitation

First, significant differences existed in hospital level and symptom onset to admission time between primary PCI and no reperfusion groups, which may influence the clinical outcomes. Although we had taken them into adjustment model, as an observational study in nature, bias could not be completely eliminated. However, in the subgroup analysis, primary PCI was consistently superior to no reperfusion regardless of hospital level or symptom onset to admission time. Second, immortal time bias can occur when patients who would have undergone primary PCI are analyzed in the no reperfusion group as they died before primary PCI was performed due to favorable clinical and hemodynamic profiles. Therefore, patients who died within 48 h were excluded as a sensitivity analysis, after that, consistent results were observed. Third, the analysis reflected the real-life settings in Chinese clinical practice, whether the same conclusions can be generalized to other ethnicities need further investigation. However, it may provide a helpful reference for developing countries that have similar situations with China. Last, the study populations were included between 2013 and 2014, which represent a relatively older data set.

6. Conclusion

Primary PCI was associated with substantial reductions in both short- and long-term all-cause mortality, MACCE, and cardiac death in STEMI patients aged ≥75 years, even in these with relatively high-risk profiles such as age ≥85 years, cardiogenic shock or delaying hospital admission. Recurrent MI, stroke, revascularization, or major bleeding were similar between primary PCI and no reperfusion groups. However, primary PCI was underutilized in Chinese clinical practice.

CRediT authorship contribution statement

Mengjin Hu: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Xinyue Lang:** Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Jingang Yang:** Conceptualization, Data curation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft. **Yang Wang:** Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft. **Wei Li:** Conceptualization, Formal analysis, Methodology, Project administration, Software, Supervision, Validation, Writing – original draft. **Xiaojin Gao:** Conceptualization, Data curation, Funding acquisition, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – review & editing. **Yuejin Yang:** Conceptualization, Data curation, Funding acquisition, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing.

Conflict of interest

All authors declared no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcrp.2024.200251.

References

[1] R. Sharma, B. Hiebert, D. Cheung, D.S. Jassal, K. Minhas, Primary coronary intervention in octogenarians and nonagenarians with ST-segment elevation myocardial infarction: a Canadian single-center perspective, Angiology 69 (2018) 718–723.
[2] A. Ariza-Solé, O. Alegre, F.J. Elola, C. Fernández, F. Formiga, M. Martínez-Sellés, et al., Management of myocardial infarction in the elderly. Insights from Spanish minimum basic data set, Eur. Heart J. Acute Cardiovasc. Care 8 (2019) 242–251.
[3] L. Antonsen, L.O. Jensen, C.J. Terkelsen, H.H. Tilsted, A. Junker, M. Maeng, et al., Outcomes after primary percutaneous coronary intervention in octogenarians and nonagenarians with ST-segment elevation myocardial infarction: from the Western Denmark heart registry, Cathet. Cardiovasc. Interv. 81 (2013) 912–919.
[4] D.G. Beevers, The atlas of heart disease and stroke, J. Hum. Hypertens. 19 (2005) 505.
[5] J.P. Collet, H. Thiele, E. Barbato, O. Barthélémy, J. Bauersachs, D.L. Bhatt, et al., 2020 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation, Eur. Heart J. 42 (2021) 1289–1367.
[6] J.S. Lawton, J.E. Tamis-Holland, S. Bangalore, E.R. Bates, T.M. Beckie, J. M. Bischoff, et al., 2021 ACC/AHA/SCAI guideline for coronary artery revascularization: a report of the American College of Cardiology/American heart association joint committee on clinical practice guidelines, Circulation (2021). Cir0000000000001038.
[7] T. Bauer, O. Koeth, C. Jünger, T. Heer, H. Wienbergen, A. Gitt, et al., Effect of an invasive strategy on in-hospital outcome in elderly patients with non-ST-elevation myocardial infarction, Eur. Heart J. 28 (2007) 2873–2878.
[8] G. Devlin, J.M. Gore, J. Elliott, N. Wijesinghe, K.A. Eagle, A. Avezum, et al., Management and 6-month outcomes in elderly and very elderly patients with high-risk non-ST-elevation acute coronary syndromes: the Global Registry of Acute Coronary Events, Eur. Heart J. 29 (2008) 1275–1282.
[9] P. Kunniardy, A.N. Koshy, G. Meehan, A.C. Murphy, J. Ramchand, D.J. Clark, et al., Invasive versus conservative management in patients ≥85 years presenting with non-ST elevation myocardial infarction, Intern. Med. J. (2021).
[10] D.I. Bromage, D.A. Jones, K.S. Rathod, C. Grout, M.B. Iqbal, P. Lim, et al., Outcome of 1051 octogenarian patients with ST-segment elevation myocardial infarction treated with primary percutaneous coronary intervention: observational cohort from the London heart Attack group, J. Am. Heart Assoc. 5 (2016).
[11] A. Komócsi, M. Simon, B. Merkely, T. Szűk, R.G. Kiss, D. Aradi, et al., Underuse of coronary intervention and its impact on mortality in the elderly with myocardial infarction. A propensity-matched analysis from the Hungarian Myocardial Infarction Registry, Int. J. Cardiol. 214 (2016) 485–490.
[12] T. Petroni, A. Zaman, J.L. Georges, N. Hammoudi, E. Berman, A. Segev, et al., Primary percutaneous coronary intervention for ST elevation myocardial infarction in nonagenarians, Heart 102 (2016) 1648–1654.
[13] M. Rashid, D.L. Fischman, M. Gulati, K. Tamman, J. Potts, C.S. Kwok, et al., Temporal trends and inequalities in coronary angiography utilization in the management of non-ST-Elevation acute coronary syndromes in the U.S, Sci. Rep. 9 (2019) 240.
[14] H. Xu, W. Li, J. Yang, S.D. Wiviott, M.S. Sabatine, E.D. Peterson, et al., The China Acute Myocardial Infarction (CAMI) Registry: a national long-term registry-research-education integrated platform for exploring acute myocardial infarction in China, Am. Heart J. 175 (2016) 193–201.e3.
[15] K. Thygesen, J.S. Alpert, A.S. Jaffe, M.L. Simoons, B.R. Chaitman, H.D. White, et al., Third universal definition of myocardial infarction, J. Am. Coll. Cardiol. 60 (2012) 1581–1598.
[16] J.H. Yang, J.Y. Hahn, Y.B. Song, S.H. Choi, J.H. Choi, S.H. Lee, et al., Association of beta-blocker therapy at discharge with clinical outcomes in patients with ST-segment elevation myocardial infarction undergoing primary percutaneous coronary intervention, JACC Cardiovasc. Interv. 7 (2014) 592–601.
[17] S.D. Wiviott, E. Braunwald, C.H. McCabe, G. Montalescot, W. Ruzyllo, S. Gottlieb, et al., Prasugrel versus clopidogrel in patients with acute coronary syndromes, N. Engl. J. Med. 357 (2007) 2001–2015.
[18] F.J. Neumann, M. Sousa-Uva, A. Ahlsson, F. Alfonso, A.P. Banning, U. Benedetto, et al., 2018 ESC/EACTS Guidelines on myocardial revascularization, Eur. Heart J. 40 (2019) 87–165.
[19] P.T. O'Gara, F.G. Kushner, D.D. Ascheim, D.E. Casey Jr., M.K. Chung, J.A. de Lemos, et al., 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology foundation/American heart association task force on practice guidelines, Circulation 127 (2013) e362–e425.
[20] A. Goch, P. Misiewicz, J. Rysz, M. Banach, The clinical manifestation of myocardial infarction in elderly patients, Clin. Cardiol. 32 (2009) E46–E51.
[21] M.W. Rich, Epidemiology, clinical features, and prognosis of acute myocardial infarction in the elderly, Am. J. Geriatr. Cardiol. 15 (2006) 7–11, quiz 2.
[22] D. Hasdai, D.R. Holmes Jr., D.A. Criger, E.J. Topol, R.M. Califf, R.A. Harrington, Age and outcome after acute coronary syndromes without persistent ST-segment elevation, Am. Heart J. 139 (2000) 858–866.

[23] S. Yusuf, M. Flather, J. Pogue, D. Hunt, J. Varigos, L. Piegas, et al., Variations between countries in invasive cardiac procedures and outcomes in patients with suspected unstable angina or myocardial infarction without initial ST elevation. OASIS (Organisation to Assess Strategies for Ischaemic Syndromes) Registry Investigators, Lancet 352 (1998) 507–514.
[24] P.A. McCullough, R. Wolyn, L.L. Rocher, R.N. Levin, W.W. O'Neill, Acute renal failure after coronary intervention: incidence, risk factors, and relationship to mortality, Am. J. Med. 103 (1997) 368–375.
[25] Y.C. Wang, J.J. Hwang, C.S. Hung, H.L. Kao, F.T. Chiang, C.D. Tseng, Outcome of primary percutaneous coronary intervention in octogenarians with acute myocardial infarction, J. Formos. Med. Assoc. 105 (2006) 451–458.
[26] A.W. Schoenenberger, D. Radovanovic, J.C. Stauffer, S. Windecker, P. Urban, F. R. Eberli, et al., Age-related differences in the use of guideline-recommended medical and interventional therapies for acute coronary syndromes: a cohort study, J. Am. Geriatr. Soc. 56 (2008) 510–516.
[27] M. Di Bari, D. Balzi, S. Fracchia, A. Barchielli, F. Orso, A. Sori, et al., Decreased usage and increased effectiveness of percutaneous coronary intervention in complex older patients with acute coronary syndromes, Heart 100 (2014) 1537–1542.
[28] B. Ricci, O. Manfrini, E. Cenko, Z. Vasiljevic, M. Dorobantu, S. Kedev, et al., Primary percutaneous coronary intervention in octogenarians, Int. J. Cardiol. 222 (2016) 1129–1135.
[29] M.B. Yudi, N. Jones, D. Fernando, D.J. Clark, J. Ramchand, E. Jones, et al., Management of patients aged ≥85 Years with ST-elevation myocardial infarction, Am. J. Cardiol. 118 (2016) 44–48.
[30] R. Sappa, M.T. Grillo, M. Cinquetti, G. Prati, L. Spedicato, G. Nucifora, et al., Short and long-term outcome in very old patients with ST-elevation myocardial infarction after primary percutaneous coronary intervention, Int. J. Cardiol. 249 (2017) 112–118.
[31] V.S. Pajjuru, A. Thandra, R.R. Guddeti, S.R. Kothapalli, R.W. Walters, A. Jhand, et al., ST-elevation myocardial infarction in nonagenarians: a nationwide analysis of trends and outcomes in the United States, Cathet. Cardiovasc. Interv. 98 (2021) 638–646.
[32] N. Tegn, M. Abdelnoor, L. Aaberge, K. Endresen, P. Smith, S. Aakhus, et al., Invasive versus conservative strategy in patients aged 80 years or older with non-ST-elevation myocardial infarction or unstable angina pectoris (After Eighty study): an open-label randomised controlled trial, Lancet 387 (2016) 1057–1065.
[33] V.B. Shanmugam, R. Harper, I. Meredith, Y. Malaiapan, P.J. Psaltis, An overview of PCI in the very elderly, J. Geriatr. Cardiol. 12 (2015) 174–184.
[34] M. Valgimigli, A. Gagnor, P. Calabró, E. Frigoli, S. Leonardi, T. Zaro, et al., Radial versus femoral access in patients with acute coronary syndromes undergoing invasive management: a randomised multicentre trial, Lancet 385 (2015) 2465–2476.
[35] A.A. Damluji, K. Bandeen-Roche, C. Berkower, C.M. Boyd, M.S. Al-Damluji, M. G. Cohen, et al., Percutaneous coronary intervention in older patients with ST-segment elevation myocardial infarction and cardiogenic shock, J. Am. Coll. Cardiol. 73 (2019) 1890–1900.
[36] Y.B. Pride, J.G. Canto, P.D. Frederick, C.M. Gibson, Outcomes among patients with ST-segment-elevation myocardial infarction presenting to interventional hospitals with and without on-site cardiac surgery, Circ. Cardiovasc. Qual. Outcomes 2 (2009) 574–582.
[37] E.J. Topol, R.M. Califf, M. Vandormael, C.L. Grines, B.S. George, M.L. Sanz, et al., A randomized trial of late reperfusion therapy for acute myocardial infarction. Thrombolysis and Angioplasty in Myocardial Infarction-6 Study Group, Circulation 85 (1992) 2090–2099.
[38] Z.R. Yousef, S.R. Redwood, C.A. Bucknall, A.N. Sulke, M.S. Marber, Late intervention after anterior myocardial infarction: effects on left ventricular size, function, quality of life, and exercise tolerance: results of the Open Artery Trial (TOAT Study), J. Am. Coll. Cardiol. 40 (2002) 869–876.
[39] A. Avezum, M. Makdisse, F. Spencer, J.M. Gore, K.A. Fox, G. Montalescot, et al., Impact of age on management and outcome of acute coronary syndrome: observations from the Global Registry of Acute Coronary Events (GRACE), Am. Heart J. 149 (2005) 67–73.
[40] M. Behan, G. Dixon, P. Haworth, L. Blows, D. Hildick-Smith, S. Holmberg, et al., PCI in octogenarians–our centre 'real world' experience, Age Ageing 38 (2009) 469–473.
[41] D.Q. Phan, A.H. Rostomian, F. Schweis, J. Chung, B. Lin, R. Zadegan, et al., Revascularization versus medical therapy in patients aged 80 Years and older with acute myocardial infarction, J. Am. Geriatr. Soc. 68 (2020) 2525–2533.