ST-segment elevation myocardial infarction in China from 2001 to 2011 (the China PEACE-Retrospective Acute Myocardial Infarction Study): a retrospective analysis of hospital data

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Summary

Background Despite the importance of ST-segment elevation myocardial infarction (STEMI) in China, no nationally representative studies have characterised the clinical profiles, management, and outcomes of this cardiac event during the past decade. We aimed to assess trends in characteristics, treatment, and outcomes for patients with STEMI in China between 2001 and 2011.

Methods In a retrospective analysis of hospital records, we used a two-stage random sampling design to create a nationally representative sample of patients in China admitted to hospital for STEMI in 3 years (2001, 2006, and 2011). In the first stage, we used a simple random-sampling procedure stratified by economic–geographical region to generate a list of participating hospitals. In the second stage we obtained case data for rates of STEMI, treatments, and baseline characteristics from patients attending each sampled hospital with a systematic sampling approach. We weighted our findings to estimate nationally representative rates and assess changes from 2001 to 2011. This study is registered with ClinicalTrials.gov, number NCT01624883.

Findings We sampled 175 hospitals (162 participated in the study) and 18 631 acute myocardial infarction admissions, of which 13 815 were STEMI admissions. 12 264 patients were included in analysis of treatments, procedures, and tests, and 11 986 were included in analysis of in-hospital outcomes. Between 2001 and 2011, estimated national rates of hospital admission for STEMI per 100 000 people increased (from 3·7 in 2001, to 8·1 in 2006, to 15·8 in 2011; p_{trend}<0·0001) and the prevalence of risk factors—including smoking, hypertension, diabetes, and dyslipidaemia—increased. We noted significant increases in use of aspirin within 24 h (79·3% [95% CI 77·3–81·3] in 2001 *vs* 91·2% [90·5–91·9] in 2011, p_{trend}<0·0001) and clopidogrel (95% CI 1·5% [0·9–2·1] in 2001 *vs* 80·7% [79·8–81·6] in 2011, p_{trend}<0·0001) in patients without documented contraindications. Despite an increase in the use of primary percutaneous coronary intervention (10·2% [95% CI 8·1–12·3] in 2001 *vs* 27·6% [26·1–29·1] in 2011, p_{trend}<0·0001), the proportion of patients who did not receive reperfusion did not significantly change (44·8% [95% CI 41·3–48·3] in 2001 *vs* 45·0% [43·3–46·7] in 2011, p_{trend}=0·82). The median length of hospital stay decreased from 13 days (IQR 7–18) in 2001 to 11 days (7–14) in 2011 (p_{trend}<0·0001). Adjusted in-hospital mortality did not significantly change between 2001 and 2011 (odds ratio 0·84, 95% CI 0·62–1·12, p_{trend}=0·06).

Interpretation During the past decade in China, hospital admissions for STEMI have risen; in these patients, comorbidities and the intensity of testing and treatment have increased. Quality of care has improved for some treatments, but important gaps persist and in-hospital mortality has not decreased. National efforts are needed to improve the care and outcomes for patients with STEMI in China.

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Introduction

As China has grown economically, it has experienced an epidemiological transition, with mortality due to ischaemic heart disease more than doubling during the past two decades to more than 1 million deaths per year.[1,2] This trend is expected to accelerate, with the World Bank estimating that the number of individuals with myocardial infarction in China will increase to 23 million by 2030.[3] Concurrent with this changing epidemiology, the Chinese medical care system has developed rapidly, implementing policies that have improved access by reducing financial barriers and increasing the numbers of hospitals and physicians.[4,5]

Despite the importance of acute myocardial infarction in China—particularly ST-segment elevation myocardial infarction (STEMI), which accounts for more than 80% of such events in the country[6,7]—no nationally representative studies have defined the clinical profiles, management, and outcomes of patients with this disorder during the past decade. The scarcity of contemporary national estimates and data for changes in burden of disease, quality of care (including use of recommended treatments and inappropriate use of non-evidence-based treatments), and treatment outcomes are important barriers to implementation of interventions to improve care and outcomes. In particular, little information is available about acute myocardial infarction in rural areas, where most of the Chinese population lives.[8–10]

In the China Patient-centered Evaluative Assessment of Cardiac Events Retrospective Study of Acute Myocardial Infarction (China PEACE-Retrospective AMI Study), we aimed to assess trends in STEMI management and outcomes in China during the past decade in a retrospective analysis of hospital records. We selected representative hospitals from 2011 to assess present practices and traced this cohort of hospitals backwards to 2006 and 2001 to describe temporal changes.

See Online for appendix

Methods

Study design

The design of the China PEACE-Retrospective AMI Study has been described previously.[11] Briefly, we used a two-stage random sampling design to create a nationally representative sample of patients in China admitted to hospital for acute myocardial infarction in 3 years (2001, 2006, and 2011). In the first stage, we assessed all non-military hospitals in China and excluded prison hospitals, specialised hospitals without a division for cardiovascular disease, and hospitals for traditional Chinese medicine. We stratified the remaining hospitals into five economic–geographical regions (eastern rural, central rural, western rural, eastern urban, and central-western urban). We used these groups because hospital volumes and clinical capacities differ between urban and rural areas and the three official economic–geographical regions (eastern, central, and western) of mainland China. We grouped the central and western urban regions together because incomes and health services capacity per person are much the same. We randomly sampled all highest-level hospitals in urban regions and all central hospitals in rural regions, and excluded hospitals that did not admit patients with acute myocardial infarction or that declined to participate, to give the sample of participating hospitals.

In the second stage, we used systematic random sampling procedures to select for patients with acute myocardial infarction from the local hospital database of each sampled hospital in each study year. Patients with acute myocardial infarction were identified according to International Classification of Diseases—Clinical Modification codes, including versions 9 (410.xx) and 10 (I21.xx) when available, or through principal diagnosis terms noted at discharge. We collected data by central abstraction of medical charts with use of standardised data definitions. We used rigorous monitoring at each stage to ensure data quality.[11] Data abstraction quality was monitored by random auditing of 5% of the medical records, with overall variable accuracy exceeding 98%.

Participants

Only patients with a definite discharge diagnosis of STEMI were included in the study sample. The diagnosis of STEMI was determined by the combination of clinical discharge diagnosis terms and electrocardiogram (ECG) results. If the local diagnosis was not definitive, cardiologists at the coordinating centre reviewed the medical record and ECG to establish diagnosis. We treated left bundle branch block as a STEMI equivalent. The type of acute myocardial infarction was validated by review of ECGs from randomly selected records by a cardiologist not involved in data abstraction (appendix). We excluded all patients whose STEMI occurred during the course of the hospital admission.

The central ethics committee at the China National Center for Cardiovascular Diseases approved the China PEACE-Retrospective AMI Study. All collaborating hospitals accepted the central ethics approval except for five hospitals, which obtained local approval by internal ethics committees.

Procedures

We abstracted data for the following patient characteristics: age, sex, cardiovascular risk factors, medical history, and clinical characteristics at admission. Information about the medical record abstraction has been described in detail previously.[11] Briefly, comorbidities (including hypertension, diabetes, and dyslipidaemia) were defined as documented history in the admission notes, discharge diagnosis, or positive laboratory test results (total cholesterol >5·18 mmol/L or LDL ≥3·37 mmol/L, or HDL <1·04 mmol/L in men or <1·30 mmol/L in women).

We assessed clinical severity at admission from information collected at admission about systolic blood pressure, heart rate, estimated glomerular filtration rate, cardiac arrest, and cardiogenic shock. We also used the mini-Global Registry of Acute Coronary Events (mini-GRACE) risk score—a modified version of the GRACE risk score including age, systolic blood pressure, ST-segment deviation, cardiac arrest at admission, elevated cardiac enzymes, and heart rate—which has been validated as a means of predicting 6-month mortality for STEMI.[12]

We assessed use of treatments recommended by the 2010 China National Guideline for STEMI,[13] which are consistent with those recommended by guidelines in the USA.[14] These treatments included reperfusion therapy, aspirin within 24 h of admission, clopidogrel within 24 h of admission, β blockers within 24 h of admission, angiotensin-converting-enzyme inhibitors or angiotensin receptor blockers during hospital admission, and statins during hospital admission. We assessed rates of use only in patients thought to be ideal for treatment, defined (consistent with previously studies) as patients without documented contraindications (appendix).[15] We also assessed the use of magnesium sulfate (a treatment that is ineffective),[16,17] traditional Chinese medicine, other

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procedures, and tests. We included the seven main categories of traditional Chinese medicine used for coronary heart disease (appendix). We did not include some care processes (eg, counselling for smoking cessation) because of inadequate documentation.

We compared patients' in-hospital outcomes with four measures: death, death or withdrawal from treatment because of terminal status at discharge (referred to as treatment withdrawal), composite complications (including death, treatment withdrawal, reinfarction, cardiogenic shock, ischaemic stroke, or congestive heart failure [defined in appendix]), and major bleeding. Treatment withdrawal is common in China because of reluctance by many patients to die in hospital. The Chinese Government uses in-hospital death or treatment withdrawal as a quality measure for hospitals.[18,19] Cardiologists in the coordinating study centre adjudicated the clinical status of patients who withdrew from treatment on the basis of medical records. Major bleeding included any intracranial bleeding, absolute

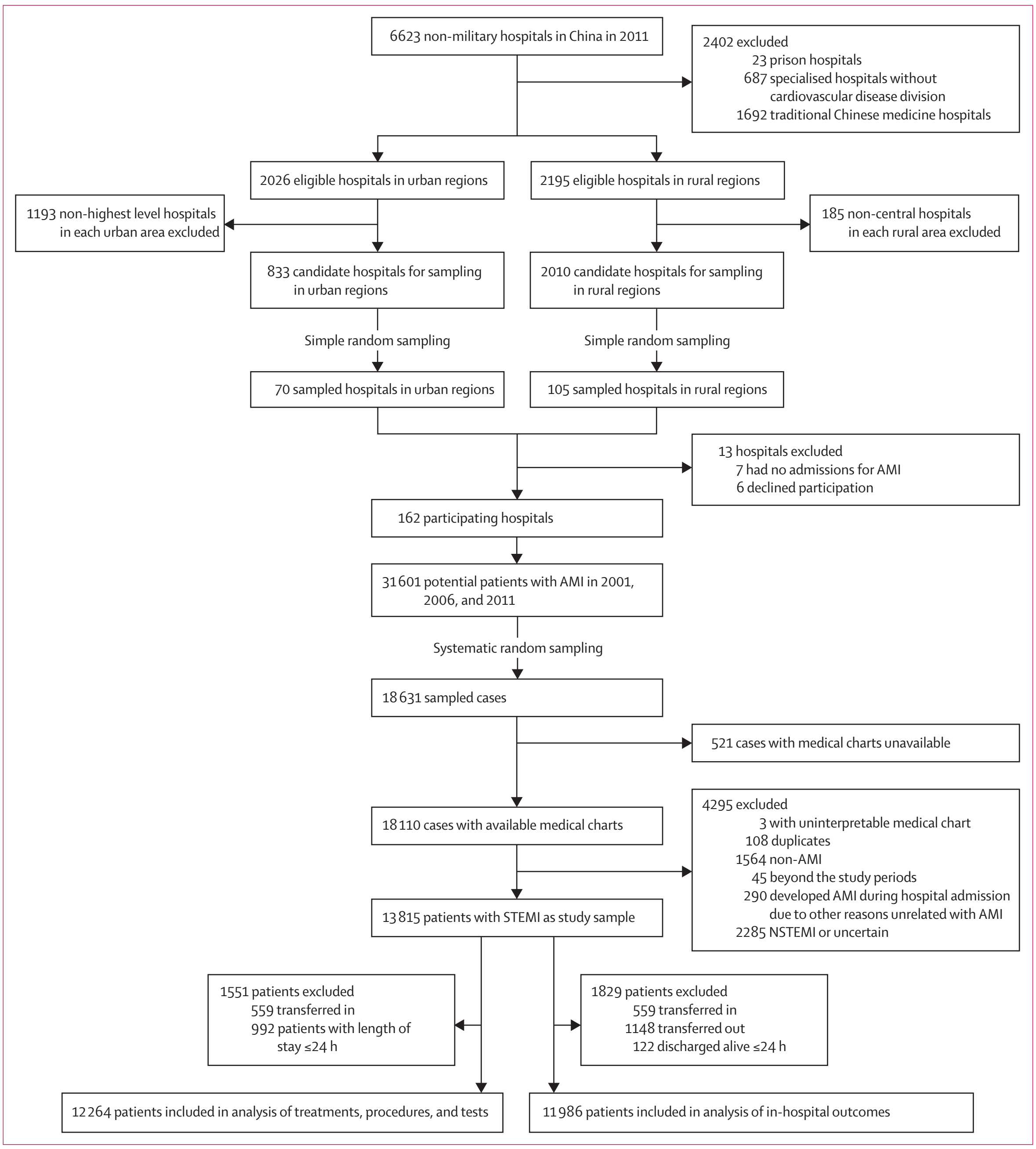

Figure 1: **Study profile**
AMI=acute myocardial infarction. STEMI=ST-segment elevation myocardial infarction. NSTEMI=non-ST-segment elevation myocardial infarction.

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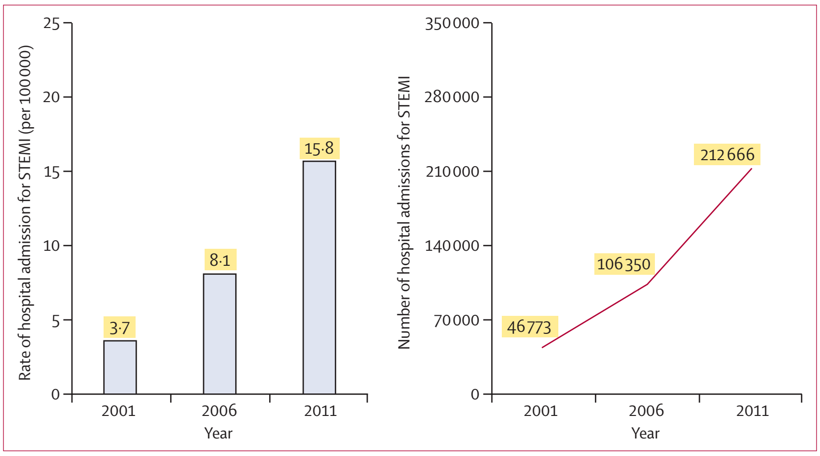

Figure 2: **Hospital admissions for STEMI in China**
STEMI=ST-segment elevation myocardial infarction.

haemoglobin decrease of at least 50 g/L, bleeding resulting in hypovolaemic shock, or fatal bleeding (bleeding that resulted directly in death within 7 days). For the main analysis of in-hospital outcomes, we excluded patients who were transferred in from another hospital because we sought to characterise patients admitted directly to the hospital. We also excluded patients who were transferred out, because their admissions were truncated. We further excluded patients who were discharged alive within 24 h because they probably left against medical advice and there was very little time for treatment. For the analysis of treatments, procedures, and tests, we excluded patients who had transferred in from other hospitals, or who had a length of stay of 24 h or shorter.

Statistical analysis

To estimate nationally representative rates for each study year, we applied weights proportional to the inverse sampling fraction of hospitals within each stratum and the sampling fraction of patients within each hospital to account for differences in the sampling fraction for each period in all analyses. We examined patient characteristics, treatments, tests, procedures, and crude rate of outcomes across different study years using the Cochran-Armitage trend test for the trend of binary variables, and the Mann-Kendall trend test for trends of continuous variables. All trend tests were based on three timepoints (2001, 2006, and 2011). We used percentages with 95% CIs to describe categorical variables and medians with IQRs to describe continuous variables. We calculated the rate of hospital admissions due to STEMI in China in each study year by estimating the number of patients admitted to hospital for STEMI and dividing by the total population in the corresponding year; 1·23 billion people lived in China in 2001, 1·29 billion in 2006, and 1·34 billion in 2011.[8–10] We imputed missing age values as the median age of the known set.

We constructed two indicator variables representing years 2006 and 2011, leaving 2001 as the reference. We did logistical regressions including these indicators for time as key explanatory variables, while adjusting for patients' demographics (age and sex), risk factors or medical history (hypertension, diabetes, current smoker, previous myocardial infarction, previous coronary heart disease, and previous stroke), and clinical characteristics at admission (chest discomfort, cardiac arrest, acute stroke, heart rate, systolic blood pressure, and symptom onset to admission time). To account for clustering of patients within hospitals, we established multilevel logistical regression models with use of generalised estimating equations. The dependent variables were in-hospital death, in-hospital death or treatment withdrawal, and in-hospital composite complications, respectively. We transformed continuous variables (eg, age, heart rate, and systolic blood pressure) into categorical variables according to clinically meaningful cutoff values (appendix). We also tested the linear trend over time in the models. We report odds ratios (ORs) and 95% CIs from the multilevel logistical regression related to the year indicators.

We did a sensitivity analysis with adjustment according to mini-GRACE risk score. To account for patients without a mini-GRACE risk score because of missing measurement of cardiac enzymes, we used two methods. The first method was to exclude these patients. Our other technique was to use the multiple imputation method to impute the variable (yes or no) for missing elevated cardiac enzymes so that the mini-GRACE risk score could be calculated.[20,21] We also did a sensitivity analysis in the entire study sample. In view of the small decrease in length of hospital stay over time, we compared the results with the results with 7-day outcomes instead of the original outcomes.

All comparisons were two-sided, with statistical significance defined as p less than 0·05. All p values are for trend. Statistical analysis was done with SAS software, version 9.2, and R software, version 3.0.2. The study is registered with ClinicalTrials.gov, number NCT01624883.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author has full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

According to government documents, China had 6623 non-military hospitals in 2011 (figure 1). We excluded 23 prison hospitals, 687 specialised hospitals without divisions for cardiovascular disease, and 1692 hospitals for traditional Chinese medicine. The sampling framework comprised 2010 central hospitals in 2010 rural regions in three rural strata, and 833 highest-level hospitals in 287 urban regions in two urban strata.

Retracted paper, errors highlighted

	2001 (n=2127)	2006 (n=3992)	2011 (n=7696)	p_{trend}
Demographic				
Age (years)	65 (55–72)	66 (56–74)	65 (55–74)	0·10
Women	614 (28·8% [26·7–30·9])	1137 (28·6% [27·2–30·0])	2247 (29·6% [28·6–30·6])	0·33
Cardiovascular risk factors				
Hypertension	866 (41·1% [38·8–43·4])	1894 (49·1% [47·5–50·6])	3890 (51·6% [50·5–52·7])	<0·0001
Diabetes	296 (13·5% [11·9–15·1])	747 (20·0% [18·8–21·3])	1558 (21·2% [20·3–22·1])	<0·0001
Dyslipidaemia	908 (41·5% [39·2–43·8])	2101 (53·5% [52·0–55·1])	4843 (64·2% [63·1–65·2])	<0·0001
Current smoker	629 (30·3% [28·2–32·5])	1306 (34·9% [33·4–36·3])	2854 (39·2% [38·1–40·2])	<0·0001
Number of risk factors				
≥3	214 (9·9% [8·5–11·3])	658 (18·5% [17·3–19·7])	1612 (22·7% [21·8–23·6])	<0·0001
2	609 (28·8% [26·7–30·9])	1308 (33·2% [31·8–34·7])	2878 (38·1% [37·0–39·2])	<0·0001
1	822 (38·5% [36·2–40·8])	1390 (33·6% [32·2–35·1])	2357 (29·1% [28·1–30·1])	<0·0001
None	482 (22·8% [20·9–24·8])	636 (14·7% [13·6–15·8])	849 (10·1% [9·4–10·7])	<0·0001
Medical history				
Myocardial infarction	218 (10·0% [8·6–11·4])	374 (10·2% [9·3–11·1])	814 (11·1% [10·5–11·8])	0·08
Coronary heart disease	503 (23·2% [21·2–25·2])	790 (20·7% [19·4–21·9])	1568 (20·8% [19·9–21·7])	0·08
Percutaneous coronary intervention	14 (0·8% [0·4–1·2])	40 (1·2% [0·8–1·5])	180 (2·7% [2·3–3·0])	<0·0001
Coronary artery bypass graft	10 (0·6% [0·3–1·0])	9 (0·3% [0·1–0·5])	21 (0·3% [0·1–0·4])	0·022
Stroke	198 (9·8% [8·4–11·2])	421 (11·2% [10·2–12·2])	897 (12·1% [11·4–12·8])	0·004
Clinical characteristic				
Symptom onset to admission (h)	14 (3–72)	15 (3–72)	13 (4–72)	0·29
Chest discomfort	1970 (92·9% [91·7–94·1])	3680 (92·6% [91·8–93·4])	7118 (93·0% [92·4–93·5])	0·69
Left bundle branch block	31 (1·6% [1·0–2·2])	74 (1·7% [1·3–2·1])	97 (1·1% [0·9–1·4])	0·018
Cardiac arrest	21 (1·0% [0·5–1·4])	49 (1·4% [1·1–1·8])	125 (1·7% [1·4–2·0])	0·025
Cardiogenic shock	94 (4·7% [3·7–5·7])	245 (5·8% [5·0–6·5])	508 (6·3% [5·8–6·9])	0·009
Acute stroke	18 (0·8% [0·4–1·2])	69 (1·7% [1·3–2·2])	83 (0·9% [0·7–1·1])	0·20
Heart rate (beats per min)				
<50	109 (5·0% [4·0–6·0])	221 (5·2% [4·5–5·9])	384 (4·9% [4·4–5·3])	0·56
50–110	1888 (88·7% [87·2–90·2])	3494 (87·9% [86·8–88·9])	6917 (90·2% [89·5–90·8])	0·002
>110	130 (6·3% [5·1–7·4])	277 (6·9% [6·1–7·7])	395 (4·9% [4·5–5·4])	0·0003
Heart rate (beats per min)	78 (68–90)	78 (66–90)	76 (65–89)	<0·0001
Systolic blood pressure (mm Hg)				
<90	154 (7·4% [6·2–8·6])	264 (6·1% [5·4–6·8])	408 (5·0% [4·5–5·5])	<0·0001
90–139	1281 (59·6% [57·3–61·9])	2399 (60·6% [59·1–62·1])	4658 (60·5% [59·4–61·5])	0·63
≥140	692 (33·0% [30·8–35·2])	1329 (33·3% [31·8–34·7])	2630 (34·5% [33·5–35·6])	0·11
Systolic blood pressure (mm Hg)	125 (107–145)	125 (110–143)	128 (110–145)	<0·0001
Estimated glomerular filtration rate (mL/min per 1·73 m²)*				
<30	67 (5·3% [4·0–6·7])	140 (4·3% [3·6–5·0])	232 (3·2% [2·8–3·6])	0·0001
30–59	317 (24·7% [22·1–27·3])	756 (22·2% [20·8–23·6])	1263 (16·7% [15·9–17·6])	<0·0001
≥60	910 (70·0% [67·2–72·7])	2300 (73·5% [72·0–75·0])	5583 (80·0% [79·1–80·9])	<0·0001
Estimated glomerular filtration rate (mL/min per 1·73 m²)*	72 (56–91)	75 (58–96)	86 (66–107)	<0·0001
Troponin concentration (multiple of upper limit of normal)*	18 (2–89)	24 (6–108)	31 (6–202)	<0·0001
Haematocrit (proportion of 1·0)*	0·39 (0·35–0·43)	0·39 (0·36–0·43)	0·40 (0·36–0·44)	<0·0001
Ejection fraction ≤0·40*	72 (17·4% [13·5–21·3])	284 (17·9% [16·1–19·8])	568 (12·7% [11·8–13·6])	<0·0001
Mini-GRACE risk score*	139 (120–158)	142 (123–160)	140 (120–160)	0·50
Transfer status				
Transferred in	37 (1·7% [1·1–2·4])	103 (3·0% [2·5–3·6])	419 (7·0% [6·4–7·5])	<0·0001
Transferred out	142 (6·4% [5·3–7·5])	270 (6·8% [6·0–7·6])	736 (8·1% [7·5–8·7])	0·002

GRACE=Global Registry of Acute Coronary Events. Data are median (IQR) or n (weighted % [95% CI]), for which n is the number of patients in the study sample and weighted % is a nationally representative rate. STEMI=ST-segment elevation myocardial infarction. *Among patients with measurements available.

Table 1: **Characteristics of patients with STEMI in 2001, 2006, and 2011**

Retracted paper, errors highlighted

We sampled 175 hospitals and invited them to participate in the study. Seven hospitals (two rural and five urban) were excluded because they did not admit patients with acute myocardial infarction and six (four rural, two urban) declined to participate. Examination of patient databases from the 162 remaining hospitals yielded 31 601 hospital admissions for acute myocardial infarction (3859 in 2001, 8863 in 2006, and 18 879 in 2011). We sampled 18 631 cases and acquired medical records for 18 110 (97·2%) cases (figure 1). We excluded 4295 cases that did not meet the study criteria to create the study sample of 13 815 patients admitted to hospital for STEMI.

2127 patients were sampled in 2001, 3992 in 2006, and 7696 in 2011. On the basis of these data, we estimate the number of patients admitted to hospital for STEMI in China nationwide to be 46 773 in 2001, 106 350 in 2006, and 212 666 in 2011. Hospital admissions for STEMI per 100 000 people increased during the study period from 3·7 in 2001 to 8·1 in 2006 and 15·8 in 2011 (p_{trend}<0·0001; figure 2).

Between 2001 and 2011, the age and sex of patients admitted to hospital for STEMI did not change (table 1). Information about age was missing for 18 (0·1%) patients. In 2011, the median age was 65 years (IQR 55–74), and 2247 of 7696 patients (weighted rate 29·6%, 95% CI 28·6–30·6) were women. Risk factors for cardiovascular disease and previous atherosclerotic events increased in prevalence over time (table 1).

The median time between symptom onset and hospital admission did not change between 2001 and 2011 (table 1). Between 2001 and 2011, patients became less likely to present with hypotension, tachycardia, ejection fraction of 0·40 or less, or low estimated glomerular filtration rate (table 1). The prevalence of cardiac arrest and cardiogenic shock increased slightly. The median troponin concentration increased over time. Mini-GRACE scores did not differ across the study period.

After exclusion of 559 patients transferred in from other facilities (37 in 2001, 103 in 2006, and 419 in 2011) and 992 patients whose length of stay was 24 h or shorter

	2001 (n=1995)		2006 (n=3626)		2011 (n=6643)		p_{trend}
	Relative frequency	Weighted %	Relative frequency	Weighted %	Relative frequency	Weighted %	
Reperfusion therapies*							
No reperfusion	425/917	44·8% (41·3–48·3)	786/1689	46·1% (43·7–48·5)	1509/3278	45·0% (43·3–46·7)	0·82
Primary PCI	74/917	10·2% (8·1–12·3)	218/1689	17·0% (15·2–18·8)	691/3278	27·6% (26·1–29·1)	<0·0001
Fibrinolytic therapy	418/917	45·0% (41·5–48·5)	685/1689	36·8% (34·5–39·1)	1078/3278	27·4% (25·9–28·9)	<0·0001
Acute drugs							
Aspirin within 24 h*	1559/1953	79·3% (77·3–81·3)	3089/3545	87·0% (85·9–88·1)	5904/6490	91·2% (90·5–91·8)	<0·0001
Clopidogrel within 24 h*	24/1832	1·5% (0·9–2·1)	1490/3551	46·3% (44·7–47·9)	5069/6498	80·7% (79·8–81·2)	<0·0001
β blockers within 24 h*	422/840	52·3% (48·6–56·0)	1037/1624	64·0% (61·7–66·3)	1846/3106	57·7% (56·0–59·4)	0·74
Statins*†	573/1995	29·7% (27·5–31·9)	2675/3626	75·2% (73·8–76·6)	6045/6642	92·0% (91·4–92·7)	<0·0001
ACE inhibitors or angiotensin receptor blockers*†	1177/1932	61·8% (59·4–64·2)	2429/3513	70·6% (69·1–72·1)	4224/6440	66·2% (65·1–67·3)	0·45
Traditional Chinese medicine within 24 h	903/1995	44·1% (41·7–46·5)	2003/3626	50·5% (48·9–52·1)	4200/6643	58·2% (57·1–59·4)	<0·0001
Traditional Chinese medicine†	1181/1995	57·4% (55·0–59·8)	2420/3626	62·6% (61·0–64·2)	4827/6643	69·2% (68·1–70·3)	<0·0001
Magnesium sulfate†	656/1995	32·3% (30·1–34·5)	719/3626	19·3% (18·0–20·6)	1159/6643	16·4% (15·5–17·2)	<0·0001
Procedures†							
Cardiac catheterisation	209/1995	12·3% (10·8–13·9)	736/3626	25·2% (23·8–26·6)	2204/6643	40·9% (39·8–42·1)	<0·0001
PCI (non-primary)	60/1995	3·3% (2·4–4·2)	368/3626	12·0% (10·9–13·1)	1077/6643	19·9% (18·9–20·8)	<0·0001
Coronary artery bypass graft	14/1995	1·0% (0·5–1·5)	21/3626	0·9% (0·6–1·2)	30/6643	0·6% (0·4–0·8)	0·022
Intra-aortic balloon pump	8/1995	0·5% (0·2–0·8)	32/3626	1·0% (0·7–1·3)	137/6643	2·4% (2·0–2·8)	<0·0001
Stents†‡							
Drug-eluting stents only	37/89	39·7% (28·3–51·1)	354/442	80·8% (77·1–84·5)	1306/1329	98·6% (98·0–99·3)	<0·0001
Bare-metal stents only	44/89	50·0% (38·3–61·7)	71/442	15·4% (12·0–18·8)	23/1329	1·4% (0·8–2·0)	<0·0001
Both	8/89	10·3% (3·2–17·4)	17/442	3·8% (2·0–5·6)	0/1329	0	<0·0001
Tests†							
Troponin	385/1995	21·4% (19·4–23·4)	1560/3626	45·5% (43·9–47·1)	4195/6643	66·4% (65·3–67·5)	<0·0001
Cardiac enzymes	1732/1995	85·4% (83·7–87·1)	3344/3626	92·9% (92·1–93·7)	6443/6643	97·0% (96·6–97·4)	<0·0001
Creatinine	1241/1995	61·0% (58·7–63·3)	2981/3626	83·5% (82·3–84·7)	6253/6643	94·8% (94·3–95·3)	<0·0001
Echocardiogram	572/1995	29·1% (26·9–31·3)	1581/3626	46·4% (44·8–48)	4191/6643	67·1% (66·0–68·2)	<0·0001

PCI=percutaneous coronary intervention. ACE=angiotensin-converting enzyme. STEMI=ST-segment elevation myocardial infarction. Data are n/N or weighted % (95% CI), for which n is the number of patients in the study sample and weighted % is a nationally representative rate, unless otherwise stated. *Only among ideal patients for the treatment (ie, patients with no documented contraindications). †During hospital admission. ‡Among patients who received at least one stent.

Table 2: **Use of treatments, procedures, and tests among patients with STEMI**

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(95 in 2001, 263 in 2006, and 634 in 2011), 12 264 patients were included in analysis of trends in treatments, procedures, and tests (table 2, figure 1). The proportion of patients classified as ideal candidates did not change substantially over time for all recommended treatments (appendix).

Among ideal candidates for reperfusion therapy, the weighted rate of primary percutaneous coronary intervention increased between 2001 and 2011 (from 10·2% to 27·6%, p_{trend}<0·0001; table 2). Meanwhile, the use of fibrinolytic therapy concurrently decreased, from 45·0% to 27·4% (p_{trend}<0·0001). Overall, use of reperfusion therapy, β blockers, angiotensin-converting-enzyme inhibitors, or angiotensin receptor blockers did not change between 2001 and 2011 (table 2). From 2001 to 2011, the treatment rate for all other recommended therapies increased among ideal patients (table 2). Use of magnesium sulfate decreased (table 2). By contrast, the use of traditional Chinese medicine within 24 h and at any time during hospital admission increased (table 2).

The weighted proportion of patients that underwent cardiac catheterisation, underwent non-primary percutaneous coronary intervention, or received drug-eluting stents also increased between 2001 and 2011 (table 2). The proportion of patients that underwent coronary artery bypass graft surgery was very small (14 of 1995 patients in 2001 *vs* 30 of 6643 patients in 2011). Substantial increases occurred in the use of diagnostic tests, such as troponin measurement and echocardiography.

After exclusion of 559 patients transferred in from other facilities, 1148 patients transferred out to other facilities (142 in 2011, 270 in 2006, and 736 in 2011), and 122 patients discharged alive within 24 h (15 in 2001, 38 in 2006, and 69 in 2011), 11 986 patients were included in the analysis of trends in length of hospital stay and in-hospital outcomes (figure 1). The median hospital length of stay was 13 days (IQR 7–18) in 2001, 11 days (6–16) in 2006, and 11 days (7–14) in 2011 (p_{trend}<0·0001). 165 of 1933 patients died in hospital in 2001 (unadjusted weighted mortality rate 8·4%, 95% CI 7·1–9·8), 351 of 3581 died in 2006 (9·4%, 8·5–10·4), and 496 of 6472 died in 2011 (7·0%, 6·4–7·6). After adjustment for patient demographic and clinical characteristics in the multilevel logistical regression, the risk of in-hospital mortality did not significantly decrease over time (figure 3). Similarly, the adjusted risk of death or treatment withdrawal and complications did not change over time (figure 3). Adjusted outcomes calculated with a 7-day timeframe were much the same as the primary analyses using the entire hospital stay (figure 4). A sensitivity analysis compared the results of the entire cohort with those of the population excluding transferred patient. The results of these two analyses did not differ (appendix).

1038 (7·5%) of 13 815 patients (308 in 2001, 373 in 2006, and 357 in 2011) with missing data for cardiac enzymes were excluded from mini-GRACE risk score calculations. The risk of in-hospital death or treatment withdrawal, adjusted by mini-GRACE risk score, was 1·17 (95% CI 0·92–1·47) in 2006 and 0·95 (0·74–1·21) in 2011 (appendix). The risk of in-hospital mortality adjusted for mini-GRACE risk score was 1·06 (95% CI 0·80–1·40) in 2006 and 0·76 (0·56–1·01) in 2011. The results of these analyses were much the same as those of imputation for missing data and use of a 7-day timeframe (appendix). Six of 1933 patients in 2001 (weighted rate 0·3%, 95% CI 0·1–0·6), 34 of 3581 patients in 2006 (1·1%, 0·8–1·4), and 62 of 6472 patients in 2011 (0·9%, 0·7–1·1) had major bleeding (p_{trend}=0·16). Only four fatal bleeding events occurred, three in 2006 and one in 2011.

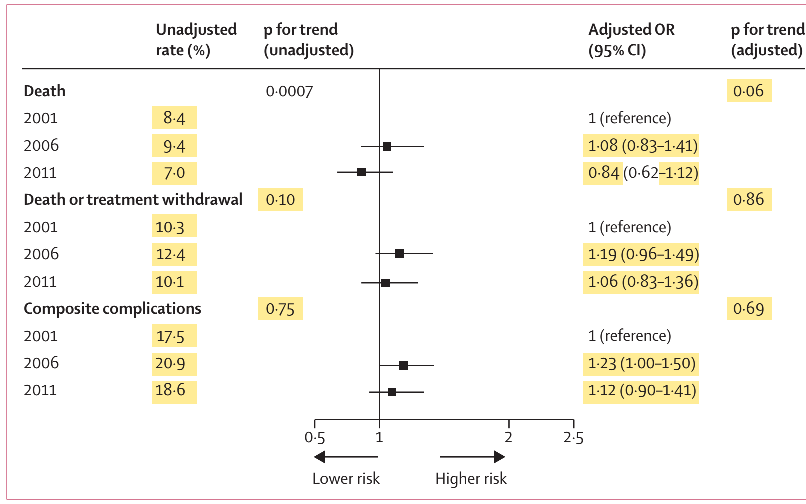

Figure 3: **Adjusted in-hospital outcomes for patients with STEMI**
Adjusted odds ratio of 1 shows no difference from year 2001. We included 11 986 patients (1933 in 2001, 3581 in 2006, and 6472 in 2011); 559 patients transferred in from other facilities, 1148 patients transferred out, and 122 patients discharged alive within 24 h were excluded. *C*=0·76 for mortality, *C*=0·78 for death or treatment withdrawal, and *C*=0·68 for composite complications. STEMI=ST-segment elevation myocardial infarction.

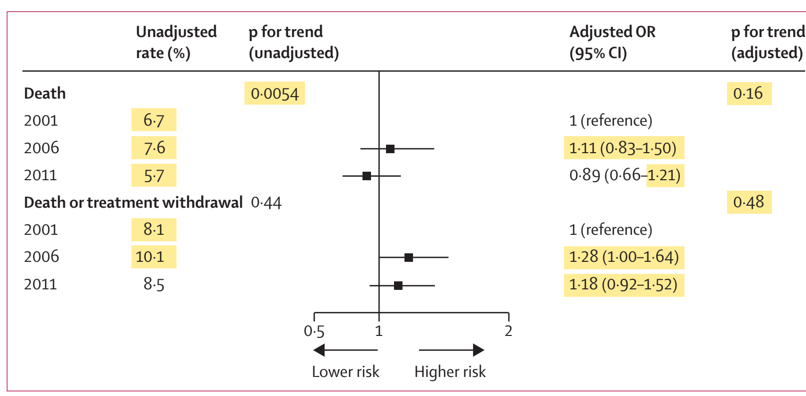

Figure 4: **Adjusted 7-day outcomes among patients with STEMI**
Adjusted odds ratio of 1 shows no difference from year 2001. We included 12 421 patients (2010 in 2001, 3696 in 2006, and 6715 in 2011); 559 patients transferred in from other facilities, 713 patients transferred out within 7 days, and 122 patients discharged alive within 24 h were excluded. *C*=0·76 for mortality and *C*=0·79 for death or treatment withdrawal. STEMI=ST-segment elevation myocardial infarction.

Discussion

In the China PEACE-Retrospective AMI Study we aimed to document changes in the clinical profiles, treatment

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Panel: Research in context

Systematic review

We searched PubMed for articles published in English and Chinese between Jan 1, 2000, and March 12, 2014, with the terms "ST-segment elevation myocardial infarction", "acute myocardial infarction", "acute coronary syndrome", and "China". We identified three large nationwide studies, one a clinical trial undertaken in 1999–2005,[6] and the other two observational studies. Both observational studies used a convenience sample of hospitals. One studied 2973 patients with acute coronary syndrome from 51 hospitals between 2004 and 2005.[7] The other study included 3323 patients with acute coronary syndrome from 65 hospitals in 2006.[22]

Interpretation

To our knowledge, this study, which included 13815 patients from 162 randomly selected hospitals across China, is the first nationally representative investigation of ST-segment elevation myocardial infarction (STEMI). We studied the trends in admissions, the clinical profiles, quality of care, and outcomes of STEMI between 2001 and 2011, a period of epidemiological transition. We noted that hospital admissions for STEMI have become increasingly common, patients are more likely to have comorbidities, and the intensity of testing and treatment has increased. Quality of care has improved for some treatments, but important gaps persist and in-hospital mortality has not significantly improved. Policy makers and health professionals in China have opportunities to improve quality care and outcomes for patients with STEMI and to work to slow the rise in these events.

patterns, quality of care, and in-hospital mortality of patients admitted to hospital for STEMI in China during the past decade. This study, funded by the Chinese Government, was designed to generate the knowledge to support future national initiatives to improve STEMI care and patient outcomes in China.

Our study of a nationally representative sample of patients between 2001 and 2011 characterises the trends in the epidemiology, treatment, and outcomes of patients with STEMI. We identified substantial increases in the estimated national rate of hospital admission for STEMI. Furthermore, we identified a growing burden of prevalent coronary risk factors, persistent delays in admission to hospital, increasing use of procedures and tests, relatively long hospital stays, and gaps in quality of care with the underuse of guideline-recommended therapies and the use of therapies of unknown effectiveness. Concurrent with these trends, outcomes have not improved. To our knowledge, the China PEACE-Retrospective AMI Study is the first large study with rigorous random sampling of a hospital cohort to study national trends in STEMI in China (panel), and identifies important opportunities for quality improvement and policy making.[11]

Because of the random sampling strategy used to identify hospitals and patients in our study, we believe that the results represent practice in China in general—a large country with great variations across regions and hospitals.[23] The experience in China, with the growth in admissions for STEMI, the gaps in treatment, and the growing complexity of patients is similar to previous experience in the USA. This study, like the Cooperative Cardiovascular Project (CCP)[24] undertaken 20 years ago in the USA, provides important information about opportunities for improvement. Since the CCP, the USA has invested substantially in quality improvement for cardiovascular disease and has had marked improvements in admission rates, and process of care and outcomes for acute myocardial infarction.[25–28]

The economic transition in China is resulting in more non-communicable diseases such as STEMI, which has substantial implications for the strategies needed to develop the health-care system. The growing needs for inpatient STEMI care will create pressure for Chinese hospitals to increase capacity, adequately train health-care professionals, develop infrastructure, and improve care. The striking increases in hospital admissions for STEMI noted in our study show that important improvements in capacity have been made; however, national STEMI mortality[5] suggests that further growth will be necessary to ensure adequate access for patients with the disorder in China. Furthermore, our study underlines that access to care does not ensure the delivery of the highest-quality care; suggesting that in addition to improvements in capacity, hospitals in China must simultaneously strive to improve care.

The quality of care has improved during the past decade, but substantial gaps still persist. Increases in the use of aspirin, clopidogrel, and statins are encouraging. However, β blockers and angiotensin-converting-enzyme inhibitors, which reduce mortality in patients with STEMI, remain very underused. Only half of ideal candidates for reperfusion therapy received treatment, a proportion that did not improve over time. This finding suggests that obstacles persist—eg, difficulty in identification of ideal patients, balancing of the risks and benefits of treatment, and the growing proportion of comorbidities—that render treatment more challenging. Gaps in care might also result from inadequate provider knowledge, structural inadequacies of the systems of care, or concern about potential patient disputes and litigation due to risk of treatment.[29–31] Our findings underscore the need for national initiatives to understand the reasons for persistent gaps in care and improve the use of evidence-based care for STEMI in China.[32,33]

Importantly, our results raise a particular concern that the increased intensity of treatment, procedure use, and testing has not been associated with major decrements in mortality between 2001 and 2011. Moreover, this change occurred in the context of a decrease in length of stay over time. The reported in-hospital mortality in our representative study is consistent with a large trial of 46 000 Chinese patients, but is higher than that reported in two prospective studies with non-randomly selected patients admitted to hospital between 2004 and 2006.[6,7,22] By contrast with the improvement achieved in a similar period in the USA and the UK, the lack of change in mortality in China suggests an opportunity for quality

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improvement.[27,34] If the in-hospital mortality of STEMI could be reduced by 1% in China, at least 2100 lives could be saved every year. The number of lives saved would rise rapidly if the number of STEMI increases, as is anticipated. Our data do not show significant improvement in mortality between 2001 and 2011, but we cannot exclude a meaningful effect in view of the point estimates and confidence intervals. Comparison of mini-GRACE-adjusted mortality rates between 2001 and 2011 suggested a borderline-significant reduction in in-hospital mortality, but when treatment withdrawal was included the results were not significant and the point estimate did not suggest a benefit. In China, many patients withdraw from treatment at terminal status, which could be attributed to culture or affordability. Therefore, a focus on in-hospital mortality alone, without accounting for these patients, could result in an underestimate of actual short-term mortality rates. Nevertheless, we cannot exclude the possibility that a modest benefit occurred based on the confidence intervals.

Several factors could account for why mortality did not improve significantly. First, we noted little improvement in the time from symptom onset to hospital admission, which is much longer than that reported in other national databases.[35,36] Second, rates of reperfusion therapies, which were much lower than are those in the USA or Europe, did not improve.[28,37] Third, the rate of primary percutaneous coronary intervention was still low in 2011 despite an increase during the past decade.[28,37] This rate, in particular, might be able to be increased in some settings but not others. Improvement of these three factors alone could substantially reduce mortality.[38] Fourth, we did detect increasing rates of cardiac arrest and cardiogenic shock, which is a concern, but they did not account for the lack of substantial improvement in mortality.

We also noted that several therapies that are known to be ineffective, or lack strong evidence, are often given in China. About a sixth of patients received magnesium sulfate, despite a large body of evidence that this therapy is either ineffective or could cause harm.[16,17] Traditional Chinese medicine is increasingly used, despite little evidence of its efficacy and safety for treatment of STEMI.[39] Further research is needed to elucidate the clinical benefit of traditional Chinese medicine for the management of STEMI.

The findings of this study should be interpreted in view of several limitations. First, the lack of regular biomarker measurement, particularly in 2001, precludes a gold-standard diagnosis of STEMI. Increasing use of biomarker-based diagnosis would likely increase the number of less severe cases in our cohort in 2006 and 2011.[13,40,41] This change would be expected to bias towards improvements in outcomes in 2006 and 2011, but we noted no difference. The early years of our cohort might have included more patients without STEMI, but we collected detailed information about clinical condition and no evidence suggested that the risk based on the initial vital signs and clinical condition changed importantly over time. Second, we measured clinical characteristics on the basis of documentation in medical records. Definitions of some disorders and completeness of documentation can differ across hospitals and over time. Third, we could only measure in-hospital outcomes, which might vary from those measured with use of a standardised timeframe (eg, 30 days),[42] because we were unable to link patient-level data to a national registry of deaths. Nevertheless, the long length of stay in China permits a fairly long observation period for patients admitted to hospital. Furthermore, analysis with a standardised 7-day timeframe did not provide different results from the primary analysis. Fourth, the use of laboratory tests, including measurement of cardiac biomarkers and creatinine, is inconsistent in China, which might have affected our findings. However, the risk factors that were available for all patients predicted mortality very well and were probably sufficient for comparisons over time.[12] Fifth, the study was not powered to detect trends in mortality and our study cannot exclude the possibility of a meaningful improvement in mortality during the study period. However, we detected no strong indication of improvement, especially when we took into account patients who had treatment withdrawn. Finally, we cannot comment on patients with STEMI who were not admitted to hospital during the study period, and we cannot establish whether the increase in the number of patients admitted to hospital with STEMI over time represented increased access to health care or an increasing prevalence of STEMI in the population (or both). Nevertheless, to our knowledge this study is the most comprehensive of patients admitted to hospital with STEMI during the past decade in China.

Our study showed that, among patients admitted to hospital with STEMI, persistent gaps are present between practice and recommended care and outcomes have not significantly improved during the past decade. Although China has launched health-care reform and recently doubled annual expenditures for health care to improve access, challenges exist in optimisation of the use of scarce resources to provide the highest-quality care. Our findings provide evidence for policy makers and health professionals in China and other countries with a rapidly growing burden of STEMI to inform future strategies for medical resource allocation, system improvement, and disease management.

Contributors

HMK and LJ conceived of the China PEACE-Retrospective AMI Study and take responsibility for all aspects of it. JL, XL, FAM, JAS, HMK, and LJ designed the study. JL, XL, FAM, HMK, and LJ conceived of this Article. JL wrote the first draft of the Article, with further contributions from XL, YW, FAM, JAS, HMK, and LJ. QW and SH did the statistical analysis, with support from XL and YW. All authors interpreted data and approved the final version of the article.

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Declaration of interests
We declare no competing interests.

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ST-segment elevation myocardial infarction in China from 2001 to 2011 (the China PEACE-Retrospective Acute Myocardial Infarction Study): a retrospective analysis of hospital data

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Summary

Background Despite the importance of ST-segment elevation myocardial infarction (STEMI) in China, no nationally representative studies have characterised the clinical profiles, management, and outcomes of this cardiac event during the past decade. We aimed to assess trends in characteristics, treatment, and outcomes for patients with STEMI in China between 2001 and 2011.

Methods In a retrospective analysis of hospital records, we used a two-stage random sampling design to create a nationally representative sample of patients in China admitted to hospital for STEMI in 3 years (2001, 2006, and 2011). In the first stage, we used a simple random-sampling procedure stratified by economic–geographical region to generate a list of participating hospitals. In the second stage we obtained case data for rates of STEMI, treatments, and baseline characteristics from patients attending each sampled hospital with a systematic sampling approach. We weighted our findings to estimate nationally representative rates and assess changes from 2001 to 2011. This study is registered with ClinicalTrials.gov, number NCT01624883.

Findings We sampled 175 hospitals (162 participated in the study) and 18 631 acute myocardial infarction admissions, of which 13 815 were STEMI admissions. 12 264 patients were included in analysis of treatments, procedures, and tests, and 11 986 were included in analysis of in-hospital outcomes. Between 2001 and 2011, estimated national rates of hospital admission for STEMI per 100 000 people increased (from 3·5 in 2001, to 7·9 in 2006, to 15·4 in 2011; $p_{trend}<0·0001$) and the prevalence of risk factors—including smoking, hypertension, diabetes, and dyslipidaemia—increased. We noted significant increases in use of aspirin within 24 h (79·7% [95% CI 77·9–81·5] in 2001 *vs* 91·2% [90·5–91·8] in 2011, $p_{trend}<0·0001$) and clopidogrel (1·5% [95% CI 1·0–2·1] in 2001 *vs* 82·1% [81·1–83·0] in 2011, $p_{trend}<0·0001$) in patients without documented contraindications. Despite an increase in the use of primary percutaneous coronary intervention (10·6% [95% CI 8·6–12·6] in 2001 *vs* 28·1% [26·6–29·7] in 2011, $p_{trend}<0·0001$), the proportion of patients who did not receive reperfusion did not significantly change (45·3% [95% CI 42·1–48·5] in 2001 *vs* 44·8% [43·1–46·5] in 2011, $p_{trend}=0·69$). The median length of hospital stay decreased from 12 days (IQR 7–18) in 2001 to 10 days (6–14) in 2011 ($p_{trend}<0·0001$). Adjusted in-hospital mortality did not significantly change between 2001 and 2011 (odds ratio 0·82, 95% CI 0·62–1·10, $p_{trend}=0·07$).

Interpretation During the past decade in China, hospital admissions for STEMI have risen; in these patients, comorbidities and the intensity of testing and treatment have increased. Quality of care has improved for some treatments, but important gaps persist and in-hospital mortality has not decreased. National efforts are needed to improve the care and outcomes for patients with STEMI in China.

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See **Comment** pages 400 and 402

A previous version of this Article has been retracted. For changes made see appendix 1.

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Introduction

As China has grown economically, it has experienced an epidemiological transition, with mortality due to ischaemic heart disease more than doubling during the past two decades to more than 1 million deaths per year.[1,2] This trend is expected to accelerate, with the World Bank estimating that the number of individuals with myocardial infarction in China will increase to 23 million by 2030.[3] Concurrent with this changing epidemiology, the Chinese medical care system has developed rapidly, implementing policies that have improved access by reducing financial barriers and increasing the numbers of hospitals and physicians.[4,5]

Despite the importance of acute myocardial infarction in China—particularly ST-segment elevation myocardial infarction (STEMI), which accounts for more than 80% of such events in the country[6,7]—no nationally representative studies have defined the clinical profiles, management, and outcomes of patients with this disorder during the past decade. The scarcity of contemporary national estimates and data for changes in burden of disease, quality of care (including use of recommended treatments and inappropriate use of non-evidence-based treatments), and treatment outcomes are important barriers to implementation of interventions to improve care and outcomes. In particular, little information is available about acute myocardial infarction in rural areas, where most of the Chinese population lives.[8–10]

In the China Patient-centered Evaluative Assessment of Cardiac Events Retrospective Study of Acute Myocardial Infarction (China PEACE-Retrospective AMI Study), we aimed to assess trends in STEMI management and outcomes in China during the past decade in a retrospective analysis of hospital records. We selected representative hospitals from 2011 to assess present practices and traced this cohort of hospitals backwards to 2006 and 2001 to describe temporal changes.

See Online for appendix

Methods

Study design

The design of the China PEACE-Retrospective AMI Study has been described previously.[11] Briefly, we used a two-stage random sampling design to create a nationally representative sample of patients in China admitted to hospital for acute myocardial infarction in 3 years (2001, 2006, and 2011). In the first stage, we assessed all non-military hospitals in China and excluded prison hospitals, specialised hospitals without a division for cardiovascular disease, and hospitals for traditional Chinese medicine. We stratified the remaining hospitals into five economic–geographical regions (eastern rural, central rural, western rural, eastern urban, and central-western urban). We used these groups because hospital volumes and clinical capacities differ between urban and rural areas and the three official economic–geographical regions (eastern, central, and western) of mainland China. We grouped the central and western urban regions together because incomes and health services capacity per person are much the same. We randomly sampled all highest-level hospitals in urban regions and all central hospitals in rural regions, and excluded hospitals that did not admit patients with acute myocardial infarction or that declined to participate, to give the sample of participating hospitals.

In the second stage, we used systematic random sampling procedures to select for patients with acute myocardial infarction from the local hospital database of each sampled hospital in each study year. Patients with acute myocardial infarction were identified according to International Classification of Diseases—Clinical Modification codes, including versions 9 (410.xx) and 10 (I21.xx) when available, or through principal diagnosis terms noted at discharge. We collected data by central abstraction of medical charts with use of standardised data definitions. We used rigorous monitoring at each stage to ensure data quality.[11] Data abstraction quality was monitored by random auditing of 5% of the medical records, with overall variable accuracy exceeding 98%.

Participants

Only patients with a definite discharge diagnosis of STEMI were included in the study sample. The diagnosis of STEMI was determined by the combination of clinical discharge diagnosis terms and electrocardiogram (ECG) results. If the local diagnosis was not definitive, cardiologists at the coordinating centre reviewed the medical record and ECG to establish diagnosis. We treated left bundle branch block as a STEMI equivalent. The type of acute myocardial infarction was validated by review of ECGs from randomly selected records by a cardiologist not involved in data abstraction (appendix 2). We excluded all patients whose STEMI occurred during the course of the hospital admission.

The central ethics committee at the China National Center for Cardiovascular Diseases approved the China PEACE-Retrospective AMI Study. All collaborating hospitals accepted the central ethics approval except for five hospitals, which obtained local approval by internal ethics committees.

Procedures

We abstracted data for the following patient characteristics: age, sex, cardiovascular risk factors, medical history, and clinical characteristics at admission. Information about the medical record abstraction has been described in detail previously.[11] Briefly, comorbidities (including hypertension, diabetes, and dyslipidaemia) were defined as documented history in the admission notes, discharge diagnosis, or positive laboratory test results (total cholesterol >5·18 mmol/L or LDL ≥3·37 mmol/L, or HDL <1·04 mmol/L in men or <1·30 mmol/L in women).

We assessed clinical severity at admission from information collected at admission about systolic blood pressure, heart rate, estimated glomerular filtration rate, cardiac arrest, and cardiogenic shock. We also used the mini-Global Registry of Acute Coronary Events (mini-GRACE) risk score—a modified version of the GRACE risk score including age, systolic blood pressure, ST-segment deviation, cardiac arrest at admission, elevated cardiac enzymes, and heart rate—which has been validated as a means of predicting 6-month mortality for STEMI.[12]

We assessed use of treatments recommended by the 2010 China National Guideline for STEMI,[13] which are consistent with those recommended by guidelines in the USA.[14] These treatments included reperfusion therapy, aspirin within 24 h of admission, clopidogrel within 24 h of admission, β blockers within 24 h of admission, angiotensin-converting-enzyme inhibitors or angiotensin receptor blockers during hospital admission, and statins during hospital admission. We assessed rates of use only in patients thought to be ideal for treatment, defined (consistent with previously studies) as patients without documented contraindications (appendix 2).[15] We also assessed the use of magnesium sulfate (a treatment that is ineffective),[16,17] traditional Chinese medicine, other

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procedures, and tests. We included the seven main categories of traditional Chinese medicine used for coronary heart disease (appendix 2). We did not include some care processes (eg, counselling for smoking cessation) because of inadequate documentation.

We compared patients' in-hospital outcomes with four measures: death, death or withdrawal from treatment because of terminal status at discharge (referred to as treatment withdrawal), composite complications (including death, treatment withdrawal, reinfarction, cardiogenic shock, ischaemic stroke, or congestive heart failure [defined in appendix 2]), and major bleeding. Treatment withdrawal is common in China because of reluctance by many patients to die in hospital. The Chinese Government uses in-hospital death or treatment withdrawal as a quality measure for hospitals.[18,19] Cardiologists in the coordinating study centre adjudicated the clinical status of patients who withdrew from treatment on the basis of medical records. Major bleeding included any intracranial bleeding, absolute

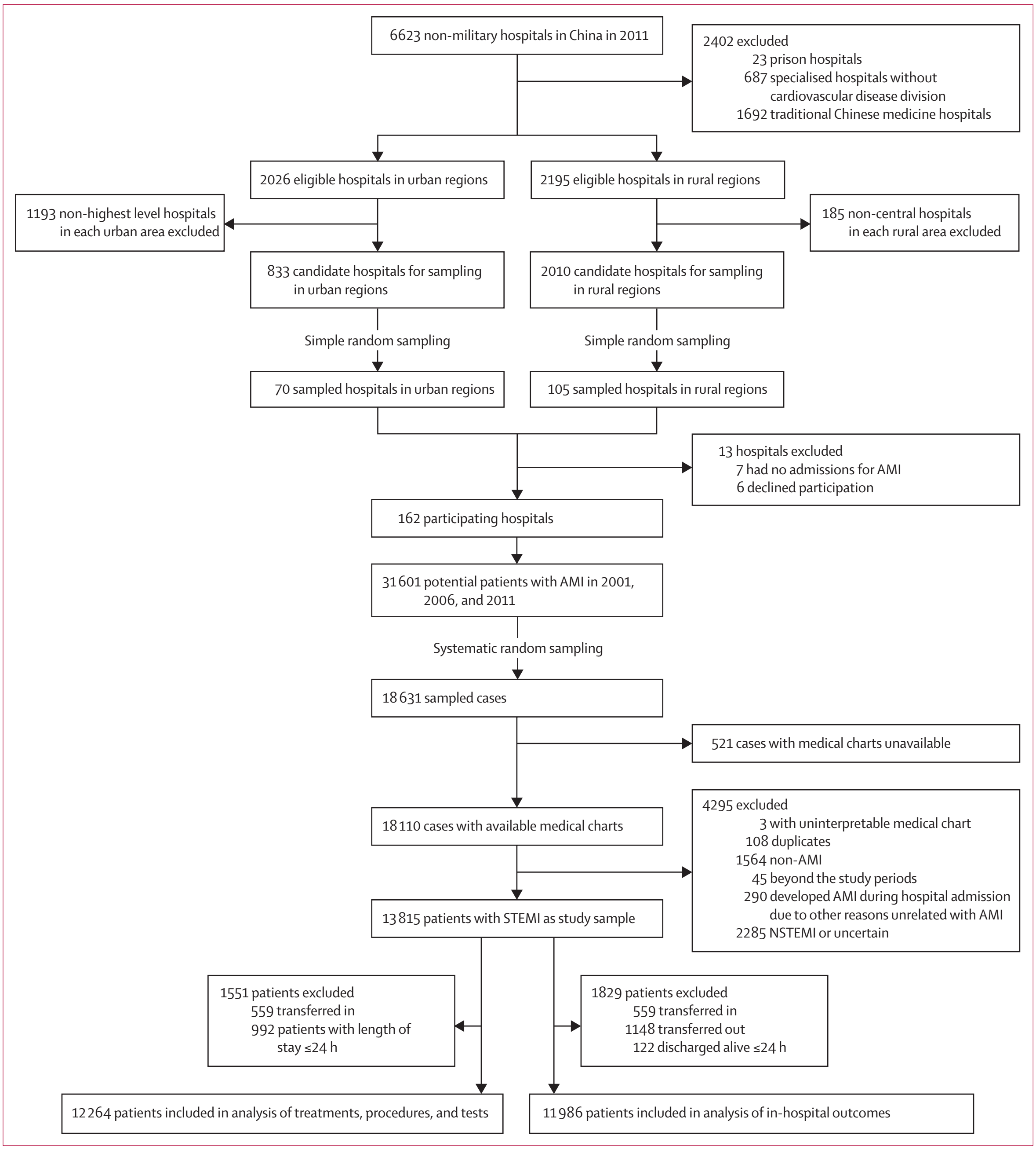

Figure 1: **Study profile**
AMI=acute myocardial infarction. STEMI=ST-segment elevation myocardial infarction. NSTEMI=non-ST-segment elevation myocardial infarction.

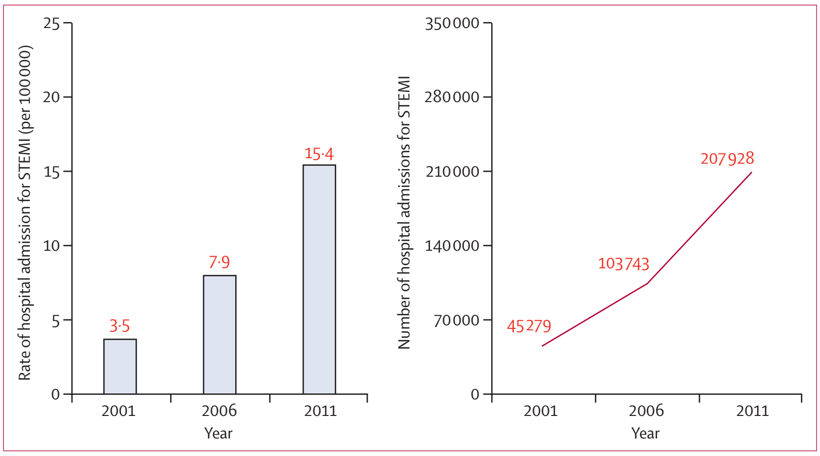

Figure 2: **Hospital admissions for STEMI in China**
STEMI=ST-segment elevation myocardial infarction.

haemoglobin decrease of at least 50 g/L, bleeding resulting in hypovolaemic shock, or fatal bleeding (bleeding that resulted directly in death within 7 days). For the main analysis of in-hospital outcomes, we excluded patients who were transferred in from another hospital because we sought to characterise patients admitted directly to the hospital. We also excluded patients who were transferred out, because their admissions were truncated. We further excluded patients who were discharged alive within 24 h because they probably left against medical advice and there was very little time for treatment. For the analysis of treatments, procedures, and tests, we excluded patients who had transferred in from other hospitals, or who had a length of stay of 24 h or shorter.

Statistical analysis

To estimate nationally representative rates for each study year, we applied weights proportional to the inverse sampling fraction of hospitals within each stratum and the sampling fraction of patients within each hospital to account for differences in the sampling fraction for each period in all analyses. We examined patient characteristics, treatments, tests, procedures, and crude rate of outcomes across different study years using the Cochran-Armitage trend test for the trend of binary variables, and the Mann-Kendall trend test for trends of continuous variables. All trend tests were based on three timepoints (2001, 2006, and 2011). We used percentages with 95% CIs to describe categorical variables and medians with IQRs to describe continuous variables. We calculated the rate of hospital admissions due to STEMI in China in each study year by estimating the number of patients admitted to hospital for STEMI and dividing by the total population in the corresponding year; 1·27 billion people lived in China in 2001, 1·31 billion in 2006, and 1·34 billion in 2011.[8–10] We imputed missing age values as the median age of the known set.

We constructed two indicator variables representing years 2006 and 2011, leaving 2001 as the reference. We did logistic regressions including these indicators for time as key explanatory variables, while adjusting for patients' demographics (age and sex), risk factors or medical history (hypertension, diabetes, current smoker, previous myocardial infarction, previous coronary heart disease, and previous stroke), and clinical characteristics at admission (chest discomfort, cardiac arrest, acute stroke, heart rate, systolic blood pressure, and symptom onset to admission time). To account for clustering of patients within hospitals, we established multilevel logistic regression models with use of generalised estimating equations. The dependent variables were in-hospital death, in-hospital death or treatment withdrawal, and in-hospital composite complications, respectively. We transformed continuous variables (eg, age, heart rate, and systolic blood pressure) into categorical variables according to clinically meaningful cutoff values (appendix 2). We also tested the linear trend over time in the models. We report odds ratios (ORs) and 95% CIs from the multilevel logistic regression related to the year indicators.

We did a sensitivity analysis with adjustment according to mini-GRACE risk score. To account for patients without a mini-GRACE risk score because of missing measurement of cardiac enzymes, we used two methods. The first method was to exclude these patients. Our other technique was to use the multiple imputation method to impute the variable (yes or no) for missing elevated cardiac enzymes so that the mini-GRACE risk score could be calculated.[20,21] We also did a sensitivity analysis in the entire study sample. In view of the small decrease in length of hospital stay over time, we compared the results with the results with 7-day outcomes instead of the original outcomes.

All comparisons were two-sided, with statistical significance defined as p less than 0·05. All p values are for trend. Statistical analysis was done with SAS software, version 9.2, and R software, version 3.0.2. The study is registered with ClinicalTrials.gov, number NCT01624883.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author has full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

According to government documents, China had 6623 non-military hospitals in 2011 (figure 1). We excluded 23 prison hospitals, 687 specialised hospitals without divisions for cardiovascular disease, and 1692 hospitals for traditional Chinese medicine. The sampling framework comprised 2010 central hospitals in 2010 rural regions in three rural strata, and 833 highest-level hospitals in 287 urban regions in two urban strata.

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	2001 (n=2127)	2006 (n=3992)	2011 (n=7696)	p_{trend}
Demographic				
Age (years)	65 (56–72)	66 (55–74)	65 (55–74)	0·14
Women	614 (28·9% [27·0–30·8])	1137 (28·7% [27·3–30·1])	2247 (29·5% [28·4–30·5])	0·47
Cardiovascular risk factors				
Hypertension	866 (41·5% [39·4–43·6])	1894 (49·3% [47·8–50·9])	3890 (51·7% [50·6–52·8])	<0·0001
Diabetes	296 (13·9% [12·4–15·4])	747 (20·2% [19·0–21·5])	1558 (21·2% [20·3–22·1])	<0·0001
Dyslipidaemia	908 (42·7% [40·6–44·8])	2101 (54·1% [52·6–55·7])	4843 (64·6% [63·5–65·6])	<0·0001
Current smoker	629 (30·4% [28·5–32·4])	1306 (35·1% [33·6–36·5])	2854 (39·5% [38·4–40·6])	<0·0001
Number of risk factors				
≥3	214 (10·4% [9·1–11·7])	658 (18·8% [17·5–20·0])	1612 (22·8% [21·9–23·8])	<0·0001
2	609 (29·1% [27·2–31·0])	1308 (33·5% [32·1–35·0])	2878 (38·3% [37·2–39·3])	<0·0001
1	822 (38·5% [36·4–40·5])	1390 (33·4% [31·9–34·8])	2357 (29·3% [28·3–30·3])	<0·0001
None	482 (22·1% [20·3–23·8])	636 (14·3% [13·3–15·4])	849 (9·7% [9·0–10·3])	<0·0001
Medical history				
Myocardial infarction	218 (10·3% [9·0–11·6])	374 (10·0% [9·1–11·0])	814 (11·2% [10·5–11·9])	0·10
Coronary heart disease	503 (23·7% [21·9–25·5])	790 (20·4% [19·2–21·7])	1568 (20·7% [19·8–21·6])	0·020
Percutaneous coronary intervention	14 (0·8% [0·4–1·2])	40 (1·2% [0·8–1·5])	180 (2·7% [2·3–3·0])	<0·0001
Coronary artery bypass graft	10 (0·6% [0·3–0·9])	9 (0·3% [0·2–0·5])	21 (0·2% [0·1–0·3])	0·012
Stroke	198 (9·5% [8·3–10·8])	421 (11·2% [10·2–12·2])	897 (12·1% [11·4–12·9])	0·0008
Clinical characteristic				
Symptom onset to admission (h)	15 (3–72)	15 (3–72)	13 (4–72)	0·22
Chest discomfort	1970 (93·1% [92·0–94·2])	3680 (92·7% [91·9–93·5])	7118 (93·0% [92·4–93·6])	0·95
Left bundle branch block	31 (1·5% [1·0–2·0])	74 (1·7% [1·3–2·1])	97 (1·1% [0·9–1·4])	0·043
Cardiac arrest	21 (0·9% [0·5–1·3])	49 (1·5% [1·1–1·9])	125 (1·7% [1·4–2·0])	0·0075
Cardiogenic shock	94 (4·6% [3·7–5·4])	245 (5·9% [5·2–6·6])	508 (6·2% [5·7–6·7])	0·0085
Acute stroke	18 (0·8% [0·4–1·2])	69 (1·7% [1·3–2·1])	83 (0·9% [0·7–1·1])	0·31
Heart rate (beats per min)				
<50	109 (5·2% [4·2–6·1])	221 (5·2% [4·5–5·9])	384 (4·9% [4·4–5·4])	0·53
50–110	1888 (88·7% [87·3–90·0])	3494 (87·9% [86·9–88·9])	6917 (90·2% [89·6–90·9])	0·0021
>110	130 (6·1% [5·1–7·2])	277 (6·9% [6·1–7·7])	395 (4·9% [4·4–5·4])	0·0004
Heart rate (beats per min)	78 (67–90)	78 (66–90)	76 (65–89)	<0·0001
Systolic blood pressure (mm Hg)				
<90	154 (7·1% [6·0–8·2])	264 (6·2% [5·4–6·9])	408 (4·7% [4·2–5·2])	<0·0001
90–139	1281 (60·0% [57·9–62·1])	2399 (60·5% [59·0–62·0])	4658 (60·8% [59·7–61·9])	0·47
≥140	692 (33·0% [31·0–34·9])	1329 (33·3% [31·8–34·8])	2630 (34·5% [33·4–35·5])	0·12
Systolic blood pressure (mm Hg)	125 (109–143)	125 (110–143)	128 (110–145)	<0·0001
Estimated glomerular filtration rate (mL/min per 1·73 m²)*				
<30	67 (5·3% [4·0–6·5])	140 (4·3% [3·6–5·0])	232 (3·2% [2·8–3·7])	<0·0001
30–59	317 (24·6% [22·2–26·9])	756 (22·1% [20·6–23·5])	1263 (16·8% [15·9–17·7])	<0·0001
≥60	910 (70·2% [67·7–72·7])	2300 (73·7% [72·1–75·2])	5583 (80·0% [79·0–80·9])	<0·0001
Estimated glomerular filtration rate (mL/min per 1·73 m²)*	72 (56–91)	75 (58–96)	86 (66–107)	<0·0001
Troponin concentration (multiple of upper limit of normal)*	18 (2–89)	24 (6–106)	32 (6–202)	<0·0001
Haematocrit (proportion of 1·0)*	0·39 (0·35–0·43)	0·39 (0·36–0·43)	0·40 (0·37–0·44)	<0·0001
Ejection fraction ≤0·40*	72 (17·6% [14·0–21·2])	284 (17·7% [15·7–19·6])	568 (12·6% [11·6–13·5])	<0·0001
Mini-GRACE risk score*	139 (120–158)	142 (123–160)	140 (120–160)	0·42
Transfer status				
Transferred in	37 (1·7% [1·1–2·2])	103 (3·1% [2·6–3·7])	419 (7·1% [6·5–7·7])	<0·0001
Transferred out	144 (6·7% [5·7–7·8])	275 (7·0% [6·2–7·8])	752 (8·3% [7·7–8·9])	0·0028

GRACE=Global Registry of Acute Coronary Events. Data are median (IQR) or n (weighted % [95% CI]), for which n is the number of patients in the study sample and weighted % is a nationally representative rate. STEMI=ST-segment elevation myocardial infarction. *Among patients with measurements available.

Table 1: **Characteristics of patients with STEMI in 2001, 2006, and 2011**

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We sampled 175 hospitals and invited them to participate in the study. Seven hospitals (two rural and five urban) were excluded because they did not admit patients with acute myocardial infarction and six (four rural, two urban) declined to participate. Examination of patient databases from the 162 remaining hospitals yielded 31 601 hospital admissions for acute myocardial infarction (3859 in 2001, 8863 in 2006, and 18 879 in 2011). We sampled 18 631 cases and acquired medical records for 18 110 (97·2%) cases (figure 1). We excluded 4295 cases that did not meet the study criteria to create the study sample of 13 815 patients admitted to hospital for STEMI.

2127 patients were sampled in 2001, 3992 in 2006, and 7696 in 2011. On the basis of these data, we estimate the number of patients admitted to hospital for STEMI in China nationwide to be 45 279 in 2001, 103 743 in 2006, and 207 928 in 2011. Hospital admissions for STEMI per 100 000 people increased during the study period from 3·5 in 2001 to 7·9 in 2006 and 15·4 in 2011 (p_{trend}<0·0001; figure 2).

Between 2001 and 2011, the age and sex of patients admitted to hospital for STEMI did not change (table 1). Information about age was missing for 18 (0·1%) patients. In 2011, the median age was 65 years (IQR 55–74), and 2247 of 7696 patients (weighted rate 29·5%, 95% CI 28·4–30·5) were women. Risk factors for cardiovascular disease and previous atherosclerotic events increased in prevalence over time (table 1).

The median time between symptom onset and hospital admission did not change between 2001 and 2011 (table 1). Between 2001 and 2011, patients became less likely to present with hypotension, tachycardia, ejection fraction of 0·40 or less, or low estimated glomerular filtration rate (table 1). The prevalence of cardiac arrest and cardiogenic shock increased slightly. The median troponin concentration increased over time. Mini-GRACE scores did not differ across the study period.

After exclusion of 559 patients transferred in from other facilities (37 in 2001, 103 in 2006, and 419 in 2011) and 992 patients whose length of stay was 24 h or shorter

	2001 (n=1995)		2006 (n=3626)		2011 (n=6643)		p_{trend}
	Relative frequency	Weighted %	Relative frequency	Weighted %	Relative frequency	Weighted %	
Reperfusion therapies*							
No reperfusion	425/917	45·3% (42·1–48·5)	786/1689	45·5% (43·1–47·9)	1509/3278	44·8% (43·1–46·5)	0·69
Primary PCI	74/917	10·6% (8·6–12·6)	218/1689	17·4% (15·6–19·2)	691/3278	28·1% (26·6–29·7)	<0·0001
Fibrinolytic therapy	418/917	44·1% (40·8–47·3)	685/1689	37·1% (34·8–39·4)	1078/3278	27·0% (25·5–28·6)	<0·0001
Acute drugs							
Aspirin within 24 h*	1559/1953	79·7% (77·9–81·5)	3089/3545	86·8% (85·7–87·9)	5904/6490	91·2% (90·5–91·8)	<0·0001
Clopidogrel within 24 h*	24/1832	1·5% (1·0–2·1)	1490/3551	47·4% (45·7–49·0)	5069/6498	82·1% (81·1–83·0)	<0·0001
β blockers within 24 h*	422/840	51·3% (47·9–54·7)	1037/1624	63·7% (61·4–66·0)	1846/3106	57·3% (55·6–59·0)	0·58
Statins*†	573/1995	30·2% (28·2–32·2)	2675/3626	75·9% (74·5–77·3)	6045/6642	92·5% (91·9–93·1)	<0·0001
ACE inhibitors or angiotensin receptor blockers*†	1177/1932	61·7% (59·5–63·8)	2429/3513	70·7% (69·2–72·2)	4224/6440	66·4% (65·2–67·5)	0·26
Traditional Chinese medicine within 24 h	903/1995	43·6% (41·5–45·8)	2003/3626	49·7% (48·1–51·3)	4200/6643	57·4% (56·2–58·6)	<0·0001
Traditional Chinese medicine†	1181/1995	57·2% (55·0–59·4)	2420/3626	61·9% (60·4–63·5)	4827/6643	68·8% (67·7–69·9)	<0·0001
Magnesium sulfate†	656/1995	33·1% (31·0–35·1)	719/3626	18·6% (17·4–19·9)	1159/6643	16·1% (15·2–17·0)	<0·0001
Procedures†							
Cardiac catheterisation	209/1995	12·7% (11·3–14·2)	736/3626	25·8% (24·3–27·2)	2204/6643	41·9% (40·7–43·1)	<0·0001
PCI (non-primary)	60/1995	3·4% (2·6–4·2)	368/3626	12·3% (11·2–13·4)	1077/6643	20·3% (19·4–21·3)	<0·0001
Coronary artery bypass graft	14/1995	1·1% (0·6–1·5)	21/3626	0·9% (0·6–1·3)	30/6643	0·6% (0·4–0·8)	0·019
Intra-aortic balloon pump	8/1995	0·5% (0·2–0·8)	32/3626	1·0% (0·7–1·3)	137/6643	2·5% (2·1–2·9)	<0·0001
Stents†‡							
Drug-eluting stents only	37/89	39·7% (29·6–49·9)	354/442	80·7% (77·1–84·4)	1306/1329	98·6% (98·0–99·3)	<0·0001
Bare-metal stents only	44/89	50·0% (39·6–60·4)	71/442	15·5% (12·1–18·9)	23/1329	1·4% (0·7–2·0)	<0·0001
Both	8/89	10·3% (4·0–16·6)	17/442	3·8% (2·0–5·6)	0/1329	0	<0·0001
Tests†							
Troponin	385/1995	22·3% (20·5–24·1)	1560/3626	46·9% (45·3–48·5)	4195/6643	68·6% (67·5–69·7)	<0·0001
Cardiac enzymes	1732/1995	87·3% (85·9–88·8)	3344/3626	93·1% (92·3–93·9)	6443/6643	97·2% (96·8–97·6)	<0·0001
Creatinine	1241/1995	63·8% (61·7–65·9)	2981/3626	84·7% (83·5–85·9)	6253/6643	94·9% (94·4–95·5)	<0·0001
Echocardiogram	572/1995	30·1% (28·1–32·1)	1581/3626	47·6% (46·0–49·2)	4191/6643	67·7% (66·6–68·8)	<0·0001

PCI=percutaneous coronary intervention. ACE=angiotensin-converting enzyme. STEMI=ST-segment elevation myocardial infarction. Data are n/N or weighted % (95% CI), for which n is the number of patients in the study sample and weighted % is a nationally representative rate, unless otherwise stated. *Only among ideal patients for the treatment (ie, patients with no documented contraindications). †During hospital admission. ‡Among patients who received at least one stent.

Table 2: **Use of treatments, procedures, and tests among patients with STEMI**

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(95 in 2001, 263 in 2006, and 634 in 2011), 12 264 patients were included in analysis of trends in treatments, procedures, and tests (table 2, figure 1). The proportion of patients classified as ideal candidates did not change substantially over time for all recommended treatments (appendix 2).

Among ideal candidates for reperfusion therapy, the weighted rate of primary percutaneous coronary intervention increased between 2001 and 2011 (from 10·6% to 28·1%, p_{trend}<0·0001; table 2). Meanwhile, the use of fibrinolytic therapy concurrently decreased, from 44·1% to 27·0% (p_{trend}<0·0001). Overall, use of reperfusion therapy, β blockers, angiotensin-converting-enzyme inhibitors, or angiotensin receptor blockers did not change between 2001 and 2011 (table 2). From 2001 to 2011, the treatment rate for all other recommended therapies increased among ideal patients (table 2). Use of magnesium sulfate decreased (table 2). By contrast, the use of traditional Chinese medicine within 24 h and at any time during hospital admission increased (table 2).

The weighted proportion of patients that underwent cardiac catheterisation, underwent non-primary percutaneous coronary intervention, or received drug-eluting stents also increased between 2001 and 2011 (table 2). The proportion of patients that underwent coronary artery bypass graft surgery was very small (14 of 1995 patients in 2001 *vs* 30 of 6643 patients in 2011). Substantial increases occurred in the use of diagnostic tests, such as troponin measurement and echocardiography.

After exclusion of 559 patients transferred in from other facilities, 1148 patients transferred out to other facilities (142 in 2011, 270 in 2006, and 736 in 2011), and 122 patients discharged alive within 24 h (15 in 2001, 38 in 2006, and 69 in 2011), 11 986 patients were included in the analysis of trends in length of hospital stay and in-hospital outcomes (figure 1). The median hospital length of stay was 12 days (IQR 7–18) in 2001, 10 days (6–15) in 2006, and 10 days (6–14) in 2011 (p_{trend}<0·0001). 165 of 1933 patients died in hospital in 2001 (unadjusted weighted mortality rate 8·4%, 95% CI 7·1–9·8), 351 of 3581 died in 2006 (9·4%, 8·5–10·4), and 496 of 6472 died in 2011 (7·0%, 6·4–7·6). After adjustment for patient demographic and clinical characteristics in the multilevel logistic regression, the risk of in-hospital mortality did not significantly decrease over time (figure 3). Similarly, the adjusted risk of death or treatment withdrawal and complications did not change over time (figure 3). Adjusted outcomes calculated with a 7-day timeframe were much the same as the primary analyses using the entire hospital stay (figure 4). A sensitivity analysis compared the results of the entire cohort with those of the population excluding transferred patient. The results of these two analyses did not differ (appendix 2).

1038 (7·5%) of 13 815 patients (308 in 2001, 373 in 2006, and 357 in 2011) with missing data for cardiac enzymes were excluded from mini-GRACE risk score calculations. The risk of in-hospital death or treatment withdrawal, adjusted by mini-GRACE risk score, was 1·16 (95% CI 0·92–1·47) in 2006 and 0·94 (0·74–1·21) in 2011 (appendix 2). The risk of in-hospital mortality adjusted for mini-GRACE risk score was 1·07 (95% CI 0·80–1·42) in 2006 and 0·77 (0·57–1·03) in 2011. The results of these analyses were much the same as those of imputation for missing data and use of a 7-day timeframe (appendix 2). Six of 1933 patients in 2001 (weighted rate 0·3%, 95% CI 0·1–0·6), 34 of 3581 patients in 2006 (1·1%, 0·7–1·4), and 62 of 6472 patients in 2011 (0·9%, 0·7–1·1) had major bleeding (p_{trend}=0·08). Only four fatal bleeding events occurred, three in 2006 and one in 2011.

	Unadjusted rate (%)	p for trend (unadjusted)	Adjusted OR (95% CI)	p for trend (adjusted)
Death		0·0007		0·07
2001	8·7		1 (reference)	
2006	9·6		1·05 (0·82–1·36)	
2011	7·1		0·82 (0·62–1·10)	
Death or treatment withdrawal		0·104		0·85
2001	10·5		1 (reference)	
2006	12·5		1·17 (0·94–1·45)	
2011	10·2		1·03 (0·80–1·33)	
Composite complications		0·49		0·88
2001	18·0		1 (reference)	
2006	21·1		1·20 (0·98–1·47)	
2011	18·5		1·08 (0·87–1·35)	

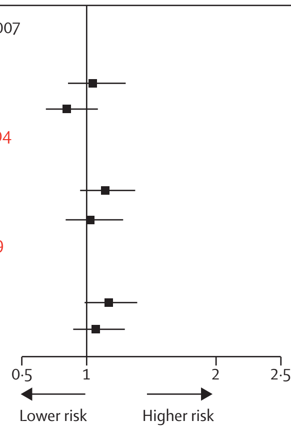

Figure 3: **Adjusted in-hospital outcomes for patients with STEMI**
Adjusted odds ratio of 1 shows no difference from year 2001. We included 11 986 patients (1933 in 2001, 3581 in 2006, and 6472 in 2011); 559 patients transferred in from other facilities, 1148 patients transferred out, and 122 patients discharged alive within 24 h were excluded. *C*=0·76 for mortality, *C*=0·78 for death or treatment withdrawal, and *C*=0·68 for composite complications. STEMI=ST-segment elevation myocardial infarction.

	Unadjusted rate (%)	p for trend (unadjusted)	Adjusted OR (95% CI)	p for trend (adjusted)
Death		0·0078		0·22
2001	6·9		1 (reference)	
2006	7·7		1·10 (0·82–1·48)	
2011	5·8		0·89 (0·66–1·20)	
Death or treatment withdrawal		0·48		0·47
2001	8·2		1 (reference)	
2006	10·2		1·26 (0·98–1·62)	
2011	8·5		1·16 (0·90–1·51)	

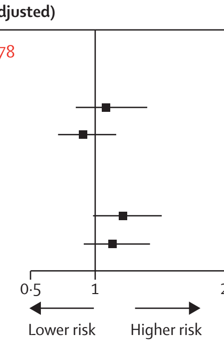

Figure 4: **Adjusted 7-day outcomes among patients with STEMI**
Adjusted odds ratio of 1 shows no difference from year 2001. We included 12 421 patients (2010 in 2001, 3696 in 2006, and 6715 in 2011); 559 patients transferred in from other facilities, 713 patients transferred out within 7 days, and 122 patients discharged alive within 24 h were excluded. *C*=0·76 for mortality and *C*=0·79 for death or treatment withdrawal. STEMI=ST-segment elevation myocardial infarction.

Discussion

In the China PEACE-Retrospective AMI Study we aimed to document changes in the clinical profiles, treatment

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Panel: Research in context

Systematic review

We searched PubMed for articles published in English and Chinese between Jan 1, 2000, and March 12, 2014, with the terms "ST-segment elevation myocardial infarction", "acute myocardial infarction", "acute coronary syndrome", and "China". We identified three large nationwide studies, one a clinical trial undertaken in 1999–2005,[6] and the other two observational studies. Both observational studies used a convenience sample of hospitals. One studied 2973 patients with acute coronary syndrome from 51 hospitals between 2004 and 2005.[7] The other study included 3323 patients with acute coronary syndrome from 65 hospitals in 2006.[22]

Interpretation

To our knowledge, this study, which included 13815 patients from 162 randomly selected hospitals across China, is the first nationally representative investigation of ST-segment elevation myocardial infarction (STEMI). We studied the trends in admissions, the clinical profiles, quality of care, and outcomes of STEMI between 2001 and 2011, a period of epidemiological transition. We noted that hospital admissions for STEMI have become increasingly common, patients are more likely to have comorbidities, and the intensity of testing and treatment has increased. Quality of care has improved for some treatments, but important gaps persist and in-hospital mortality has not significantly improved. Policy makers and health professionals in China have opportunities to improve quality care and outcomes for patients with STEMI and to work to slow the rise in these events.

patterns, quality of care, and in-hospital mortality of patients admitted to hospital for STEMI in China during the past decade. This study, funded by the Chinese Government, was designed to generate the knowledge to support future national initiatives to improve STEMI care and patient outcomes in China.

Our study of a nationally representative sample of patients between 2001 and 2011 characterises the trends in the epidemiology, treatment, and outcomes of patients with STEMI. We identified substantial increases in the estimated national rate of hospital admission for STEMI. Furthermore, we identified a growing burden of prevalent coronary risk factors, persistent delays in admission to hospital, increasing use of procedures and tests, relatively long hospital stays, and gaps in quality of care with the underuse of guideline-recommended therapies and the use of therapies of unknown effectiveness. Concurrent with these trends, outcomes have not improved. To our knowledge, the China PEACE-Retrospective AMI Study is the first large study with rigorous random sampling of a hospital cohort to study national trends in STEMI in China (panel), and identifies important opportunities for quality improvement and policy making.[11]

Because of the random sampling strategy used to identify hospitals and patients in our study, we believe that the results represent practice in China in general—a large country with great variations across regions and hospitals.[23] The experience in China, with the growth in admissions for STEMI, the gaps in treatment, and the growing complexity of patients is similar to previous experience in the USA. This study, like the Cooperative Cardiovascular Project (CCP)[24] undertaken 20 years ago in the USA, provides important information about opportunities for improvement. Since the CCP, the USA has invested substantially in quality improvement for cardiovascular disease and has had marked improvements in admission rates, and process of care and outcomes for acute myocardial infarction.[25–28]

The economic transition in China is resulting in more non-communicable diseases such as STEMI, which has substantial implications for the strategies needed to develop the health-care system. The growing needs for inpatient STEMI care will create pressure for Chinese hospitals to increase capacity, adequately train health-care professionals, develop infrastructure, and improve care. The striking increases in hospital admissions for STEMI noted in our study show that important improvements in capacity have been made; however, national STEMI mortality[5] suggests that further growth will be necessary to ensure adequate access for patients with the disorder in China. Furthermore, our study underlines that access to care does not ensure the delivery of the highest-quality care; suggesting that in addition to improvements in capacity, hospitals in China must simultaneously strive to improve care.

The quality of care has improved during the past decade, but substantial gaps still persist. Increases in the use of aspirin, clopidogrel, and statins are encouraging. However, β blockers and angiotensin-converting-enzyme inhibitors, which reduce mortality in patients with STEMI, remain very underused. Only half of ideal candidates for reperfusion therapy received treatment, a proportion that did not improve over time. This finding suggests that obstacles persist—eg, difficulty in identification of ideal patients, balancing of the risks and benefits of treatment, and the growing proportion of comorbidities—that render treatment more challenging. Gaps in care might also result from inadequate provider knowledge, structural inadequacies of the systems of care, or concern about potential patient disputes and litigation due to risk of treatment.[29–31] Our findings underscore the need for national initiatives to understand the reasons for persistent gaps in care and improve the use of evidence-based care for STEMI in China.[32,33]

Importantly, our results raise a particular concern that the increased intensity of treatment, procedure use, and testing has not been associated with major decrements in mortality between 2001 and 2011. Moreover, this change occurred in the context of a decrease in length of stay over time. The reported in-hospital mortality in our representative study is consistent with a large trial of 46 000 Chinese patients, but is higher than that reported in two prospective studies with non-randomly selected patients admitted to hospital between 2004 and 2006.[6,7,22] By contrast with the improvement achieved in a similar period in the USA and the UK, the lack of change in mortality in China suggests an opportunity for quality

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improvement.[27,34] If the in-hospital mortality of STEMI could be reduced by 1% in China, at least 2100 lives could be saved every year. The number of lives saved would rise rapidly if the number of STEMI increases, as is anticipated. Our data do not show significant improvement in mortality between 2001 and 2011, but we cannot exclude a meaningful effect in view of the point estimates and confidence intervals. Comparison of mini-GRACE-adjusted mortality rates between 2001 and 2011 suggested a borderline-significant reduction in in-hospital mortality, but when treatment withdrawal was included the results were not significant and the point estimate did not suggest a benefit. In China, many patients withdraw from treatment at terminal status, which could be attributed to culture or affordability. Therefore, a focus on in-hospital mortality alone, without accounting for these patients, could result in an underestimate of actual short-term mortality rates. Nevertheless, we cannot exclude the possibility that a modest benefit occurred based on the confidence intervals.

Several factors could account for why mortality did not improve significantly. First, we noted little improvement in the time from symptom onset to hospital admission, which is much longer than that reported in other national databases.[35,36] Second, rates of reperfusion therapies, which were much lower than are those in the USA or Europe, did not improve.[28,37] Third, the rate of primary percutaneous coronary intervention was still low in 2011 despite an increase during the past decade.[28,37] This rate, in particular, might be able to be increased in some settings but not others. Improvement of these three factors alone could substantially reduce mortality.[38] Fourth, we did detect increasing rates of cardiac arrest and cardiogenic shock, which is a concern, but they did not account for the lack of substantial improvement in mortality.

We also noted that several therapies that are known to be ineffective, or lack strong evidence, are often given in China. About a sixth of patients received magnesium sulfate, despite a large body of evidence that this therapy is either ineffective or could cause harm.[16,17] Traditional Chinese medicine is increasingly used, despite little evidence of its efficacy and safety for treatment of STEMI.[39] Further research is needed to elucidate the clinical benefit of traditional Chinese medicine for the management of STEMI.

The findings of this study should be interpreted in view of several limitations. First, the lack of regular biomarker measurement, particularly in 2001, precludes a gold-standard diagnosis of STEMI. Increasing use of biomarker-based diagnosis would likely increase the number of less severe cases in our cohort in 2006 and 2011.[13,40,41] This change would be expected to bias towards improvements in outcomes in 2006 and 2011, but we noted no difference. The early years of our cohort might have included more patients without STEMI, but we collected detailed information about clinical condition and no evidence suggested that the risk based on the initial vital signs and clinical condition changed importantly over time. Second, we measured clinical characteristics on the basis of documentation in medical records. Definitions of some disorders and completeness of documentation can differ across hospitals and over time. Third, we could only measure in-hospital outcomes, which might vary from those measured with use of a standardised timeframe (eg, 30 days),[42] because we were unable to link patient-level data to a national registry of deaths. Nevertheless, the long length of stay in China permits a fairly long observation period for patients admitted to hospital. Furthermore, analysis with a standardised 7-day timeframe did not provide different results from the primary analysis. Fourth, the use of laboratory tests, including measurement of cardiac biomarkers and creatinine, is inconsistent in China, which might have affected our findings. However, the risk factors that were available for all patients predicted mortality very well and were probably sufficient for comparisons over time.[12] Fifth, the study was not powered to detect trends in mortality and our study cannot exclude the possibility of a meaningful improvement in mortality during the study period. However, we detected no strong indication of improvement, especially when we took into account patients who had treatment withdrawn. Finally, we cannot comment on patients with STEMI who were not admitted to hospital during the study period, and we cannot establish whether the increase in the number of patients admitted to hospital with STEMI over time represented increased access to health care or an increasing prevalence of STEMI in the population (or both). Nevertheless, to our knowledge this study is the most comprehensive of patients admitted to hospital with STEMI during the past decade in China.

Our study showed that, among patients admitted to hospital with STEMI, persistent gaps are present between practice and recommended care and outcomes have not significantly improved during the past decade. Although China has launched health-care reform and recently doubled annual expenditures for health care to improve access, challenges exist in optimisation of the use of scarce resources to provide the highest-quality care. Our findings provide evidence for policy makers and health professionals in China and other countries with a rapidly growing burden of STEMI to inform future strategies for medical resource allocation, system improvement, and disease management.

Contributors

HMK and LJ conceived of the China PEACE-Retrospective AMI Study and take responsibility for all aspects of it. JL, XL, FAM, JAS, HMK, and LJ designed the study. JL, XL, FAM, HMK, and LJ conceived of this Article. JL wrote the first draft of the Article, with further contributions from XL, YW, FAM, JAS, HMK, and LJ. QW and SH did the statistical analysis, with support from XL and YW. All authors interpreted data and approved the final version of the article.

Republished paper, new data highlighted

Declaration of interests
We declare no competing interests.

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