Percutaneous coronary intervention in patients with acute coronary syndrome in Chinese Military Hospitals, 2011–2014: a retrospective observational study of a national registry

Ren Zhao, Kai Xu, Yi Li, Miaohan Qiu, Yaling Han, the NRCIMH Program

ABSTRACT

Objectives Interventional treatment of patients with acute coronary syndrome (ACS) is surging dramatically in China in recent years, whereas nationwide assessments of the quality of percutaneous coronary intervention (PCI) procedural performance and outcomes are scarce. We aimed to provide an updated and real-world overview of the performance of PCI in patients with ACS since 2011 in China after the China PEACE study from 2001 to 2011.

Methods In this cross-sectional study, data were extracted from the National Registry of Cardiovascular Intervention in Military Hospitals database to create a national sample of 144 659 patients with ACS undergoing PCI at 117 military hospitals in all regions of China from calendar years 2011–2014. Patient characteristics, procedural performance, PCI outcomes and adverse events and temporal changes were analysed.

Results During 2011–2014, patients with ACS undergoing PCI increased dramatically. Small numbers of high-volume hospitals performed the majority of PCI procedures. However, only half of these patients were adequately covered and proportions for the use of assisted devices and novel medications were relatively small. Radial artery access was still increasing with time. Primary PCs were performed on 45.4% ST-segment elevation myocardial infarction patients with PCI procedures. 3.8% lesion vessels involve left main artery. Implanted stents, the overall complications and in-hospital mortality were decreasing remarkably.

Conclusions In Chinese military hospitals, interventional resources were limited with great regional disparities, there are still gaps to be filled to better serve patients with ACS. Our findings can serve as an indispensable supplement to a more comprehensive understanding of the practice of contemporary cardiac intervention in China.

INTRODUCTION

Due to an ageing population and increasing prevalence of cardiovascular risk factors, China is facing an epidemic of acute coronary syndrome (ACS). In China, military hospitals play an indispensable role in providing healthcare service largely to civilian patients in peacetime, yet their performance of care were underinvestigated. The drastic increase of acute coronary syndrome (ACS) in China has also catalysed the growth of percutaneous coronary intervention (PCI) in quantity. However, whether the rapid growth of PCI volume has translated into good quality of care for these patients with ACS treated in military hospitals remains unclear. The adoption of emerging technologies varies substantially across different areas of China. The lack of a nationwide comprehensive assessment of interventional practice hampered the improvement of healthcare provided to these patients. Understand these barriers within the healthcare system of China is imperative to implement change.

The China patient-centered evaluative assessment of cardiac event (PEACE) study was a nationally representative, retrospective study of patients undergoing coronary catheterisation and PCI at 55 urban Chinese...
non-military hospitals in calendar years 2001, 2006 and 2011. This study found that there were notable changes in practice, including use of radial PCI and medicated stents, yet persistent gaps still existed to improve care. Military hospitals are independently administered by the Joint Logistic Support Center (the former General Logistics Department) of People’s Liberation Army (PLA) in China. To facilitate the management of cardiovascular intervention in military hospitals, the Quality Control Center of Intervention for Cardiovascular Diseases was founded in 2009 by the Bureau of Healthcare of the General Logistics Department. Quality Improvement Initiatives were launched thereafter to standardise the care of acute myocardial infarction nationwide in military hospitals, including the establishment of Chest Pain Center in qualified cardiac centres. To standardise and monitor the quality of care for patients undergoing PCI procedures, we conducted the National Registry of Cardiovascular Intervention in Military Hospitals (NRCIMH) study. During calendar years 2011–2014, 117 PCI-capable military hospitals in all seven geographical regions of China and 144,659 patients with ACS undergoing PCI procedures were included in this study. Patient characteristics, quality of procedural performance, PCI outcomes, and in-hospital adverse events and their temporal changes were analysed over time.

METHODS
Study design
This study was a cross-sectional study using a registered dataset. The original data for this study were extracted from the NRCIMH (web access via http://www.xxgjr.com). This database collected social-demographic, medical and interventional data of patients who had cardiovascular disease and underwent cardiac interventions since October 2010 in all military hospitals nationwide that are qualified to perform cardiac catheterization and PCI. Patient demographics, clinical characteristics and treatment patterns during hospitalisation were collected by physicians who were in charge of the patient, and coronary catheterisation or PCI-related information were collected by the responsible operator or technical assistant. Patient data were censored and uploaded into the database by designated medical personnel in each individual hospital. The majority of patients had coronary artery disease and underwent PCI. All participating hospitals accepted the ethics committee approval.

Study population
Patients with ACS (with definite discharge diagnosis of either ST-segment elevation myocardial infarction (STEMI), non-ST-segment elevation myocardial infarction (NSTEMI) or unstable angina) undergoing interventional procedures in all 117 military hospitals (online table S1) from 1 January 2011 to 31 December 2014 were included in this study. Diagnoses were made according to the China National Guidelines for ACS, which are consistent with guidelines in the USA. Due to the large-volume information inputted into this registry, patients with missing data were excluded in specific categorical analyses, including age, gender, region of hospital, access artery, contrast type, lesion vessel and target vessel. For measured categories like artery stenosis and lesion category, their sum exceed the total number of patients enrolled in each study year is because each patient usually had more than one stenosed/lesioned vessel. For the sake of clarity, the sum for each measured variable category was listed in the column of each category unless otherwise specified. Data integrity for each measure category was not less than 91.8% in this study.

Variables and definitions
We collected data from a unified registry form abstracted from the original database systems, including baseline characteristics (diagnosis, patient category, age, gender, ethnicity, region of admission hospital, medical history), perioperative characteristics (primary PCI composition, access artery, contrast type, antiplatelet and anticoagulation medications, assisted devices), PCI outcomes (stenosis pre-PCI, lesion category, lesion vessel, target vessel) and adverse outcomes including complication and death both during PCI and post-PCI. Medical histories including histories of myocardial infarction, cerebrovascular disease, peripheral vascular disease, cardiac valve surgery, coronary artery bypass graft (CABG) and PCI were collected by physicians in charge of that patient (mainly via patient’s own statement and further verified, if any, by documentation in previous admission notes, discharge diagnoses or corroborating laboratory test results) and were uploaded into the registry database. For the convenience of calculation, anomalous artery, intermediate artery and vessel graft lesion as well as interventions done in these vessels were all merged into the individual categories. In addition, due to a systematic revision of the registry form since 2013, partial data were analysed and summarised in the supplement, including location and Killip classification of myocardial infarction history, assisted device used during 2011–2013, information regarding medical coverage, thrombolysis of STEMI patient, PCI outcomes and stent manufacturer during 2013–2014.

Patients with corrected TIMI frame count values exceeding the thresholds by >2 SD for the particular vessel were recognised as having coronary slow flow. Major bleeding was defined as any intracranial bleeding, absolute haemoglobin decrease of at least 50 g/L, bleeding resulting in hypovolemic shock or fatal bleeding (bleeding that resulted directly in death within 7 days). Acute/subacute stent thrombosis was defined according to the Academic Research Consortium criteria. Postoperative myocardial infarction was diagnosed in accordance with the universal definition of type 4 myocardial infarction. The cause of death was adjudicated as cardiogenic death, PCI-related death or uncertain.
analyses were performed using GraphPad Prism V.6.01 and SAS software V.9.3.

Patient and public involvement
Patients and public were not involved in this study.

RESULTS
A total of 144,659 patients with ACS undergoing PCI in 117 military hospitals were recruited into this study from 2011 to 2014, located in all seven geographic regions of mainland China, including North China (n=25), Northwest (n=14), Northeast (n=10), East China (n=29), Southwest (n=14), Central China (n=12) and South China (n=13). Of these, 82 hospitals provided 140,374 cases (97.0%) across all the study years (online table S1). In brief, only 20 (17.1%) hospitals performed more than 400 PCIs on ACS patients annually (figure 1A), and these hospitals performed 71.9% PCIs (104,026 cases) during 2011–2014 (figure 1B). Geographically, although the total number of hospitals in Northern China (North China, Northwest, Northeast regions) was less than that in Southern China (South China, East China, Central China and Southwest regions), there were more military hospitals in Northern China performed PCI procedures>400 cases per year than those in Southern China (figure 1C), and northern military hospitals performed the majority of PCIs during the study years (66.5%) (figure 1D).

Generally, the number of patients with ACS undergoing PCI has increased by 27.8%, while the proportions of most comorbidities of these patients had concordant decrease over time. Hospitals in northern China (North China, Northwest and Northeast) performed the majority of PCIs, with most patients being civilian and with Han ethnicity. There were significant increases in the proportions of patients diagnosed as unstable angina pectoris, of civilian identity, male gender, treated in hospitals classified as military, and with prior PCI within the last 2 years. There were slight decreases in the proportions of patients diagnosed as STEMI, treated in hospitals in North China, Northwest and Northeast, and significant decreases in the proportions of patients classified as NSTEMI treated in hospitals in North China, Northwest and Central China (table 1). During 2013–2014, only half of these patients were covered by urban resident medical service (53.4%–53.6%) (online table S2).

The proportion of primary PCI dropped significantly in patients with ACS in all categories. In STEMI patients, the fraction of primary PCI in all PCI performed did not change dramatically (44.0%–47.9%, table 2). There is remarkable increase in the proportion of anterior myocardial infarction and significant decrease in the proportion of cardiac function defined as Killip III/IV (online table S3). There was more time delay on first medical contact to balloon dilation in 2014 than in 2013 (median 50 vs 40, p<0.01) (online table S4). PCI procedures done through the radial artery had increased markedly from 72% in 2011 to 90.4% in 2014. The use of clopidogrel and GP IIb/IIIa inhibitor dropped significantly. Proportions of novel drugs like ticagrelor and bivalirudin, and of assisted devices such as intra-aortic
|                  | 2011  | %   | 2012  | %   | 2013  | %   | 2014  | %   | P values for trend |
|------------------|-------|-----|-------|-----|-------|-----|-------|-----|-------------------|
| ACS              | 30800 |     | 34974 |     | 39524 |     | 39361 |     |                   |
| UAP              | 22038 | 71.6| 24847 | 71.0| 28727 | 72.7| 28508 | 72.4| <0.0001           |
| STEMI            | 6514  | 21.1| 7302  | 20.9| 7889  | 20.0| 7856  | 20.0| <0.0001           |
| NSTEMI           | 2248  | 7.3 | 2825  | 8.1 | 2908  | 7.4 | 2997  | 7.6 | 0.87              |
| Age, years       |       |     |       |     |       |     |       |     |                   |
| 18–24            | 12    | 0.0 | 8     | 0.0 | 16    | 0.0 | 15    | 0.0 | 0.70              |
| 25–34            | 177   | 0.6 | 223   | 0.6 | 246   | 0.6 | 243   | 0.6 | 0.62              |
| 35–44            | 1597  | 5.2 | 1930  | 5.5 | 2149  | 5.4 | 2187  | 5.6 | 0.09              |
| 45–54            | 5849  | 19.1| 6663  | 19.1| 7283  | 18.5| 7507  | 19.1| 0.52              |
| 55–64            | 10291 | 33.6| 11990 | 34.4| 13888 | 35.2| 13381 | 34.0| 0.11              |
| 65–74            | 8615  | 28.1| 9510  | 27.3| 10650 | 27.0| 10832 | 27.5| 0.09              |
| 75–84            | 3850  | 12.6| 4227  | 12.1| 4884  | 12.4| 4800  | 12.2| 0.33              |
| >84              | 260   | 0.8 | 321   | 0.9 | 350   | 0.9 | 386   | 1.0 | 0.11              |
| Gender           |       |     |       |     |       |     |       |     |                   |
| Male             | 22017 | 73.0| 25423 | 74.4| 29104 | 74.3| 29193 | 74.2| <0.01             |
| Female           | 8138  | 27.0| 8768  | 25.6| 10085 | 25.7| 10143 | 25.8|                   |
| Ethnicity        |       |     |       |     |       |     |       |     |                   |
| Han              | 30589 | 99.3| 34691 | 99.2| 38974 | 98.6| 38620 | 98.1| <0.0001           |
| Others           | 211   | 0.7 | 283   | 0.8 | 550   | 1.4 | 741   | 1.9 |                   |
| Region of hospital|      |     |       |     |       |     |       |     |                   |
| North China      | 9156  | 29.7| 9631  | 27.5| 9914  | 25.1| 11086 | 28.2| <0.0001           |
| Northwest        | 7632  | 24.8| 7939  | 22.7| 9728  | 24.6| 7821  | 19.9| <0.0001           |
| Northeast        | 3924  | 12.7| 5347  | 15.3| 6691  | 16.9| 7284  | 18.5| <0.0001           |
| East China       | 3742  | 12.2| 4630  | 13.2| 5053  | 12.8| 5241  | 13.3| <0.001            |
| Southwest        | 3515  | 11.4| 4346  | 12.4| 4877  | 12.3| 4549  | 11.6| 0.96              |
| Central China    | 1977  | 6.4 | 1928  | 5.5 | 1910  | 4.8 | 1944  | 4.9 | <0.0001           |
| South China      | 837   | 2.7 | 1149  | 3.3 | 1351  | 3.4 | 1436  | 3.6 | <0.0001           |
| Comorbidities    |       |     |       |     |       |     |       |     |                   |
| Hypertension     | 17600 | 57.1| 19942 | 57.0| 21260 | 53.8| 21701 | 55.1| <0.0001           |
| Hyperlipidaemia  | 6844  | 22.2| 7774  | 22.2| 7420  | 18.8| 7330  | 18.6| <0.0001           |
| Diabetes mellitus| 6829  | 22.2| 7817  | 22.4| 8394  | 21.2| 8819  | 22.4| 0.75              |

Continued
|                        | 2011 n | 2011 % | 2012 n | 2012 % | 2013 n | 2013 % | 2014 n | 2014 % | P values for trend |
|------------------------|--------|--------|--------|--------|--------|--------|--------|--------|-------------------|
| COPD                   | 541    | 1.8    | 448    | 1.3    | 478    | 1.2    | 447    | 1.1    | <0.0001           |
| Current smoking        | 9093   | 29.5   | 10838  | 31.0   | 11467  | 29.0   | 10568  | 26.8   | <0.0001           |
| Heart failure*         | 1378   | 4.5    | 1373   | 3.9    | 1331   | 3.4    | 1122   | 2.9    | <0.0001           |
| Renal failure*         | 277    | 0.9    | 297    | 0.8    | 259    | 0.7    | 276    | 0.7    | <0.001            |
| Under dialysis*        | 34     | 0.1    | 52     | 0.1    | 45     | 0.1    | 45     | 0.1    | 0.71              |
| Prior MI               | 7560   | 24.5   | 7828   | 22.4   | 7928   | 20.1   | 5648   | 14.3   | <0.0001           |
| Prior CVD              | 2014   | 6.5    | 1912   | 5.5    | 1990   | 5.0    | 2018   | 5.1    | <0.0001           |
| Prior PVD              | 457    | 1.5    | 430    | 1.2    | 489    | 1.2    | 515    | 1.3    | 0.09              |
| Prior PCI              | 5702   | 18.5   | 6125   | 17.5   | 6467   | 16.4   | 5973   | 15.2   | <0.0001           |
| Prior CVS              | 1077   | 3.5    | 1192   | 3.4    | 563    | 1.4    | 14     | 0.0    | <0.0001           |
| Prior CABG             | 936    | 3.0    | 952    | 2.7    | 580    | 1.5    | 204    | 0.5    | <0.0001           |
| Familial CAD           | 805    | 2.6    | 867    | 2.5    | 681    | 1.7    | 615    | 1.6    | <0.0001           |

*Assessed and recorded at admission.

CABG, coronary artery bypass graft; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; CVD, cerebrovascular disease; CVS, cardiac valve surgery; MI, myocardial infarction; NSTEMI, non-ST elevation myocardial infarction; PVD, peripheral vascular disease; STEMI, ST elevation myocardial infarction; UAP, unstable angina pectoris.
Table 2  Perioperative characteristics of patients with acute coronary syndrome (ACS) undergoing percutaneous coronary intervention (PCI) during 2011–2014

|                | 2011   | 2012   | 2013   | 2014   | P values for trend |
|----------------|--------|--------|--------|--------|--------------------|
| n             | 30800  | 34974  | 39524  | 39361  |                    |
| pPCI           | Yes    | 3689   | 12.0   | 4359   | 12.5               | 4263 | 10.8 | 4211 | 10.7 | <0.0001 |
| On STEMI       | 2866   | 9.3    | 3499   | 10.0   | 3505              | 8.9  | 3544 | 9.0  | 0.78  | <0.01   |
| pPCI/PCI       | 2866/6514 | 44.0 | 3499/7302 | 47.9 | 3505/7889 | 44.4 | 3544/7856 | 45.1 | 0.78  | <0.01   |
| On NSTEMI      | 334    | 1.1    | 372    | 1.1    | 349               | 0.9  | 365  | 0.9  | <0.0001 |
| On UAP         | 489    | 1.6    | 488    | 1.4    | 409               | 1.0  | 302  | 0.8  | <0.0001 |
| No             | 27111  | 88.0   | 30615  | 87.5   | 35261             | 92.9 | 35150 | 92.9 |        |
| Access artery  | 30800  | 34974  | 39524  | 39361  |                    |
| Radial         | 22171  | 72.0   | 28266  | 81.2   | 34520             | 87.3 | 35582 | 90.4 | <0.0001 |
| Femoral        | 8453   | 27.4   | 6527   | 18.7   | 4803              | 12.2 | 3545 | 9.0  | <0.0001 |
| Brachial       | 165    | 0.5    | 170    | 0.5    | 187               | 0.5  | 209  | 0.5  | 0.94   |
| Others         | 11     | 0.0    | 11     | 0.0    | 14                | 0.0  | 25   | 0.1  | 0.06   |
| Contrast type  | 30800  | 34974  | 39524  | 39361  |                    |
| Non-ionic      | 30027  | 99.8   | 34119  | 99.9   | 38493             | 99.8 | 39198 | 99.6 | <0.0001 |
| Iso-osmolar    | 10055  | 33.4   | 12988  | 38.0   | 16540             | 42.9 | 20034 | 50.9 | <0.0001 |
| Low-osmolar    | 19972  | 66.4   | 21131  | 61.9   | 21953             | 56.9 | 19164 | 48.7 | <0.0001 |
| Ionic          | 53     | 0.2    | 35     | 0.1    | 92                | 0.2  | 163  | 0.4  | <0.0001 |
| Antiplatelet   | 30800  | 34974  | 39524  | 39361  |                    |
| Aspirin        | 29459  | 95.6   | 34189  | 97.8   | 38267             | 96.8 | 38547 | 97.9 | <0.0001 |
| Clopidogrel    | 29486  | 95.7   | 34231  | 97.9   | 37165             | 94.0 | 36122 | 91.8 | <0.0001 |
| Ticagrelor     | 30     | 0.1    | 13     | 0.0    | 222               | 0.6  | 1299 | 3.3  | <0.0001 |
| Ticlopidine    | 54     | 0.2    | 50     | 0.1    | 520               | 1.3  | 1202 | 3.1  | <0.0001 |
| Cilostazol     | 22     | 0.1    | 17     | 0.0    | 23                | 0.1  | 15   | 0.0  | 0.11   |
| GP IIb/IIIa inhibitor | 4670 | 15.2 | 6232 | 17.8 | 6135 | 15.5 | 5099 | 13.0 | <0.0001 |
| Anticoagulation| 30800  | 34974  | 39524  | 39361  |                    |
| UFH            | 18788  | 61.0   | 21343  | 61.0   | 22885             | 57.9 | 24547 | 62.4 | 0.19   |
| LMWH           | 9248   | 30.0   | 10398  | 29.7   | 12622             | 31.9 | 12012 | 30.5 | <0.01   |
| Fondaparinux   | 373    | 1.2    | 939    | 2.7    | 886               | 2.2  | 0    | 0.0  | <0.0001 |
| Bivalirudin    | 0      | 0.0    | 0      | 0.0    | 93                | 0.2  | 395  | 1.0  | <0.0001 |
| IABP           | 30800  | 34974  | 39524  | 39361  |                    |
| Yes            | 450    | 1.5    | 579    | 1.7    | 584               | 1.5  | 432  | 1.1  | <0.0001 |
| No             | 30350  | 98.5   | 34395  | 98.3   | 38940             | 98.5 | 38929 | 98.9 |        |
| IVUS           | 30800  | 34974  | 39524  | 39361  |                    |
| Yes            | 439    | 1.4    | 399    | 1.1    | 383               | 1.0  | 439  | 1.1  | <0.0001 |
| No             | 30361  | 98.6   | 34575  | 98.9   | 39141             | 99.0 | 38922 | 98.9 |        |

GP IIb/IIIa, glycoprotein IIb/IIIa; IABP, intra-aortic balloon pump; IVUS, intravascular ultrasound; LMWH, low molecular weight heparin; NSTEMI, non-ST elevation myocardial infarction; pPCI, primary percutaneous coronary intervention; STEMI, ST elevation myocardial infarction; UAP, unstable angina pectoris; UFH, unfractionated heparin.

Balloon pump (IABP), intravascular ultrasound (IVUS), optical coherence tomography (OCT) and fractional flow reserve (FFR) measurement, were low in all time periods (table 2, online table S5). In addition, from 2013 to 2014, thrombolysis in patients with STEMI was not altered in terms of performance rate, thrombolytics and time delay from angina to thrombolysis increased remarkably and the success rate dropped significantly as well (online table S6).

Under catheterisation, artery stenosis >75% increased significantly in proportions during the study years. Long lesion constitutes approximately one-third of the overall
lesions, there were increased trends in the proportion of general lesion, total occluded lesion and thrombus lesion, and decreased trends in long lesion, calcified lesion and bifurcation lesion. The proportion of triple-vessel lesion significantly decreased, while that of solitary vessel lesion increased dramatically. Under PCI, target vessels were primarily solitary with increased trends in proportions of all arteries, followed by double vessels with decreased proportions. Target vessels involving LM consist 3.4% to 4.2% of all PCI procedures. PCI procedures targeting triple vessels had also decreased both in amount and in proportion (table 3). From 2013 to 2014, the mean implanted stent per patient decreased from 1.5 to 1.4 (p=0.01) (online table S7), the majorities implanted stents were made by domestic companies with a decreased proportion over time (online table S8).

In general, more complications were recorded during PCI than post PCI, and the overall complications were significantly decreased both in amount and in proportion, either during PCI or post-PCI. During PCI procedures, slow flow, serious dissection, acute thrombosis, perforation and cardiac tamponade had markedly decreased. As for complications after PCI, acute/subacute stent thrombosis, organ failure, major bleeding/haematoma, contrast reaction and thromboembolism had decreased trends in proportion during the study years. There were also significantly decreased trends of death both in amount and in proportion, during/after PCI, with the majority of death found after PCI procedures due to cardiogenic triggers (table 4). After adjustment for patient demographic and clinical characteristics in the multilevel logistic regression, the risk of in-hospital mortality also significantly decreased over time (figure 2).

DISCUSSION

To the best of our knowledge, this is the first large, nationwide study of patients with ACS undergoing PCI in Chinese military hospitals. Compared with contemporary developed country such as the USA, the proportion of hospitals capable of performing PCIs >400 cases was substantially low (17.1% vs 41.5% in USA).19 Accordingly, the application rates of assisted devices were also low, such as IABP (1.1%–1.7%), temporary pacemaker (1.9%–2.4%), IVUS (1.0%–1.4%), OCT (0.1%) and FFR measurement (0.1%–0.5%) as the support is available with experienced interventional cardiologists and skilled support staff in high-volume well-equipped facilities. Out data also suggest great regional disparities of PCI procedures performed on patients with ACS, with patients in the north region of China (North China, Northwest and Northeast) consumed the majority of interventional resources (65.5%–67.2% of all PCI cases for patients with ACS, table 1). This also reflects pandemic state of unstable coronary artery disease in these regions.20–22 In this regard, medical resources shall be prioritised to better serve disparate needs in different regions, especially the north region of China. Furthermore, the healthcare coverage system in contemporary China is also concerning, as during 2013–2014 only 53.4%–53.6% patients with ACS were covered under urban resident medical service with high reimbursement rate, while 20.1%–22.1% patients were covered under new rural cooperative medical service with low reimbursement rate, and 16.3%–17.2% patients were uncovered.23–25 Given the great economic burdens patients with ACS bear on PCI procedures and medications during hospitalisation and thereafter,26–28 the current medical coverage patterns shall be optimised to improve the quality of life for these patients as well as their families. Nevertheless, the overall decreased trends in proportions of comorbidities suggest the effectiveness of cardiovascular-related disease control during 2011–2014 in China.

Primary PCI was performed with high prevalence in hospitals of developed countries. For example, in a recent nationwide Belgian STEMI registry during 2009–2013, 89.6% of patients with STEMI underwent primary PCI.29 In the US National Cardiovascular Data Registry (NCDR) 2010–2011 report, the primary PCI consisted 84.8% of all PCI performed for patients with STEMI.30 However, the proportion of primary PCI performed on STEMI patients was still very low in this study, and this proportion did not change significantly over time (44.0% in 2011 to 45.1% in 2014). This could be explained by the low proportion of high-volume PCI-capable hospitals in China as these hospitals are well-equipped with experienced interventional cardiologists and skilled support staff, which are all required for the successful implementation of primary PCI. Nevertheless, median time delay of first medical contract (FMC) to balloon dilation for primary PCIs done with patients with STEMI during 2013–2014 were 50 min, which were far below the guideline-recommended threshold of 90 min.31 This important quality improvement might be catalysed by the awareness of the performance metric for participating hospitals as the study demonstrated that patients treated in hospitals that had been enrolled in the D2B Alliance for >3 months were significantly more likely to have D2B times of <90 min than patients treated in non-enrolled hospitals.32 In this regard, the scenario of D2B time in real-world practice might be less satisfying as performance metrics were largely unmonitored. Furthermore, given that time delay of angina onset to FMC was still huge (median 270 min), great efforts are still needed to promote broader initiatives at a systems level to reduce total ischaemic time, which was shown as the principal determinant of outcome.33 34 These efforts might include patient education, improvements in emergent medical service and emergent department care, establishment of networks of non-PCI-capable and PCI-capable hospitals, and work with policymakers to implement healthcare system reform.35–41

The current study depicted several notable changes as compared with the former China PEACE study. In their study, Xin Zheng and colleagues reported dramatic increase of the adoption of radial artery access from 3.5%
|                          | 2011     | 2012     | 2013     | 2014     | P values for trend |
|--------------------------|----------|----------|----------|----------|-------------------|
| **Artery stenosis (%)**  |          |          |          |          |                   |
| 75–99                    | 39090    | 42260    | 46915    | 46938    | <0.0001           |
| 100                      | 27879    | 31048    | 34976    | 35971    | 76.6              |
| 50–75                    | 3557     | 2326     | 2003     | 1540     | 3.3               |
| <50                      | 426      | 244      | 232      | 42       | 0.1               |
| **Lesion category**      |          |          |          |          |                   |
| Long lesion*             | 13571    | 14939    | 16375    | 15736    | 34.2              |
| General lesion           | 12686    | 13036    | 14874    | 15878    | 34.5              |
| Total occluded lesion    | 4597     | 5532     | 6058     | 5930     | 12.9              |
| Calcified lesion         | 3184     | 3006     | 3473     | 2781     | 6.0               |
| Bifurcation lesion       | 2545     | 2463     | 2479     | 2891     | 6.3               |
| Thrombus lesion          | 1782     | 2469     | 2711     | 2549     | 5.5               |
| Small vessel†            | 217      | 246      | 277      | 272      | 0.6               |
| Bypass graft lesion      | 24       | 22       | 45       | 36       | 0.1               |
| **Lesion vessel‡**       |          |          |          |          |                   |
| Triple                   | 12298    | 12803    | 13253    | 12301    | 31.3              |
| Solitary                 | 8580     | 11567    | 14395    | 14912    | 37.9              |
| LAD                      | 5397     | 7090     | 8544     | 8599     | 21.9              |
| RCA                      | 2147     | 3111     | 3866     | 4222     | 10.7              |
| LCX                      | 1036     | 1366     | 1985     | 2038     | 5.2               |
| Double                   | 7308     | 8104     | 9180     | 9374     | 23.9              |
| LAD+RCA                  | 3694     | 3936     | 4270     | 4285     | 10.9              |
| LAD+LCX                  | 2558     | 2968     | 3475     | 3554     | 9.0               |
| LCX+RCA                  | 1056     | 1200     | 1435     | 1535     | 3.9               |
| Triple+LM                | 1540     | 1481     | 1638     | 1644     | 4.2               |
| Double+LM                | 489      | 502      | 574      | 593      | 1.5               |
| LAD+LCX + LM             | 230      | 247      | 339      | 315      | 0.8               |
| LAD+RCA + LM             | 195      | 212      | 198      | 215      | 0.5               |
| LCX+RCA + LM             | 64       | 43       | 37       | 63       | 0.2               |
| Solitary+LM              | 178      | 253      | 300      | 367      | 0.9               |
| LAD+LM                   | 139      | 197      | 220      | 281      | 0.7               |
| RCA+LM                   | 26       | 37       | 51       | 49       | 0.1               |
| LCX+LM                   | 13       | 19       | 29       | 37       | 0.1               |
| LM                       | 64       | 90       | 107      | 128      | 0.3               |
| **Target vessel‡**       |          |          |          |          |                   |
| Solitary                 | 28278    | 32836    | 38176    | 39224    | <0.0001           |
| LAD                      | 20801    | 25513    | 30592    | 31456    | 80.2              |
| LCX                      | 10735    | 13277    | 15749    | 15960    | 40.7              |
| RCA                      | 3017     | 3563     | 4665     | 4867     | 12.4              |
| Double                   | 7049     | 8673     | 10178    | 10629    | 27.1              |
| LAD+LCX                  | 5713     | 5685     | 5906     | 5886     | 15.0              |
| LAD+RCA                  | 2723     | 2683     | 2865     | 2815     | 7.2               |
| LCX+RCA                  | 1978     | 1937     | 1904     | 1932     | 4.9               |
| LCX+RCA                  | 1012     | 1065     | 1137     | 1139     | 2.9               |

Continued
Open access to 79.0% in the practice of interventional cardiology in China during 2001–2011. In this study of patients with ACS, the trend is still rising, with 72.0% PCI procedures accessed via radial artery in 2011 to 90.4% in 2014, compared with 10.9% cases/procedures performed by means of a radial approach in 2011 to 25.2% in 2014 in the USA (NCDR). Also, the China PEACE-Retrospective CathPCI Study group reported that the proportions of patients who received a glycoprotein IIb/IIIa inhibitor and clopidogrel both increased from 2001 to 2011 in non-military hospitals in China. Unlike their findings, in our study, the proportions of clopidogrel and glycoprotein IIb/IIIa inhibitor both decreased significantly (95.7% to 91.8% and 15.2% to 13.0%, respectively), it might suggest different patterns of medications between non-military and military hospitals in the field of interventional cardiology, or just be a result of rapidly evolved medical practice in all hospitals in contemporary China, possibly due to the emergence of novel P2Y12 inhibitor ticagrelor and novel anticoagulant bivalirudin in China. Meanwhile, operators implanted less stents per patient in 2014 than in 2013 (mean 1.4 vs 1.5), which was also remarkably less than those implanted during 2001–2011 in China PEACE study (mean 1.4 in 2001, 1.7 in 2006 and 1.8 in 2011). This may be as a result of the enforcement of quality improvement initiatives during 2011–2014 by the Quality Control Center of Intervention for Cardiovascular Diseases. Finally, although domestic-made stents consist the majority of stents used during PCI procedures, their proportion dropped significantly (65.1% in 2013 to 61.8% in 2014), which was quite different from the scenario of dramatic increase of domestic stents used in non-military hospitals in China PEACE study during 2001–2011 (1.6% in 2001 to 74.8% in 2011).

In a recent meta-analysis of large, high-quality, contemporary randomised studies comparing radial and femoral access in invasively managed patients with ACS, radial access was found to reduce mortality, major adverse cardiovascular events and major bleeding. Similarly, with the rising adoption of radial access from 2011 to 2014 in this study, the proportion of major bleeding or haematoma after PCI and in-hospital mortality were both significantly decreased over time. In this regard, transradial access shall be advocated in countries that use it less frequently.

Compared with data reported from the NCDR in the USA during 2010–2011, uses of ticagrelor and bivalirudin were extremely low for patients with ACS undergoing PCI during 2011–2014 (<3.3% and 1.0%, respectively), although their proportions were rising. This might be explained by the delayed introduction of these drugs into Chinese pharmaceutical market, as well as uncovered status under the drug list of Medical Service in China. Given the great superiorities of these novel antiplatelet and anticoagulation drugs, coordinated advocacy efforts are needed to work with policymakers to include these drugs into the list for coverage, to improve the quality of care for patients with ACS and the outcomes of PCI procedures. Nevertheless, our data demonstrated great improvement in the quality metrics of PCI procedures during the study years. The proportion of non-obstructive CAD (stenosis <50%) was 1.1% in 2011. Although the proportion is much higher than that reported in NCDR during 2010–2011 (0.2%), it has dropped substantially to 0.1% in 2014. Out study also revealed dramatic changes in the pattern of the extent of CAD, with the dominance of three-vessel disease in 2011 (40.4%) shifted to the dominance of one-vessel disease

### Table 3

|                | 2011 |   % | 2012 |   % | 2013 |   % | 2014 |   % | P values for trend |
|----------------|------|-----|------|-----|------|-----|------|-----|-------------------|
| Solitary+LM    | 566  | 2.0 | 603  | 1.8 | 690  | 1.8 | 923  | 2.4 | <0.001            |
| LAD+LM         | 482  | 1.7 | 531  | 1.6 | 600  | 1.6 | 782  | 2.0 | <0.01             |
| LCX+LM         | 68   | 0.2 | 58   | 0.2 | 71   | 0.2 | 123  | 0.3 | <0.05             |
| RCA+LM         | 16   | 0.1 | 14   | 0.0 | 19   | 0.0 | 18   | 0.0 | 0.68              |
| Double+LM      | 483  | 1.7 | 455  | 1.4 | 462  | 1.2 | 464  | 1.2 | <0.0001           |
| LAD+LCX+LM     | 405  | 1.4 | 375  | 1.1 | 387  | 1.0 | 382  | 1.0 | <0.0001           |
| LAD+RCA+LM     | 73   | 0.3 | 69   | 0.2 | 69   | 0.2 | 72   | 0.2 | <0.05             |
| LCX+RCA+LM     | 5    | 0.0 | 11   | 0.0 | 6    | 0.0 | 10   | 0.0 | 0.92              |
| Triple         | 568  | 2.0 | 433  | 1.3 | 354  | 0.9 | 298  | 0.8 | <0.0001           |
| LM             | 97   | 0.3 | 113  | 0.3 | 153  | 0.4 | 173  | 0.4 | <0.05             |
| Triple+LM      | 50   | 0.2 | 34   | 0.1 | 19   | 0.0 | 24   | 0.1 | <0.0001           |

*Denotes length of lesion >20 mm.
†Denotes vessel diameter <2.5 mm.
‡Include anomalous artery, intermediate artery and vessel graft.
LAD, left anterior descending artery; LCX, left circumflex artery; LM, left main artery; RCA, right coronary artery.
in 2014 (37.9%) and no obvious change in two-vessel disease (23.3%–24.0%). This trend was quite different with distributions found in patients undergoing PCI in the USA during 2010–2011 (38.1%, 32.6% and 39.1% for one-vessel, two-vessel and three-vessel disease, respectively).60 In treated lesion vessels, although there were

| Table 4: In-hospital adverse events of patients with acute coronary syndrome (ACS) undergoing percutaneous coronary intervention (PCI) during 2011–2014 |
|---------------------------------------------|---------------|---------------|---------------|---------------|--------------|
|                                           | 2011 (n=30 800) | 2012 (n=34 974) | 2013 (n=39 361) | 2014 (n=39 361) | P values trend |
| Complication                              | 496 16.1       | 539 15.4       | 429 10.9       | 256 6.5         | <0.0001       |
| During procedure*                         | 342 11.1       | 334 9.5        | 269 6.8        | 151 3.8         | <0.0001       |
| Slow flow                                 | 201 6.5        | 168 4.8        | 159 4.0        | 87 2.2          | <0.0001       |
| Serious dissection                        | 71 2.3         | 75 2.1         | 64 1.6         | 32 0.8          | <0.0001       |
| Acute thrombosis                          | 54 1.8         | 48 1.4         | 36 0.9         | 23 0.6          | <0.0001       |
| Perfusion                                 | 22 0.7         | 32 0.9         | 17 0.4         | 17 0.4          | <0.05         |
| Cardiac tamponade                         | 11 0.4         | 17 0.5         | 9 0.2          | 7 0.2           | <0.05         |
| Acute occlusion                           | 11 0.4         | 24 0.7         | 19 0.5         | 12 0.3          | 0.38          |
| Post-procedure                            | 154 5.0        | 205 5.9        | 160 4.0        | 105 2.7         | <0.0001       |
| Acute/subacute ST                         | 46 1.5         | 49 1.4         | 37 0.9         | 30 0.8          | <0.001        |
| Organ failure                             | 37 1.2         | 31 0.9         | 29 0.7         | 19 0.5          | <0.001        |
| Organ support                             | 8 0.3          | 2 0.0          | 7 0.2          | 3 0.0           | 0.15          |
| Major bleeding/haematoma                  | 19 0.6         | 19 0.5         | 23 0.6         | 6 0.2           | <0.01         |
| Organ bleeding                            | 14 0.5         | 21 0.6         | 11 0.3         | 11 0.3          | 0.06          |
| Postoperative MI                          | 10 0.3         | 20 0.6         | 14 0.4         | 7 0.2           | 0.10          |
| Contrast reaction                         | 7 0.2          | 10 0.3         | 3 0.0          | 2 0.0           | <0.01         |
| Postoperative infection                   | 5 0.2          | 6 0.2          | 8 0.2          | 3 0.0           | 0.40          |
| Thromboembolism                           | 4 0.1          | 11 0.3         | 2 0.0          | 2 0.0           | <0.05         |
| Emergent surgery                          | 4 0.1          | 2 0.0          | 1 0.0          | 2 0.0           | 0.18          |
| Others                                    | 28 0.9         | 56 1.6         | 43 1.1         | 26 0.7          | 0.06          |
| Death                                     | 166 5.4        | 179 5.1        | 150 3.8        | 113 2.9         | <0.0001       |
| During PCI                                | 41 1.3         | 30 0.9         | 22 0.6         | 16 0.4          | <0.0001       |
| Cardiogenic                               | 34 1.1         | 25 0.7         | 16 0.4         | 16 0.4          | <0.0001       |
| No                                        | 1 0.0          | 1 0.0          | 2 0.0          | 0 0.0           | 0.52          |
| Uncertain                                 | 6 0.2          | 4 0.1          | 4 0.1          | 0 0.0           | <0.05         |
| PCI related                               | 4 0.1          | 1 0.0          | 1 0.0          | 4 0.1           | 0.76          |
| No                                        | 23 0.7         | 15 0.4         | 11 0.3         | 11 0.3          | <0.01         |
| Uncertain                                 | 14 0.5         | 14 0.4         | 10 0.3         | 1 0.0           | <0.001        |
| Post-PCI                                  | 125 4.1        | 149 4.3        | 128 3.2        | 97 2.5          | <0.0001       |
| Cardiogenic                               | 102 3.3        | 108 3.1        | 108 2.7        | 82 2.1          | <0.01         |
| No                                        | 10 0.3         | 22 0.6         | 8 0.2          | 9 0.2           | 0.08          |
| Uncertain                                 | 13 0.4         | 19 0.5         | 12 0.3         | 6 0.2           | <0.05         |
| PCI related                               | 4 0.1          | 5 0.1          | 7 0.2          | 8 0.2           | 0.40          |
| No                                        | 88 2.9         | 120 3.4        | 100 2.5        | 80 2.0          | <0.01         |
| Uncertain                                 | 33 1.1         | 24 0.7         | 21 0.6         | 9 0.2           | <0.0001       |

MI, myocardial infarction; ST, stent thrombosis.
remarkable increase of one-vessel disease and significant decreases of two-vessel and three-vessel diseases in proportions, interventional operators in Chinese military hospitals still treated lower proportion of one-vessel disease and higher proportion of two-vessel disease in 2014 than peers in the USA during 2010–2011 (80.2% vs 86.2% and 15.0% vs 12.8%, respectively). Of note, the proportion of treated vessels involving left main artery (3.4%–4.2%) was significantly higher than proportions reported in the USA during 2010–2011 (1.8%) as well as in Chinese non-military hospitals during 2001–2011 (0.4%–2.1%) in China PEACE study. The facts that considerable amount of grade 0–2 TIMI flow before PCI almost disappeared after PCI suggest high quality of performance of PCI procedures. Especially, compared with data in 2013, higher proportions of grade 0 and 1 TIMI flow before PCI turned to higher proportion of grade 3 TIMI flow after PCI in 2014, suggesting the quality of performance was still improving. The relatively low and decreasing rate of overall complications (1.6% in 2011 to 0.7% in 2014) and death (0.5% in 2011 to 0.3% in 2014) for PCI procedures might be attributable to the decrease of worse cardiac function over time (patients with Killip III–IV grades decreased significantly from 2011 to 2013, online table S3). On the other hand, the consistent low rates are also suggestive of good performance of cardiac intervention on these patients.

Some limitations of this study should be noted. First, the partial revision of the registry form in 2013 has made comparisons of some critical measures impossible during 2011–2014 consecutively. However, the purpose of the necessary revision was to reflect contemporary changes in the practice of cardiac intervention during the study years. And we analysed all critical measures provided they were available. Second, due to the gigantic number of nationwide enrolled patients and limit of sufficient funding and other resources, we only compared the in-hospital outcomes for the patients. However, it is possible to follow-up the long-term outcomes for these patients, given that contact information of most patients were collected. Third, in this study comparisons of data with other studies were not matched exactly both temporally and categorically, as to the best of our knowledge, the same large-scale, nationwide registries of acute coronary syndromes during the same study period were not available. Nevertheless, we believe this study has given an updated and comprehensive overview of contemporary practice of interventional cardiology in military hospitals in China.

CONCLUSION
This study outlined the general profiles of cardiac intervention practice in contemporary military hospital in China. Our data revealed the overall interventional resources were still limited in military hospitals, with great disparities of resources and consumptions in different geographical regions across China, and major gaps still exist in optimal medical coverage for patients with ACS. Other than data from non-military hospitals, our findings can serve as an indispensable addition to a comprehensive overview of the practice of cardiac intervention in China.
General Hospital of PLA General Hospital of Shanxi PAP Corps The 451 Hospital The 3 Hospital The 474 Hospital The 323 Hospital The 273 Hospital The 18 Hospital General Hospital of Ningxia PAP Corps General Hospital of Xinjiang PAP Corps The 1 Hospital Kunming General Hospital of PLA Xingiao Hospital of TMU Southwest Hospital of TMU Daping Hospital of TMU The General Hospital of Chengdu Military Region The 452 Hospital The 59 Hospital Tibet General Hospital of PLA The 324 Hospital The 37 Hospital Chengdu Hospital of Sichuan PAP Corps General Hospital of Sichuan PAP Corps Leshan Hospital of Sichuan PAP Corps

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