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Effect of chest pain center accreditation on timely reperfusion and in-hospital mortality for STEMI in China

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Existing studies in developing countries on the impact of chest pain center (CPC) accreditation on treatment quality have limited ability to demonstrate causal relationships. This retrospective study aims to utilize the data from national-level database and explore the impact of chest pain center certification on the treatment quality of ST-segment elevation myocardial infarction (STEMI) patients through a more appropriate method. At the hospital level, taking timely reperfusion and in-hospital mortality as outcomes, the impact was evaluated using the Counterfactual Synthetic Difference-in-Differences (CS-DID) method, a statistical technique that allows for the estimation of causal effects by comparing the differences over time between treated and non-treated groups. The results showed that CPC accreditation improved timely reperfusion of STEMI. Once a CPC was certified, without considering covariates, the timely reperfusion rate increased on average by 5.4%, the 90-min PCI rate by 7.1%, and the 30-min thrombolysis rate by 2.0% in comparison with non-accredited hospitals, and this effect shows a downward trend over time and varies between different regions. We found no evidence to confirm that CPC accreditation decreases in-hospital mortality in patients with STEMI. CPC accreditation in China has improved the timeliness of reperfusion therapy for STEMI patients. CPC accreditation and re-accreditation are crucial to maintaining high-quality care for STEMI patients.

Keywords Accreditation, Chest pain center, Timely reperfusion, STEMI, CS-DID, Treatment quality

Acute myocardial infarction (AMI) has a high mortality rate[1]. The World Health Organization Monitoring CVD Trends and Determinants Project showed that AMI caused approximately three-quarters of cardiovascular deaths in 37 populations across 21 countries over a 10-year period[2]. AMI is an important problem in China[3], especially ST-segment elevation myocardial infarction (STEMI), which warrants more attention as it typically leads to a larger area of myocardial necrosis. Between 2001 and 2015, the number of patients with STEMI increased steadily in China[4]. With the increase in risk factors and population aging, the number of new myocardial infarctions in China continues to be substantial[5].

STEMI is a type of acute myocardial infarction characterized by significant ST-segment elevation on an electrocardiogram (ECG), typically caused by complete occlusion of a coronary artery. Shortening the interval between symptom onset and opening of the target blood vessel and improving the timely reperfusion rate after ischemia are the keys to treatment of STEMI[5]. Chest pain centers (CPCs) have been established worldwide to enable patients with acute chest pain to be sent to hospitals with treatment capabilities and receive the best treatment possible. However, the early experiences suggested that these centers have not achieved a significant reduction in the timely reperfusion rate for patients with STEMI[6–8]. Therefore, accreditation has been implemented to standardize the development of CPCs[9,10]. Studies suggest that CPC accreditation can shorten the diagnosis time of chest pain diseases, reduce the reperfusion time and readmission rate of patients with STEMI, and lower the treatment cost[11–15].

The Chinese Society of Cardiology initiated CPC accreditation in 2013[16]. However, despite more than ten years having passed since accreditation of the first CPC in China, research on the outcomes of accreditation in patients with STEMI has been limited. The China CPC Quality Control Reports have shown that the door-to-

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wire and door-to-needle times for STEMI have trended downwards, while the 90-min door-to-wire and 30-min door-to-needle compliance rates have been trending upwards[17]. A study that were certified during the Improving Care for Cardiovascular Disease in China-Acute Coronary Syndrome project found that CPC accreditation was associated with better in-hospital outcomes (i.e., major adverse cardiac events and all-cause mortality) in patients with STEMI but that the effect diminished over time[18]. There have also been studies indicating a relationship between CPC accreditation and a shorter door-to-balloon time,[19]. Another study that analyzed data held in the Chinese Hospital Quality Monitoring System suggested that CPC accreditation shortened the hospital stay in patients with STEMI[16].

However, these studies had some limitations. First, most had a single-center design with limited generalizability. Second, the few studies with a multicenter design enrolled patients in accredited CPCs but overlooked the influence of time elapsed since accreditation[17]. Third, some analyzed cross-sectional data, which limited their ability to infer a causal relationship[17]. Finally, none of these studies investigated the effects of year-to-year or regional variations.

The aims of this longitudinal study were to (1) evaluate the impact of CPC accreditation on the timeliness of reperfusion and in-hospital mortality rate in Chinese patients with STEMI and (2) to determine the temporal and spatial changes in specific effect values within the initial accreditation period.

Methods

Data source

The data analyzed in this study were obtained from the Specific Disease Medical Service Quality Management and Control Systems in China[20,21]. The system has served as the receiving platform for a nationwide, web-based, voluntary hospital quality reporting initiative since 2009, with the number of monitored diseases increasing from the initial 6 to 51 over time. It collects retrospective data from hospitals across 31 provinces, autonomous regions, and municipalities in China and has already covered 74% of the country's tertiary hospitals[22]. The system compiles and manages comprehensive data on disease diagnosis and treatment, providing crucial evidence to assess and improve the quality of care. The data collected include patient demographics, comorbidities, diagnostic and treatment procedures, key time points, major in-hospital outcomes, and hospital characteristics. These data were sourced from inpatient medical records, medication charts, discharge summaries, and assessment forms, and were reported by a designated representative from each participating hospital using standardized definitions. Hospital accreditation data were obtained from the China CPC website (https://www.chinacpc.org). The need for ethical approval and informed consent was waived by the Institutional Research Board of Harbin Medical University for this study in view of its observational noninterventional nature and the anonymity of the routine service data analyzed.

Selection of patients and hospitals

Inclusion Criteria for the Study: To be eligible for this study, patients must meet the following criteria: (1) A first diagnosis of STEMI with no contraindications for reperfusion therapy. (2) Clear emergency admission records. (3) Complete key clinical indicators. (4) Complete admission time records. (5) Age of 18 years or older. (6) The hospital must have established a CPC prior to 2015 and must have had PCI capabilities (There are records of patients undergoing PCI.) since 2013. Furthermore, during the study period, the hospital must have at least 20 patients who meet the above criteria each year.

Study design

Considering that the COVID-19 epidemic may have impacted treatment[23,24], the data for 2013–2019 were analyzed. Hospitals that were certified during the study period were defined as the intervention group and those that were not were defined as the control group. Considering that a hospital must operate a CPC for at least 6 months before submitting an application for accreditation and submit 6 months of an acute chest pain care data[25], we took the 6 months before the accreditation date as the intervention time point, which was divided into pre-intervention and post-intervention. This research analyzes by taking the year as the time point. Given that the hospital has at most merely 6 months of the pre-intervention period in the year when the intervention commences, therefore, the year when the accreditation starts is not a "pure" intervention time point. Including the year when the accreditation started was likely to underestimate the influence of CPC accreditation on the main outcome variables. Therefore, we did not include the data for the accreditation year, and CS-DID analysis was used to evaluate the impact of CPC accreditation on reperfusion and in-hospital mortality. Several sensitivity analyses and placebo tests were also performed. All methods were performed in accordance with the relevant guidelines and regulations.

Outcome variables

Timely reperfusion is not only a key measure of effective treatment of STEMI but also an indicator of the quality of treatment, which generally includes percutaneous coronary intervention (PCI) and thrombolysis. The Chinese Society of Cardiology has developed evidence-based guidelines for treatment of STEMI that recommend time targets for reperfusion[26]. Time from diagnosis to wire crossing is recommended to be <90 min for patients presenting at a primary PCI hospital. For patients treated by fibrinolysis, the recommended interval between diagnosis of STEMI and introduction of fibrinolysis is <30 min. In this study, patients were considered to have received timely reperfusion treatment if they underwent either a 90-min PCI or 30-min thrombolysis. In-hospital mortality is an indicator of the quality of care. Due to data limitations, in this study, in-hospital mortality is defined as all-cause death occurring from arrival in the emergency department to discharge. This study focused on the impact of timely reperfusion, specifically PCI within 90 min, thrombolysis within 30 min, and in-hospital mortality in patients with STEMI.

Statistical analysis

Researches suggested that the ability of CPC accreditation to improve the quality of treatment for patients with AMI could be time-dependent[16,18]. Therefore, the CS-DID method developed by Callaway and Sant'anna (2021)[27–30] was used to analyze the data in this study and obtain ATT (Average Treatment Effect on the Treated). CS-DID is a statistical technique used to estimate causal effects by comparing the changes over time between treated and non-treated groups. It is particularly useful for evaluating the impact of policies or interventions, especially in situations where treatment times differ and treatment effects vary across different groups. This method is based on the traditional Difference-in-Differences (DID) approach, combined with synthetic control methods, and addresses some limitations of traditional methods, especially in situations where there are differences in the timing of treatment across units. It can be understood simply as constructing multiple DID analyses by comparing data from several time points after the intervention for different groups (with varying intervention times) against pre-intervention data and control group data. Appropriate methods are then used to weight these effects and assess the significance of the results.

The core idea of the CS-DID method is to divide analysis of DID into three independent steps: (1) determination of policy-relevant categorical causal parameters; (2) aggregation of these parameters to form a summary measure of causal effect; and (3) estimation and inference of the various target parameters. The CS-DID model circumventing the problem of negative two-way-fixed-effects regression weights by avoiding undesirable comparisons between treated units (late vs. early treatment)[31].

The CS-DID model has the following advantages: it can be applied when the timing of treatment varies and the treatment effects vary among groups; it can be used when the parallel trend assumption is met only after adjusting for covariates; it is appropriate for analyzing unbalanced data; and when the sample size is small, the estimated effect is more accurate than that of two-way-fixed-effects regression. While the CS-DID model assumes treatment irreversibility, it was still considered applicable in this study because only the data for the last year for 15 hospitals exceeded the valid accreditation period[27]. Furthermore, CS-DID provides three parameter estimation methods: based on outcome regression, inverse probability weighting and double-robust method respectively. Here, a double-robust approach was used for estimation.

The parallel trend hypothesis is essential for implementation of all DID methods[32], including CS-DID. The parallel trend assumption requires that the change trends of the treatment group and the control group are parallel before the intervention. If this assumption holds, then after the intervention, the difference in changes between the treatment and control groups can be attributed to the effect of the intervention. In parallel trend testing, it is generally done by examining the significance of the regression coefficient of the interaction term between time and group in the regression model. When this regression coefficient is not significant, it indicates that the assumption holds; conversely, if the regression coefficient is significant, it indicates that the assumption is violated, and the CS-DID results may be inaccurate. Here, the Wald chi-square test is used to assess whether the parallel trends assumption is satisfied.

Someone may question whether the change in timely reperfusion reflects other incidental factors. The placebo test addresses this issue by generating random policy hospital and random treat years[33]. Regressions with the same model specification in the principal analysis were repeated. If placebo test regressions remain positive and significant, similar to the principal analysis results, causality is from random factors and does not exist. If the regression coefficient is distributed normally around zero, causality is real[34]. In this study we used two placebo tests, the in-time placebo test and the in-space placebo test. The reliability of the results was assessed by adjusting the intervention time points and randomly assigning treatment methods, respectively.

All analyses were performed using Stata/MP18 software (StataCorp LLC, College Station, TX, USA).

Results

A total of 171 hospitals (involving 52,674 patients) were included in this study. All the hospitals equipped with CPC and having PCI capabilities since the beginning of the study. Among them, 15 hospitals completed the accreditation of the chest pain center in 2015, 30 in 2016, and 61 in 2017. The remaining 65 hospitals did not achieve CPC accreditation during the study period. A total of 42,049 patients received timely reperfusion therapy, including 32,151 who underwent 90-minute PCI, 16,776 who received 30-minute intravenous thrombolysis, and 6,878 who received both treatments. Additionally, 1,010 patients had in-hospital death as their discharge outcome. The procedure of including and excluding research subjects can be seen from Fig. 1.

Baseline characteristics

The main characteristics of hospitals that were considered as covariates included hospital level, university affiliation, ownership status (public or private), and hospital location (eastern, central, northeastern, or western). Considering that some covariates may change, hospital level, university affiliation, and ownership status were taken as the level at the intervention start time. All hospitals were comprehensive rather than specialized. The characteristics of covariates at the hospital level can be seen from Table 1. Although this study was conducted at the hospital level and patient-level covariates were not used in the analysis, patient-level covariates have been provided (See the Supplementary Table S1 online).

Parallel trend test

Table 2 shows the results of the parallel trend tests for the main outcome variables. The results suggest that the parallel trend hypothesis of most analyses was met, with a significance level of $P > 0.05$. However, during the subgroup analysis, all the main outcome variables in the Northeast region did not meet this assumption, with a significance level of $P < 0.01$. Trends of four indicators in hospitals of different groups are shown in Fig. 2.

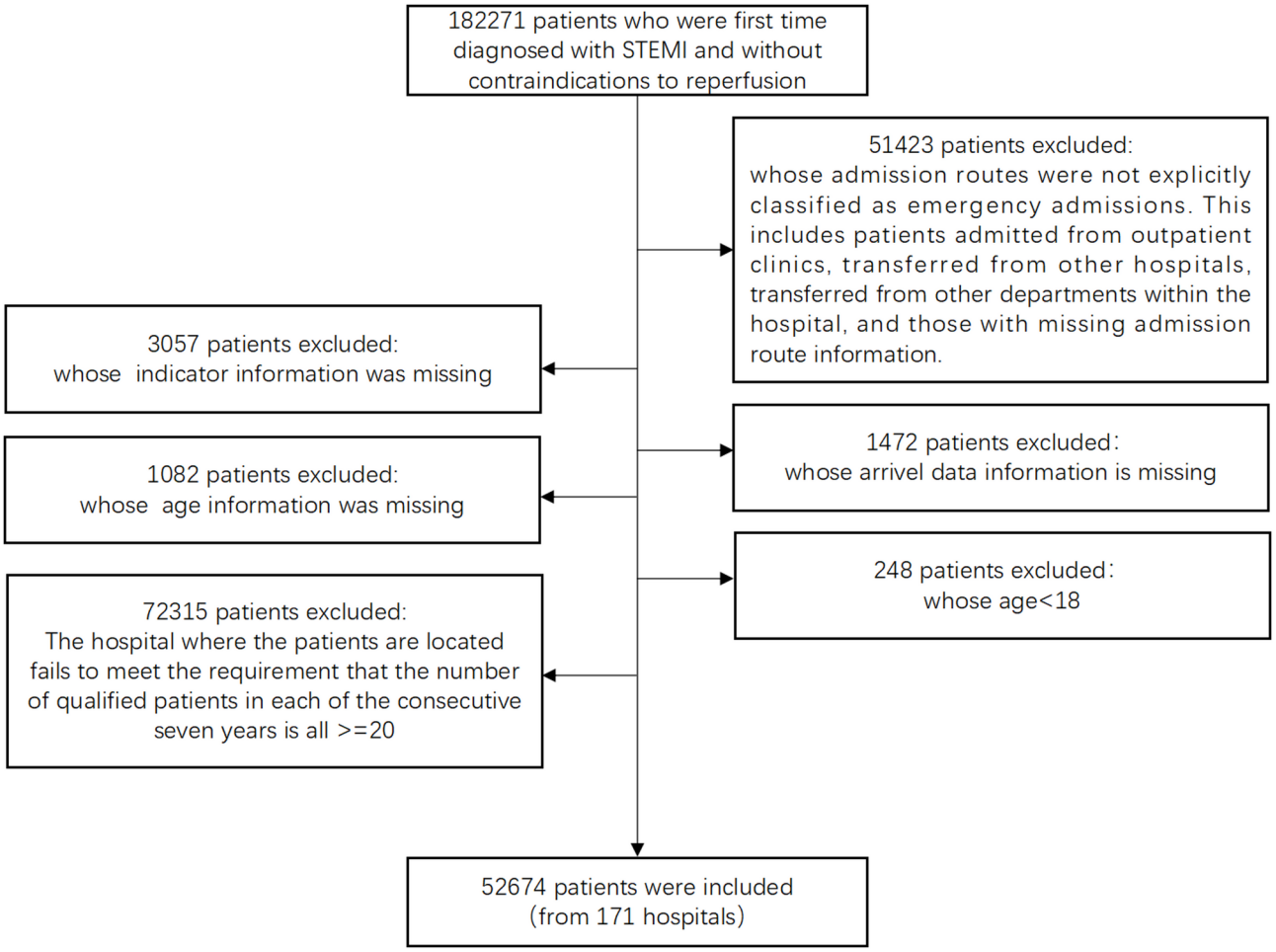

Fig. 1. The procedure of including and excluding patients.

Variable name	Variable value	Non-CPC	CPC	x^2	*p*-value
Level	Level II	13(20.00)	17(16.04)	3.0610	0.0802
	Level III	52(80.00)	89 (83.96)		
University affiliated	No	36(55.38)	56(52.83)	0.7404	0.3895
	Yes	29(44.62)	50(47.17)		
Ownership	Private	2(3.08)	6(5.66)	4.2212	0.0399
	Public	63(96.92)	100(94.34)		
Region	East	27(41.54)	53(50.00)	28.3108	<0.0001
	Central	10(15.38)	22(20.75)		
	Northeast	5(7.69)	8(7.55)		
	West	23(35.38)	23(21.70)		

Table 1. The characteristics of covariates at the hospital level. CPC represents the certified hospitals, and Non-CPC represents the non-certified hospitals.

Principal analysis

Regardless of whether or not the covariates were considered, the effect values for timely reperfusion, 90-min PCI, and 30-min thrombolysis were all statistically significant. After the CPC passed accreditation, without considering the covariates, the hospital reperfusion rate increased on average by 5.44%, the 90-min PCI rate by 7.08%, and the 30-min thrombolysis rate by 2.00% in comparison with unaccredited hospitals (Table 3). Figure 3 shows the scenario for the average treatment effect for the main outcome indicators at each time point. The intervention effect values for the four main indicators were enhanced at the outset of the intervention but gradually diminished as the time progressed. This trend lends support to the assertion that the CS-DID method

Principal analysis				Subgroup analysis							
Covariate circumstances	Indicator	x^2	*p*-value	Region	Indicator	x^2	*p*-value	Region	Indicator	x^2	*p*-value
Without covariates	Timely Reperfusion	3.0166	0.8068	East	Timely Reperfusion	5.5961	0.4699	Northeast	Timely Reperfusion	103.7782	0.0000
	90-min PCI	2.4282	0.8764		90-min PCI	4.2401	0.6442		90-min PCI	27.6615	0.0001
	30-min Thrombolysis	2.3333	0.8866		30-min Thrombolysis	5.1924	0.5194		30-min Thrombolysis	100.4218	0.0000
	In-hospital Death	6.5141	0.3681		In-hospital Death	6.9458	0.3259		In-hospital Death	930.0029	0.0000
With covariates	Timely Reperfusion	3.7028	0.7168	Central	Timely Reperfusion	8.9253	0.1778	West	Timely Reperfusion	3.1306	0.7923
	90-min PCI	6.7202	0.3475		90-min PCI	3.7984	0.7039		90-min PCI	3.3720	0.7609
	30-min Thrombolysis	3.8029	0.7033		30-min Thrombolysis	6.3037	0.3900		30-min Thrombolysis	13.0199	0.0427
	In-hospital Death	6.7507	0.3445		In-hospital Death	7.7300	0.2586		In-hospital Death	7.4928	0.2777

Table 2. Results of the parallel trend test. The subgroup analysis had not taken covariates into account.

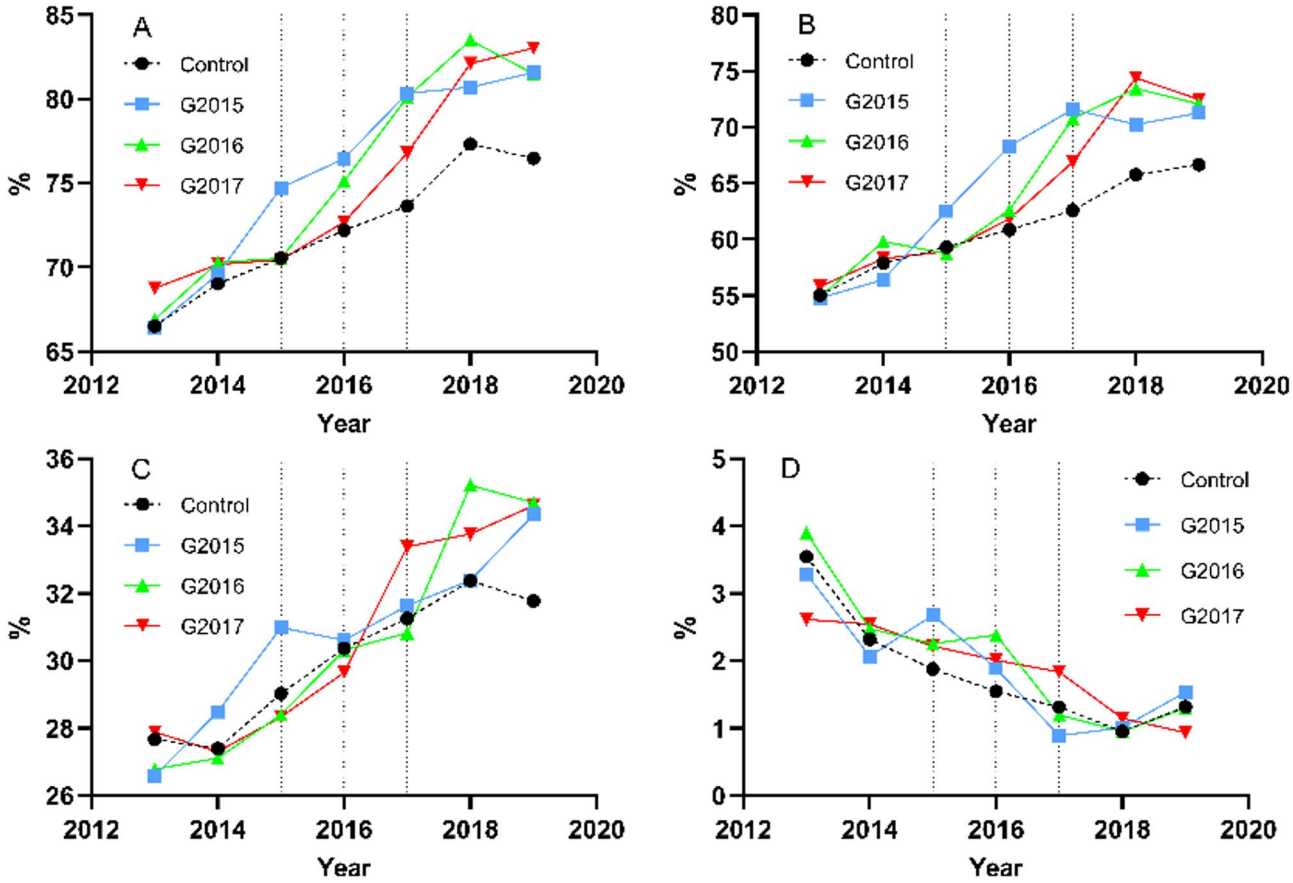

Fig. 2. Trends of four indicators in hospitals of different groups. Remarks: A, B, C and D respectively represent the trends of changes in four indicators: timely reperfusion, 90-min PCI, 30-min thrombolysis and in-hospital mortality. G2015, G2016, and G2017 respectively represent the groups that passed the certification in 2015, 2016, and 2017; Control represents the control group.

of analysis was correct. However, no evidence was found that CPC certification can reduce in-hospital mortality in STEMI patients.

Placebo test

In-time placebo test

We adjusted the data for the time points before intervention forward by 1 year and by 2 years. Analysis was conducted using the data before the real accreditation point. The 95% confidence intervals of the effect values

	Indicator		Coefficient	95% CI	*p*-value		Coefficient	95% CI	*p*-value
Principle analysis	Timely Reperfusion	Without covariates	0.054383	0.0333859 ~ 0.0753801	0.000	With covariates	0.0563286	0.0343244 ~ 0.0783327	0.000
	90-min PCI		0.0708135	0.0478085 ~ 0.0938185	0.000		0.0730321	0.0495426 ~ 0.0965215	0.000
	30-min Thrombolysis		0.0200028	0.0048349 ~ 0.0351707	0.010		0.0187627	0.0027124 ~ 0.0348129	0.022
	In-hospital Death		-0.003227	-0.0098438 ~ 0.0033898	0.339		-0.0018269	-0.0090073 ~ 0.0053536	0.618
Subgroup analysis	Timely Reperfusion	East	0.0516784	0.0195691 ~ 0.0837878	0.002	Northeast	0.0060913	-0.053834 ~ 0.0660167	0.842
	90-min PCI		0.0777339	0.0436433 ~ 0.1118245	0.000		0.0261819	-0.0427227 ~ 0.0950864	0.456
	30-min Thrombolysis		0.0188082	-0.0002896 ~ 0.037906	0.054		-0.000812	-0.0596034 ~ 0.0579795	0.978
	In-hospital Death		-0.0044739	-0.0139647 ~ 0.0050169	0.356		0.0047139	-0.0157826 ~ 0.0252105	0.652
	Timely Reperfusion	Central	0.054208	0.0043433 ~ 0.1064983	0.033	West	0.0764159	0.0383438 ~ 0.114488	0.000
	90-min PCI		0.0742724	0.0169128 ~ 0.131632	0.011		0.0641474	0.0189415 ~ 0.1093533	0.005
	30-min Thrombolysis		0.0093758	-0.0265312 ~ 0.0452828	0.609		0.0387668	0.0038991 ~ 0.0736344	0.029
	In-hospital Death		-0.0105669	-0.0267266 ~ 0.0055927	0.200		0.0001805	-0.0151781 ~ 0.0155391	0.982

Table 3. The influence of CPC accreditation on timely reperfusion and in-hospital death of hospital STEMI patients.

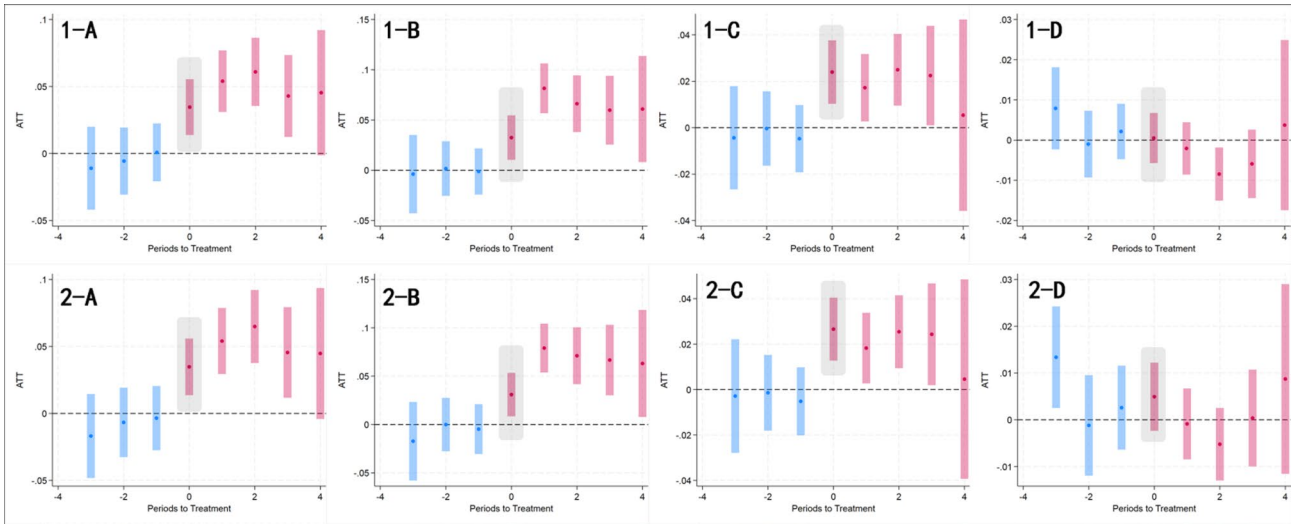

Fig. 3. Effect values of the main outcome indicators at different time points. Remarks: 1 and 2 respectively represent with covariates and without covariates. A, B, C, and D respectively represent timely reperfusion, 90-minute percutaneous coronary intervention (PCI), 30-minute thrombolysis, and in-hospital mortality. For example, "1-A" represents the effect value situation of timely reperfusion at different time points without considering covariates. Blue indicates the situation before intervention, and red indicates the situation after intervention. The horizontal coordinate "Periods" represents time points. "Periods" being 0 represents the effect of the accreditation year. "Periods" < 0 indicates the effect of years before accreditation, and "Periods" > 0 represents the effect of years after accreditation. The effect value at the time point "Periods = 0" is not included in the main analysis and subgroup analysis.

the four main outcome indicators all contained 0, so were not statistically significant, indicating that our results were reliable (See the Supplementary Table S2 online).

In-space placebo test

Using the number of hospitals in the real intervention group as a reference, 106 hospitals were randomly selected as the pseudo-intervention group and the remaining 65 hospitals formed the pseudo-control group. CS-DID analysis was repeated 500 times for the four main outcome indicators. The results suggest that our results for timely reperfusion, 90-min PCI, and 30-min thrombolysis were not accidental; As the result for in-hospital mortality was not an extreme value, which again confirmed that the effect value for in-hospital mortality

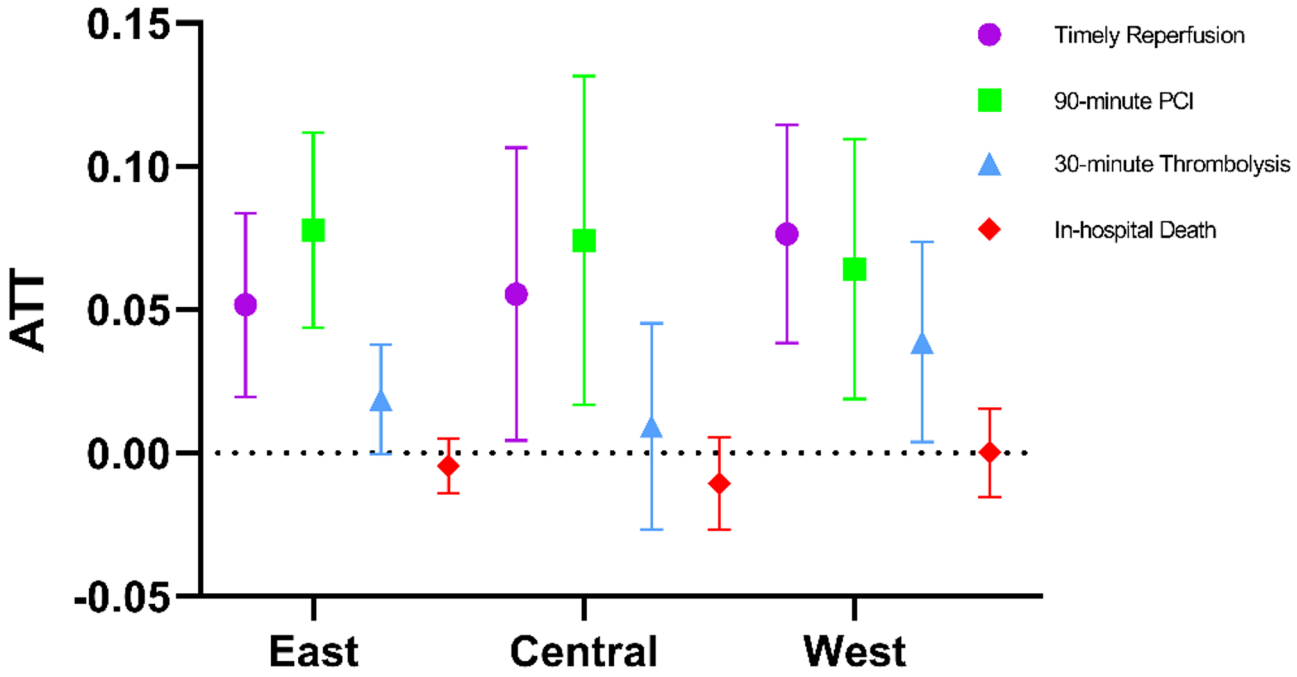

Fig. 4. Effect values of the main outcome indicators after certification in different regions. Remarks: The results of the Northeast region were not trustworthy and were left out of the figure.

was not statistically significant. The results of the placebo test were consistent with the main results (See the Supplementary Fig. S1 online).

Subgroup analysis

We found a statistically significant difference in the geographic distribution of hospitals between the treatment and control groups. Geographic distribution may affect allocation of medical resources and the quality of medical care. The various geographic regions were divided into subgroups to examine the influence of geographic distribution on our results. The results of the Northeast region were not considered trustworthy for the small sample size of hospitals and the failure to meet the parallel trend assumption. The effect value for 30-min thrombolysis in the eastern region was not statistically significant at the 0.05 level but was statistically significant at the 0.10 level. Other results of the subgroup analysis were consistent with those of the principle analysis (Table 3). The effect values for the four indicators in different regions are plotted in Fig. 4. The effect value for timely reperfusion showed a gradually decreasing trend from the west to the east, being highest in the west, followed by the central region, and the lowest in the east.

Sensitivity analyses

Inclusion of data for accreditation year

The CS-DID analysis was repeated after incorporation of the data for the year of accreditation. Regardless of whether covariates ware considered, the results remained stable. Except for the decreased effect values, the effect values of timely reperfusion, 90-min PCI, and 30-min thrombolysis remained statistically significant (See the Supplementary Table S3 online). The changing trend in effect values is shown in Fig. 3.

Change of the control group

We took the hospitals that completed CPC accreditation first as the intervention group, and the corresponding time points for hospitals that completed it later were taken as the control group. The analysis was repeated using the data including the accreditation year. Whether the influence of covariates was considered or not, the effect values for reperfusion and 90-min PCI were both robust. Although the effect value for 30-min thrombolysis was not statistically significant when covariates were not considered, it remained robust after adjustment for covariates (See the Supplementary Table S3 online).

Relaxation of inclusion criteria

The restriction on the number of patients reported at each time point for the target hospitals was relaxed to ≥ 15, which added a further 15,415 patients from 69 other hospitals. The analysis was then repeated. No matter whether the data for accreditation year was included or whether covariate adjustment was performed, the results remained stable. When the data for intervention year were excluded and the test level was relaxed (adjusted to 0.1), the result for in-hospital mortality was statistically significant (See the Supplementary Table S3 online).

Application of other robust methods

In the setting of staggered DID, there are currently three main solutions to the problem of heterogeneity in treatment effect that may obtain more reasonable results[35,36]. The first is to calculate the group-period average treatment effect and then the weighted sum. The CS-DID used in this study fits into this category; there are also the methods of de Chaisemartin & D'Haultfoeuille and Sun & Abraham. The second is to use the imputed estimator to construct counterfactual results for estimation. This solution relies on correct model setting and was used in the studies by Borusyak et al., Liu et al., and Gardner et al. The third solution is the stacked regression estimator method described by Cengiz et al. The methods used by Sun & Abraham and the stacked DID were used in our sensitivity analysis[37,38].

Regardless of whether covariates were considered or not, the significance of timely reperfusion, 90-min PCI, and in-hospital mortality using both methods ware in line with that of the principal analysis. However, the result for 30-min thrombolysis was no longer statistically significant (See the Supplementary Table S3 online).

Discussion

This study analyzed data for patients with STEMI obtained from a nationwide database in China using timeliness of reperfusion and in-hospital mortality as the main outcomes. Hospitals that did not complete CPC accreditation during the study period were used as a control group to explore the impact of CPC accreditation on the quality of hospital-level treatment for STEMI. Considering the heterogeneity of the accreditation time and the time-varying nature of the effect value, the CS-DID method was considered to be a more appropriate method for the statistical analysis[27,39]. We found that CPC accreditation increased the overall level of timely reperfusion by 5.44%, 90-min PCI by 7.08%, and 30-min thrombolysis by 2.00%. However, this benefit weakened over time and showed regional differences. Our study can't provide evidence that CPC accreditation reduces in-hospital mortality risk in STEMI patients.

In our study, the significance of the effect value for 30-min thrombolysis was not as stable as that for 90-min PCI. This result is consistent with a previous report from the USA[11] and may be explained as follows. Several studies have found that PCI is superior to fibrinolytic therapy as a reperfusion strategy for STEMI[40–42], and PCI has become the preferred option for reperfusion. Furthermore, the pre-hospital delay for patients with STEMI is longer in China than in developed countries[43,44]. Most patients miss the optimal period for thrombolysis upon arrival at the hospital, so are treated by PCI or another method. The increased utilization rate of 90-min PCI may be the main reason for our finding that the effect value for 30-min thrombolysis was not as significant as that for 90-min PCI.

Unlike the impact on reperfusion, this study cannot provide evidence that chest pain center accreditation reduces in-hospital mortality risk for STEMI patients. Evidence from developed countries typically indicates that certification significantly reduces in-hospital mortality. For example, a study in the United States showed a 2.1% reduction in-hospital mortality after hospitals underwent certification[15]. However, there is no unified evidence regarding whether this benefit exists in China[45–48]. This might reflect differences in research design and the statistical methods used. Due to data limitations, in-hospital mortality in this study was based on all-cause mortality, which has a lower correlation with timely reperfusion compared to deaths directly caused by other STEMI-related factors. In addition, the CS-DID method used in our study considers both the intervention group and the control group, as well as the pre-intervention and post-intervention periods in both groups, providing a stronger ability to demonstrate causal effects[30].

In this study, the benefits of accreditation decreased gradually with the passage of time since accreditation, which is similar to the findings of Sun et al. and Fan et al.[16,18]. The decreasing focus on improving treatment quality, and the gradual stabilization of resource input[49], and the lack of a continuous supervision mechanism may affect the sustainability of the benefits of accreditation. In addition, other non-accredited hospitals may narrow the gap with accredited hospitals by improving treatment methods and increasing resources. These factors may contribute to the gradual decrease in the benefits after CPC accreditation. This finding provides a reasonable explanation for the three-year validity period limit of the first accreditation and the re-accreditation policy for CPCs in China. However, owing to the involvement of more indicators, it is impossible to give the specific validity period for the first accreditation. We also found that the benefits of accreditation varied by region, being greatest in the west, followed by the central region, and least in the east. This reflects the lack of geographic balance in healthcare improvements in China[50]. In the less economically developed western region, there are fewer medical resources and the quality of hospital care is relatively low[51,52]. Studies have shown that the benefits of medical institution accreditation are more evident in hospitals with lower baseline levels[53,54] In the western region, the increased resource input resulting from accreditation may be the primary reason for this phenomenon, as such resources are typically hard to obtain under normal circumstances. CPC accreditation is more conducive to improving reperfusion rates in hospitals with resource shortages and relatively low quality of care in treating patients with STEMI.

The certification of CPC plays a crucial role in standardizing the diagnosis and treatment of chest pain conditions, reducing the time between symptom onset and treatment, and ensuring that more patients receive timely and standardized care within the therapeutic window. This ultimately enhances the quality of treatment for chest pain diseases. Although the impact of CPC certification on reducing in-hospital mortality for STEMI patients was not significant in this study, it provided evidence that it improves timely reperfusion. Moreover, the study found that the benefits of certification exhibit temporal and spatial variations: (1) over time, these benefits gradually diminish, and (2) the certification effect is more pronounced in economically less developed regions. To further improve the treatment quality for STEMI patients in China, it is crucial to accelerate the development of CPCs, while actively implementing CPC certification and re-certification. This is especially important in the economically underdeveloped western regions, where the benefits of certification are likely to be more pronounced due to the relative scarcity of medical resources.

Limitations

This study had several limitations. First, certification is a voluntary decision made by hospitals, and those that become certified may inherently perform better, which could lead to an overestimation of the certification effect. Second, the retrospective design of this study is less robust for establishing causality compared to prospective studies. However, this study used causal inference methods for data analysis, which strengthens the causal argument more than other retrospective studies. Third, there are relatively few covariates at the hospital level. However, before accreditation, all indicators in both groups met the parallel trends assumption, meaning that covariates likely have minimal influence on the study's findings. Fourth, this study only assessed in-hospital all-cause mortality and lacked follow-up data. Therefore, the impact of CPC accreditation on in-hospital mortality in STEMI patients may have been underestimated, and its effects on long-term outcomes could not be evaluated. Other potential benefits of accreditation may also have been overlooked. Finally, only data for the first-time accreditation validity period was analyzed, so it was impossible to determine changes in the effect value in the long term, which can be further studied in the future.

Conclusion

CPC accreditation in China can improve the timeliness of reperfusion in patients with STEMI. However, the benefits of accreditation decrease over time and show regional variation, being best at present in the western region. CPC accreditation and re-accreditation are necessary to ensure the quality of treatment for patients with acute chest pain such as STEMI. Expanding the coverage of CPC accreditation may narrow the gap in quality of treatment for chest pain between the western region and the eastern and central regions.

Data availability

The data type is anonymized participant data from the Specifc Disease Medical Service Quality Management and Control Systems in China. The data are owned by a third party and the authors are not authorized to share the data. The availability of these data is restricted and the data are used in this study with permission. The data is intended for use by qualifed researchers only and is not to be used for commercial purposes. Confdential data access standards need to be adhered to and written authorization from the licensor is required for re-use of the data. For questions about other additional information, you may contact the frst author or corresponding author of this article [liumeina369@163.com].

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Author contributions

MNL, LY and JKL designed the study. LY was responsible for the analysis mission of the data, and wrote the article together with JKL. MYL and RZG revised it for important intellectual content. QNL and SH provided advice on the first manuscript. CY provided population data for the study. All authors made substantial contributions to the data analysis and interpretation.

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Declarations

Competing interests
The authors declare no competing interests.

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