Intra-aortic balloon pump on in-hospital outcomes of cardiogenic shock: findings from a nationwide registry, China

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Abstract

Aims   The real-world usage of intra-aortic balloon pump (IABP) in various cardiogenic shocks (CS) and the association with outcomes are lacking. We aimed to investigate IABP adoption in CS in a nationwide registry in China.

Methods and results   We retrospectively retrieved data of 30 106 CS patients (age 67.1 ± 14.6 years, 37.6% female patients) in the Hospital Quality Monitoring System registry from 2013 to 2016. Ischaemic heart disease was the leading cause of CS (73.9%). Hypertension, cardiomyopathy, myocarditis, valvular, and congenital heart disease were seen in 36.0%, 7.5%, 2.6%, 7.3%, and 2.4% of the population. IABP was employed in 2320 (7.7%) subjects. The association between IABP usage and primary outcome of in-hospital mortality and secondary outcomes of expenses and lengths of stay were investigated. The patients with IABP support had similar in-hospital mortality to those without IABP (39.6% vs. 38.3%, $P = 0.226$), but longer hospital-stay [8.0 (2.0–16.0) vs. 6.0 (2.0–13.0) days, $P < 0.001$] and higher expenses [7.1(4.4–11.1) vs. 2.3 (0.8–5.5) 10 000RMB, $P < 0.001$]. IABP support was not associated with reduced mortality in the overall CS population in multivariate regression analysis [odds ratio (OR) 1.05, 95% confidence interval (CI) 0.95–1.17], except for subgroups with myocarditis (OR 0.61, 95% CI 0.39–0.95, P for interaction = 0.010) and those who did not receive the early percutaneous coronary intervention (PCI) (OR 0.86, 95% CI 0.75–0.97, P for interaction < 0.001). Similar results were further confirmed in the propensity-score-matched population.

Conclusions   In this nationwide registry of CS patients, IABP was not noted with improved survival but increased healthcare consumption. However, IABP appears protective in those with myocarditis or who failed to receive early PCI.

Introduction

Cardiogenic shock (CS), although constituting less than 1% of the total heart failure burden, is a leading cause of cardiovascular mortality.[1] Because most CS is caused by acute myocardial infarction (AMI), the majority of the data are derived from registries of AMI; only 5–8% of cases in these registries, although, presented with CS.[2–4] The clinical profiles and outcomes of patients with whole spectrum aetiologies of CS are infrequently reported. The intra-aortic balloon pump (IABP) has been the most commonly used mechanical circulatory support for haemodynamic stabilization in patients with CS. However, IABP failed to show benefits in the reduction of infarct size, short-term and long-term morbidity or mortality in large randomized control trials in patients with acute coronary syndrome (ACS), and high risk percutaneous coronary intervention (PCI).[5] The disappointing results led to the down-regulation of the guideline recommendation for

IABP.[6–9] The advent of newer devices such as extracorporeal membrane oxygenation (ECMO) and ventricular assist device also provide more options for circulatory support in modern practice. However, the IABP was still used occasionally in our daily clinical practice in those with CS, as IABP is not only well established for circulatory support but also simplest, easy to implant and explant in the coronary catheterization laboratory. To date, real-world usage of IABP in patients with CS has been largely unknown in China, especially considering the heterogeneous nature of CS and the imbalanced development of medical care across China. The present study attempted to evaluate the characteristics of patients with CS who were admitted with and without the use of IABP and to assess the efficacy of IABP in CS in a nationwide registry database.

Methods

Study database

The Hospital Quality Monitoring System (HQMS) is a mandatory patient-level national database for hospital accreditation, authorized by the National Health Commission of the People's Republic of China. Details of the HQMS database have been previously described.[10] Each HQMS record includes demographic information, up to 10 discharge diagnosis coded with International Classification of Diseases (ICD) codes; interventional and surgical treatment information; and in-hospital outcome information, such as death, length of stay, and total charges. During the study period (1 Jan 2013 to 31 Dec 2016), the database contains over 140 million inpatient discharge records, covering 996 tertiary hospitals. The investigation conforms with the principles outlined in the Declaration of Helsinki. The study was authorized by the HQMS Committee Board and approved by the ethics committee of Peking University First Hospital. As the retrospective nature of the analysis, no informed consent was required.

Study population, variables, and outcomes

Using the HQMS data from 2013 to 2016, a retrospective analysis of admissions including patients > 18 years with the discharge diagnosis of CS (ICD-10 R57.000) or Killip IV (I50.900 × 016) was included. Cases with duplicate records or no available IABP in the hospitals were excluded. Demographic characteristics, underlying heart disease, comorbidities, mechanical support devices usage, and hospital characteristics were identified from the HQMS database. Specifically, the underlying heart disease and comorbidities were defined and retrieved by ICD-10 codes as follows: hypertension (I10–11), diabetes (E10–14), chronic kidney disease (N18–19), chronic obstructive pulmonary disease (J44), stroke (I60–63), and anaemia (D46–64). The primary outcome was in-hospital mortality, and secondary outcomes included lengths of stay and hospitalized expenses, which was also retrieved and confirmed from the HQMS database.

To further clarify the association between IABP usage and the in-hospital outcomes in the CS population, CS subjects with no other shock state (e.g. haemorrhagic shock, hypovolemic shock, septic shock, and allergic shock) coexistent were analysed. In addition, a subanalysis of CS complicated AMI (with Killip IV diagnosis) was conducted.

Statistical analysis

Baseline characteristics were described for the overall population and each treatment group. Categorical variables were described with numbers or percentages. Continuous variables were described with means, standard deviations, medians, and interquartile ranges as appropriate. χ^2 and Student's t-test or Mann–Whitney U-tests were used to compare categorical and continuous variables, respectively. Mixed-effect models were used to control for hospital-related random effects.

Logistic regression was constructed to evaluate the associations between IABP treatment and in-hospital mortality; adjustments were made for age, sex, underlying cardiovascular disease (myocardial infarction, hypertension, cardiomyopathy, myocarditis, valvular heart disease, and congenital heart disease) and comorbidities (diabetes, chronic kidney disease, chronic obstructive pulmonary disease, stroke, and anaemia), mechanical support [early (within 24 h) PCI, ECMO, mechanical ventilation, and continuous renal replacement therapy], hospital type and level, and medical insurance type. We further performed stratified analyses to assess the relationship between IABP usage and in-hospital mortality in various subgroups. P values for interaction were analysed based on a logistic regression model that included IABP treatment together as an interaction variable by two-way interaction tests.

The propensity score for IABP usage was calculated for each patient by a logistic regression model incorporating clinically relevant covariates, such as age, sex, underlying cardiovascular disease and comorbidities, mechanical support, hospital types and levels, and medical insurance type. IABP recipients were matched 1:2 to non-IABP recipients by their propensity scores, using the nearest neighbour method with a calliper of 0.05 and no replacement. The propensity-matched sample had standardized differences $< 10\%$ for all baseline characteristics, which was considered insignificant. Mixed-effect models were then used in the matched data, and a logistic regression model was used for in-hospital mortality as in the overall population.

Two-tailed $P < 0.05$ was considered statistically significant. All statistical analyses were performed using R, Version 3.4.1 (http://www.R-project.org).

Results

Baseline characteristics of patients with cardiogenic shock and stratified by intra-aortic balloon pump usage

In the 4 year period from 2013 to 2016, 30 106 patients diagnosed with CS were screened from the total admissions of the HQMS registry and enrolled into the analysis (*Figure 1*). Baseline characteristics of the overall subjects, patients with and without the use of IABP, are detailed in *Table 1*. In the whole study population, the average age was 67.1 ± 14.6 years, and 37.6% were female patients. Ischaemic heart disease was the leading underlying heart disease (73.9%), and AMI accounted for 56.6% of the patients. Hypertension was seen in 36.0% of the cases. Other potential cardiac aetiologies, such as cardiomyopathy (7.5%), valvular heart disease (7.3%), myocarditis (2.6%), and congenital heart disease (2.4%), were less. The most common comorbidity was diabetes (21.0%), then chronic kidney disease (13.3%), stroke

(8.3%), anaemia (6.5%), and chronic obstructive pulmonary disease (6.3%). IABP was used in 2320 (7.7%) of the CS admissions. Patients receiving IABP were more likely to be young, male gender; have an AMI, hypertension, acute myocarditis, and congenital heart disease as underlying heart disease; and had less comorbidity burden except for diabetes. The procedures were more conducted in tertiary A and specialized hospitals than in other levels or general hospitals (all $P < 0.05$) (*Table 1*).

Invasive procedure or mechanical support usage in CS patients was not common. Although AMI patients constituted more than half of the CS population, early PCI (within 24 h after admission) was conducted in only 13.3% of the CS subjects (23.5% of AMI patients). Patients with IABP received more early PCI procedures than those without IABP (39.0% vs. 11.2%). Mechanical support measures other than IABP were generally less used. Greater rates of ECMO (2.0% vs. 0.2%), mechanical ventilation (10.0% vs. 6.2%), and continuous renal replacement therapy (3.6% vs. 2.0%) were noted in the patients who received IABP than those who did not (*Table 1*).

The propensity score matching identified 5737 patients. The performance of the propensity score model is shown in *Table 1*, depicting baseline characteristics that entered the propensity matching. The post-matching standardized difference < 10% indicates excellent covariate balance.

Figure 1 Flow diagram of selection of the study population. Abbreviations: HQMS, the Hospital Quality Monitoring System; IABP, intra-aortic balloon pump.
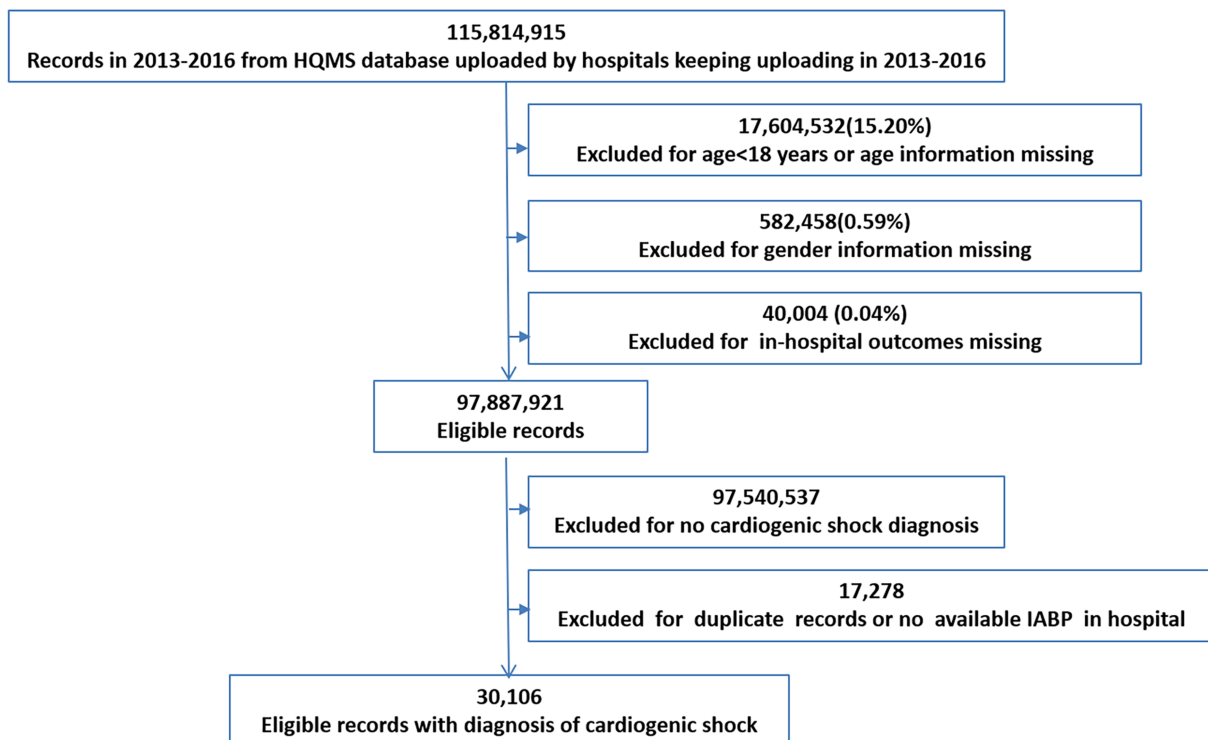
Table 1 Baseline characteristics of the overall cardiogenic shock patients and propensity-score-matched patients stratified by IABP usage

	Whole population				Propensity-score-matched population				
Variable	Overall (N = 30 106)	IABP (N = 2320)	No IABP (N = 27 786)	P value	Overall (N = 5737)	IABP (N = 2027)	No IABP (N = 3710)	P value	Absolute standardized difference
Age, years (mean ± SD)	67.1 ± 14.6	63.3 ± 14.0	67.4 ± 14.6	<0.001	64.2 ± 14.2	63.6 ± 13.9	64.5 ± 14.3	0.020	0.065
Female gender, n (%)	11 314 (37.6%)	702 (30.3%)	10 612 (38.2%)	<0.001	1794 (31.3%)	623 (30.7%)	1171 (31.6%)	0.518	0.018
Underlying cardiovascular disease, n (%)									
IHD	22 244 (73.9%)	2095 (90.3%)	20 149 (72.5%)	<0.001	5204 (90.7%)	1838 (90.7%)	3366 (90.7%)	0.948	0.002
AMI	17 051 (56.6%)	1895 (81.7%)	15 156 (54.5%)	<0.001	4387 (76.5%)	1661 (81.9%)	2726 (73.5%)	<0.001	
Hypertension	10 850 (36.0%)	911 (39.3%)	9939 (35.8%)	0.001	2276 (39.7%)	800 (39.5%)	1476 (39.8%)	0.814	0.006
Cardiomyopathy	2251 (7.5%)	71 (3.1%)	2180 (7.8%)	<0.001	179 (3.1%)	60 (3.0%)	119 (3.2%)	0.606	0.014
Myocarditis	797 (2.6%)	152 (6.6%)	645 (2.3%)	<0.001	338 (5.9%)	118 (5.8%)	220 (5.9%)	0.867	0.005
VHD	2193 (7.3%)	107 (4.6%)	2086 (7.5%)	<0.001	274 (4.8%)	97 (4.8%)	177 (4.8%)	0.980	0.001
CHD	730 (2.4%)	73 (3.1%)	657 (2.4%)	0.019	170 (3.0%)	61 (3.0%)	109 (2.9%)	0.879	0.004
Comorbidities, n (%)									
CKD	4000 (13.3%)	251 (10.8%)	3749 (13.5%)	<0.001	651 (11.3%)	230 (11.3%)	421 (11.3%)	0.999	0.000
Diabetes	6315 (21.0%)	568 (24.5%)	5747 (20.7%)	<0.001	1426 (24.9%)	498 (24.6%)	928 (25.0%)	0.709	0.010
COPD	1907 (6.3%)	62 (2.7%)	1845 (6.6%)	<0.001	164 (2.9%)	58 (2.9%)	106 (2.9%)	0.993	0.000
Stroke	2491 (8.3%)	115 (5.0%)	2376 (8.6%)	<0.001	324 (5.6%)	110 (5.4%)	214 (5.8%)	0.592	0.015
Anaemia	1949 (6.5%)	103 (4.4%)	1846 (6.6%)	<0.001	264 (4.6%)	94 (4.6%)	170 (4.6%)	0.924	0.003
Hospital type, n (%)									
Specialized hospital	1122 (3.7%)	173 (7.5%)	949 (3.4%)	<0.001	425 (7.4%)	159 (7.8%)	266 (7.2%)	0.351	0.026
General hospital	28 984 (96.3%)	2147 (92.5%)	26 837 (96.6%)		5312 (92.6%)	1868 (92.2%)	3444 (92.8%)		
Hospital level, n (%)									
Tertiary level A	25 571 (84.9%)	1998 (86.1%)	23 573 (84.8%)	<0.001	4935 (86.0%)	1747 (86.2%)	3188 (85.9%)	0.782	0.019
Tertiary level B	3025 (10.0%)	118 (5.1%)	2907 (10.5%)		287 (5.0%)	96 (4.7%)	191 (5.1%)		
Other	1510 (5.0%)	204 (8.8%)	1306 (4.7%)		515 (9.0%)	184 (9.1%)	331 (8.9%)		
Treatment modality, n (%)									
Early PCI	4014 (13.3%)	905 (39.0%)	3109 (11.2%)	<0.001	2036 (35.5%)	778 (38.4%)	1258 (33.9%)	0.001	0.093
ECMO	102 (0.3%)	46 (2.0%)	56 (0.2%)	<0.001	63 (1.1%)	30 (1.5%)	33 (0.9%)	0.040	0.055
MV	1948 (6.5%)	231 (10.0%)	1717 (6.2%)	<0.001	590 (10.3%)	216 (10.7%)	374 (10.1%)	0.493	0.019
CRRT	636 (2.1%)	84 (3.6%)	552 (2.0%)	<0.001	197 (3.4%)	70 (3.5%)	127 (3.4%)	0.952	0.002

AMI, acute myocardial infarction; CHD, congenital heart disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CRRT, continuous renal replacement therapy; ECMO, extracorporeal membrane oxygenation; IHD, ischemic heart disease; IABP, intra-aortic balloon pump; MV, mechanical ventilation; PCI, percutaneous coronary intervention; SD, standard deviation; VHD, valvular heart disease.

The in-hospital outcome of cardiogenic shock and the association with intra-aortic balloon pump usage

All-cause death occurred in 11 572 (38.4%) of patients with CS during hospitalization. The subjects with IABP support had similar in-hospital mortality to those without IABP (39.6% vs. 38.3%, $P = 0.226$) but longer hospital-stay [8.0 (2.0–16.0) vs. 6.0 (2.0–13.0) days, $P < 0.001$] and higher expenses [7.1 (4.4–11.1) vs. 2.3 (0.8–5.5) 10 000¥, $P < 0.001$] (*Table 2*). In a multivariate model adjusting for age, sex, underlying cardiovascular disease and comorbidities, mechanical support, hospital type and level, and medical insurance type, the IABP usage showed no significant association with improved in-hospital mortality [odds ratio (OR) 1.05, 95% confidence interval (CI) 0.95–1.17].

After propensity matching for baseline variables, the results observed in the overall population was further confirmed in this propensity score-matched sample. The in-hospital mortality was 40.0% in the IABP group vs. 39.1% in the control group ($P = 0.505$). The hospital-stay and expenses were [8.0 (2.0–16.0) vs. 7.0 (2.0–14.0) days, $P = 0.002$] and [7.1 (4.4–11.1) vs. 4.4 (1.7–7.7) 10 000¥, $P < 0.001$] for patients with and without IABP, respectively (*Table 2*). In the multivariate model, the use of IABP was still not suggestive for improved in-hospital mortality (propensity-adjusted OR 1.09, 95% CI 0.96–1.23).

Subgroup analysis

Stratification and interaction analyses were performed based on important baseline information in the whole study population (*Figure 2*). IABP usage was not associated with a reduced risk of mortality in most of the subgroups. Interactions were found between subgroups of patients who did and did not receive early PCI and between patients with and without myocarditis. Subjects who did not undergo early PCI benefited from IABP (OR 0.86, 95% CI 0.75–0.97), while those who received early PCI did not (OR 1.60, 95% CI 1.34–1.90, $P < 0.001$ for interaction). The protective effect of IABP was also observed in patients with myocarditis (OR 0.61, 95% CI 0.39–0.95) but not for patients without myocarditis (OR 1.09, 95% CI 0.98–1.21, $P = 0.010$ for interaction) (*Figure 2*).
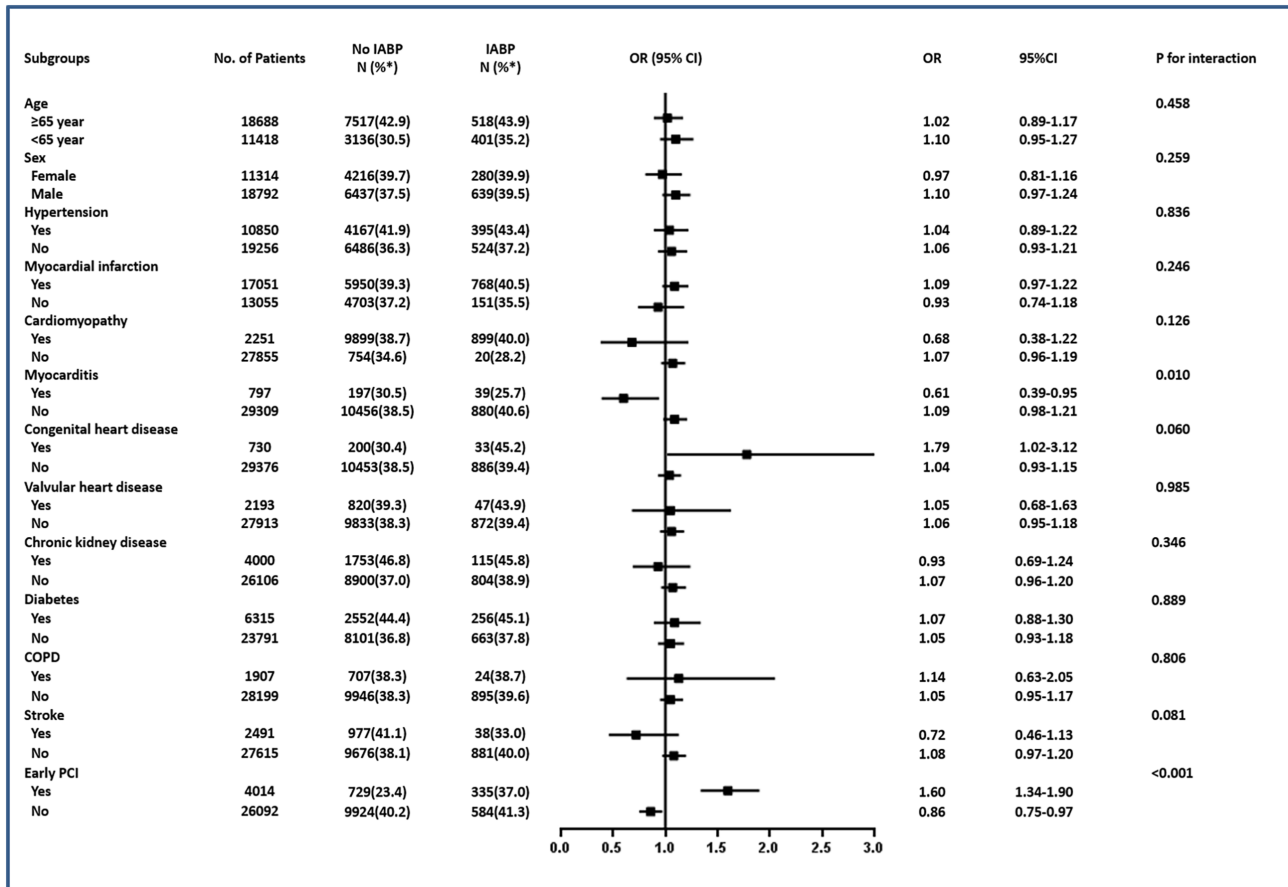
Supplementary analysis

In further analysis of our study population, less than 5% of patients [$n = 1465$ (4.9%)] in our study population had a shock state other than CS. We have also supplemented the analysis excluding those with mixed shocks. The main results were consistent with the original research (*Data S1*, 1).

Table 2 In-hospital outcomes of the cardiogenic shock patients and stratified by IABP usage

Variable	Whole population				Propensity-score-matched population			
	Overall (N = 30 106)	IABP (N = 2320)	No IABP (N = 27 786)	P value	Overall (N = 5737)	IABP (N = 2027)	No IABP (N = 3710)	P value
In-hospital outcome								
All-cause death, n (%)	11 572 (38.4%)	919 (39.6%)	10 653 (38.3%)	0.226	2262 (39.4%)	811 (40.0%)	1451 (39.1%)	0.505
Length of stay, days, median (IQR)	6.0 (2.0–14.0)	8.0 (2.0–16.0)	6.0 (2.0–13.0)	<0.001	7.0 (2.0–15.0)	8.0 (2.0–16.0)	7.0 (2.0–14.0)	0.002
Expenses, 10 000¥, median (IQR)	2.6 (0.9–6.1)	7.1 (4.4–11.1)	2.3 (0.8–5.5)	<0.001	5.3 (2.5–9.1)	7.1 (4.4–11.1)	4.4 (1.7–7.7)	<0.001

IABP, intra-aortic balloon pump; IQR, interquartile range; SD, standard deviation.

Figure 2 Interaction analyses for in-hospital mortality of the whole study population. Abbreviations: CI, confidence interval; COPD, chronic obstructive pulmonary disease; IABP, intra-aortic balloon pump; OR, odds ratio; PCI, percutaneous coronary intervention. *in-hospital mortality.

Subgroups	No. of Patients	No IABP N (%*)	IABP N (%*)	OR (95% CI)	OR	95%CI	P for interaction
Age							0.458
≥65 year	18688	7517(42.9)	518(43.9)		1.02	0.89-1.17	
<65 year	11418	3136(30.5)	401(35.2)		1.10	0.95-1.27	
Sex							0.259
Female	11314	4216(39.7)	280(39.9)		0.97	0.81-1.16	
Male	18792	6437(37.5)	639(39.5)		1.10	0.97-1.24	
Hypertension							0.836
Yes	10850	4167(41.9)	395(43.4)		1.04	0.89-1.22	
No	19256	6486(36.3)	524(37.2)		1.06	0.93-1.21	
Myocardial infarction							0.246
Yes	17051	5950(39.3)	768(40.5)		1.09	0.97-1.22	
No	13055	4703(37.2)	151(35.5)		0.93	0.74-1.18	
Cardiomyopathy							0.126
Yes	2251	9899(38.7)	899(40.0)		0.68	0.38-1.22	
No	27855	754(34.6)	20(28.2)		1.07	0.96-1.19	
Myocarditis							0.010
Yes	797	197(30.5)	39(25.7)		0.61	0.39-0.95	
No	29309	10456(38.5)	880(40.6)		1.09	0.98-1.21	
Congenital heart disease							0.060
Yes	730	200(30.4)	33(45.2)		1.79	1.02-3.12	
No	29376	10453(38.5)	886(39.4)		1.04	0.93-1.15	
Valvular heart disease							0.985
Yes	2193	820(39.3)	47(43.9)		1.05	0.68-1.63	
No	27913	9833(38.3)	872(39.4)		1.06	0.95-1.18	
Chronic kidney disease							0.346
Yes	4000	1753(46.8)	115(45.8)		0.93	0.69-1.24	
No	26106	8900(37.0)	804(38.9)		1.07	0.96-1.20	
Diabetes							0.889
Yes	6315	2552(44.4)	256(45.1)		1.07	0.88-1.30	
No	23791	8101(36.8)	663(37.8)		1.05	0.93-1.18	
COPD							0.806
Yes	1907	707(38.3)	24(38.7)		1.14	0.63-2.05	
No	28199	9946(38.3)	895(39.6)		1.05	0.95-1.17	
Stroke							0.081
Yes	2491	977(41.1)	38(33.0)		0.72	0.46-1.13	
No	27615	9676(38.1)	881(40.0)		1.08	0.97-1.20	
Early PCI							<0.001
Yes	4014	729(23.4)	335(37.0)		1.60	1.34-1.90	
No	26092	9924(40.2)	584(41.3)		0.86	0.75-0.97	

Further analysis for subgroups of CS patients with AMI was conducted. The conclusion drawn in the subgroup of CS patients complicated with AMI was consistent with the general CS population, as well as earlier research reports. No survival benefit was obtained from IABP support, yet early PCI showed a favourite effect for CS patients with AMI (*Data S1*, 2).

CS Patients with myocarditis consumed the most interventional support modalities while achieved the lowest in-hospital mortality among CS patients with various underlying heart disease (*Data S1*, 3).

Discussion

By access to a large real-world population with CS, we demonstrated that the usage of IABP was not associated with increased survival but with a longer hospital stay and higher costs. However, the survival benefit was observed in some subgroups of patients.

Cardiogenic shock is a severe state of cardiac dysfunction, often resulting in high in-hospital mortality. AMI with ventricular dysfunction and/or mechanical complications are the most common cause of CS. Non-AMI-related CS may be caused by decompensated heart failure with heterogeneous underlying heart disease. In prior studies, IABP-SHOCK II is the largest randomized trial in CS, yet only patients with MI were included.[11] Contemporary data on CS patients with varied aetiologies are lacking.[12] The CardShock study[12] is the largest European prospective, multicentre observational study including the whole spectrum of aetiologies of CS. ST-segment elevation myocardial infarction and other forms of ACS are still the leading causes of CS, and ST-segment elevation myocardial infarction patients accounted for 68% of all patients.[12] Furthermore, four-fifth of those CS subjects had ACS.[12] In our study population by access to national register database in China, despite AMI accounted for more than half of the patients, the proportions of ischemic heart disease were much lower than in the aforementioned cohorts, representing comprehensive aetiology of CS in our real-world clinical settings.

Our findings were mostly in line with earlier reports, showing the usage of IABP generally could not lead to a better in-hospital prognosis in CS patients. The primary outcome was consistent across most subgroups with diverse demographic and clinical characteristics, with only two notable exceptions. First of all, there was a significant interaction between IABP support and early PCI usage. This was supported by our data from the whole population and the subgroup of CS complicated with AMI. Patients who had not received early PCI had significantly lower mortality with IABP support than those without, whereas patients who had undergone early PCI had even further elevated mortality with IABP support. In fact, one of the controversies about the usefulness of IABP in most of the prior investigations has arisen from the failure of taking into account the revascularization manners for AMI.[13] For example, a significant benefit of IABP was seen in patients who did not receive revascularization or thrombolysis as reperfusion treatment in the IABP-Shock II trial,[11] in which a neutral result of the primary outcome was found in the whole population. Multiple observatory studies and adjusted meta-analysis, on the contrary, demonstrated the effect of IABP on in-hospital mortality was significantly in disfavour in the PCI subgroup.[13,14] The lack of efficacy of IABP might well result from the minimal add-on effect after salvage of the ischemic myocardium by successful reperfusion. Indeed, because the landmark SHOCK trial established the role of early revascularization in AMI patients with shock,[15] primary PCI was recommended as the first-line management of AMI complicated with CS[7,16] owing to its significant survival benefit. Moreover, data from the studies focusing on the time course of CS indicate that percutaneous mechanical cardiac support has a limited ability to change the outcome if initiated when overt multi-organ dysfunction has already occurred. The prognosis could only be improved when cardiac support was initiated early in the disease course (e.g. before reperfusion).[17] Therefore, IABP could act as a bridge while waiting for PCI, or supplementary support when CS patients could not receive reperfusion or are not fit for timely or sufficient reperfusion. If the early revascularization could be achieved, IABP should not be routinely used, especially considering the possible delay to reperfusion for IABP implantation.

Notably, one of the significant differences between earlier studies and ours lies in the percentage of patients undergoing early PCI. Even in the CARDShock study that enrolled all-cause CS, nearly 90% of the CS patients with ACS underwent PCI.[12] In contrast, early PCI was conducted in only 13.3% of our CS population (23.5% of AMI patients). Total PCI were conducted in less than 30% of our CS patients complicated with MI. The results were consistent with contemporary data on MI patients[18,19] and might reflect the more conservative strategies for CS patients in our population or delayed reperfusion to some extent. Further national efforts are needed to improve the care for CS patients with MI

considering the gaps between guidelines and our practice. Meanwhile, early PCI was more often undergone in patients with IABP (39.0%) than in patients without IABP (11.2%). The combinational usages of IABP and early PCI might be because of the beliefs of the doctors performing the PCI. This is, however, not supported by our findings as a combination could not result in better outcomes rather than contributing to the higher total expenses and longer hospital stay.

Intra-aortic balloon pump usage was also observed to have different impacts on subgroups of patients with and without myocarditis as underlying heart disease. CS patients with myocarditis got protection from in-hospital death with IABP support. The findings are noteworthy as prior studies regarding CS with causes other than AMI were scarce. IABP therapy has been suggested leading to clinical stabilization and improved tissue perfusion in CS in some small, single-centre studies and registries,[20–23] serving as a bridge to ventricular assist device implantation or heart transplantation. Compared with other decompensated heart failure, patients with fulminant myocarditis might be more likely to experience acute deterioration processes with the overall self-limited course. Therefore, temporary aggressive mechanical cardiac support might be more effective in providing help to the patients to live through the critical stage. In line with this, the CS patients with myocarditis in our study population consumed the most mechanical support devices while showed the lowest in-hospital mortality in comparison to CS patients with other causes (*Data S1*, 3). The various supportive measures demonstrated the efficacy in this subgroup of subjects.

Finally, despite advances in the management of CS worldwide, the mortality in this population has remained high at 30% to 40%.[24,25] Although mortality as well as other outcomes between our study and the prior studies cannot be directly compared due to the different study populations and definition of endpoint events, the overall in-hospital mortality of 38.4% in our study population was consistent with earlier studies. And these data were achieved with fewer early PCI procedures employed in MI patients while PCI was demonstrated with significant survival benefits. As critical salvage for MI patients complicated with CS, early PCI should be more stressed and be put effort into our future practice. And as the subgroup analysis has shown, further stratification on subjects with different aetiologies and intervention manners, and planning for optimal timing in the usage of IABP might also provide valuable help for CS patients.

Limitations

The present study was a retrospective registry study, and the identification of the diagnosis was based on the ICD-10 code, in which inherent ascertain bias exists. Due to the data extraction process and the heterogeneous nature of heart

failure, there might be multiple diagnoses of underlying heart disease in one subject identified, leading to overlapped diagnoses, which might be assumed both as potential aetiologies of CS. Meanwhile, the diagnosis of AMI, as the most common cause of CS, was definite. A more precise evaluation of the severity of CS and the impacts of medical treatment (e.g. vasoactive agents) were difficult because the detailed information on laboratory results and medications were unavailable. However, the report of the invasive interventions, as well as the endpoint events (including in-hospital mortality, hospital stay and expenses), were accurate.

Conclusions

Intra-aortic balloon pump is currently used in less than 10% of patients with CS in this nationwide registry. Patients receiving IABP had no reduction for in-hospital mortality but longer length-of-stay and higher hospital expenses in general. However, in selected subgroups such as AMI patients who did not receive early PCI and patients with myocarditis, IABP showed protective results. Further research is warranted to determine the optimal patient populations, clinical characteristics, and timing for IABP as the simplest circulatory support to improve clinical outcomes of this high-risk population.

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Conflict of interest

None.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Data S1. Supplementary files.
1. Analysis for CS patients excluding those with other shocks.
Table S1. Baseline characteristics of the cardiogenic shock patients with no other shock co-existed and stratified by IABP usage.
Table S2. In-hospital outcomes of the CS patients with no other shock co-existed and stratified by IABP usage.
Table S3. The association between IABP usage and in-hospital mortality of CS patients with no other shock co-existed assessed by multi-variate regression.
Figure S1. Interaction analyses for in-hospital mortality of the CS patients with no other shock co-existed.
2. Analysis for subgroups of CS patients with AMI.
Table S1. Baseline characteristics of the CS patients with AMI and stratified by IABP usage.
Table S2. In-hospital outcomes of the CS patients with AMI and stratified by IABP usage.
Table S3. The association between IABP usage and in-hospital mortality assessed by multi-variate regression.
Table S4. Interaction analysis for In-hospital mortality of the CS with AMI patients stratified by early PCI.
3. Comparison of mechanical support modalities and in-hospital outcomes for CS patients with myocarditis and other underlying heart diseases.
Table S1. Mechanical support usage of CS patients with different underlying heart disease.
Table S2. In-hospital outcomes of CS patients with different underlying heart disease.

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