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Research Paper

Comparative analysis of cardiogenic shock outcomes in acute myocardial infarction with polyvascular disease

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ABSTRACT

Background: Cardiogenic shock (CS) is the leading cause of mortality in acute myocardial infarction (AMI) patients, especially in those with vascular disease. This study aimed to assess the association between extent of polyvascular disease and the in hospital management and outcome of patients with AMI-induced CS.
Method: Using the National Inpatient Sample from 2016 to 2019, adult patients with AMI and CS with known vascular disease were identified and stratified by number of diseased vascular beds and into STEMI and NSTEMI subgroups. The study assessed in-hospital major adverse cardiovascular and cerebrovascular events (MACCE), mortality, acute CVA and major bleeding, as well as invasive management by number of diseased vascular beds.
Results: Out of 136,245 patients, 57.9 % attributed to STEMI and 42.1 % to NSTEMI. The study revealed that the likelihood of percutaneous coronary intervention (PCI) [(aOR for 2 beds 0.94, CI 0.91–0.96, p-value < 0.001; 3 beds 1.0, CI 0.94–1.06, p-value 0.96)] and coronary artery bypass grafting (CABG) [(aOR for 2 beds 0.66, CI 0.64–0.69, p-value < 0.001; 3 beds 0.76, CI 0.71–0.81, p-value < 0.001)] decreased as the number of diseased vascular sites increased. The study also highlighted a direct dose-response relationship between the number of diseased vascular beds and major adverse outcomes, including MACCE, mortality and acute CVA, underscoring the prognostic significance of polyvascular disease in this patient population.
Conclusion: The study demonstrated that polyvascular disease significantly worsens AMI-induced CS outcomes. The findings highlight the importance of early identification and aggressive management of polyvascular disease in these patients. Further research is needed to develop targeted treatment strategies for this high-risk population.

1. Introduction

Despite advances in treatment, cardiogenic shock is the leading cause of death in patients with acute myocardial infarction (AMI) with a 30-day mortality rate of approximately 40 % and a 1-year mortality rate of 50 % [1]. Recent studies indicate that even in non-acute myocardial infarction patients, the mortality rate associated with cardiogenic shock remains high ranging between of 35 % to 60 % [2].

Poly-vascular disease defined as the presence of atherosclerosis in two or more major arterial beds. Previous studies among patients with diabetes demonstrated increase in the long term risk of MACE with the number of diseased vascular beds [3,4]. A recent global registry study among patients undergoing PCI reported an incremental increase of one year risk of target lesion failure and MACE with the number of diseased vascular beds [5]. Among patients admitted with AMI, an analysis of the nationwide inpatient sample revealed that the odds of major adverse cardiovascular and cerebrovascular events (MACCE), mortality, ischemic stroke, and major bleeding incrementally increased with the number of diseased vascular beds involved [6].

While the association of vascular disease with worse outcomes in patients with AMI and CS is well established [7], data on the impact of the extent of the vascular disease are limited. Therefore, the study aims

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to explore the diagnostic and prognostic implications of the extent of polyvascular disease in AMI patients with CS, seeking to improve management strategies and patient outcomes in this high-risk population.

2. Methods

2.1. Data source

The National Inpatient Sample (NIS), which has been available since 1988, is one of the largest publicly available all-payer inpatient healthcare databases in the United States. It contains data from around 7 million hospital stays each year, which approximates a 20 % stratified sample of all discharges from U.S. community hospitals, excluding rehabilitation and long-term acute care hospitals. The NIS is part of the Healthcare Cost and Utilization Project (HCUP) and it intends to produce U.S. regional and national estimates of inpatient utilization, access, cost, quality, and outcomes [8].

2.2. Study design and population

In this retrospective study, we conducted a comprehensive analysis of adult patients (aged ≥18 years) hospitalized between 2016 and 2019 with a diagnosis of acute myocardial infarction (AMI) and cardiogenic shock (CS), who also had a history of previously known vascular disease. The study population was divided into two distinct cohorts based on their primary diagnosis upon hospital admission. The first cohort consisted of patients whose primary diagnosis was AMI, and the second cohort comprised patients primarily diagnosed with CS. These patients were chosen based on the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) diagnosis codes that were implemented in 2016 which provided more granular data as opposed to the previous ICD-9 coding. Table S4 provided the ICD – 10 codes of the patient and procedural characteristics. Patient demographics were recorded for each hospital discharge including age, gender, race, admission day (weekday or weekend), expected primary payer and median household income according to ZIP code.

Missing data on age, gender, elective and weekend admission, and mortality status were excluded from the analysis (Fig. 1 for study flow diagram). Also, patients with type 2 MI or elective admissions were excluded from analysis. Each discharge record contained data on up to

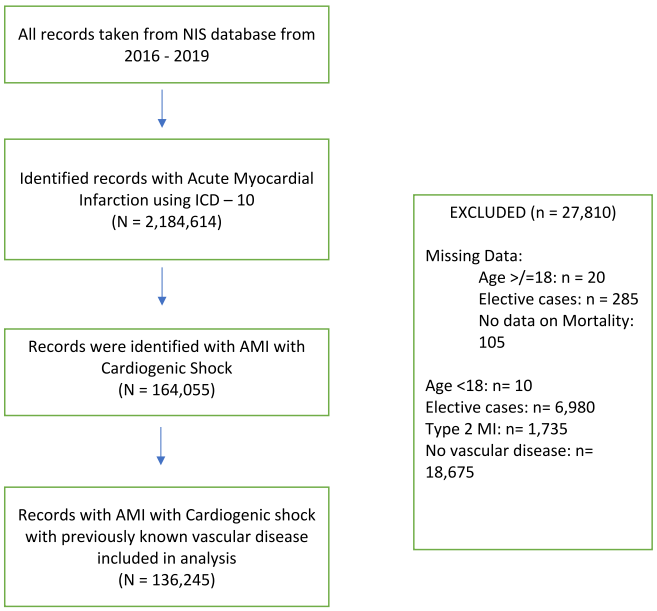

Fig. 1. Flow diagram.

30 diagnoses. Vascular disease was defined as a comprised ischemic heart disease, cerebrovascular disease (including carotid artery stenosis), renal disease (excluding nephrotic syndrome and chronic renal calculus), aortic disease and peripheral vascular disease of extremities [5]. In this study, a "vascular bed" is defined based on the presence of vascular disease, with one vascular bed corresponding to one type of vascular disease, two vascular beds to two types, and so on. A full list of ICD 10-CM codes used to identify vascular disease is provided in Supplementary Table S4. ICD 10-CM codes were also used to classify complications and procedural information during hospitalization including coronary angiography, percutaneous coronary intervention (PCI), coronary artery bypass graft (CABG), thrombolysis, use of mechanical ventilation and circulatory support (inc. IABP, LV assist device and ECMO).

Patients were further stratified based on the number of vascular beds affected, and an analysis was conducted for patients with STEMI and NSTEMI. This allowed for a more detailed comparison and understanding of the disease progression and outcomes in these specific patient groups.

2.3. Outcomes

The main outcomes assessed included in-hospital adverse events, including major adverse cardiovascular and cerebrovascular events (MACCE), all-cause mortality, acute ischemic cerebrovascular accident (CVA) and major bleeding. MACCE was characterized as a composite of all-cause mortality, acute ischemic CVA or transient ischemic attack and cardiac complications. Cardiac complications included coronary artery dissection, pericardial effusion (including tamponade), Dressler's syndrome, post MI angina, intracardiac thrombus and acute mechanical complications. Major bleeding was defined as a collection of gastrointestinal, retroperitoneal, intracranial, and intracerebral hemorrhage, periprocedural hemorrhage, unspecified hemorrhage, or needing blood transfusion. Additionally, the participants' receipt of invasive management procedures such as coronary angiography (CA), PCI and CABG were also measured.

2.4. Statistical analysis

Statistical analysis was performed on IBM SPSS version 25. Continuous variables were presented as median and interquartile range, due to skewed data, and categorical data were presented as frequencies and percentages. Categorical variables were compared using Pearson's chi square test, while continuous variables were compared using the *t*-test or the Kruskal Wallis test, as appropriate. Sampling weights were used to calculate the estimated total discharges as specified by AHRQ. Multivariable logistic regression models were used to examine the association between in-hospital outcomes and number as well as site of diseased vascular bed, expressed as odds ratios (OR) with corresponding 95 % confidence intervals (CI). All models were adjusted for baseline differences between the groups, controlling for the following covariates: age, gender, weekend admission, hospital bed size, region and location/teaching status, ST-elevation myocardial infarction, CABG, PCI, CA, circulatory support (inc. IABP, LV assist device and ECMO), ventricular fibrillation (VF), ventricular tachycardia (VT), atrial fibrillation, heart failure, hypertension, diabetes mellitus, valvular heart disease, smoking status, chronic liver disease, anemia, thrombocytopenia, coagulopathies, and malignancies.

3. Results

In the study, records of 164,055 patients were identified with acute myocardial infarction (AMI) with cardiogenic shock, encompassing those with or without previously known vascular disease. From this group, a total of 136,245 patients (83.1 %) with pre-existing vascular disease were included in the detailed analysis; among them, 57.9 % were

cases of STEMI, and 42.1 % were NSTEMI.

Baseline characteristics of patients with 1, 2 or ≥3 pre-existent diseased vascular beds are shown in Table 1. The mean age shows a statistically significant progressive increase, from 67.23 years for patients with one diseased vascular bed, to 70.42 years for those with two diseased beds, and 72.01 years for those with three or more diseased beds ($p < 0.001$). A statistically significant progressive increase is seen in the proportion of females as the number of diseased vascular beds increases, from 33.1 % in the group with one bed, to 35.1 % with two beds, and 37.9 % with three or more beds ($p < 0.001$). Additionally, the proportion of Black patients and Medicare insured patients increases with the number of diseased vascular beds. The data also reveals a higher burden of comorbidities such as heart failure, valvular heart disease, atrial flutter/fibrillation, hypertension, smoking, dementia, chronic kidney disease, obesity, anemia, chronic liver disease, intracerebral hemorrhage, and solid malignancy in groups with more diseased vascular beds, with a *p*-value of <0.001. On the other hand, the likelihood of diabetes, thrombocytopenia and coagulopathy decreases as the number of diseased vascular beds increases, with a *p*-value of <0.001. In addition, the probability of patients having ST-elevation MI, cardiac arrest, VT and VF decreases as the number of diseased vascular beds increases, with a p-value of <0.001.

Table 1
Stratification of patient demographics, hospital record characteristics, and comorbidities based on the number of involved vascular beds.

	Number of involved vascular beds			
	1	2	≥3	P-value
NIS discharge weight	97,105	32,985	6155	
Mean age	67.23	70.42	72.01	<0.001
Female, %	33.1 %	35.1 %	37.9 %	<0.001
Ethnicity				<0.001
White	74.4 %	69.5 %	69.6 %	
Black	7.8 %	11.4 %	11.6 %	
Hispanic	9.4 %	10.2 %	10.4 %	
Asian	3.8 %	4.3 %	4.3 %	
Native	0.7 %	0.7 %	0.8 %	
Other	3.9 %	3.9 %	3.3 %	
Hospital region				<0.001
Northeast	15.9 %	14.7 %	13.3 %	
Midwest or North Central	22.3 %	22.9 %	24.4 %	
South	39.6 %	40.0 %	36.9 %	
West	22.2 %	22.4 %	25.4 %	
Hospital bed size				<0.001
Small	13.4 %	13.5 %	13.2 %	
Medium	28.0 %	27.5 %	26.8 %	
Large	58.6 %	59.1 %	60.0 %	
Hospital location/teaching status				<0.001
Rural	4.4 %	3.9 %	3.4 %	
Urban non-teaching	20.3 %	17.7 %	21.6 %	
Teaching	75.4 %	78.4 %	75 %	
Median ZIP income				<0.001
1st quartile	28.6 %	30.8 %	27.1 %	
2nd quartile	27.0 %	26.7 %	28.5 %	
3rd quartile	24.2 %	23.9 %	23.8 %	
4th quartile	20.2 %	18.6 %	20.7 %	
Primary expected payer				<0.001
Medicare	55.8 %	70.6 %	79.5 %	
Medicaid	9.7 %	7.8 %	5.7 %	
Private insurance	25.7 %	16.3 %	11.4 %	
Self-pay	5.5 %	3.1 %	1.0 %	
No charge	0.4 %	0.1 %	0.0 %	
Other	2.9 %	2.1 %	2.4 %	
Record characteristics				
STEMI	63.6 %	45.1 %	35.7 %	<0.001
Cardiac arrest	10.3 %	9.0 %	8.2 %	<0.001
Ventricular fibrillation	19.5 %	13.3 %	9.3 %	<0.001
Ventricular tachycardia	22.2 %	20.0 %	17.5 %	<0.001
Length of stay, days, mean	8.3	9.8	9.7	<0.001
Total charge, $, mean	$230,581	$248,294	$236,975	<0.001
Comorbidities				
Heart failure	57.6 %	71.3 %	74.8 %	<0.001
Atrial fibrillation/flutter	30.2 %	35.8 %	36.6 %	<0.001
Valvular heart disease	16.5 %	23.2 %	29.2 %	<0.001
Hypertension	72.6 %	87.4 %	90.7 %	<0.001
Diabetes	40.0 %	54.2 %	53.1 %	<0.001
Smoking	43.9 %	42.3 %	45.3 %	<0.001
Dementia	4.3 %	5.7 %	7.0 %	<0.001
CKD	15.5 %	66.8 %	79.4 %	<0.001
Obesity	17.0 %	16.7 %	17.9 %	<0.001
Anemia	37.3 %	51.7 %	57.4 %	<0.001
Thrombocytopenia	14.0 %	16.7 %	16.5 %	<0.001
Coagulopathy	5.8 %	6.6 %	5.2 %	<0.001
Chronic liver disease	0.6 %	1.0 %	1.4 %	<0.001
Intracerebral hemorrhage	0.9 %	0.5 %	0.6 %	<0.001
Hematologic malignancy	0.9 %	1.3 %	1.1 %	<0.001
Solid malignancy	2.0 %	2.2 %	2.7 %	<0.001
Metastatic malignancy	0.8 %	0.9 %	0.9 %	<0.001

3.1. *In-hospital procedures and outcomes by number of diseased vascular beds*

Table 1 showed that the mean length of stay increased from 8.3 days for patients with 1 involved vascular bed to 9.8 days for 2 beds and 9.7 days for ≥3 beds ($p < 0.001$). Additionally, the mean total charges revealed an increasing trend, from $230,581 for 1 bed to $248,294 for 2 beds and $236,975 for ≥3 beds ($p < 0.001$).

Fig. 2 demonstrated a dose-response relationship with the in-hospital procedures and outcomes with varying extents of vascular bed involvement. We found a decrease in the performance of CA and PCI as the number of involved vascular beds increased, indicating an inverse dose-response. In contrast, CABG rates exhibited a dose-response relationship with more vascular beds involved. Similarly, the incidence of MACCE and mortality demonstrated a direct dose-response relationship as the number of diseased vascular beds increases. Notably, the utilization of circulatory support devices (including IABP, LV assist devices, and ECMO) decreased with increasing number of involved vascular beds, from 48.7 % in the single vascular bed group to 38.5 % in the ≥3 vascular bed group.

Fig. S1 provides a visual representation of the disposition of patients after hospitalization. As the severity of the disease increases, the likelihood of a patient being discharged to home decreases, while the likelihood of requiring intermediate care or dying in the hospital increases. This pattern indicates that patients with more extensive polyvascular disease have worse outcomes and may require more intensive care.

3.2. *Multivariable analysis for the overall cohort*

A comparative analysis of the procedures and in-hospital outcomes is presented for patients with 1, 2, or ≥3 pre-existing diseased vascular beds is shown in the Supplementary Table S1. Table 2 and Fig. 3 revealed the adjusted odds ratios for in-hospital procedures and outcomes, stratified by the number of diseased vascular beds. We observed that that patients with more severe vascular disease have lower adjusted odds ratios for undergoing invasive cardiac procedures such as percutaneous coronary intervention (aOR for 2 beds 0.94, CI 0.92–0.97, *p*-value < 0.001; 3 beds 1.0, CI 0.95–1.07, p-value 0.68) and coronary artery bypass grafting (aOR for 2 beds 0.69, CI 0.66–0.71, p-value < 0.001; 3 beds 0.81, CI 0.75–0.87, p-value < 0.001). These findings suggest that as the number of diseased vascular beds increases, patients are less likely to receive PCI and CABG. The odds for MACCE, mortality and ischemic stroke were highest in those with involvement of three or more vascular sites. A "dose response" was seen based on the number of vascular beds involved. The probability of MACCE, mortality and ischemic stroke appeared to be higher in those with ≥3 diseased vascular beds (aOR for MACCE 1.56, CI 1.47–1.65; mortality 1.59, CI 1.50–1.69; stroke 1.72, CI 1.52–1.95, *p*-value < 0.001) compared with two diseased vascular beds (aOR for MACCE 1.34, CI 1.31–1.38; mortality 1.43, CI 1.38–1.48; stroke 1.31, CI 1.22–1.40, p-value < 0.001). However, the incidence of major bleeding does not show a clear dose-

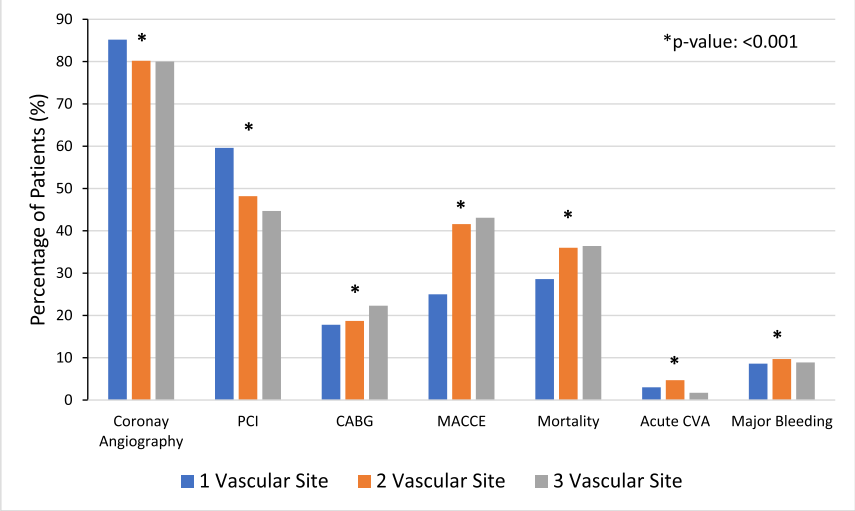

Fig. 2. Dose-response relationship between number of affected vascular beds and clinical procedures and outcomes.

Table 2
Multivariable analysis showing adjusted OR for in-hospital procedures and complications based on the number of disease vascular beds.

	2 vascular site		3 vascular site	
	OR (95 % CI)	*P* value	OR (95 % CI)	P value
Coronary angiography	0.899 (0.868–0.932)	<0.001	1.037 (0.967–1.113)	0.308
PCI	0.947 (0.920–0.974)	<0.001	1.012 (0.955–1.073)	0.684
CABG	0.687 (0.661–0.714)	<0.001	0.807 (0.751–0.867)	<0.001
MACCE	1.342 (1.305–1.380)	<0.001	1.558 (1.473–1.649)	<0.001
Mortality	1.426 (1.384–1.479)	<0.001	1.590 (1.498–1.688)	<0.001
Acute CVA	1.305 (1.216–1.399)	<0.001	1.721 (1.516–1.954)	<0.001
Major bleeding	1.037 (0.991–1.086)	0.120	0.966 (0.879–1.061)	0.470

Reference: 1 vascular site; adjusted for age, gender, weekend admission, hospital bed size, region and location/teaching status, STEMI, CABG, PCI, angiography, circulatory support (inc. IABP, LV assist device and ECMO), VF, VT, AF, HF, hypertension, diabetes mellitus, valvular heart disease, smoking status, chronic liver disease, anemia, thrombocytopenia, coagulopathies, and malignancies.

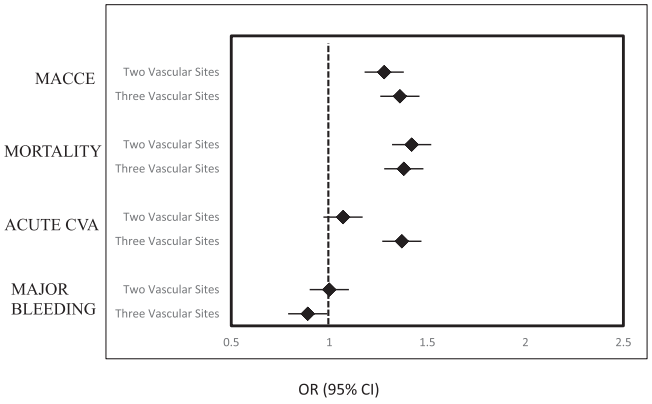

Fig. 3. Adjusted OR for in-hospital procedures and complications based on the number of disease vascular beds.

response relationship with the number of diseased vascular beds (aOR for 2 beds 1.04, CI 0.99–1.09, p-value 0.12; 3 beds 0.97, CI 0.88–1.07, p-value 0.47).

3.3. *STEMI vs. NSTEMI analysis*

Tables 3 and 4 presents the baseline characteristics of STEMI and NSTEMI-Induced CS patients with 1, 2 or ≥3 pre-existent diseased vascular beds. Both tables demonstrate a statistically significant increase in the mean age and proportion of female patients as the number of diseased vascular beds increases. In both groups we observed a higher burden of comorbidities with an increasing number of diseased vascular beds. However, the likelihood of diabetes decreases in the STEMI group as the number of diseased vascular beds increases, but this trend is not consistent in the NSTEMI group.

After adjustment for baseline characteristics as the number of vascular bed involvement increases, the likelihood of patients undergoing PCI decreases in STEMI induced CS patients but is increased in those with NSTEMI induced CS (Tables 5 and 6). However, the likelihood of undergoing CABG varies between the two groups. In the STEMI subgroup, the likelihood of undergoing CABG increases with the number of diseased vascular beds (aOR for 2 beds 0.94, CI 0.88–1.00, *p*-value 0.05; 3 beds 1.19, CI 1.04–1.36, p-value 0.072). This could imply that CABG is considered more often as an alternative to PCI in more complex cases, although not statistically significant (Fig. 4). Conversely, in the NSTEMI subgroup, the likelihood of CABG being performed decreases as the number of diseased vascular beds increases (aOR for 2 beds 0.57, CI 0.55–0.60, p-value < 0.001; 3 beds 0.70, CI 0.64–0.76, p-value < 0.001) (Fig. 5).

Furthermore, the risk of MACCE, mortality, and acute cerebrovascular accidents increase with the number of diseased vascular beds in both subgroups; aligning with the overall cohort's findings that more severe vascular disease correlates with worse outcomes.

Supplementary Tables S2 and S3 shows a comparative analysis of the procedures and in-hospital outcomes for STEMI and NSTEMI-induced Cardiogenic Shock patients with 1, 2, or ≥3 pre-existing diseased vascular beds.

4. Discussion

The study provided several interesting findings upon the comprehensive analysis of 136,245 cardiogenic shock patients with a previously known vascular disease between 2016 and 2019. First, there was a statistically significant progressive increase in the mean age, number of

Table 3
Stratification of vascular disease impact in STEMI-induced cardiogenic shock patients.

	Number of involved vascular beds			
	1	2	≥3	P-value
NIS discharge weight	61,805	14,865	2195	
Age	65.8	69.6	71.4	<0.001
Female, %	31.6 %	34.1 %	40.3 %	<0.001
Ethnicity				<0.001
White	74.8 %	71.0 %	71.6 %	
Black	7.3 %	19.4 %	10.3 %	
Hispanic	9.1 %	9.1 %	10.0 %	
Asian	4.0 %	4.3 %	3.1 %	
Native	0.6 %	0.7 %	1.2 %	
Other	4.3 %	4.5 %	3.8 %	
Hospital region				<0.001
Northeast	15.8 %	15.1 %	15.3 %	
Midwest or North Central	22.6 %	23.8 %	25.7 %	
South	38.9 %	38.3 %	35.5 %	
West	22.7 %	22.7 %	23.5 %	
Hospital bed size				<0.001
Small	13.2 %	13.4 %	17.3 %	
Medium	28.2 %	27.5 %	25.3 %	
Large	58.6 %	59.1 %	57.4 %	
Hospital location/teaching status				<0.001
Rural	4.2 %	4.2 %	4.6 %	
Urban non-teaching	21.0 %	18.0 %	25.7 %	
Teaching	74.7 %	77.8 %	69.7 %	
Median ZIP income				<0.001
1st quartile	27.8 %	30.8 %	26.0 %	
2nd quartile	27.0 %	26.7 %	28.3 %	
3rd quartile	24.2 %	24.1 %	23.0 %	
4th quartile	21.0 %	18.5 %	22.7 %	
Primary expected payer				<0.001
Medicare	50.6 %	65.5 %	77.3 %	
Medicaid	10.5 %	9.1 %	7.3 %	
Private insurance	29.0 %	19.6 %	11.7 %	
Self-pay	6.4 %	3.6 %	1.4 %	
No charge	0.4 %	0.2 %	0.0 %	
Other	3.0 %	2.0 %	2.3 %	
Record characteristics				
Cardiac arrest	11.6 %	10.1 %	8.4 %	<0.001
Ventricular fibrillation	24.9 %	18.6 %	13.4 %	<0.001
Ventricular tachycardia	25.0 %	23.9 %	20.0 %	<0.001
Length of stay, days, mean	7.3	8.7	7.9	<0.001
Total charge, $, mean	$218,166	$240,249	$222,840	<0.001
Comorbidities				
Heart failure	49.6 %	61.7 %	62.4 %	<0.001
Atrial fibrillation/flutter	26.1 %	32.0 %	35.1 %	<0.001
Valvular heart disease	12.0 %	16.6 %	22.1 %	<0.001
Hypertension	67.8 %	82.9 %	87.2 %	<0.001
Diabetes	34.3 %	47.4 %	46.2 %	<0.001
Smoking	45.6 %	44.3 %	46.2 %	<0.001
Dementia	3.7 %	6.3 %	7.1 %	<0.001
CKD	10.3 %	61.4 %	75.9 %	<0.001
Obesity	15.6 %	15.9 %	15.7 %	<0.001
Anemia	31.8 %	43.6 %	49.4 %	<0.001
Thrombocytopenia	12.7 %	14.5 %	13.4 %	<0.001
Coagulopathy	5.6 %	6.0 %	4.8 %	<0.001
Chronic liver disease	0.5 %	0.7 %	0.9 %	<0.001
Intracerebral hemorrhage	1.0 %	0.8 %	0.9 %	<0.001
Hematologic malignancy	0.7 %	1.1 %	0.5 %	<0.001
Solid malignancy	2.0 %	1.8 %	3.4 %	<0.001
Metastatic malignancy	0.8 %	0.6 %	1.1 %	<0.001

Table 4
Stratification of vascular disease impact in NSTEMI-induced cardiogenic shock patients.

	Number of involved vascular beds			
	1	2	≥3	P-value
NIS discharge weight	35,300	18,120	3960	
Mean age	69.7	71.1	72.3	<0.001
Female, %	35.8 %	36.0 %	36.6 %	<0.001
Ethnicity				<0.001
White	73.9 %	68.2 %	68.5 %	
Black	8.5 %	12.2 %	12.4 %	
Hispanic	9.8 %	11.0 %	10.5 %	
Asian	3.6 %	4.4 %	5.0 %	
Native	1.0 %	0.8 %	0.5 %	
Other	3.2 %	3.4 %	3.0 %	
Hospital region				<0.001
Northeast	16.1 %	14.4 %	12.2 %	
Midwest or North Central	21.9 %	22.0 %	23.6 %	
South	40.7 %	41.4 %	37.6 %	
West	21.3 %	22.1 %	26.5 %	
Hospital bed size				<0.001
Small	13.8 %	13.6 %	11.0 %	
Medium	27.5 %	27.4 %	27.7 %	
Large	58.7 %	59.0 %	61.4 %	
Hospital location/teaching status				<0.001
Rural	4.5 %	3.6 %	2.8 %	
Urban non-teaching	18.9 %	17.5 %	19.3 %	
Teaching	76.6 %	78.9 %	77.9 %	
Median ZIP income				0.018
1st quartile	30.0 %	30.9 %	27.6 %	
2nd quartile	26.9 %	26.7 %	28.6 %	
3rd quartile	24.4 %	23.7 %	24.3 %	
4th quartile	18.7 %	18.7 %	19.5 %	
Primary expected payer				<0.001
Medicare	65.0 %	74.9 %	80.7 %	
Medicaid	8.2 %	6.7 %	4.8 %	
Private insurance	19.9 %	13.6 %	11.3 %	
Self-pay	3.90 %	2.6 %	0.8 %	
No charge	0.2 %	0.1 %	0.0 %	
Other	2.8 %	2.2 %	2.5 %	
Record characteristics				
Cardiac arrest	8.2 %	8.1 %	8.0 %	<0.001
Ventricular fibrillation	10.0 %	8.9 %	7.1 %	<0.001
Ventricular tachycardia	17.3 %	16.8 %	16.0 %	0.045
Length of stay, days, mean	10.1	10.8	10.8	<0.001
Total charge, $, mean	$252,323	$254,914	$244,870	<0.001
Comorbidities				
Heart failure	71.7 %	79.2 %	81.7 %	<0.001
Atrial fibrillation/flutter	37.3 %	39.0 %	37.5 %	<0.001
Valvular heart disease	24.5 %	28.7 %	33.1 %	<0.001
Hypertension	81.2 %	91.1 %	92.6 %	<0.001
Diabetes	49.8 %	59.7 %	56.9 %	<0.001
Smoking	41.1 %	40.7 %	44.8 %	<0.001
Dementia	5.2 %	5.2 %	6.9 %	<0.001
CKD	24.5 %	71.3 %	81.4 %	<0.001
Obesity	19.6 %	17.4 %	19.1 %	<0.001
Anemia	47.0 %	58.4 %	61.9 %	<0.001
Thrombocytopenia	16.4 %	18.5 %	18.2 %	<0.001
Coagulopathy	6.2 %	7.1 %	5.4 %	<0.001
Chronic liver disease	0.8 %	1.2 %	1.6 %	<0.001
Intracerebral hemorrhage	0.7 %	0.3 %	0.4 %	<0.001
Hematologic malignancy	1.3 %	1.6 %	1.5 %	0.152
Solid malignancy	2.2 %	2.5 %	2.3 %	<0.001
Metastatic malignancy	0.8 %	1.0 %	0.8 %	<0.001

females and a higher burden of comorbidities such as heart failure, valvular heart disease, atrial flutter/fibrillation, hypertension, smoking, dementia, chronic kidney disease, obesity, anemia, chronic liver disease, intracerebral hemorrhage, and solid malignancy in groups with more diseased vascular beds. Second, as the number of affected vascular beds increases, the likelihood of performing coronary angiography, percutaneous coronary intervention and CABG decreases. Finally, the study shows a clear association between the extent of vascular involvement and worse in-hospital outcomes. Notably, a striking 83.1 % of patients with AMI and CS had pre-existing vascular disease, underscoring the significant role of vascular comorbidities in this high-risk population. Polyvascular disease is associated with differences in the invasive evaluation, management, and outcomes among patients with MI and CS, which may have important implications for the care of this patient population.

The findings of our study that there is a statistically significant progressive increase in the proportion of females as the number of diseased vascular beds increases is further supported by the work of Ya'qoub et al.

Table 5
Multivariable analysis showing adjusted OR for in-hospital procedures and complications for cardiogenic shock secondary to STEMI based on the number of disease vascular beds.

	2 vascular site		3 vascular site	
	OR (95 % CI)	P value	OR (95 % CI)	P value
Coronary angiography	0.868 (0.819–0.919)	<0.001	0.872 (0.765–0.994)	0.040
PCI	0.775 (0.745–0.808)	<0.001	0.744 (0.678–0.816)	<0.001
CABG	0.940 (0.884–1.001)	0.053	1.192 (1.043–1.363)	0.010
MACCE	1.390 (1.336–1.446)	<0.001	1.900 (1.735–2.080)	<0.001
Mortality	1.418 (1.360–1.478)	<0.001	1.972 (1.795–2.167)	<0.001
Acute CVA	1.537 (1.402–1.685)	<0.001	2.242 (1.869–2.689)	<0.001
Major bleeding	1.089 (1.022–1.160)	0.009	1.103 (0.953–1.276)	0.190

Reference: 1 vascular site; adjusted for age, gender, weekend admission, hospital bed size, region and location/teaching status, STEMI, CABG, PCI, angiography, circulatory support (inc. IABP, LV assist device and ECMO), VF, VT, AF, HF, hypertension, diabetes mellitus, valvular heart disease, smoking status, chronic liver disease, anemia, thrombocytopenia, coagulopathies, and malignancies.

Table 6
Multivariable analysis showing adjusted OR for in-hospital procedures and complications for cardiogenic shock secondary to NSTEMI based on the number of disease vascular beds.

	2 vascular site		3 vascular site	
	OR (95 % CI)	P value	OR (95 % CI)	P value
Coronary angiography	0.894 (0.852–0.938)	<0.001	1.076 (0.988–1.173)	0.093
PCI	1.148 (1.102–1.195)	<0.001	1.243 (1.156–1.337)	<0.001
CABG	0.575 (0.548–0.603)	<0.001	0.697 (0.641–0.758)	<0.001
MACCE	1.282 (1.231–1.335)	<0.001	1.360 (1.264–1.463)	<0.001
Mortality	1.416 (1.356–1.478)	<0.001	1.376 (1.272–1.487)	<0.001
Acute CVA	1.073 (0.965–1.194)	0.195	1.374 (1.150–1.641)	<0.001
Major Bleeding	0.996 (0.932–1.064)	0.898	0.893 (0.789–1.011)	0.073

Reference: 1 vascular site; adjusted for age, gender, weekend admission, hospital bed size, region and location/teaching status, STEMI, CABG, PCI, angiography, circulatory support (inc. IABP, LV assist device and ECMO), VF, VT, AF, HF, hypertension, diabetes mellitus, valvular heart disease, smoking status, chronic liver disease, anemia, thrombocytopenia, coagulopathies, and malignancies.

[9]. Their analysis of 159,339 patients with STEMI and cardiogenic shock revealed significant disparities in procedural utilization and clinical outcomes based on race, ethnicity, and sex. Women, as well as Black and Hispanic patients, had a higher likelihood of in-hospital mortality compared to White men. Furthermore, women underwent fewer invasive cardiac procedures, including revascularization, right heart catheterization, and mechanical circulatory support, compared to men [9].

Our results expand on prior data regarding the outcomes of patients with polyvascular disease and MI or CS. Polyvascular disease has been associated with significantly higher risk of all-cause death in patients with cardiogenic shock and studies have shown that patients with polyvascular disease experience worse outcomes after acute MI [5] and PCI [6], highlighting its role as an independent predictor of major adverse cardiovascular events and in the development of heart failure [3]. While the worse prognosis of patients with vascular disease is well established

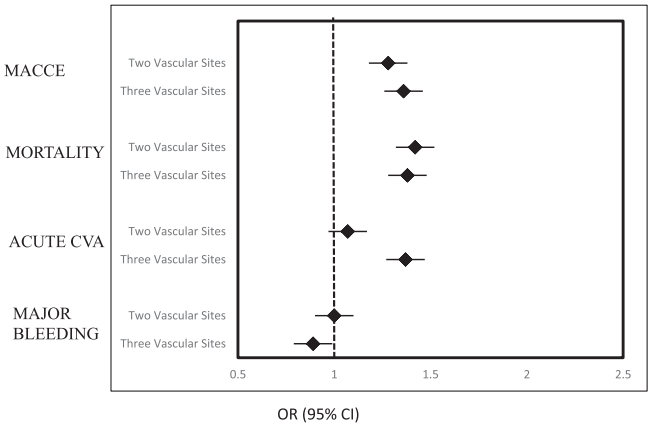

Fig. 4. Adjusted OR for in-hospital procedures and complications for cardiogenic shock secondary to STEMI based on the number of disease vascular beds.

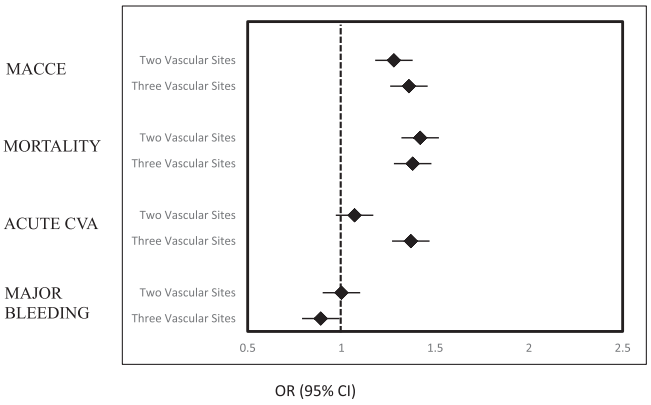

Fig. 5. Adjusted OR for in-hospital procedures and complications for cardiogenic shock secondary to NSTEMI based on the number of disease vascular beds.

[7], the study specifically examined the association between the extent of vascular disease and outcomes in patients with CS following AMI. In this analysis, it was noted that as the number of affected vascular beds increases, the likelihood of performing coronary angiogram and PCI decreases. This finding is consistent with prior studies [6,10,11] which also reported that the odds of undergoing coronary angiogram and PCI decreases with an increasing number of vascular beds involved, as well as prior studies [12,13] demonstrating lower rates of invasive evaluation for patients with AMI in the presence of other high-risk comorbidities. Additionally, several studies [14,15] further support these observations, demonstrating lower rates of invasive evaluation for patients with AMI in the presence of other high-risk comorbidities, including cancer, polyvascular disease and heart failure. Several potential explanations for this trend are the following: (a) Patients with polyvascular disease usually present with multiple comorbidities, complicating their management and increasing the risks associated with invasive procedures; (b) Patients with more extensive disease may be less inclined to undergo invasive procedures due to the perceived risks, recovery time, and potential for limited improvement in quality of life; (c) The overall prognosis may be poorer, and the focus of care may shift towards palliation and symptom control rather than aggressive interventions.

Contrasting trends were observed in our analysis for CABG. For STEMI-induced CS, the likelihood of CABG increases with more diseased vascular beds, though not statistically significant (aOR for 2 beds 0.90, CI 0.85–0.96, *p*-value 0.904; 3 beds 1.13, CI 0.99–1.29, p-value 0.072), suggesting it may be a viable alternative in complex cases. Conversely,

for NSTEMI-induced CS, the preference shifts towards percutaneous PCI as the number of diseased beds increases, indicating a lesser likelihood of choosing CABG. Similar findings have been seen in prior smaller studies [10]. This is likely due to the higher prevalence of comorbidities in these patients, which may increase the risk of adverse outcomes associated with invasive procedures.

We reported that the likelihood of MACCE, mortality, and acute cerebrovascular accidents also increases as the number of diseased vascular beds increases. This is consistent with the findings of Bashar et al. [16], who investigated the impact of extracardiac vascular disease on outcomes of 1.4 million patients undergoing percutaneous coronary intervention and found that the adjusted odds ratios (aOR) for MACCE and acute ischemic stroke increased with the number of diseased vascular beds. Furthermore, according to Jang et al. [17], in a study of 1247 CS patients, the risk of 12-month all-cause death was significantly higher in the polyvascular disease group than in the non-polyvascular disease group. This may indicate that polyvascular disease is a significant risk factor for mortality in patients with cardiogenic shock.

While this study provides valuable insights into the impact of polyvascular disease on the outcomes of patients with cardiogenic shock, it is important to acknowledge several limitations. These limitations are inherent to the nature of analyzing data from an administrative dataset, which relies on ICD codes related to specific hospitalizations. The potential for misclassification, incomplete, and omitted diagnoses or procedures exists. However, the NIS is a validated database, and the use of ICD-10 diagnosis and procedural codes have been previously validated for cardiovascular research [18,19]. Another potential confounding factor is that the NIS database does not have information about multiple hospitalizations of a patient within a year or across different years. This is because, the NIS captures inpatient stays rather than individual patients so it is possible that a patient was counted more than once in the analysis if he or she was admitted more than once within the study period. This could potentially lead to overestimation or duplication of certain events or outcomes. Moreover, while the NIS data contains some information on the hospital characteristics (e.g. teaching status, bed capacity, location), these data may not necessarily be related to the quality of hospital care. The study does not account for the potential impact of different treatment strategies on the outcomes. This is a significant limitation because the choice of treatment strategy could be influenced by a variety of factors, including the patient's overall health, the severity of their condition, and the presence of other comorbidities.

Previously, only small scale studies looked at polyvascular disease in those with AMI and CS. Building on the insights from a previous, smaller study that assessed the prevalence and impact of pre-existing vascular disease on clinical outcomes in patients with cardiogenic shock [17], our study significantly extends the scope of research by examining how the extent of vascular disease may correlate with a worse prognosis in AMI patients with CS. This study is the largest to compare the outcomes of AMI patients with CS with polyvascular disease. By leveraging the NIS database, which encompasses a wide and diverse patient population, our research provides several novel insights into the management and prognosis of this high-risk group.

These results have implications for clinical practice. For healthcare providers, understanding that the extent of vascular disease plays a critical role in the outcomes of cardiogenic shock patients is vital. The study highlights the need for more research on cardiogenic shock in patients with polyvascular disease, suggesting the potential for improved management and outcomes through targeted and preventive therapies. It emphasizes the importance of personalized care to reduce mortality and complications in this high-risk group.

5. Conclusion

The study highlights the impact of polyvascular disease on the management and prognosis of AMI patients with CS, revealing a reduction in in the use of coronary angiography and PCI as the number of diseased vascular beds increases. This trend is accompanied by a significant rise in adverse outcomes, including MACCE, mortality, and acute cerebrovascular accidents, underscoring the severity of polyvascular disease.

CRediT authorship contribution statement

Marlon V. Gatuz: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Investigation, Formal analysis, Data curation. **Rami Abu-Fanne:** Writing – review & editing, Supervision. **Dmitry Abramov:** Writing – review & editing, Validation, Resources, Conceptualization. **Maguli Barel:** Writing – review & editing, Supervision. **Mamas A. Mamas:** Writing – review & editing, Validation, Resources, Conceptualization. **Ariel Roguin:** Writing – review & editing, Validation, Supervision, Conceptualization. **Ofer Kobo:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ahjo.2024.100452.

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