

Supplemental Material

Appendix eTable 1. Administrative Codes Used to Define Exposures, Major Covariates, and Outcomes

Variable Name	ICD-9-CM Code
ND-MCS	
	Percutaneous Non-percutaneous
	37.68 37.60, 36.65
IABP	37.61
ECMO	39.65
PCPS	39.66
Coronary angiography	37.22, 37.23, 88.52, 88.53, 88.54, 88.55, 88.56, 88.57
PCI	00.66, 17.55, 36.01, 36.02, 36.05, 36.06, 36.07
CABG	36.10-36.17, 36.19
Right heart catheterization	37.21
Congestive heart failure	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 428.0- 428.9
Valvular disease	093.20- 093.24, 394.0- 397.1, 397.9, 424.0- 424.99, 746.3- 746.6, V42.2, V43.3
Pulmonary circulation disorders	415.11- 415.19, 416.0- 416.9, 417.9
Peripheral vascular disorders	440-440.9, 441.00- 441.9, 442.0- 442.9, 443.1- 443.9, 444.21- 444.22, 447.1, 449, 557.1, 557.9, V43.4
Paralysis	342.0- 344.9, 438.20- 438.53, 780.72
Other neurological disorders	330.1- 331.9, 332.0, 333.4, 333.5, 333.71, 333.72, 333.79, 333.85, 333.94, 334.0- 335.9, 338.0, 340, 341.1- 341.9, 345.00- 345.11, 345.2- 345.3, 345.40- 345.91, 347.00- 347.01, 347.10- 347.11, 649.40- 649.44, 768.7, 768.70, 768.71, 768.72, 780.3, 780.31, 780.32, 780.33, 780.39, 780.97, 784.3
Chronic pulmonary disease	490-492.8, 493.00- 493.92, 494-494.1, 495.0-505, 506.4
Diabetes, uncomplicated	249.00- 249.31, 250.00- 250.33, 648.00- 648.04
Diabetes with chronic complications	249.40- 249.91, 250.40- 250.93, 775.1
Hypothyroidism	243-244.2, 244.8, 244.9
Renal failure	403.01, 403.11, 403.90, 403.91, 404.02, 404.03, 404.12, 404.13, 404.92, 404.93, 585.3, 585.4, 585.5, 585.6, 585.9, 586, V42.0, V45.1, V45.11, V45.12, V56.0- V56.32, V56.8
Liver disease	070.22, 070.23, 070.32, 070.33, 070.44, 070.54, 456.0, 456.1, 456.20, 456.21, 571.0, 571.2, 571.3, 571.40- 571.49, 571.5, 571.6, 571.8, 571.9, 572.3, 572.8, 573.5, V42.7
Peptic ulcer disease excluding bleeding	531.41, 531.51, 531.61, 531.70, 531.71, 531.91, 532.41, 532.51, 532.61, 532.70, 532.71, 532.91, 533.41, 533.51, 533.61, 533.70, 533.71, 533.91, 534.41, 534.51, 534.61, 534.70, 534.71, 534.91
Acquired immune deficiency syndrome	042-044.9
Lymphoma	200.00- 202.38, 202.50- 203.01, 203.02- 203.82, 203.8- 203.81, 238.6, 273.3
Metastatic cancer	196.0- 199.1, 209.70, 209.71, 209.72, 209.73, 209.74, 209.75, 209.79, 789.51
Solid tumor without metastasis	140.0- 172.9, 174.0- 175.9, 179-195.8, 209.00- 209.24, 209.25- 209.3, 209.30- 209.36, 258.01- 258.03
Rheumatoid arthritis/collagen vascular diseases	701.0, 710.0- 710.9, 714.0- 714.9, 720.0- 720.9, 725
Coagulopathy	286.0- 286.9, 287.1, 287.3- 287.5, 289.84, 649.30- 649.34
Obesity	278.0, 278.00, 278.01, 278.03, 649.10- 649.14, 793.91, V85.30- V85.39, V85.41- V85.45, V85.54
Weight loss	260-263.9, 783.21, 783.22
Fluid and electrolyte disorders	276.0- 276.9
Chronic blood loss anemia	280.0, 648.20- 648.24
Deficiency anemias	280.1- 281.9, 285.21- 285.29, 285.9
Alcohol abuse	291.0- 291.3, 291.5, 291.8, 291.81, 291.82, 291.89, 291.9, 303.00- 303.93, 305.00- 305.03

Drug abuse	292.0, 292.82- 292.89, 292.9, 304.00- 304.93, 305.20- 305.93, 648.30- 648.34
Psychoses	295.00- 298.9, 299.10, 299.11
Depression	300.4, 301.12, 309.0, 309.1, 311
Hypertension, complicated and uncomplicated	401.1, 401.9, 642.00- 642.04, 401.0, 402.00- 405.99, 437.2, 642.10- 642.24, 642.70- 642.94

Appendix eTable 2. Characteristics of Hospitalizations for Myocardial Infarction Complicated by Cardiogenic Shock by Receipt of MCS

Patient Variables	Received MCS (N = 3469)	Did not receive MCS (N = 6969)	P-value*
Age, mean (SD)	66.1 (12.3)	70.1 (13.2)	< 0.001
Female – no. (%)	1101 (31.7)	2859 (41.0)	< 0.001
Admission from Emergency Department – no. (%)	2203 (63.5)	4660 (66.9)	< 0.001
Elective admission – no. (%)	207 (6.0)	447 (6.4)	0.37
Primary Insurance – no. (%)			< 0.001
Medicare	1909 (55.1)	4689 (67.4)	
Medicaid	312 (9.0)	584 (8.4)	
Private	932 (26.9)	1210 (17.4)	
Self-pay	190 (5.5)	284 (4.1)	
Other	119 (3.5)	191 (2.7)	
Heart Failure – no. (%)	293 (8.5)	1426 (20.5)	< 0.001
Valvular disease – no. (%)	92 (2.6)	390 (5.6)	< 0.001
Hypertension – no. (%)	2155 (62.1)	4393 (63.0)	0.36
Renal Failure – no. (%)	780 (22.5)	2267 (32.5)	< 0.001
Peripheral vascular disorders – no. (%)	514 (14.8)	1158 (16.6)	0.02
Diabetes mellitus – no. (%)	1373 (39.6)	2782 (39.9)	0.74
Hypothyroidism – no. (%)	327 (9.4)	789 (11.3)	0.0032
Chronic pulmonary disease – no. (%)	690 (19.9)	1804 (25.9)	< 0.001
Pulmonary circulatory disorders – no. (%)	51 (1.5)	290 (4.2)	< 0.001
Alcohol or Drug Abuse – no. (%)	219 (6.3)	463 (6.6)	0.52
Psychoses – no. (%)	80 (2.3)	217 (3.1)	0.02
Liver disease – no. (%)	70 (2.0)	221 (3.2)	< 0.001
Depression - no. (%)	201 (5.8)	492 (7.1)	0.01
Solid tumor without metastases – no. (%)	41 (1.2)	172 (2.5)	< 0.001
Lymphoma - no. (%)	18 (0.5)	54 (0.8)	0.14
Metastatic cancer – no. (%)	31 (0.9)	115 (1.7)	0.0019
Coagulopathy – no. (%)	819 (23.6)	1141 (16.4)	< 0.001
Chronic blood loss anemia – no. (%)	34 (1.0)	93 (1.3)	0.12
Deficiency anemias – no. (%)	716 (20.6)	1719 (24.7)	< 0.001
Paralysis – no. (%)	99 (2.9)	261 (3.8)	0.02
Other Neurologic Disorder – no. (%)	229 (6.6)	705 (10.1)	< 0.001
Peptic ulcer disease – no. (%)	2 (0.1)	1 (0.0)	0.26
Acquired Immune Deficiency Syndrome - no. (%)	6 (0.2)	6 (0.1)	0.23
Rheumatoid arthritis / collagen vascular diseases – no. (%)	85 (2.5)	165 (2.4)	0.79
Weight loss – no. (%)	322 (9.3)	760 (10.9)	0.01
Obesity – no. (%)	572 (16.5)	991 (14.2)	0.0022
Fluid and electrolyte disorders - no. (%)	1930 (55.6)	4201 (60.3)	< 0.001

*p-value for ANOVA/Chi-squared test across quartiles. †Represents the proportion in each quartile of MCS ratio in the analytical sample. Estimates for exclusions are for hospitalizations excluded due to hospitalization at a site performing <10 PCIs per year or resulting in transfer to an acute care hospital, and do not include information on missing hospitalizations (N = 3). N = the number of hospitalizations for cardiogenic shock and MI. MCS = mechanical circulatory support.

Appendix eTable 3: Rate of IABP vs. non-IABP MCS Utilization among Hospitalizations for Cardiogenic Shock and MI by Quartile of Hospital PCI Volume

	Quartile 1 (N = 789)	Quartile 2 (N = 781)	Quartile 3 (N = 794)	Quartile 4 (N = 770)
IABP use – no. (%)	743 (26.5)	710 (25.3)	686 (24.4)	669 (23.8)
Non-IABP MCS use – no. (%)	46 (14.1)	71 (21.8)	108 (33.1)	101 (31.0)

Chi square p-value < 0.001. Quartiles 1-4 represents quartiles of hospital PCI volume. Non-IABP MCS includes percutaneous and non-percutaneous ND-MCS, ECMO, and PCPS. No. = number. IABP = Intra-aortic balloon pump. MCS = Mechanical Circulatory Support. PCI = Percutaneous Coronary Intervention. MI = Myocardial infarction. ND-MCS = non-durable mechanical circulatory support. ECMO = centrally cannulated extracorporeal membrane oxygenation. PCPS = peripherally cannulated extracorporeal membrane oxygenation.

Appendix eTable 4. Multivariable Adjusted Predictors of Receipt of Mechanical Circulatory Support Among Hospitalizations for Myocardial Infarction Complicated by Cardiogenic Shock

Variables	Odds Ratio (OR)	95% CI	P-value
Age*	0.99	0.99-1.0	0.03
Admitted from Emergency Department	0.90	0.80-1.01	0.08
Elective Admission	0.86	0.69-1.08	0.20
Primary insurance			0.13
Medicare	-	-	
Medicaid	0.96	0.78-1.18	
Private	1.14	0.98-1.31	
Self-pay	1.12	0.87-1.44	
Heart Failure	0.92	0.77-1.10	0.35
Renal Failure	0.75	0.67-0.85	<0.001
Chronic pulmonary disease	0.72	0.64-0.82	<0.001
Pulmonary circulatory disorders	0.88	0.59-1.31	0.53
Psychoses	0.72	0.52-1.0	0.05
Solid tumor without metastases	0.73	0.49-1.11	0.14
Coagulopathy	1.69	1.48-1.93	<0.001
Neurologic disorders	0.75	0.62-0.90	0.0027
Weight loss	1.05	0.88-1.25	0.59
Fluid and electrolyte disorders	1.11	1.00-1.24	0.05
Receipt of Percutaneous Coronary Intervention	2.91	2.56-3.31	<0.001
Receipt of coronary angiography	4.07	3.53-4.70	<0.001
Receipt of Coronary Artery Bypass Grafting	5.28	4.53-6.16	<0.001
Receipt of Right Heart Catheterization	1.72	1.36-2.19	<0.001
Hospital Bedsize			0.67
Small	0.98	0.78-1.23	
Medium	0.93	0.80-1.09	
Large	-	-	
Hospital Ownership			0.02 [†]
Government	0.72	0.55-0.93	0.0129
Nonprofit	0.97	0.82-1.15	0.70
Private	-	-	-
Hospital Location/teaching			0.16
Rural	0.76	0.55-1.05	
Urban nonteaching	0.89	0.76-1.05	
Urban teaching	-	-	
Hospital Total Discharges	1.00	1.00-1.00	0.43

*Odds ratio for one year of age increase. Variables included in the model are those that were significant at a level of $p < 0.05$ on univariate testing. [†]Represents the omnibus p-value for the Type III fixed effect of hospital ownership. CI = Confidence Interval. IQR = interquartile range. No. = number. SD = standard deviation

Appendix eTable 5. Multivariable Adjusted Predictors of In-Hospital Mortality Among Hospitalizations for Myocardial Infarction Complicated by Cardiogenic Shock

Variables	Odds Ratio (OR)	95% CI	P-value
MCS Quartile			0.78
Quartile 1	-	-	-
Quartile 2	0.99	0.82-1.19	0.87
Quartile 3	1.05	0.86-1.28	0.63
Quartile 4	0.95	0.77-1.16	0.58
Age*	1.02	1.02-1.03	< 0.001
Female	1.17	1.02-1.35	0.03
Admitted from Emergency Department	1.10	0.94-1.26	0.24
Elective Admission	0.91	0.67-1.24	0.56
Primary insurance			0.01
Medicare	-	-	-
Medicaid	0.82	0.63-1.09	0.17
Private	0.87	0.72-1.06	0.01
Self-pay	1.60	1.13-2.26	0.14
Heart Failure	0.64	0.62-0.78	< 0.001
Valvular Heart Disease	1.23	0.87-1.72	0.24
Hypertension	1.02	0.89-1.18	0.74
Renal Failure	0.91	0.78-1.07	0.26
Peripheral Vascular Disease	1.55	1.30-1.86	< 0.001
Diabetes Mellitus	1.08	0.94-1.24	0.30
Hypothyroidism	0.80	0.64-1.00	0.05
Chronic pulmonary disease	0.90	0.77-1.05	0.18
Pulmonary circulatory disorders	1.02	0.68-1.52	0.93
Psychoses	0.65	0.42-1.01	0.05
Liver disease	1.12	0.75-1.66	0.01
Depression	0.69	0.52-0.91	0.01
Solid tumor without metastases	0.73	0.45-1.19	0.21
Lymphoma	1.15	0.51-2.58	0.74
Metastatic cancer	2.27	1.27-4.06	0.01
Coagulopathy	1.16	0.98-1.37	0.09
Blood loss	0.68	0.37-1.28	0.23
Deficiency Anemias	0.72	0.61-0.85	< 0.001
Paralysis	1.19	0.84-1.68	0.33
Neurologic disorders	1.54	1.22-1.95	< 0.001
Acquired Immune Deficiency Syndrome	0.50	0.05-5.10	0.56
Weight loss	0.59	0.56-0.86	< 0.001
Obesity	0.93	0.76-1.13	0.44
Fluid and electrolyte disorders	1.53	1.32-1.77	< 0.001
Receipt of Percutaneous Coronary Intervention	0.67	0.54-0.82	< 0.001
Receipt of coronary angiography	0.64	0.53-0.76	< 0.001
Receipt of Coronary Artery Bypass Grafting	0.19	0.15-0.25	< 0.001
Receipt of Right Heart Catheterization	1.01	0.75-1.36	0.97
Hospital Bedsize			0.58
Small	1.22	0.82-1.83	0.32
Medium	1.06	0.86-1.29	0.61
Large	-	-	-
Hospital Ownership			0.21
Government	0.76	0.55-1.04	0.09
Nonprofit	0.83	0.65-1.06	0.13
Private	-	-	-

Hospital Location/teaching				0.37
	Rural	1.39	0.87-2.23	0.17
	Urban nonteaching	1.06	0.84-1.33	0.63
	Urban teaching	-	-	-
Hospital Region				0.27
	Northeast	0.80	0.53-1.02	0.07
	Midwest	0.84	0.67-1.05	0.13
	South	0.83	0.67-1.03	0.08
	West	-	-	-
MCS Subtype				
	Percutaneous ND-MCS	3.27	2.39-4.48	< 0.001
	Non-percutaneous ND-MCS	7.34	0.64-84.17	0.11
	IABP	1.95	1.63-2.34	< 0.001
	ECMO	5.42	3.49-8.42	< 0.001
	PCPS	2.87	0.16-50.96	0.47

*Odds ratio for one year of age increase. 95% CI = 95% Confidence Interval. MCS = Mechanical Circulatory Support. ND-MCS = non-durable mechanical circulatory support. IABP = Intra-aortic balloon pump. ECMO = Extracorporeal Membrane Oxygenation. PCPS = percutaneous cardiopulmonary support.

eTable 6. Results of Sensitivity Analysis: Characteristics of Hospitals Utilizing Mechanical Circulatory Support, Limited to Hospitals with Ten or More Hospitalizations for Cardiogenic Shock and Myocardial Infarction

Hospital Variables	Quartile 1 (N = 76)	Quartile 2 (N = 70)	Quartile 3 (N = 68)	Quartile 4 (N = 71)	P-value*
Bedsizes – no. (%)					0.30
Small	2 (2.6)	3 (4.3)	2 (2.9)	6 (8.5)	
Medium	18 (23.7)	15 (21.4)	8 (11.8)	15 (21.1)	
Large	56 (73.7)	52 (74.3)	58(85.3)	50 (70.4)	
Hospital Ownership – no. (%)					0.07
Government	14 (18.4)	4 (5.7)	5 (7.4)	5 (7.0)	
Non-profit	58 (76.3)	58(82.9)	55 (88.8)	55(77.5)	
Private	4 (5.3)	8 (11.4)	8(11.8)	11 (15.5)	
Location/teaching – no. (%)					0.24
Rural	1 (1.3)	0 (0)	4 (5.9)	1 (1.4)	
Urban nonteaching	12 (15.8)	13 (18.6)	8 (11.8)	7 (9.9)	
Urban teaching	63 (82.9)	57 (81.4)	56 (82.3)	63 (88.7)	
Hospital region – no. (%)					0.06
Northeast	12 (15.8)	12 (17.1)	13 (19.1)	17(23.9)	
Midwest / North Central	17 (22.4)	12 (17.1)	9 (13.2)	25 (35.2)	
South	34 (44.7)	31(44.3)	30 (44.1)	18 (25.4)	
West	13 (17.1)	15 (21.5)	16 (13.6)	11(15.5)	
Total Discharges – median (IQR)	5376 (3959-7754)	5258 (3812-6493)	6411 (4779-7979)	4943 (3984-7926)	0.05 [†]

*p-value for Chi-squared test across quartiles except where otherwise specified. [†]p-value for Kruskal-Wallis test across quartiles. MCS = Mechanical Circulatory Support. IQR = interquartile range. N = the number of hospitals per quartile.

Appendix eTable 7. Results of Sensitivity Analysis: Crude and Unadjusted In-Hospital Mortality by Quartile of MCS Use in Hospitals with Ten or More Hospitalizations for Cardiogenic Shock and Myocardial Infarction

Quartile	Observed In-hospital mortality – no. (%)	Crude Odds Ratio for In-Hospital Mortality	95% CI	P-value
Quartile 1 (N = 1204)	458 (38.0)	-	-	-
Quartile 2 (N = 1144)	438 (38.3)	1.01	0.86-1.19	0.94
Quartile 3 (N = 1106)	442 (40.0)	1.08	0.92-1.28	0.21
Quartile 4 (N = 1085)	404 (37.2)	0.97	0.82-1.15	0.21
Quartile	Adjusted In-hospital mortality – no. (%)[*]	Adjusted Odds Ratio for In-Hospital Mortality[*]	95% CI	P-value
Quartile 1 (N = 1204)	458 (38.0)	-	-	-
Quartile 2 (N = 1144)	437 (38.2)	0.99	0.82-1.19	0.87
Quartile 3 (N = 1106)	442 (40.0)	1.05	0.96-1.28	0.63
Quartile 4 (N = 1085)	404 (37.1)	0.95	0.77-1.16	0.58

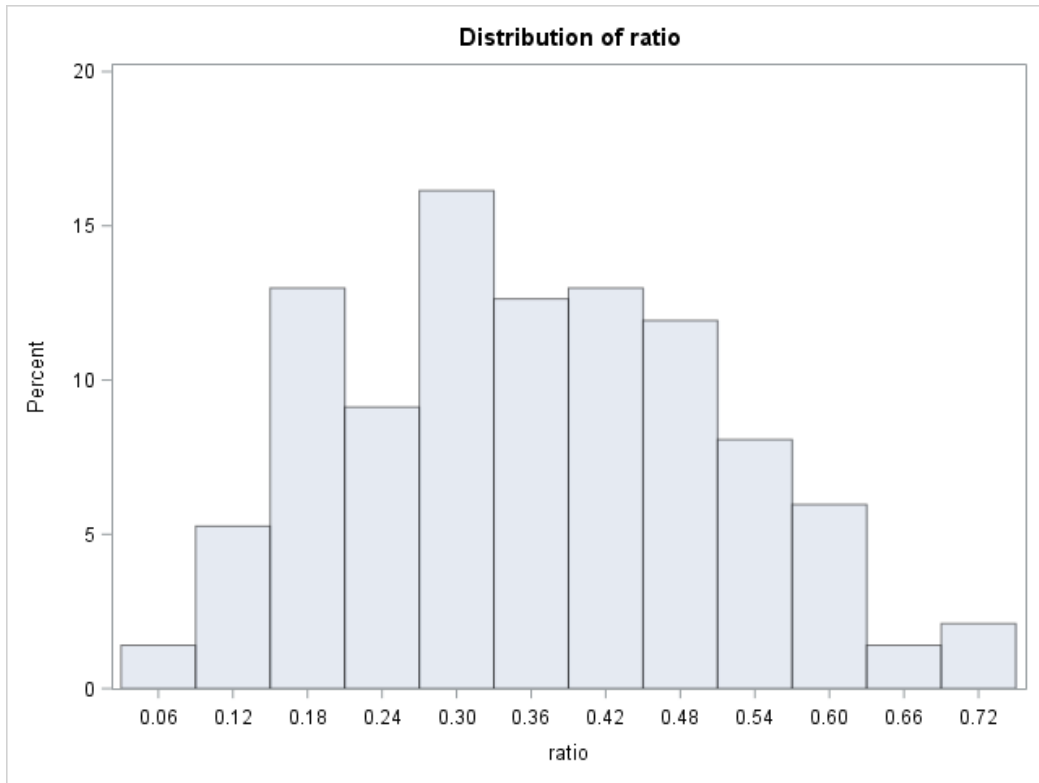
MCS = Mechanical Circulatory Support. 95% CI = 95% Confidence Interval. ^{*}Adjusted for age, sex, all patient and hospital variables, receipt of coronary angiography, PCI, CABG, RHC, and device subtype. Omnibus adjusted p-value for effect of quartile on in-hospital mortality = 0.78. Abbreviations: CI = confidence interval. N = the number of hospitalizations for cardiogenic shock and MI.

eTable 8. Results of Sensitivity Analysis in the Nationwide Readmissions Database: Quartiles of MCS ratio

Procedure	Quartile 1 (N = 2698)	Quartile 2 (N = 5744)	Quartile 3 (N = 6574)	Quartile 4 (N = 5501)	P-value*
MCS ratio (%) – median (IQR)	5.0% (0.0-12.9%)	25.0% (20.6-27.6%)	36.3% (33.3-39.3%)	50.0% (46.8-60.0%)	< 0.001
ND-MCS (percutaneous) – no. (%)	39 (1.5)	168 (2.9)	353 (5.4)	471 (8.6)	< 0.001
ND-MCS (non-percutaneous) – no. (%)	0 (0.0)	0 (0.0)	0 (0.0)	7 (0.1)	< 0.001
IABP – no. (%)	231 (8.6)	1264 (22.0)	2085 (31.7)	2452 (44.6)	< 0.001
ECMO – no. (%)	4 (0.2)	48 (0.8)	146 (2.2)	188 (3.4)	< 0.001
PCPS – no. (%)	0 (0.0)	0 (0.0)	3 (0.1)	6 (0.1)	0.03
Adjusted Odds Ratio (95% CI) for In-Hospital Mortality	-	1.03 (0.92-1.14)	0.95 (0.86-1.06)	0.98 (0.88-1.10)	0.33
Adjusted Odds Ratio (95% CI) for In-Hospital Mortality for MCS ratio [†]	0.88 (0.70-1.09)				0.23

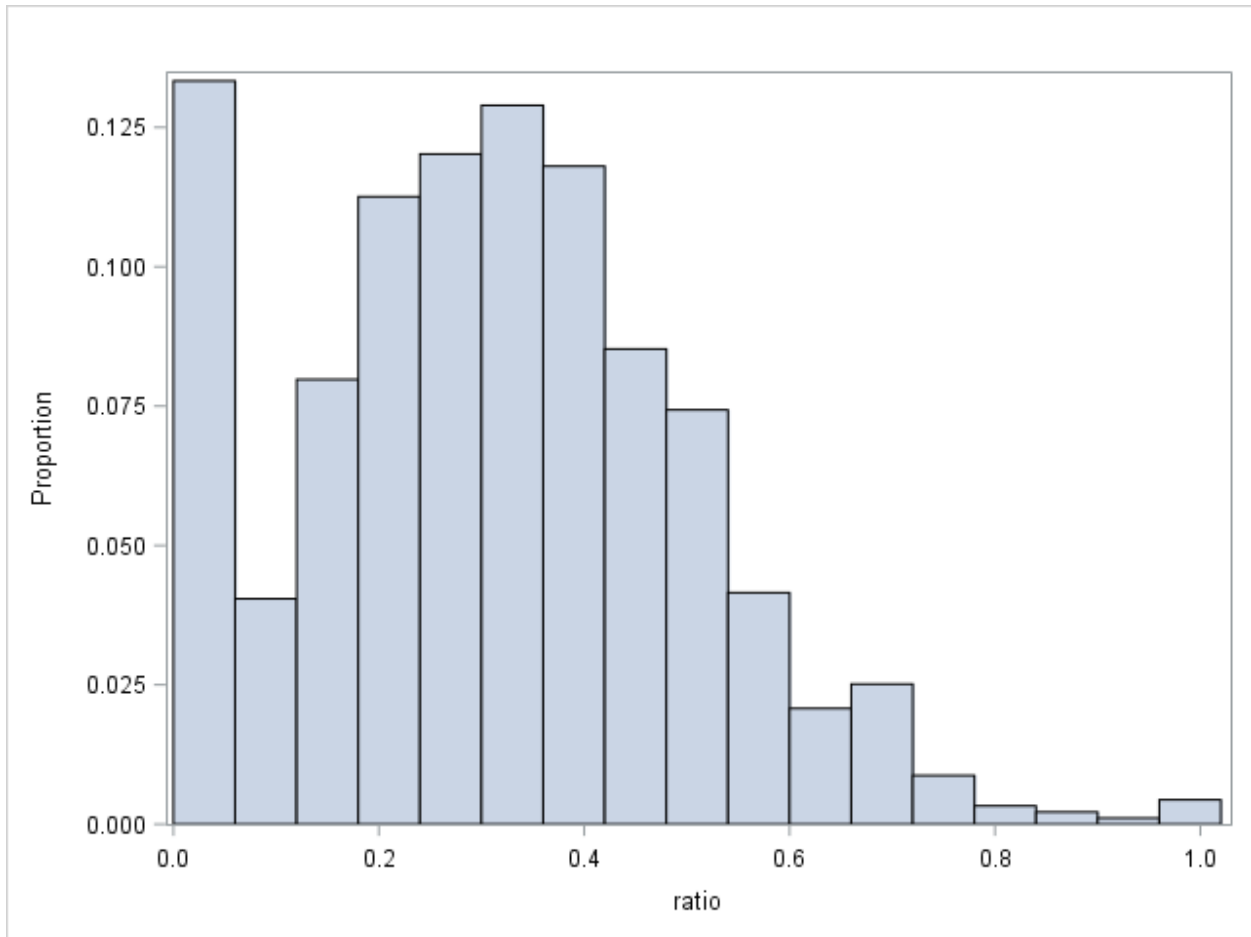
* p-value for Chi-squared test across quartiles. IQR = interquartile range. N = number of hospitals per quartile. MCS Ratio = Proportion of MCS use per hospitalization for MI with CS. [†]Represents adjusted odds ratio for the effect of MCS ratio on in-hospital mortality with MCS ratio treated as a continuous measure; p-value from Wald test.

Appendix eFigure 1. Histogram demonstrating the proportion of hospitalizations for myocardial infarction and cardiogenic shock utilizing MCS by hospital, in Hospitals with Ten or More Hospitalizations for Cardiogenic Shock and Myocardial Infarction



Ratio = Proportion of mechanical circulatory support use per hospitalization for myocardial infarction and cardiogenic shock.
Median (IQR) ratio = 36.4% (25.0-46.7%).

Appendix eFigure 2. Histogram demonstrating the proportion of hospitalizations for myocardial infarction with cardiogenic shock utilizing MCS by hospital in the Nationwide Readmissions Database



Ratio = Proportion of mechanical circulatory support use per hospitalization for myocardial infarction and cardiogenic shock.
Median (IQR) ratio = of 30.0% (17.6-62.5%)