

Supplemental Material

Table S1. ICD-10-CM and ICD-10-PCS Codes to Identify Diagnoses, Comorbidities, Procedures, and Outcomes.

Diagnosis/ Procedure	ICD-10 Codes
Cardiogenic shock	R57.0
Cardiogenic shock after cardiectomy	T8111XA
VA-ECMO	5A15223, 5A1522G, 5A1522F
Intra-aortic balloon pump	5A02110, 5A02210
Impella	5A0221D
Impella 5.0/LD/5.5	Concomitant MS-DRG codes of 1, 2
ST-elevation myocardial infarction	I21.01, I21.02, I21.09, I21.11, I21.19, I21.21, I21.29, I21.3
Non-ST-elevation myocardial infarction	I21.4, I21.9
Previous cardiac arrest	Z86.74
Prior percutaneous coronary intervention	Z98.61
Prior coronary artery bypass graft surgery	Z95.1
Chronic kidney disease	I12.0, I12.9, I13.0, I13.10, I13.11, I13.2, N04, N04.x, N07.x, N08, N18.x, N18.4, N18.5, N18.6, N18.9, N19, R94.4, Z49.01, Z49.02, Z49.31, Z49.32, Z91.15, Z99.2, Z94.0

History of congestive heart failure	I11.0, I13.0, I13.2, I09.81, I50.1, I50.20, I50.22, I50.30, I50.32, I50.40, I50.42, I50.810, I50.812, I50.814, I50.82, I50.83, I50.84, I50.89, I50.9
Atrial fibrillation/flutter	I48.0, I48.1x, I48.2x, I48.3, I48.4, I48.91, I48.92
Coagulopathy	D66, D67, D68.0, D68.00, D68.01, D68.020, D68.021, D68.022, D68.023, D68.029, D68.03, D68.1, D68.2, D68.312, D68.8, D68.9, D69.1, D69.3, D69.41, D69.42, D69.49, D69.6, D69.8, D69.9
Percutaneous coronary intervention	0210344, 02103D4, 0211344, 02113D4, 0212344, 02123D4, 0213344, 02133D4, 0270356, 027035Z, 0270366, 027036Z, 0270376, 027037Z, 02703E6, 02703EZ, 02703F6, 02703FZ, 02703G6, 02703GZ, 0271356, 027135Z, 0271366, 027136Z, 0271376, 027137Z, 02713E6, 02713EZ, 02713F6, 02713FZ, 02713G6, 02713GZ, 0272356, 027235Z, 0272366, 027236Z, 0272376, 027237Z, 02723E6, 02723EZ, 02723F6, 02723FZ, 02723G6, 02723GZ, 0273356, 027335Z, 0273366, 027336Z, 0273376, 027337Z, 02733E6, 02733EZ, 02733F6, 02733FZ, 02733G6, 02733GZ, 02C03Z6, 02C03Z7, 02C03ZZ, 02C13Z6, 02C13Z7, 02C13ZZ, 02C23Z6, 02C23Z7, 02C33Z6, 02C33Z7, 02F03ZZ, 02F13ZZ, 02F23ZZ, 02F33ZZ, 02H03DZ, 2H03YZ, 02H13DZ, 02H13YZ, 02H23DZ, 02H23YZ, 02H33DZ, 02H33YZ, 02N03ZZ,

02N13ZZ, 02N23ZZ, 02N33ZZ, 02Q03ZZ, 02Q13ZZ, 02Q23ZZ, 02Q33ZZ,
02U037Z, 02U038Z, 02U03JZ, 02U03KZ, 02U137Z, 02U138Z, 02U13JZ,
02U13KZ, 02U237Z, 02U238Z, 02U23JZ, 02U23KZ, 02U337Z, 02U338Z,
02U33JZ, 02U33KZ, X2C0361, X2C1361, X2C2361, X2C3361, 0370346, 037034Z,
03703ZZ, 03Q13ZZ, 037134Z, 03713ZZ, 03C13ZZ, 027, 0270, 0270046, 027004Z,
02700D6, 02700DZ, 02700T6, 02700TZ, 02700Z6, 02700ZZ, 0270346, 027034Z,
02703D6, 02703DZ, 02703T6, 02703TZ, 02703Z6, 02703ZZ, 0270446, 027044Z,
02704D6, 02704DZ, 02704T6, 02704TZ, 02704Z6, 02704ZZ, 0271, 0271046,
027104Z, 02710D6, 02710DZ, 02710T6, 02710TZ, 02710Z6, 02710ZZ, 0271346,
027134Z, 02713D6, 02713DZ, 02713T6, 02713TZ, 02713Z6, 02713ZZ, 0271446,
027144Z, 02714D6, 02714DZ, 02714T6, 02714TZ, 02714Z6, 02714ZZ, 0272,
0272046, 027204Z, 02720D6, 02720DZ, 02720T6, 02720TZ, 02720Z6, 02720ZZ,
0272346, 027234Z, 02723D6, 02723DZ, 02723T6, 02723TZ, 02723Z6, 02723ZZ,
0272446, 027244Z, 02724D6, 02724DZ, 02724T6, 02724TZ, 02724Z6, 02724ZZ,
0273, 0273046, 027304Z, 02730D6, 02730DZ, 02730T6, 02730TZ, 02730Z6,
02730ZZ, 0273346, 027334Z, 02733D6, 02733DZ, 02733T6, 02733TZ, 02733Z6,

02733ZZ, 0273446, 027344Z, 02734D6, 02734DZ, 02734T6, 02734TZ, 02734Z6,
02734ZZ, 02C, 02C0, 02C03ZZ, 02C04ZZ, 02C13ZZ, 02C14ZZ, 02C23ZZ,
02C24ZZ, 02C33ZZ, 02C34ZZ

Coronary artery bypass graft surgery

0210093, 02100A3, 02100J3, 02100K3, 02100Z3, 0210493, 02104A3, 02104J3,
02104K3, 02104Z3, 021008W, 021009W, 02100AW, 02100JW, 02100KW,
021049W, 02104AW, 02104JW, 02104KW, 021108W, 021109W, 02110AW,
02110JW, 02110KW, 021149W, 02114AW, 02114JW, 02114KW, 021208W,
021209W, 02120AW, 02120JW, 02120KW, 021249W, 02124AW, 02124JW,
02124KW, 021308W, 021309W, 02130AW, 02130JW, 02130KW, 021349W,
02134AW, 02134JW, 02134KW, 0210088, 0210098, 0210099, 021009C, 02100A8,
02100A9, 02100AC, 02100J8, 02100J9, 02100JC, 02100K8, 02100K9, 02100KC,
02100Z8, 02100Z9, 02100ZC, 0210498, 0210499, 021049C, 02104A8, 02104A9,
02104AC, 02104J8, 02104J9, 02104JC, 02104K8, 02104K9, 02104KC, 02104Z8,
02104Z9, 02104ZC, 0211088, 0211089, 021108C, 0211098, 0211099, 021109C,
02110A8, 02110A9, 02110AC, 02110J8, 02110J9, 02110JC, 02110K8, 02110K9,
02110KC, 02110Z8, 02110Z9, 02110ZC, 0211498, 0211499, 021149C, 02114A8,

02114A9, 02114AC, 02114J8, 02114J9, 02114JC, 02114K8, 02114K9, 02114KC,
02114Z8, 02114Z9, 02114ZC, 021209C, 02120AC, 02120JC, 02120KC, 02120ZC,
021249C, 02124AC, 02124JC, 02124KC, 02124ZC, 021309C, 02130AC, 02130JC,
02130KC, 02130ZC, 021349C, 02134AC, 02134JC, 02134KC, 02134ZC, 021008F,
021009F, 02100AF, 02100JF, 02100KF, 02100ZF, 021049F, 02104AF, 02104JF,
02104KF, 02104ZF, 0210083, 0210093, 02100A3, 02100J3, 02100K3, 02100Z3,
0210493, 02104A3, 02104J3, 02104K3, 02104Z3, 0210089, 021008C, 0210444,
0210483, 0210488, 0210489, 021048C, 021048F, 021048W, 02104D4, 0211083,
021108F, 0211093, 0211098, 021109F, 02110A3, 02110J3, 02110JF, 02110JW,
02110K3, 02110KF, 02110Z3, 02110ZF, 0211444, 0211483, 0211488, 0211489,
021148C, 021148F, 021148W, 0211493, 021149F, 02114A3, 02114AF, 02114D4,
02114J3, 02114JF, 02114KF, 02114Z3, 02114ZF, 0212083, 0212088, 0212089,
021208C, 021208F, 0212093, 0212098, 0212099, 021209F, 02120A3, 02120A8,
02120A9, 02120AC, 02120AF, 02120J3, 02120J8, 02120J9, 02120JF, 02120K3,
02120K8, 02120K9, 02120KF, 02120Z3, 02120Z8, 02120Z9, 02120ZF, 0212444,
0212483, 0212488, 0212489, 021248C, 021248F, 021248W, 0212493, 0212498,

0212499, 021249F, 02124A3, 02124A8, 02124A9, 02124AF, 02124D4, 02124J3,
02124J8, 02124J9, 02124JF, 02124K3, 02124K8, 02124K9, 02124KF, 02124Z3,
02124Z8, 02124Z9, 02124ZF, 0213083, 0213088, 0213089, 021308C, 021308F,
0213093, 0213098, 0213099, 021309F, 02130A3, 02130A8, 02130A9, 02130AF,
02130J3, 02130J8, 02130J9, 02130JF, 02130K3, 02130K8, 02130K9, 02130KF,
02130Z3, 02130Z8, 02130Z9, 02130ZF, 0213444, 0213483, 0213488, 0213489,
021348C, 021348F, 021348W, 0213493, 0213498, 0213499, 021349F, 02134A3,
02134A8, 02134A9, 02134AF, 02134D4, 02134J3, 02134J8, 02134J9, 02134JF,
02134K3, 02134K8, 02134K9, 02134KF, 02134Z3, 02134Z8, 02134Z9, 02134ZF

Pulmonary artery catheterization

02HP30Z, 02HP32Z, 02HQ30Z, 02HQ32Z, 02HR30Z, 02HR32Z,
4A0239Z, 4A023N6, 4A023N8, 4A03353, 4A033B3, 4A1239Z,
4A13353, 4A133B3

Left ventricular assist device

02HA0QZ

Heart transplantation

02YA0Z0, 02YA0Z1, 02YA0Z2

Gastrointestinal bleeding

K20.81, K20.91, K21.01, K22.11, K22.6, K25.0, K25.2, K25.4, K25.6, K26.0,
K26.2, K26.4, K26.6, K27.0, K27.2, K27.4, K27.6, K28.0, K28.2, K28.4, K28.6,

K29.01, K29.21, K29.31, K29.41, K29.51, K29.61, K29.71, K29.81, K29.91,
K31.811, K31.82, K50.011, K50.111, K50.811, K50.911, K51.011, K51.211,
K51.311, K51.411, K51.511, K51.811, K51.911, K55.21, K57.01, K57.11, K57.13,
K57.21, K57.31, K57.33, K57.41, K57.51, K57.53, K57.81, K57.91, K57.93, K62.5,
K91.62, K91.841, K91.871, K92.0, K92.1, K92.2, K94.01, K94.11, K94.21, K94.31

Intracranial bleeding I60.00, I60.01, I60.02, I60.10, I60.11, I60.12, I60.2, I60.30, I60.31, I60.32, I60.4,
I60.50, I60.51, I60.52, I60.6, I60.7, I60.8, I60.9, I61.0, I61.1, I61.2, I61.3, I61.4,
I61.5, I61.6, I61.8, I61.9, I62.00, I62.01, I62.02, I62.03, I62.1, I62.9

Hematoma M79.81, L76.02, L76.22, L76.32, L76.34

Procedure-related bleeding I97.410, I97.411, I97.418, I97.42, I97.610, I97.611, I97.618, I97.62, I97.620,
I97.621, I97.630, I97.631, I97.638, T82.837A, T82.837D, T82.837S, T82.838A,
T82.838D, T82.838S, K66.1, R58

Pulmonary alveolar bleeding J95.62, J95.830, J95.831, R04.89

Vascular complications I77.0, I77.2, I71.00, I71.010, I71.011, I71.012, I71.019, I71.02, I71.03, I77.70,
I77.71, I77.72, I77.73, I77.74, I77.75, I77.76, I77.77, I77.79, I77.70, I77.71, I77.72,
I77.73, I77.74, I77.75, I77.76, I77.77, I77.79, I72.4, T81.7, T81.71, T81.72, T81.710,

T81.711, T81.718, T81.719, T81.710A, T81.710D, T81.710S, T81.711A, T81.711D,
T81.711S, T81.718A, T81.718D, T81.718S, T81.719A, T81.719D, T81.719S,
T81.72XA, T81.72XD, T81.72XS, T81.83XA, T82.837A, T82.837D, T82.837S,
T82.838A, T82.838D, T82.838S, T82.593A, T82.593D, T82.593S

Acute limb ischemia

I743, I745, I7401

ESRD on hemodialysis

Z99.2

Hemodialysis

5A1D70Z, 5A1D80Z, 5A1D90Z

Ischemic stroke

G450, G451, G452, G453, G454, G458, G459, G460, G461, G462, G463, G464,
G465, G466, G467, G468, H3400, H3401, H3402, H3403, H3410, H3411, H3412,
H3413, H34211, H34212, H34213, H34219, H34231, H34232, H34233, H34239,
I6300, I63011, I63012, I63013, I63019, I6302, I63031, I63032, I63033, I63039,
I6309, I6310, I63111, I63112, I63113, I63119, I6312, I63131, I63132, I63133,
I63139, I6319, I6320, I63211, I63212, I63213, I63219, I6322, I63231, I63232,
I63233, I63239, I6329, I6329, I6330, I63311, I63312, I63313, I63319, I63321,
I63322, I63323, I63329, I63331, I63332, I63333, I63339, I63341, I63342, I63343,
I63349, I6339, I6340, I63411, I63412, I63413, I63419, I63421, I63422, I63423,

I63429, I63431, I63432, I63433, I63439, I63441, I63442, I63443, I63449, I6350,
I63511, I63512, I63513, I63519, I63521, I63522, I63523, I63529, I63531, I63532,
I63533, I63539, I63541, I63542, I63543, I63549, I6359, I636, I638, I6381, I6389,
I639, I6781, I6782, I97810, I97811, I97820, I97821

Community acquired pneumonia

B96.0, J09.X1, J10.00, J10.01, J10.08, J11.00, J11.08, J12.0, J12.1, J12.2, J12.3,
J12.81, J12.89, J12.9, J13, J14, J15.3, J15.4, J15.7, J16.8, J17, J18, J18.1, J18.8,
J18.9

Diarrhea

R19.7, K59.1, K58.0, A07.9, K52.9, T36.95XA, A04.7,
K52.1, A09, R11.2, K52.29, K91.89

Table S2. Standardized Differences Before and After Propensity Score (PS) Matching.

Variable	Before PS Matching, %	After PS Matching, %*
Age	12.4	0.4
Female Sex	24.1	1.0
STEMI	56.6	5.0
NSTEMI	9.6	2.6
Cardiogenic shock due to AMI	59.7	3.0
History of cardiac arrest	5.2	2.8
Hypertension	3.4	1.2
Diabetes Mellitus	12.3	0.6
Coronary artery disease	34.7	1.9
Previous PCI	1.9	1.6
Previous CABG	7.5	0.4
Chronic kidney disease	1.1	1.3
Heart failure	17.9	0.4
Atrial fibrillation	1.2	2.2

Chronic coagulopathy	0.1	0.0
Malignancy	3.6	2.7
Chronic Pulmonary Disease	10.3	2.5
Valvular heart disease	16.3	0.5
Human Immunodeficiency Virus (HIV)	1.4	0.1
Alcohol Use Disorder	3.7	3.6
Iron deficiency anemia	2.6	2.8
Arthropathy	9.9	1.2
Cerebrovascular disease	2.4	1.8
Dementia	2.4	2.6
Depression	12.5	2.2
Drug abuse	9.1	1.0
Obesity	2.5	0.9
Paralysis	1.6	0.7
Peripheral Vascular Disease	0.9	0.2

Hypothyroidism	2.3	1.7
Other thyroid disorders	2.9	1.7
Revascularization	42.2	4.2
Right heart catheterization	47.3	2.5
Income per Zip Code	8.3	2.9
Hospital Size	13.2	1.4
Insurance Status	12.4	0.7

*Standardized differences are <10% for all variables after matching, indicating successful PS matching.

Table S3. Baseline Individual- and Hospital-Level Characteristics for Patients Hospitalized with Cardiogenic Shock Requiring VA-ECMO and Left Ventricular Unloading Device, 2016-2020.

Characteristics (%)	All	IABP	Impella	P-value
Number of patients, weighted (%)	5718	3098 (19.4)	2620 (16.4)	-
Age, median (IQR)	59 (49-66)	59 (50-68)	58 (48-65)	<0.001
Age group, y				0.004
<50	1448 (25.3)	734 (23.7)	714 (27.3)	
50-64	2442 (42.7)	1289 (41.6)	1153 (44.0)	
65-79	1693 (29.6)	988 (31.9)	705 (26.9)	
≥80	136 (2.4)	87 (2.8)	48 (1.8)	
Female	1666 (29.1)	1006 (32.5)	660 (25.2)	<0.001
Causes of cardiogenic shock				
STEMI	2051 (35.9)	927 (29.9)	1123 (42.9)	<0.001
NSTEMI	879 (15.4)	507 (16.4)	372 (14.2)	0.104

Nonischemic	2788 (48.8)	1664 (53.7)	1125 (42.9)	<0.001
Previous cardiac arrest	215 (3.8)	103 (3.3)	111 (4.2)	0.263
Hypertension	3316 (58.0)	1863 (60.1)	1453 (55.5)	0.010
Diabetes mellitus	1895 (33.1)	1028 (33.2)	867 (33.1)	0.960
Known coronary artery disease	3254 (56.9)	1773 (57.2)	1481 (56.5)	0.746
Prior PCI	72 (1.3)	39 (1.3)	33 (1.3)	0.964
Prior CABG	304 (5.3)	201 (6.5)	103 (3.9)	0.001
Iron deficiency anemia	235 (4.1)	140 (4.5)	95 (3.6)	0.238
Chronic kidney disease	1796 (31.4)	1059 (34.2)	737 (28.1)	<0.001
CHF	3319 (58.0)	1817 (58.7)	1501 (57.3)	0.481
Atrial fibrillation	2132 (37.3)	1266 (40.9)	867 (33.1)	<0.001
Coagulopathy	2549 (44.6)	1420 (45.8)	1129 (43.1)	0.178
COPD (chronic pulmonary disease)	901 (15.8)	547 (17.6)	354 (13.5)	0.002

Peripheral vascular disease	1297 (22.7)	725 (23.4)	571 (21.8)	0.340
Valvular heart disease	218 (3.8)	166 (5.4)	52 (2.0)	<0.001
Elixhauser comorbidity score ≥ 4	2114 (37.0)	1237 (39.9)	877 (33.5)	0.002
Procedures/surgeries performed				
Revascularization among ischemic cardiogenic shock	2091 (71.4)	1040 (72.5)	1051 (70.3)	0.344
PCI	1611 (55.0)	668 (46.6)	943 (63.0)	<0.001
CABG	638 (21.8)	495 (34.5)	143 (9.6)	<0.001
Right heart catheterization	2349 (41.1)	1104 (35.6)	1245 (14.5)	<0.001
LVAD	452 (7.9)	229 (7.4)	222 (8.5)	0.366
Heart transplantation	370 (6.5)	291 (9.4)	79 (3.0)	<0.001

Median household income				0.446
1st quartile	1424 (24.9)	804 (25.9)	621 (23.7)	
2nd quartile	1392 (24.3)	761 (24.6)	631 (24.1)	
3rd quartile	1457 (25.5)	755 (24.4)	703 (26.8)	
4th quartile	1445 (25.3)	778 (25.1)	666 (25.4)	
Primary payer				<0.001
Medicare	2093 (36.6)	1259 (40.7)	834 (31.8)	
Medicaid	926 (16.2)	503 (16.2)	423 (16.1)	
Private including HMO	2245 (39.3)	1132 (36.6)	1113 (42.5)	
Self-pay/no charge/other	454 (7.9)	203 (6.5)	251 (9.6)	
Hospital bed size				0.009
Small	141 (2.5)	83 (2.8)	58 (2.2)	
Medium	759 (13.3)	349 (11.3)	409 (15.6)	

Large	4818 (84.2)	2665 (85.9)	2153 (82.2)	
Time to VA-ECMO, median (IQR), d	0 (0-1.9)	0.2 (0-3.4)	0 (0-1.0)	0.015
Length of hospital stay, median (IQR), d	29 (16-47)	29 (17-46)	27 (14-47)	0.323
Disposition*				0.005
Home	1251 (21.9)	718 (23.2)	533 (20.4)	
Facility†	1518 (26.6)	880 (28.4)	638 (24.5)	
Died	2935 (51.5)	1498 (48.4)	1437 (55.1)	
Cost of index hospitalization, median (IQR), \$	170199 (98911- 283933)	169158 (97903- 280557)	171386 (101507- 288212)	0.737

VA-ECMO = Veno-arterial extracorporeal membrane oxygenation; IABP = Intra-aortic balloon pump; IQR = Interquartile range;

STEMI = ST-segment elevation myocardial infarction; NSTEMI = Non-ST-elevation myocardial infarction; PCI = Percutaneous coronary intervention; CABG = Coronary artery bypass graft; CHF = Congestive heart failure; LVAD = Left ventricular assist device.

*Disposition: AMA/unknown not counted due to number of patients <10 for patient confidentiality accordingly to HCUP guideline.

†Facility includes skilled nursing facility, intermediate care facility and inpatient rehabilitation facility.

Table S4. Comparison of Baseline Individual- and Hospital-Level Characteristics for Patients Hospitalized with Cardiogenic Shock Requiring VA-ECMO With Left Ventricular Unloading Devices Between IABP and Different Platforms of Impella, 2016-2020.

Characteristics (%)	All	IABP	Impella 2.5/CP	P-value*	Impella 5.0/LD/5.5	P-value†
Number of patients, weighted (%)	5718	3098 (19.4)	2181 (13.6)	-	440 (2.7)	-
Age, median (IQR)	59 (49-66)	59 (50-68)	58 (50-66)	0.341	53 (41-61)	<0.001
Age group, y				0.402		-
<50	1448 (25.3)	734 (23.7)	525 (24.1)		190 (43.2)	
50-64	2442 (42.7)	1289 (41.6)	961 (44.0)		192 (43.7)	
65-79	1693 (29.6)	988 (31.9)	647 (29.7)		58 (13)	
≥80	136 (2.4)	87 (2.8)	48 (2.2)		0 (0)	
Female	1666 (29.1)	1006 (32.5)	561 (25.7)	<0.001	99 (22.5)	0.004

Causes of cardiogenic shock						
STEMI	2051 (35.9)	927 (29.9)	979 (44.9)	<0.001	145 (33.0)	0.371
NSTEMI	879 (15.4)	507 (16.4)	317 (14.6)	0.195	55 (12.4)	0.115
Nonischemic	2788 (48.8)	1664 (53.7)	885 (40.6)	<0.001	240 (54.6)	0.814
Previous cardiac arrest	215 (3.8)	103 (3.3)	100 (4.6)	0.140	11 (2.5)	0.466
Hypertension	3316 (58.0)	1863 (60.1)	1246 (57.1)	0.114	208 (47.3)	<0.001
Diabetes mellitus	1895 (33.1)	1028 (33.2)	736 (33.7)	0.790	131 (29.9)	0.321
Known coronary artery disease	3254 (56.9)	1773 (57.2)	1279 (58.6)	0.530	203 (46.1)	0.005
Prior PCI	72 (1.3)	39 (1.3)	29 (1.3)	0.928	-‡	0.618
Prior CABG	304 (5.3)	201 (6.5)	92 (4.2)	0.008	12 (2.7)	0.013
Iron deficiency anemia	235 (4.1)	140 (4.5)	81 (3.7)	0.299	15 (3.3)	0.348
Chronic kidney disease	1796 (31.4)	1059 (34.2)	590 (27.1)	<0.001	147 (33.4)	0.831
CHF	3319 (58.0)	1817 (58.7)	1258 (57.7)	0.632	244 (55.5)	0.405
Atrial fibrillation	2132 (37.3)	1266 (40.9)	688 (31.5)	<0.001	179 (40.7)	0.965

Coagulopathy	2549 (44.6)	1420 (45.8)	907 (41.6)	0.035	222 (50.5)	0.253
COPD (chronic pulmonary disease)	901 (15.8)	547 (17.6)	303 (13.9)	0.007	51 (11.7)	0.022
Peripheral vascular disease	1297 (22.7)	725 (23.4)	477 (21.9)	0.413	94 (21.4)	0.444
Valvular heart disease	218 (3.8)	166 (5.4)	41 (1.9)	<0.001	10 (2.3)	0.025
Elixhauser comorbidity score ≥ 4	2114 (37.0)	1237 (39.9)	725 (33.2)	0.003	152 (34.6)	0.175
Procedures/surgeries performed						
Revascularization among ischemic cardiogenic shock	2091 (71.4)	1040 (72.5)	942 (72.7)	0.940	109 (54.7)	<0.001
PCI	1611 (55.0)	668 (46.6)	847 (65.3)	<0.001	96 (48.3)	0.765
CABG	638 (21.8)	495 (34.5)	118 (9.1)	<0.001	25 (12.4)	<0.001

Right heart catheterization	2349 (41.1)	1104 (35.6)	1019 (46.7)	<0.001	227 (51.6)	<0.001
LVAD	452 (7.9)	229 (7.4)	-‡	<0.001	218 (49.7)	<0.001
Heart transplantation	370 (6.5)	291 (9.4)	-‡	<0.001	77 (17.6)	<0.001
Median household income				0.368		0.374
1st quartile	1424 (24.9)	804 (25.9)	527 (24.2)		93 (21.2)	
2nd quartile	1392 (24.3)	761 (24.6)	506 (23.2)		124 (28.3)	
3rd quartile	1457 (25.5)	755 (24.4)	600 (27.5)		102 (23.3)	
4th quartile	1445 (25.3)	778 (25.1)	547 (25.1)		119 (27.2)	
Primary payer				<0.001		<0.001
Medicare	2093 (36.6)	1259 (40.7)	733 (33.6)		101 (22.9)	
Medicaid	926 (16.2)	503 (16.2)	318 (14.6)		105 (23.9)	
Private including HMO	2245 (39.3)	1132 (36.6)	911 (41.8)		202 (46.0)	
	454 (7.9)	203 (6.5)	219 (10.0)		32 (7.2)	

Self-pay/no charge/other						
Hospital bed size				<0.001		0.090
Small	141 (2.5)	83 (2.8)	51 (2.3)		-‡	
Medium	759 (13.3)	349 (11.3)	382 (17.5)			
Large	4818 (84.2)	2665 (85.9)	1748 (80.2)			
Time to VA-ECMO, median (IQR), d	0 (0-1.9)	0.2 (0-3.4)	0 (0-0.9)	<0.001	0.3 (0-2.0)	0.861
Time to Impella, median (IQR), d	-	-	0 (0-1.9)		1.8 (0-7.0)	
Length of hospital stay, median (IQR), d	29 (16-47)	18 (6-35)	10 (3-23)	<0.001	45 (24-68)	<0.001
Disposition‡				<0.001		<0.001
Home	1251 (21.9)	718 (23.2)	353 (16.3)		180 (40.9)	
Facility†	1518 (26.6)	880 (28.4)	507 (23.4)		130 (29.6)	
Died	2935 (51.5)	1498 (48.4)	1308 (60.3)		129 (29.5)	

Time to In-Hospital Death, median (IQR), d	7.2 (2.5- 16.2)	8.4 (3.3- 17.7)	6.0 (2.0-13.1)	<0.001	19.8 (11.8-29.2)	<0.001
Cost of index hospitalization, median (IQR), \$	170199 (98911- 283933)	169158 (97903- 280557)	149444 (92062- 234588)	<0.001	397296 (274669- 625969)	<0.001

IABP = Intra-aortic balloon pump; VA-ECMO = Veno-arterial extracorporeal membrane oxygenation; STEMI = ST-elevation myocardial infarction; NSTEMI = Non-ST-elevation myocardial infarction; PCI = Percutaneous coronary intervention; CABG = Coronary artery bypass graft surgery; CHF = Congestive heart failure; LVAD = Left ventricular assist device; HMO = health maintenance organization; IQR = interquartile range.

**P*-value for comparison between IABP and Impella 2.5/CP only.

†*P*-value for comparison between Impella and Impella 5.0/LD/5.5 only.

‡LVAD for Impella 2.5/CP, OHT for Impella 2.5/CP, Hospital bed size for Impella 5.0/LD/5.5, and Prior PCI for Impella 5.0/LD/5.5 not counted due to number of patients <10 for patient confidentiality accordingly to HCUP guideline.

‡Disposition: AMA/unknown not counted due to number of patients <10 for patient confidentiality accordingly to HCUP guideline.

†Facility includes skilled nursing facility, intermediate care facility and inpatient rehabilitation facility.

Table S5. Comparison of In-Hospital Outcomes in Patients on VA-ECMO for Cardiogenic Shock Based on LV-Unloading Strategies.

In-Hospital Outcomes	Event Rate	<i>P</i>-value*	<i>P</i>-value*
In-hospital mortality		0.007	
ECMO only	50.4%	Ref	-
IABP	48.4%	0.196	Ref
Impella	54.8%	0.014	0.001
Vascular complications†		0.973	
ECMO only	7.9%	Ref	-
IABP	8.0%	0.999	Ref
Impella	8.2%	0.999	0.999
Acute limb ischemia		0.479	
ECMO only	4.0%	Ref	-
IABP	3.7%	0.999	Ref
Impella	4.6%	0.893	0.681
Bleeding‡		0.003	

ECMO only	34.8%	Ref	-
IABP	35.4%	0.999	Ref
Impella	40.1%	<0.001	0.045
AKI requiring hemodialysis		<0.001	
ECMO only	16.5%	Ref	-
IABP	16.0%	0.999	Ref
Impella	21.8%	<0.001	0.002
Ischemic stroke		0.210	
ECMO only	9.5%	Ref	-
IABP	10.0%	0.999	Ref
Impella	8.6%	0.999	0.629

IABP = Intra-aortic balloon pump; VA-ECMO = Veno-arterial extracorporeal membrane oxygenation; AKI=acute kidney injury.

*P-values are corrected based on Bonferroni Correction method for multiple comparison.

†Vascular complications: Composite of arteriovenous fistula, rupture, dissection, other vascular complications following a procedure, and acute limb ischemia.

‡Bleeding: Composite of CNS bleeding, access-related bleeding including hematoma and retroperitoneal bleeding, GI bleeding, and pulmonary alveolar bleeding.

Table S6. Comparison of In-Hospital Outcomes in Patients on VA-ECMO for Cardiogenic Shock Based on LV-Unloading Strategies Including Different Platform of Impella.

In-Hospital Outcomes	Event Rate	<i>P</i>-value*	<i>P</i>-value*
In-hospital mortality		0.007	
ECMO only	50.4%	Ref	-
IABP	48.4%	0.982	Ref
Impella 2.5/CP	60.0%	<0.001	<0.001
Impella 5.0/LD/5.5	29.5%	<0.001	<0.001
Vascular complications†		0.973	
ECMO only	7.9%	Ref	-
IABP	8.0%	0.999	Ref
Impella 2.5/CP	8.1%	0.999	0.999
Impella 5.0/LD/5.5	8.3%	0.999	0.999
Bleeding‡		0.003	
ECMO only	34.8%	Ref	-
IABP	35.4%	0.999	Ref

Impella 2.5/CP	38.1%	0.176	0.825
Impella 5.0/LD/5.5	49.7%	<0.001	<0.001
AKI requiring hemodialysis		<0.001	
ECMO only	16.5%	Ref	-
IABP	16.0%	0.999	Ref
Impella 2.5/CP	21.9%	<0.001	0.003
Impella 5.0/LD/5.5	21.0%	0.649	0.476
Ischemic stroke		0.210	
ECMO only	9.5%	Ref	-
IABP	10.0%	0.999	Ref
Impella 2.5/CP	7.3%	0.147	0.109
Impella 5.0/LD/5.5	15.1%	0.054	0.145

IABP = Intra-aortic balloon pump; VA-ECMO = Veno-arterial extracorporeal membrane oxygenation; AKI=acute kidney injury.

*P-values are corrected based on Bonferroni Correction method for multiple comparison.

†Vascular complications: Composite of arteriovenous fistula, rupture, dissection, other vascular complications following a procedure, and acute limb ischemia. ‡Bleeding: Composite of CNS bleeding, access-related bleeding including hematoma and retroperitoneal bleeding, GI bleeding, and pulmonary alveolar bleeding.

**Table S7. Comparison of In-Hospital Bleeding Outcomes in Patients on VA-ECMO for Cardiogenic Shock Based on LV-
Unloading Strategies.**

Bleeding	Event Rate (%)	<i>P</i> -value	<i>P</i> -value	Adjusted OR (95% CI); <i>P</i> -value	
CNS Bleeding					
ECMO only	4.8	Ref	-	Ref	-
IABP	4.3	0.999*	Ref	0.91 (0.61-1.35); P=0.999*	Ref
Impella	5.7	0.477†	0.300‡	1.16 (0.83-1.63); P=0.853†	1.28 (0.81-2.01); P=0.581‡
Access-Related Bleeding					
ECMO only	18.0	Ref	-	Ref	-
IABP	20.6	0.091*	Ref	1.12 (0.93-1.35); P=0.437*	Ref
Impella	22.0	0.002†	0.999‡	1.29 (1.07-1.56); P=0.003†	1.15 (0.92-1.45); P=0.398‡
GI Bleeding					

ECMO only	12.5	Ref	-	Ref	-
IABP	12.2	0.999*	Ref	0.94 (0.76-1.16); 0.999*	Ref
Impella	16.8	<0.001 †	<0.001 ‡	1.29 (1.05-1.59); 0.008†	1.38 (1.07-1.78); 0.009‡
Pulmonary Bleeding					
ECMO only	5.0	Ref	-	Ref	-
IABP	3.9	0.257*	Ref	0.81 (0.56-1.16); P=0.478*	Ref
Impella	3.1	0.021†	0.644‡	0.64 (0.41-0.99); P=0.048†	0.80 (0.49-1.29); P=0.771‡

IABP = Intra-aortic balloon pump; VA-ECMO = Veno-arterial extracorporeal membrane oxygenation; CI = Confidence interval.

*P-value: comparison between IABP and ECMO only

†P-value: comparison between Impella and ECMO only

‡ P-value: comparison between Impella and IABP

*†‡P-values are corrected based on Bonferroni Correction method for multiple comparison.

Table S8. Association of LV Unloading Strategy with In-Hospital Outcomes in Patients on VA-ECMO for Cardiogenic Shock.

In-Hospital Outcomes	Univariate Analysis		Multivariable Analysis	
	Odds Ratio (95% CI)	<i>P</i> -value*	Odds Ratio (95% CI)	<i>P</i> -value*
In-hospital mortality				
IABP vs. ECMO only	0.92 (0.78-1.09)	0.999	0.83 (0.69-1.00)	0.051
Impella 2.5/CP vs. ECMO only	1.47 (1.19-1.81)	<0.0001	1.34 (1.09-1.65)	0.001
Impella 2.5/CP vs. IABP	1.60 (1.27-2.02)	<0.0001	1.61 (1.28-2.03)	<0.001
Impella 5.0/LD/5.5 vs. ECMO only	0.41 (0.26-0.64)	<0.0001	0.40 (0.26-0.64)	<0.001
Impella 5.0/LD/5.5 vs. IABP	0.45 (0.29-0.69)	<0.0001	0.49 (0.31-0.76)	<0.001
Vascular complication				
IABP vs. ECMO only	1.01 (0.71-1.43)	0.999	1.03 (0.72-1.48)	0.999
Impella 2.5/CP vs. ECMO only	1.03 (0.73-1.44)	0.999	1.07 (0.76-1.50)	0.999
Impella 2.5/CP vs. IABP	1.02 (0.67-1.54)	0.999	1.04 (0.68-1.57)	0.999
Impella 5.0/LD/5.5 vs. ECMO only	1.05 (0.56-1.98)	0.999	1.05 (0.55-2.03)	0.999
Impella 5.0/LD/5.5 vs. IABP	1.04 (0.52-2.07)	0.999	1.02 (0.50-2.08)	0.999
Bleeding†				

IABP vs. ECMO only	1.03 (0.86-1.23)	0.999	0.99 (0.83-1.18)	0.999
Impella 2.5/CP vs. ECMO only	1.16 (0.96-1.38)	0.211	1.12 (0.93-1.34)	0.697
Impella 2.5/CP vs. IABP	1.13 (0.90-1.41)	0.999	1.13 (0.90-1.43)	0.946
Impella 5.0/LD/5.5 vs. ECMO only	1.85 (1.33-2.57)	<0.001	1.76 (1.27-2.46)	<0.001
Impella 5.0/LD/5.5 vs. IABP	1.80 (1.24-2.62)	<0.001	1.79 (1.22-2.62)	<0.001
AKI requiring hemodialysis				
IABP vs. ECMO only	0.96 (0.76-1.22)	0.999	0.95 (0.75-1.21)	0.999
Impella 2.5/CP vs. ECMO only	1.42 (1.11-1.82)	<0.001	1.50 (1.16-1.93)	<0.001
Impella 2.5/CP vs. IABP	1.48 (1.10-1.99)	0.003	1.57 (1.15-2.16)	<0.001
Impella 5.0/LD/5.5 vs. ECMO only	1.34 (0.80-2.26)	0.808	1.10 (0.67-1.81)	0.999
Impella 5.0/LD/5.5 vs. IABP	1.40 (0.82-2.38)	0.598	1.16 (0.68-1.97)	0.999
Ischemic stroke				
IABP vs. ECMO only	1.06 (0.81-1.39)	0.999	0.99 (0.75-1.31)	0.999
Impella 2.5/CP vs. ECMO only	0.75 (0.52-1.07)	0.188	0.67 (0.47-0.97)	0.023
Impella 2.5/CP vs. IABP	0.71 (0.47-1.06)	0.135	0.68 (0.46-1.01)	0.063
Impella 5.0/LD/5.5 vs. ECMO only	1.69 (0.97-2.94)	0.073	1.55 (0.87-2.76)	0.267

Impella 5.0/LD/5.5 vs. IABP	1.60 (0.90-2.83)	0.181	1.57 (0.87-2.82)	0.265
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AKI=acute kidney injury; CI = Confidence interval; IABP = Intra-aortic balloon pump; VA-ECMO = Veno-arterial extracorporeal membrane oxygenation.

*P-values are corrected based on Bonferroni Correction method for multiple comparison.

Table S9. Association of Impella vs. IABP with In-Hospital Mortality in Patients on VA-ECMO for Cardiogenic Shock.

Subgroup	Odds Ratio (95% CI)	<i>P</i>-value	<i>P</i> for interaction
Etiology of Cardiogenic Shock			0.811
Acute myocardial infarction	1.32 (1.05-1.68)	0.020	
Nonischemic	1.43 (1.14-1.79)	0.002	

IABP = Intra-aortic balloon pump; VA-ECMO = Veno-arterial extracorporeal membrane oxygenation; CI = Confidence interval.

Table S10. Association Between Left Ventricular Unloading Device and Early Mortality Based on Regression and Propensity Score Analyses.

Left ventricular unloading device	Model 1*		Model 2†		Model 3‡		Model 4§	
	Hazard Ratio (95% CI)	<i>P</i> - value	Hazard Ratio (95% CI)	<i>P</i> - value	Hazard Ratio (95% CI)	<i>P</i> - value	Hazard Ratio (95% CI)	<i>P</i> - value
Impella vs. IABP	1.28 (1.14-1.43)	<0.001	1.28 (1.15-1.44)	<0.001	1.31 (1.14-1.51)	<0.001	1.25 (1.17-1.32)	<0.001

IABP = Intra-aortic balloon pump; HR = Hazard ratio; CI = Confidence interval.

*Model 1: Cox proportional multivariable regression.

†Model 2: Propensity score (PS) included as a covariate in the multivariable logistic regression model.

‡Model 3: Analysis based on the PS matching.

§Model 4: Inverse probability of treatment weights (IPTW) analysis based on the PS after trimming by excluding those lying outside of the 1st to 99th percentiles of the PS distribution. Adjusted odds ratio (95% CI) without trimming: 1.25 (1.18-1.31), $p < 0.001$.

Table S11. Comparison of falsification endpoints among propensity-matched patients with cardiogenic shock on VA-ECMO receiving Impella vs. IABP for left ventricular unloading.

Falsification endpoint, n (%)	Impella, n=1149	IABP, n=1149	Odds Ratio (95% CI)	P-value
Pneumonia	175 (15.2)	193 (16.5)	0.90 (0.72-1.14)	0.383
Composite endpoint	129 (11.2)	118 (10.3)	1.11 (0.85-1.46)	0.445
Diarrhea	39 (3.4)	35 (3.1)	1.13 (0.70-1.83)	0.623
Cellulitis	18 (1.6)	16 (1.4)	1.13 (0.57-2.21)	0.732
Intestinal obstruction	80 (7.0)	76 (6.6)	1.06 (0.76-1.47)	0.737

VA-ECMO = Veno-arterial extracorporeal membrane oxygenation; IABP = Intra-aortic balloon pump; CI = Confidence interval.

Table S12. Sensitivity Analyses for Association of LV Unloading Strategy with In-Hospital Mortality in Patients on VA-ECMO for Cardiogenic Shock*.

In-Hospital Outcomes	Univariate Analysis		Multivariable Analysis	
	Odds Ratio (95% CI)	<i>P</i> -value†	Odds Ratio (95% CI)	<i>P</i> -value†
In-hospital Mortality				
IABP vs. ECMO only	0.58 (0.36-0.93)	0.016	0.54 (0.32-0.89)	0.010
Impella vs. ECMO only	1.28 (0.79-2.08)	0.666	1.23 (0.75-2.01)	0.980
Impella vs. IABP	2.21 (1.19-4.12)	0.007	2.29 (1.21-4.31)	0.005

VA-ECMO = Veno-arterial extracorporeal membrane oxygenation; IABP = Intra-aortic balloon pump; CI = Confidence interval.

*Among patients on ECMO only or those who had LV unloading started on days subsequent to VA-ECMO cannulation day.

†All *P*-values are corrected for multiple comparisons using Bonferroni method.

Figure S1. Primary Causes of 30-Day Readmission Following Hospitalization with Cardiogenic Shock Requiring VA-ECMO.

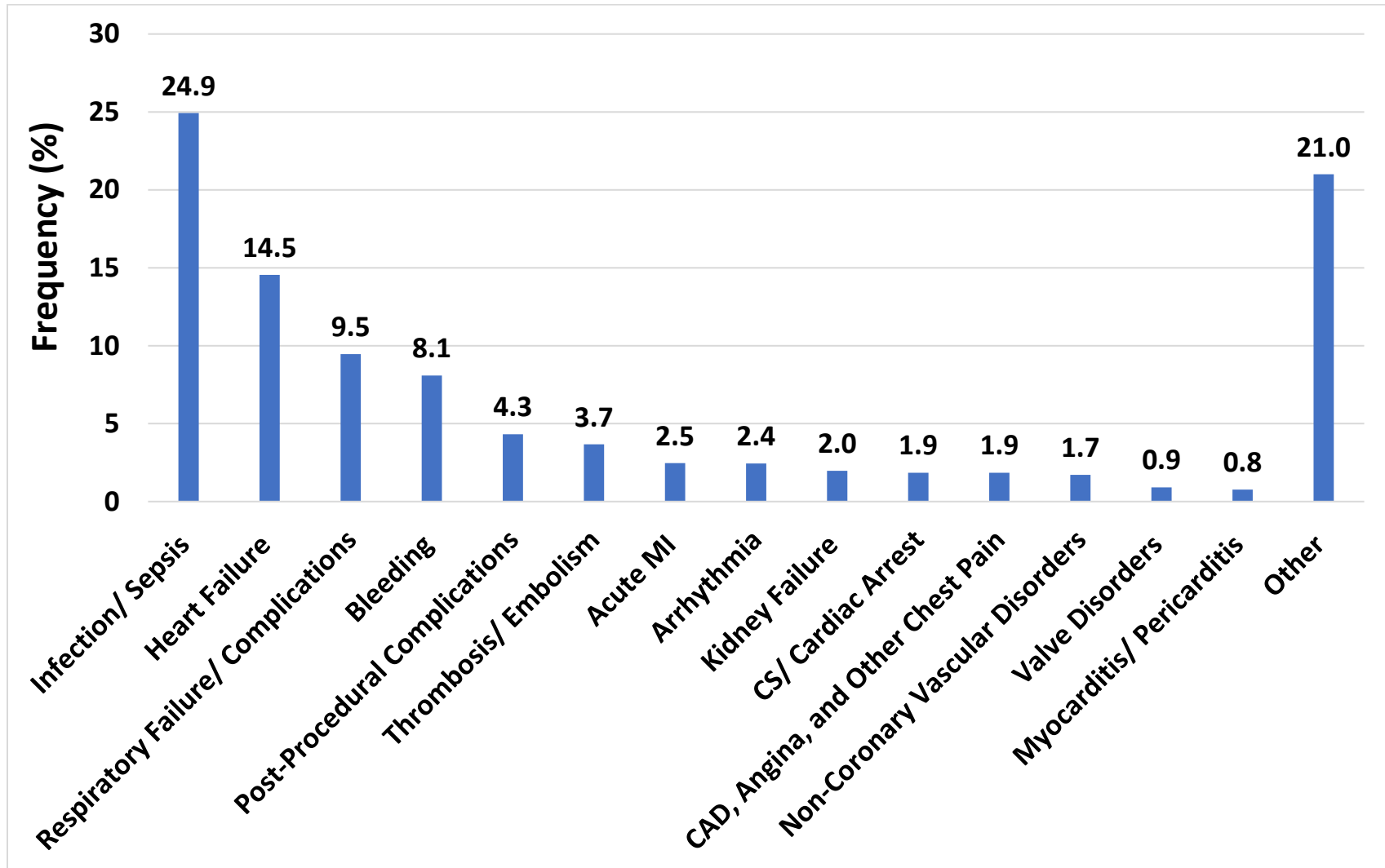


Figure S2. Primary Procedures Performed during 30-Day Readmission Following Hospitalization with Cardiogenic Shock Requiring VA-ECMO.

