Clinician and Algorithmic Application of the 2019 and 2022 SCAI Shock Stages in the Critical Care Cardiology Trials Network Registry

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TABLE OF CONTENTS

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Supplemental Methods

The vasoactive-inotropic score (VIS) is calculated using vasoactive drug doses as follows:

VIS = dobutamine + dopamine + 10*phenylephrine + 10*milrinone + 100*epinephrine +

100*norepinephrine + 10,000*vasopressin

Doses for all agents are in µg/kg/min with the exception of vasopressin which is in units/kg/min.

Supplemental Table 1: CCCTN Adaptation of the 2019 SCAI Cardiogenic Shock Staging Criteria

SCAI Stage	Original SCAI Criteria (2019)[1]	Original CCCTN Algorithm (2019 SCAI Adaptation)[2]
C ("classic")	• Hypoperfusion requiring intervention beyond volume resuscitation • Typically have relative hypotension	• Site-reported CS **AND** • Baseline eGFR <45 or AST/ALT > 150 or worst lactate ≥2 **AND** • Use of vasoactive agents or MCS
D ("deteriorating")	• Similar to stage C but getting worse • Failure to respond to initial interventions – requiring multiple pressors or addition of MCS to maintain perfusion	• Site-reported CS and lab criteria of stage C above **AND** • Use of multiple vasoactive agents or escalation to MCS >24h from admission (new or >1 device) OR • Lactate ↑ ≥ 50%
E ("extremis")	• CA with ongoing CPR or ECMO or hypotension despite maximal support • Being supported by multiple interventions • "Trying to die": lactate ≥ 5, may include pH ≤ 7.2	• Site-reported CS **AND** • Worst lactate ≥5 or pH ≤ 7.2

CA = cardiac arrest; CCCTN = Critical Care Cardiology Trials Network; CPR = cardiopulmonary resuscitation; ECMO = extracorporeal membrane oxygenation; CS = cardiogenic shock; eGFR = estimated glomerular filtration rate; MCS = mechanical circulatory support; SCAI = Society of Cardiovascular Angiography and Interventions.

Supplemental Table 2: Reclassification of Algorithm-based 2019 SCAI Stage by Clinician-assigned 2019 SCAI stage

In-Hospital Death?	Clinician Assignment (2019 SCAI) vs. Original CCCTN Algorithm (2019 SCAI)	% Reclassification (n/N)
Yes (N=472)	Agreement	40.3% (190/472)
	Correctly Up-classified	**7.0% (33/472)**
	Incorrectly Down-classified	**52.8% (249/472)**
No (N=868)	Agreement	39.6% (344/868)
	Correctly Down-classified	**56.7% (493/868)**
	Incorrectly Up-classified	**3.6% (31/868)**

CCCTN = Critical Care Cardiology Trials Network; SCAI = Society of Cardiovascular Angiography and Interventions.

Supplemental Table 3: Patient Characteristics by Algorithm-based and Clinician-assigned 2019 SCAI Stage

	SCAI Stage C		SCAI Stage D		SCAI Stage E	
	CCCTN 2019 SCAI Algorithm (N=280)	Clinician Assessment (N=778)	CCCTN 2019 SCAI Algorithm (N=535)	Clinician Assessment (N=433)	CCCTN 2019 SCAI Algorithm (N=525)	Clinician Assessment (N=129)
Demographics						
Age, years	67 (56-76)	65 (55-74)	64 (55-72)	66 (57-74)	67 (58-75)	67 (60-75)
Female	90 (32.1)	253 (32.5)	174 (32.5)	148 (34.2)	187 (35.6)	50 (38.8)
White	167 (65.2)	444 (64.0)	319 (68.5)	276 (74.4)	302 (66.1)	68 (59.6)
BMI, kg/m^2	27.9 (23.8-31.8)	27.1 (23.7-31.7)	27.6 (23.8-32.0)	27.6 (23.7-32.4)	26.8 (23.6-32.0)	27.9 (24.7-32.1)
Comorbidities						
Hypertension	176 (62.9)	475 (61.1)	321 (60.0)	258 (59.6)	313 (59.6)	77 (59.7)
Diabetes mellitus	116 (41.4)	300 (38.6)	206 (38.5)	160 (37.0)	194 (37.0)	56 (43.4)
Current smoker	48 (17.2)	128 (16.5)	71 (13.3)	67 (15.5)	99 (18.9)	23 (17.8)
Chronic kidney disease	88 (31.4)	228 (29.3)	157 (29.3)	108 (24.9)	121 (23.0)	30 (23.3)
Dialysis dependent	8 (9.1)	29 (12.7)	21 (13.4)	21 (19.4)	29 (24.0)	8 (26.7)
Coronary artery disease	108 (38.6)	284 (36.5)	199 (37.2)	155 (35.8)	172 (32.8)	40 (31.0)
Cerebrovascular disease	21 (7.5)	69 (8.9)	42 (7.9)	28 (6.5)	43 (8.2)	9 (7.0)
Peripheral artery disease	21 (7.5)	73 (9.4)	50 (9.3)	41 (9.5)	54 (10.3)	11 (8.5)
Prior heart failure	163 (58.2)	436 (56.0)	325 (60.7)	227 (52.4)	217 (41.3)	42 (32.6)
Severe valvular disease	56 (20.0)	129 (16.6)	100 (18.7)	71 (16.4)	60 (11.4)	16 (12.4)
Pulmonary hypertension	31 (11.1)	69 (8.9)	51 (9.5)	38 (8.8)	34 (6.5)	9 (7.0)
Significant pulmonary disease	43 (15.4)	99 (12.7)	59 (11.0)	57 (13.2)	74 (14.1)	20 (15.5)
Significant liver disease	9 (3.2)	20 (2.6)	15 (2.8)	6 (1.4)	4 (0.8)	2 (1.6)

All values represent n (%) for categorical measures and median (25-75th percentile) for continuous measures. BMI = body mass index; CCCTN = Critical Care Cardiology Trials Network; SCAI = Society of Cardiovascular Angiography and Interventions.

Supplemental Table 4: Illness Severity, Resource Utilization and Shock Management for Algorithm-Based vs. Clinician Assigned 2019 SCAI Stage

	SCAI Stage C		SCAI Stage D		SCAI Stage E	
	CCCTN 2019 SCAI Algorithm (N=280)	Clinician Assessment (N=778)	CCCTN 2019 SCAI Algorithm (N=535)	Clinician Assessment (N=433)	CCCTN 2019 SCAI Algorithm (N=525)	Clinician Assessment (N=129)
Illness Severity						
Total Day 1 SOFA Score	6.0 (5.0-8.5)	7.0 (5.0-9.0)	7.0 (5.0-10.0)	9.0 (6.0-12.0)	10.0 (7.0-12.0)	11.0 (9.0-13.0)
IABP SHOCK-II Score	2.0 (1.0-3.0)	2.0 (1.0-3.0)	1.0 (1.0-2.0)	2.0 (1.0-3.0)	3.0 (2.0-4.0)	3.0 (2.0-4.0)
Preceding cardiac arrest	40 (14.3)	169 (21.7)	94 (17.6)	128 (29.6)	241 (45.9)	78 (60.5)
ICU Resource Utilization						
Mechanical ventilation	72 (25.7)	330 (42.4)	282 (52.7)	297 (68.6)	391 (74.5)	118 (91.5)
Renal replacement therapy	12 (4.3)	89 (11.4)	93 (17.4)	107 (24.7)	116 (22.1)	25 (19.4)
Pulmonary Artery Catheterization	108 (38.6)	345 (44.3)	313 (58.5)	277 (64.0)	247 (47.0)	46 (35.7)
Shock Management						
Vasopressors or inotropes	1.0 (1.0-1.0)	1.0 (1.0-2.0)	2.0 (2.0-3.0)	2.0 (2.0-3.0)	2.0 (1.0-3.0)	3.0 (2.0-4.0)
≥2 agents	n/a	344 (44.4)	438 (82.3)	357 (83.0)	374 (71.5)	111 (86.7)
4h VIS	2.5 (0.0-5.0)	4.0 (2.0-7.5)	5.0 (2.5-14.0)	10.0 (4.0-28.5)	10.0 (3.3-30.5)	33.7 (10.0-80.0)
24h VIS	2.5 (0.0-5.0)	3.0 (0.0-6.5)	5.0 (2.0-12.5)	10.9 (3.6-24.1)	7.0 (2.5-20.0)	14.0 (2.0-45.0)
MCS	69 (24.6)	219 (28.1)	264 (49.3)	251 (58.0)	195 (37.1)	58 (45.0)
IABP	55 (79.7)	141 (64.4)	178 (67.4)	173 (68.9)	100 (51.3)	19 (32.8)
Advanced MCS*	16 (23.2)	96 (43.8)	140 (53.0)	129 (51.4)	117 (60.0)	48 (82.8)
>1 device	2 (2.9)	23 (10.5)	74 (28.0)	78 (31.1)	43 (22.1)	18 (31.0)
Placed ≤24h of admission	57 (82.6)	113 (51.6)	118 (44.7)	140 (55.8)	120 (61.5)	42 (72.4)

All values represent n (%) for categorical measures and median (25-75th percentile) for continuous measures.

*Advanced MCS includes Impella, TandemHeart, VA-ECMO, or surgical ventricular assist device.

CCCTN = Critical Care Cardiology Trials Network; h = hour; IABP = intra=aortic balloon pump; IABP SHOCK=II = intra=aortic balloon pump in cardiogenic shock II; MCS = mechanical circulatory support; n/a = not applicable as the algorithm does not allow for inclusion of these factors in the designated SCAI stage; SCAI = Society of Cardiovascular Angiography and Interventions; SOFA = sequential organ failure assessment; VIS = vasoactive=inotropic score.

Supplemental Table 5: Baseline Lab Values for Algorithm-Based vs. Clinician-Assigned 2019 SCAI Stage

	SCAI Stage C		SCAI Stage D		SCAI Stage E	
	CCCTN 2019 SCAI Algorithm (N=280)	Clinician Assessment (N=778)	CCCTN 2019 SCAI Algorithm (N=535)	Clinician Assessment (N=433)	CCCTN 2019 SCAI Algorithm (N=525)	Clinician Assessment (N=129)
Lactate (mmol/L)	2.5 (1.8-3.3)	2.8 (1.8-4.9)	2.1 (1.4-3.1)	3.4 (2.1-6.5)	6.7 (5.0-9.4)	8.0 (3.9-11.2)
<2	67 (28.5)	202 (29.5)	197 (42.9)	89 (22.4)	39 (7.6)	12 (9.7)
2-<5	168 (71.5)	318 (46.5)	262 (57.1)	174 (43.7)	87 (17.0)	25 (20.2)
5-<8	n/a	107 (15.6)	n/a	62 (15.6)	194 (37.9)	25 (20.2)
≥8	n/a	57 (8.3)	n/a	73 (18.3)	192 (37.5)	62 (50.0)
eGFR (mL/min/1.73^2)	38.9 (25.5-56.4)	41.2 (26.0-60.2)	41.4 (26.6-62.8)	38.6 (25.5-57.9)	39.7 (24.4-56.6)	38.2 (22.9-58.1)
≥60	63 (22.5)	195 (25.1)	145 (27.1)	100 (23.1)	116 (22.1)	29 (22.7)
45-<60	49 (17.5)	144 (18.5)	92 (17.2)	75 (17.3)	99 (18.9)	21 (16.4)
<45	168 (60.0)	439 (56.4)	298 (55.7)	258 (59.6)	309 (59.0)	78 (60.9)
pH, ABG or VBG	7.4 (7.3-7.4)	7.4 (7.3-7.4)	7.4 (7.3-7.4)	7.3 (7.2-7.4)	7.2 (7.1-7.3)	7.2 (7.1-7.3)
≤7.2	n/a	77 (12.4)	n/a	83 (22.1)	215 (42.7)	55 (44.0)

All values represent n (%) for categorical measures and median (25-75th percentile) for continuous measures.
CCCTN = Critical Care Cardiology Trials Network; eGFR = estimated glomerular filtration rate. n/a = not applicable as the algorithm does not allow for inclusion of these factors in the designated SCAI stage; SCAI - Society of Cardiovascular Angiography and Interventions

Supplemental Table 6: Reclassification of Algorithm-based 2019 SCAI Stage by the Algorithm-based 2022 SCAI Stage

| In-Hospital Death?	Revised CCCTN Algorithm (2022 SCAI) vs. Original CCCTN Algorithm (2019 SCAI)	% Reclassification (n/N)
Yes (N=472)	Agreement	55.5% (262/472)
	Correctly Up-classified	5.5% (26/472)
	Incorrectly Down-classified	39.0% (184/472)
No (N=868)	Agreement	51.0% (443/868)
	Correctly Down-classified	47.4% (411/868)
	Incorrectly Up-classified	1.6% (14/868)

CCCTN = Critical Care Cardiology Trials Network; SCAI = Society of Cardiovascular Angiography and Interventions.

Supplemental Table 7: Reclassification of Algorithm-based 2022 SCAI Stage by Clinician-assigned 2019 SCAI stage

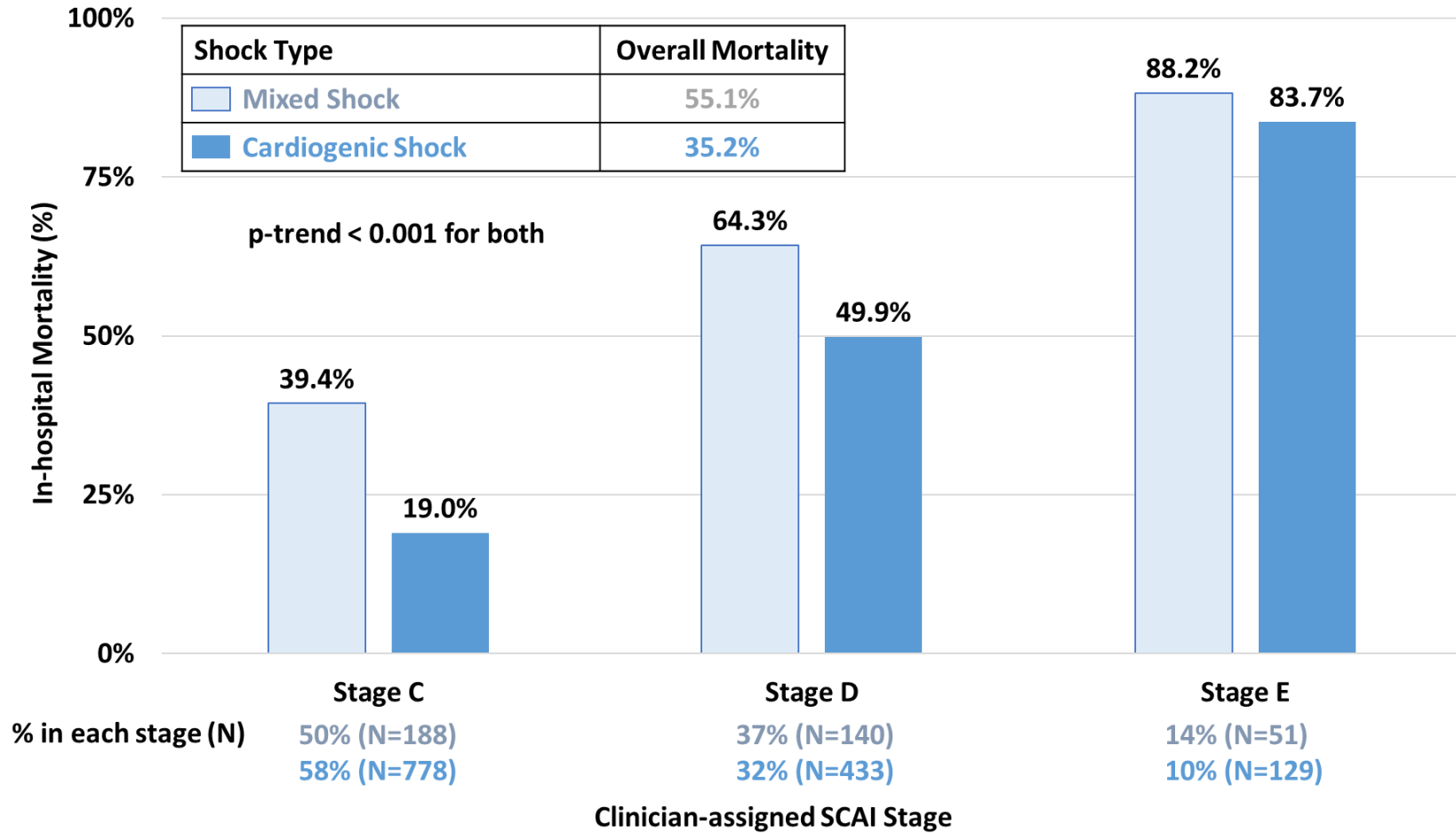| In-Hospital Death?	Clinician Assessment (2019 SCAI) vs. Revised CCCTN Algorithm (2022 SCAI)	% Reclassification (n/N)
Yes (N=472)	Agreement	50.6% (239/472)
	Correctly Up-classified	20.6% (97/472)
	Incorrectly Down-classified	28.8% (136/472)
No (N=868)	Agreement	66.9% (581/868)
	Correctly Down-classified	19.0% (165/868)
	Incorrectly Up-classified	14.1% (122/868)

CCCTN = Critical Care Cardiology Trials Network; SCAI = Society of Cardiovascular Angiography and Interventions.

Supplemental Figure 1: In-Hospital Mortality across Etiologies of Cardiogenic Shock by Clinician-Assigned SCAI Stage
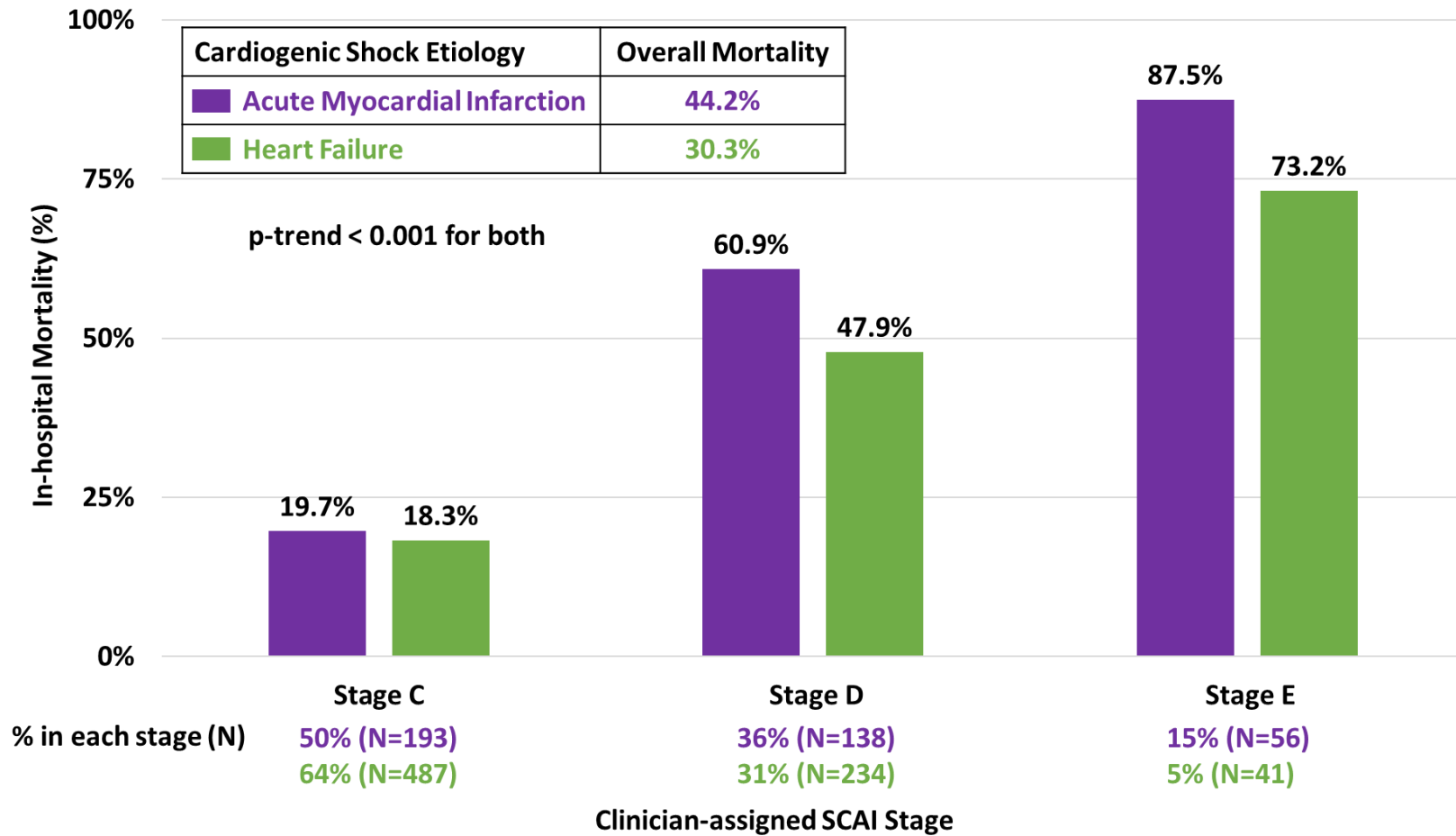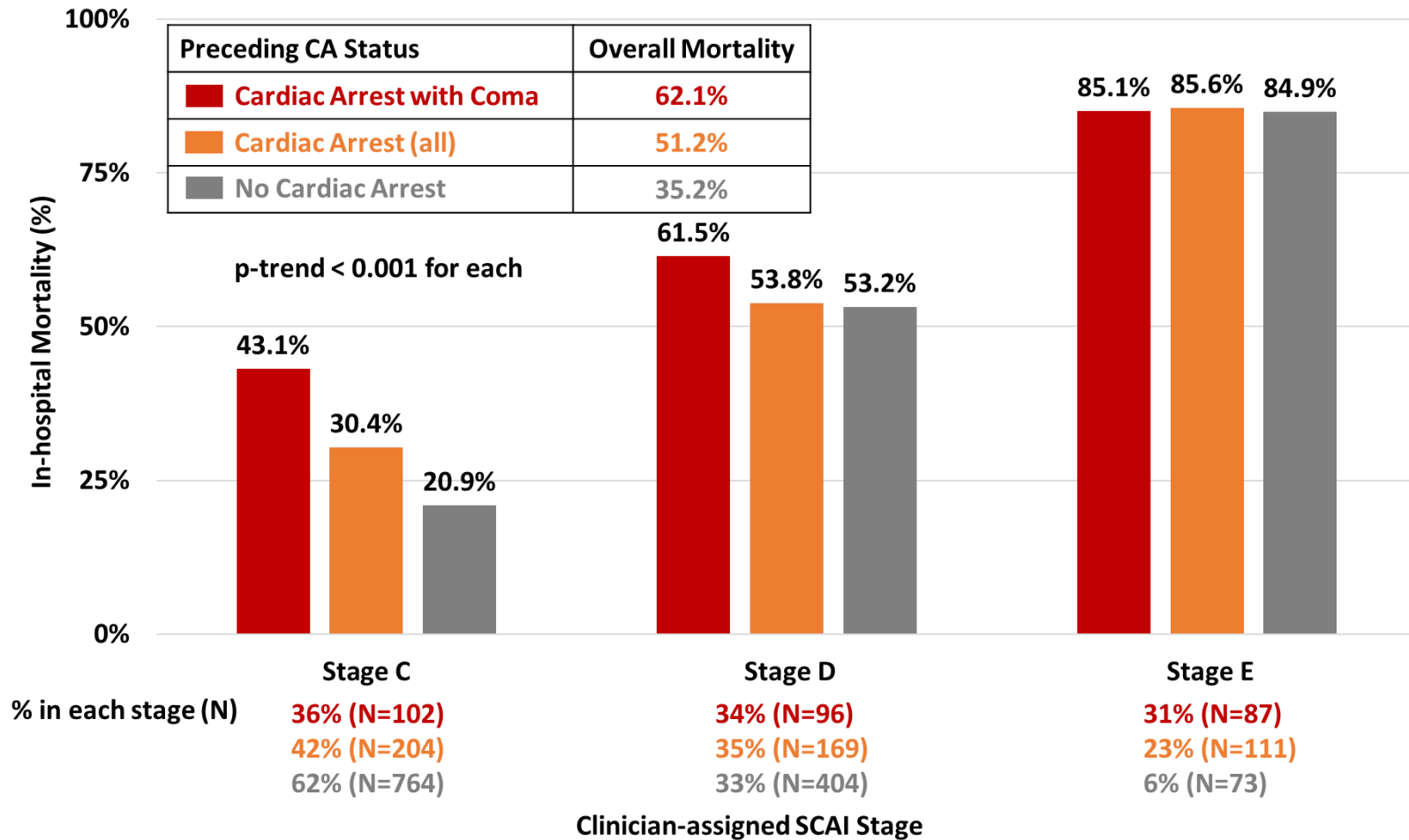

AMI-CS had higher overall mortality compared with HF-CS. Clinician application of SCAI staging identified a stepwise gradient of mortality risk within both subgroups (p-trend < 0.001 for each). AMI-CS = acute myocardial infarction cardiogenic shock. HF-CS = heart failure cardiogenic shock. SCAI = Society of Cardiovascular Angiography and Interventions.

Supplemental Figure 2: In-Hospital Mortality across Shock Types by Clinician-Assigned SCAI Stage

Shock Type	Overall Mortality
Mixed Shock	55.1%
Cardiogenic Shock	35.2%

p-trend < 0.001 for both

In-hospital Mortality (%)

Stage C — 39.4%, 19.0%
Stage D — 64.3%, 49.9%
Stage E — 88.2%, 83.7%

% in each stage (N)
- Stage C: 50% (N=188) / 58% (N=778)
- Stage D: 37% (N=140) / 32% (N=433)
- Stage E: 14% (N=51) / 10% (N=129)
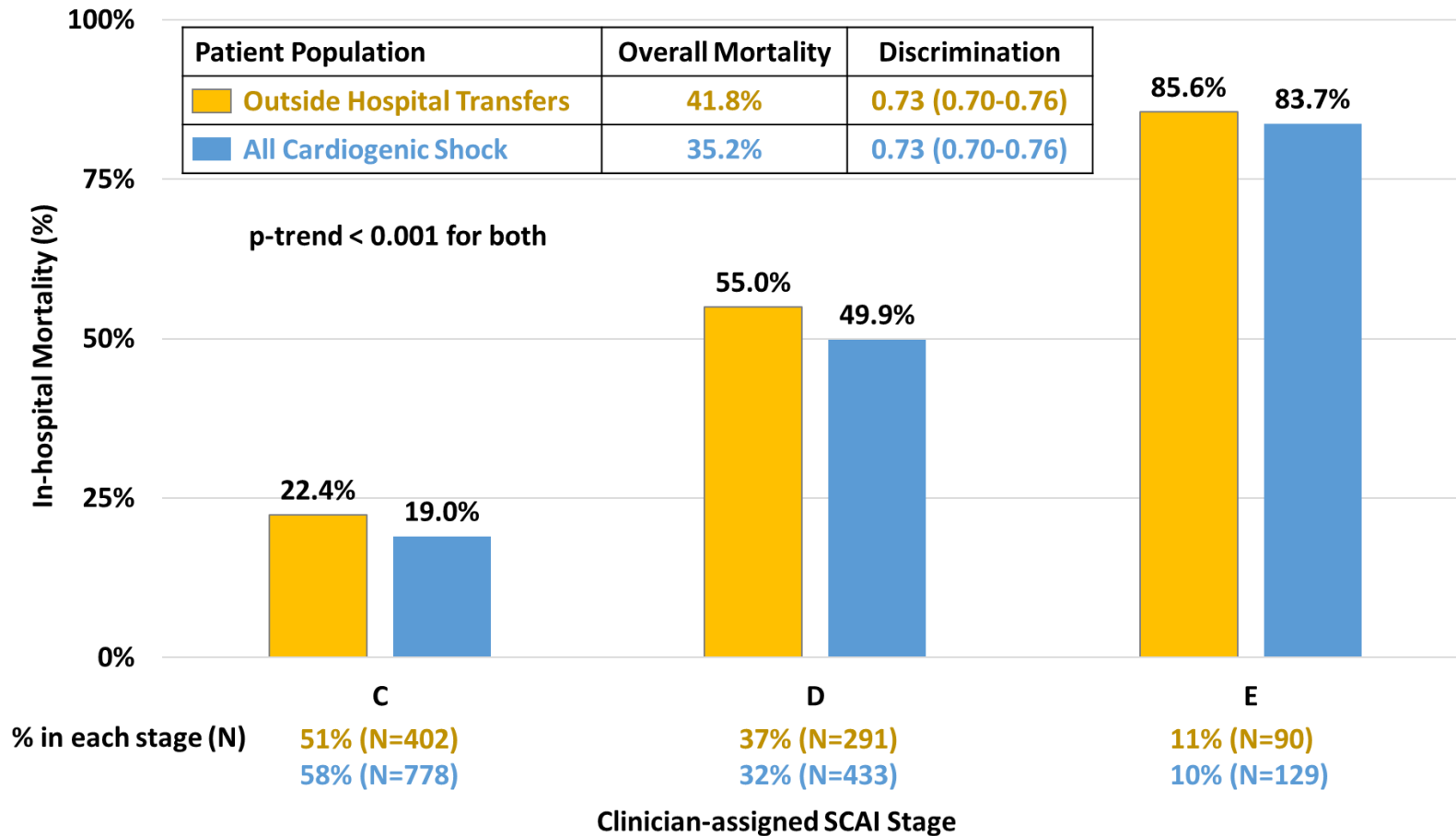
Clinician-assigned SCAI Stage

Mixed shock had higher overall mortality compared with cardiogenic shock. Clinician application of SCAI staging identified a stepwise gradient of mortality risk in both shock types (p-trend <0.001 for each). SCAI = Society of Cardiovascular Angiography and Interventions.

Supplemental Figure 3: In-Hospital Mortality across Preceding Cardiac Arrest Status by Clinician-Assigned SCAI Stage

Preceding CA Status	Overall Mortality
Cardiac Arrest with Coma	62.1%
Cardiac Arrest (all)	51.2%
No Cardiac Arrest	35.2%

p-trend < 0.001 for each

Stage C
% in each stage (N)
36% (N=102)
42% (N=204)
62% (N=764)

Stage D
34% (N=96)
35% (N=169)
33% (N=404)

Stage E
31% (N=87)
23% (N=111)
6% (N=73)

Clinician-assigned SCAI Stage

Patients with preceding cardiac arrest, with or without coma, had higher overall mortality than those without preceding cardiac arrest. Clinician application of SCAI staging identified a stepwise gradient of mortality risk irrespective of preceding cardiac arrest status (p-trend <0.001 for each). SCAI = Society of Cardiovascular Angiography and Interventions.

Supplemental Figure 4: In-Hospital Mortality for Outside Hospital Transfers and All Cardiogenic Shock Patients by Clinician-Assigned SCAI Stage

Patient Population	Overall Mortality	Discrimination
Outside Hospital Transfers	41.8%	0.73 (0.70-0.76)
All Cardiogenic Shock	35.2%	0.73 (0.70-0.76)

p-trend < 0.001 for both

In-hospital Mortality (%)

- C: 22.4% / 19.0%
- D: 55.0% / 49.9%
- E: 85.6% / 83.7%

Clinician-assigned SCAI Stage

| % in each stage (N)	C	D	E
	51% (N=402)	37% (N=291)	11% (N=90)
	58% (N=778)	32% (N=433)	10% (N=129)

In-hospital mortality within each clinician-assigned SCAI stage and overall discrimination did not differ for patients transferred from outside hospitals compared with all cardiogenic shock patients. SCAI = Society of Cardiovascular Angiography and Interventions.

Supplemental Figure 5: Probability of In-Hospital Mortality by Absolute Change and Starting Value of the Vasoactive-Inotropic Score
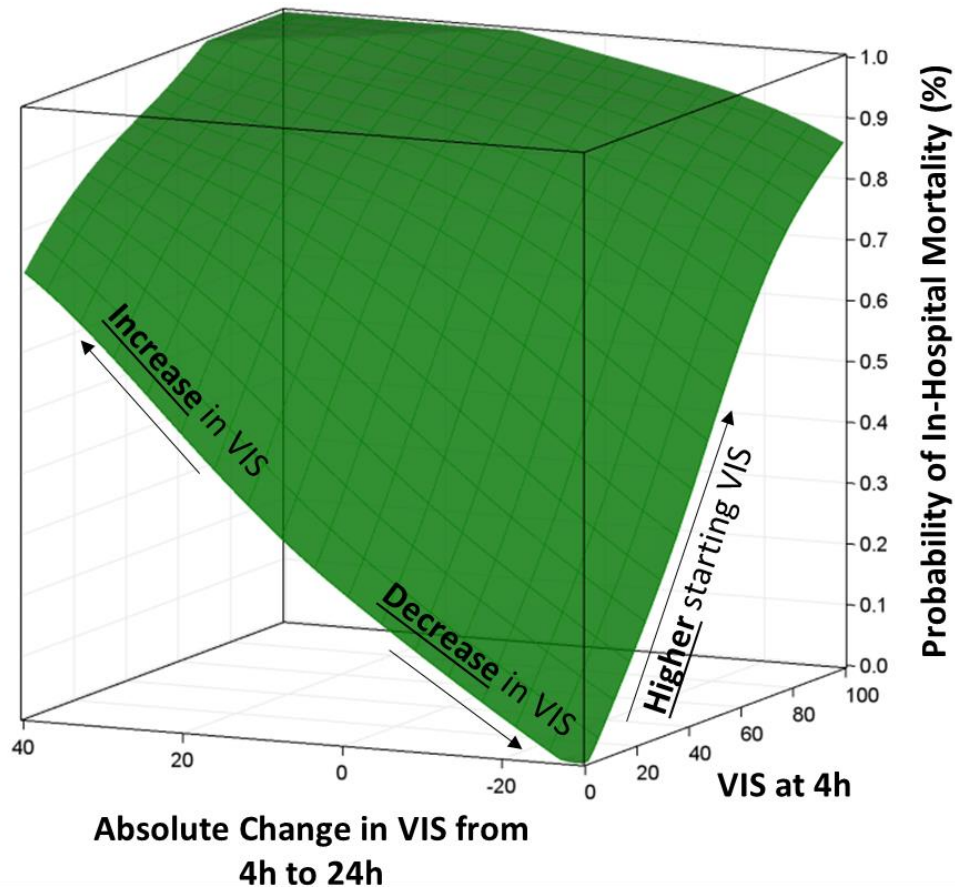

Continuous modeling of absolute changes in VIS at 24 hours as a function of the initial starting VIS at 4 hours was performed using restricted cubic splines. This surface plot illustrates that in-hospital mortality increases with higher starting VIS and with greater increases in VIS. VIS = vasoactive-inotropic score, a weighted sum reflective of combined dosing of all vasopressors and inotropes.

Supplemental Figure 6: In-Hospital Mortality by Number of Vasoactive Agents and Mechanical Circulatory Support Devices
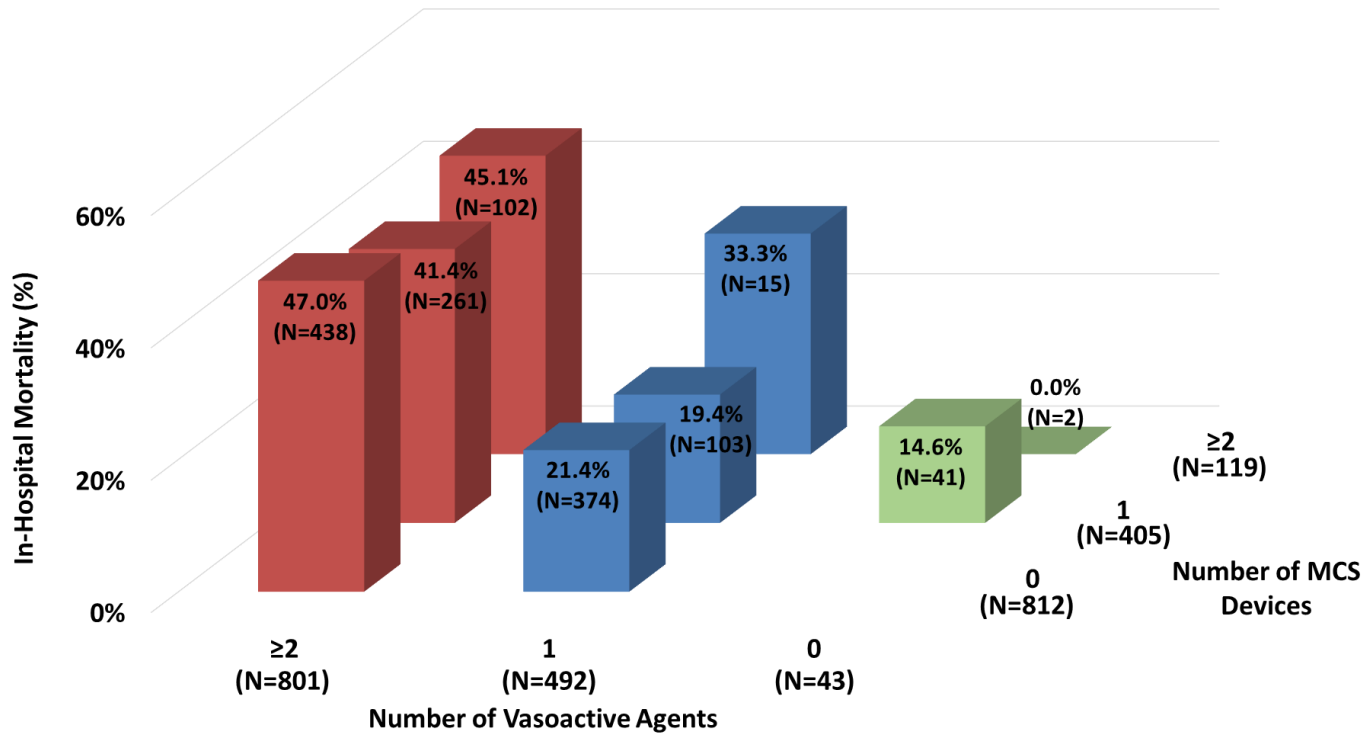
This figure displays the relationship between in-hospital mortality based on the number of vasoactive agents and MCS devices. This relationship was more variable when compared to the relationship between in-hospital mortality and VIS. MCS = mechanical circulatory support. VIS = vasoactive-inotropic score

Supplemental Figure 7: In-Hospital Mortality by Vasoactive-Inotropic Score and Number of Vasoactive Agents
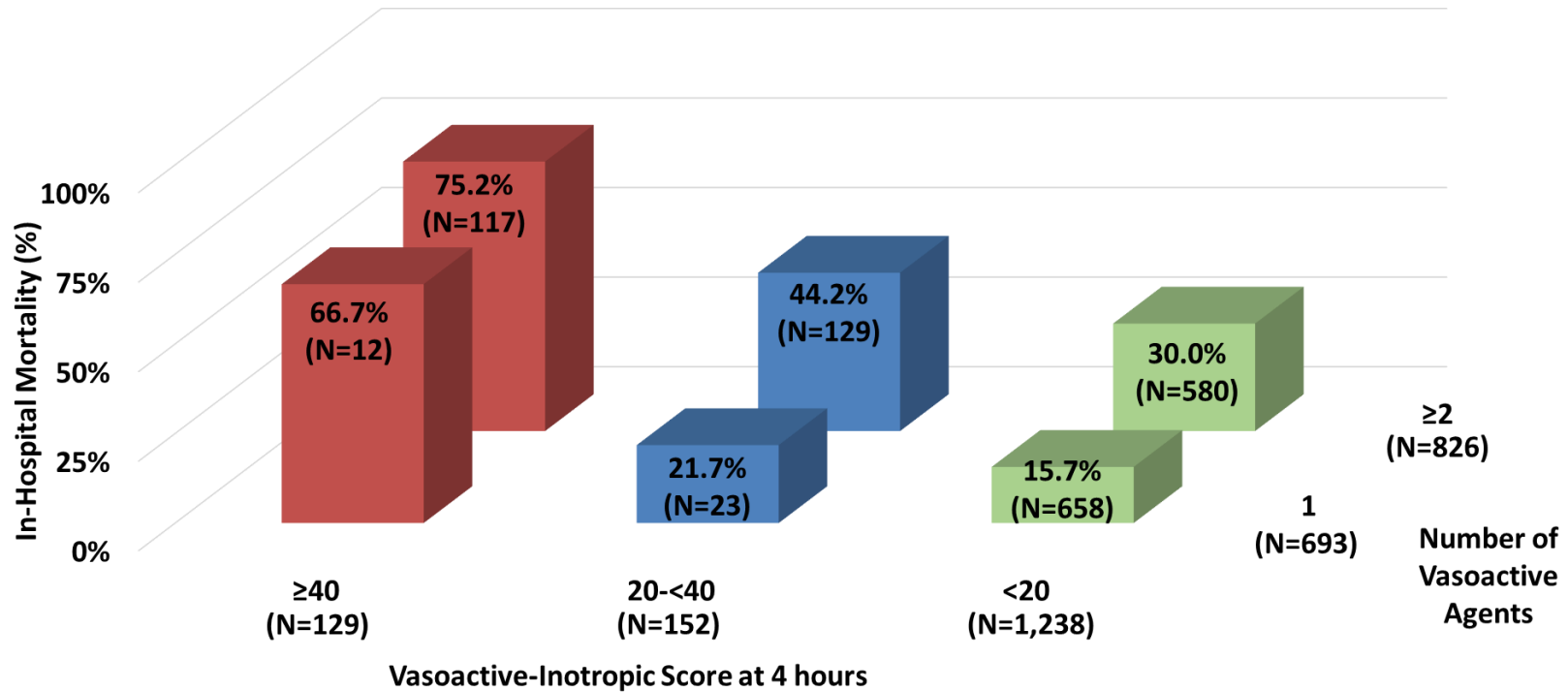
The initial starting value of VIS at 4 hours identified a gradient of risk   regardless of whether single or multiple vasoactive agents were used. VIS = vasoactive-inotropic score.