Project FORTRESS

Far-forward Organ Resuscitation Teams for Rapid Emergency Stabilization and Sustainment: *A Prolonged Casualty Care Force Multiplier*

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MN MOBILE RESUSCITATION TEAM

University of Minnesota
Driven to Discover®

ECMO

Acknowledgements

Demetris Yannopoulos, MD
Jason Bartos, MD, PhD
Paul Rees, MD
Kevin Sipprell, MD
Linda Sousse, PhD

MAJ Daniel Lammers, MD, USA, MC
LTC John McClellan, MD, USA, MC
MAJ Jason David, MD, USAF, MC3
COL Ryan Earnest, MD, USAF, MC
Rachel Russo, MD
Ed BG Barnard, MD, PhD

COI

- Adam L. Gottula, MD has no conflicts to report

The Problem: Survival When Evacuation Fails

Casualty evacuation can no longer be assumed.

- Evacuation is delayed in contested & denied environments.
- Survival depends not on rapid movement to definitive care, but on the ability to **restore and sustain physiology forward**.
- Prolonged Casualty Care (PCC) doctrine supports extended holding – but lacks advanced physiologic stabilization when casualties deteriorate in place.
- Emerging chemical and synthetic threats can cause refractory cardiac arrest where no definitive care is accessible – a critical vulnerability in combat survivability.

THE GAP

No mobile force package exists to deliver advanced resuscitation and temporary mechanical organ support far forward.

Current capability is confined to static facilities or evacuation platforms.

The FORTRESS Solution

Compact, highly trained teams delivering advanced stabilization at the point of need

1

Advanced resuscitation forward

ECPR and temporary mechanical organ support during prolonged or denied evacuation – delivered where the casualty is.

2

Field ECMO Kit (FEK)

A purpose-built, minimal-footprint kit and Long-Range Medical Backpack optimized for austere and Arctic environments.

3

Proven civilian model

Translates the Minnesota Mobile Resuscitation Consortium: >800 ECPR cases at >35% survival into DoW-ready doctrine.

Why ECPR: The Only Intervention That Works

Refractory cardiac arrest from many causes including chemical exposure and hypothermia

ECPR (extracorporeal cardiopulmonary resuscitation) provides temporary organ support while the offending insult is cleared.

Poisoned patients may be ideal candidates: in the absence of permanent end-organ damage, the natural course of overdose is recovery via renal, hepatic, or extracorporeal clearance.

Hypothermia – a persistent far-forward threat – is directly addressed: extracorporeal support enables aggressive rewarming without reliance on enclosed, temperature-controlled environments.

ECPR is the only intervention proven to significantly improve survival in refractory arrest.

Bridge-to-recovery in toxin-mediated and hypothermic collapse – the core FORTRESS use case.

Advanced reperfusion strategies for patients with out-of-hospital cardiac arrest and refractory ventricular fibrillation (ARREST): a phase 2, single centre, open-label, randomised controlled trial

Demetris Yannopoulos, Jason Bartos, Ganesh Raveendran, Emily Walser, John Connett, Thomas A Murray, Gary Collins, Lin Zhang, Rajat Kalra, Marinos Kosmopoulos, Ranjit John, Andrew Shaffer, R J Frascone, Keith Wesley, Marc Conterato, Michelle Biros, Jakub Tolar, Tom P Aufderheide

Center for Resuscitation Medicine

University of Minnesota

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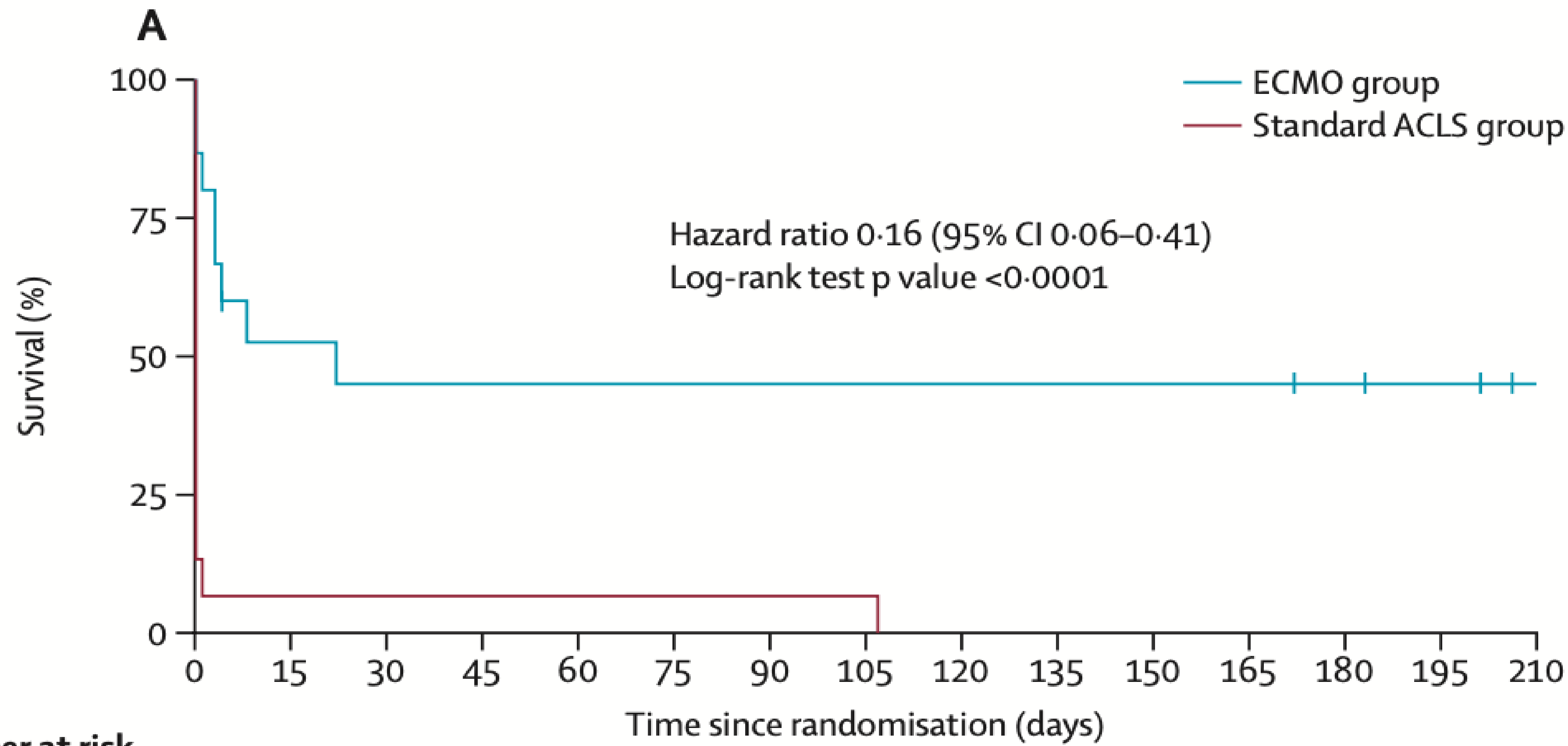
MN Mobile Resuscitation Team



Number at risk

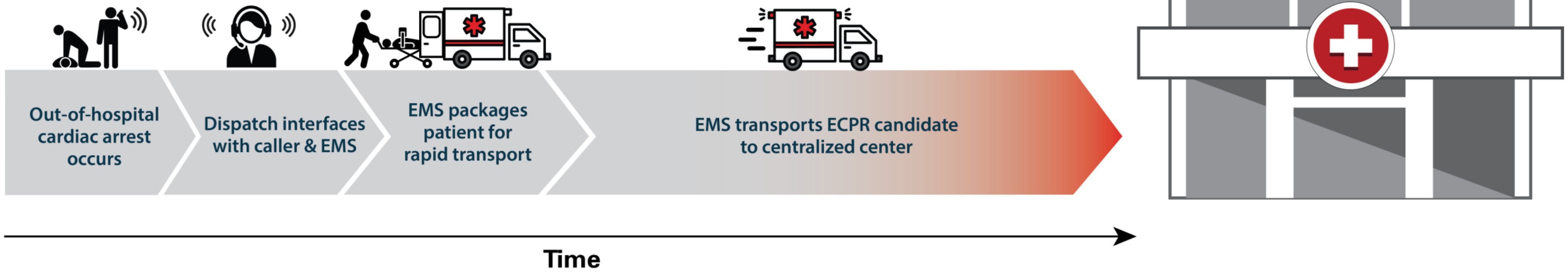
ECMO group	15	7	6	6	6	6	6	6	6	6	6	6	5	3	1
Standard ACLS group	15	1	1	1	1	1	1	1	0	0	0	0	0	0	0

1) Yannopoulos D et al. J Am Heart Assoc 2016. 2) Belohlavek J et al. The Lancet 2023.

ECPR for VT/VF

43-47%

ECPR Survival to Discharge (VT/VF)



Civilian Proof-of-Concept: The MMRC

A mature, high-volume mobile ECPR ecosystem – direct proof this model works

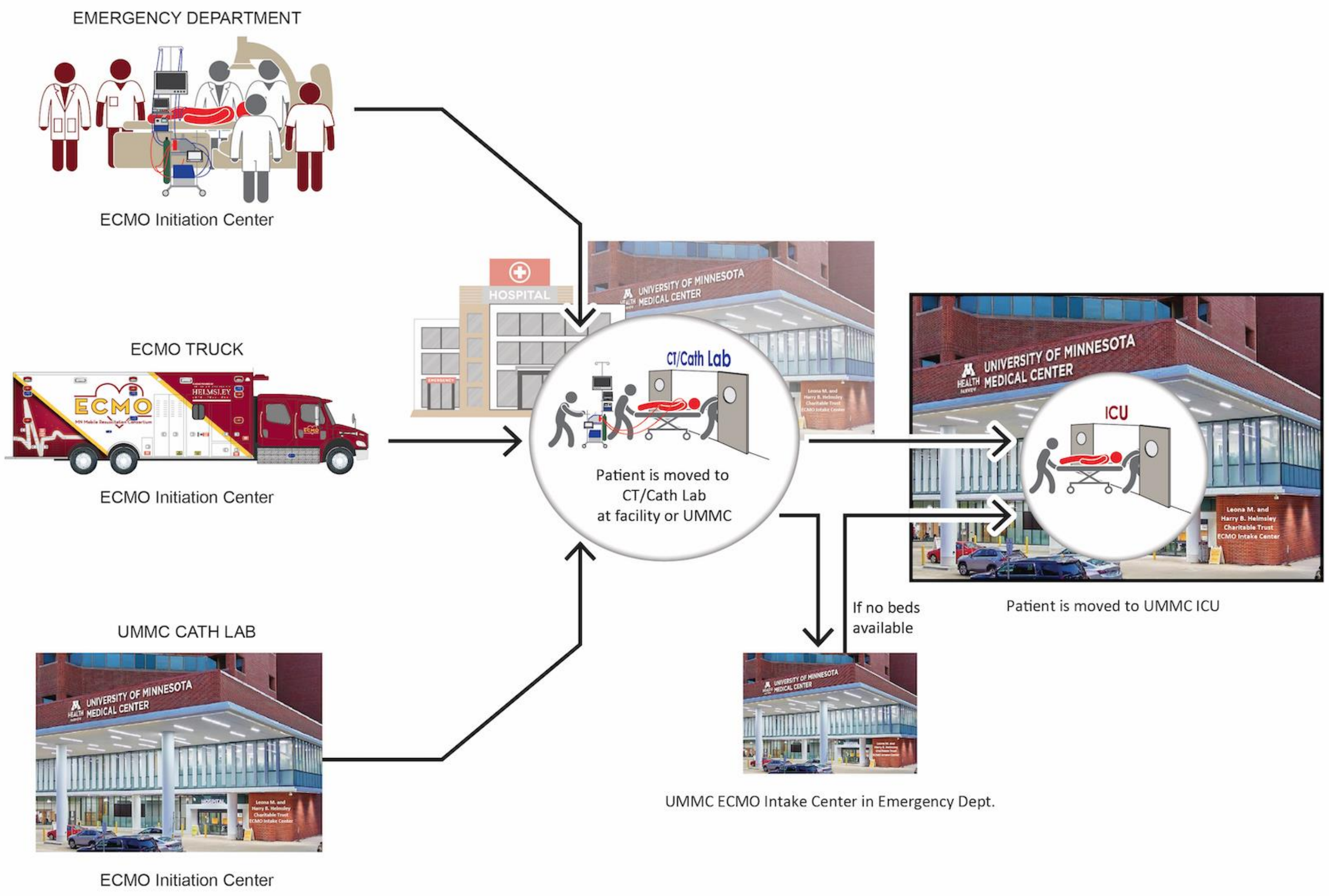
>1000	>35%	~200	24/7
Cumulative ECPR cases	Survival to discharge	Patients treated / year	Ground + HEMS response

The only program in the United States to routinely provide prehospital ECPR across both ground and air platforms.

Outcomes hinge on system design, team discipline, and workflow reproducibility – not merely technology. This is the translatable asset for LSCO.

One System, Three Delivery Models

Rendezvous, prehospital, and ECMO-hub models extend reach across a region



Rendezvous Model

Mobile team meets rural EMS / ED to cannulate and transport.

Prehospital Model

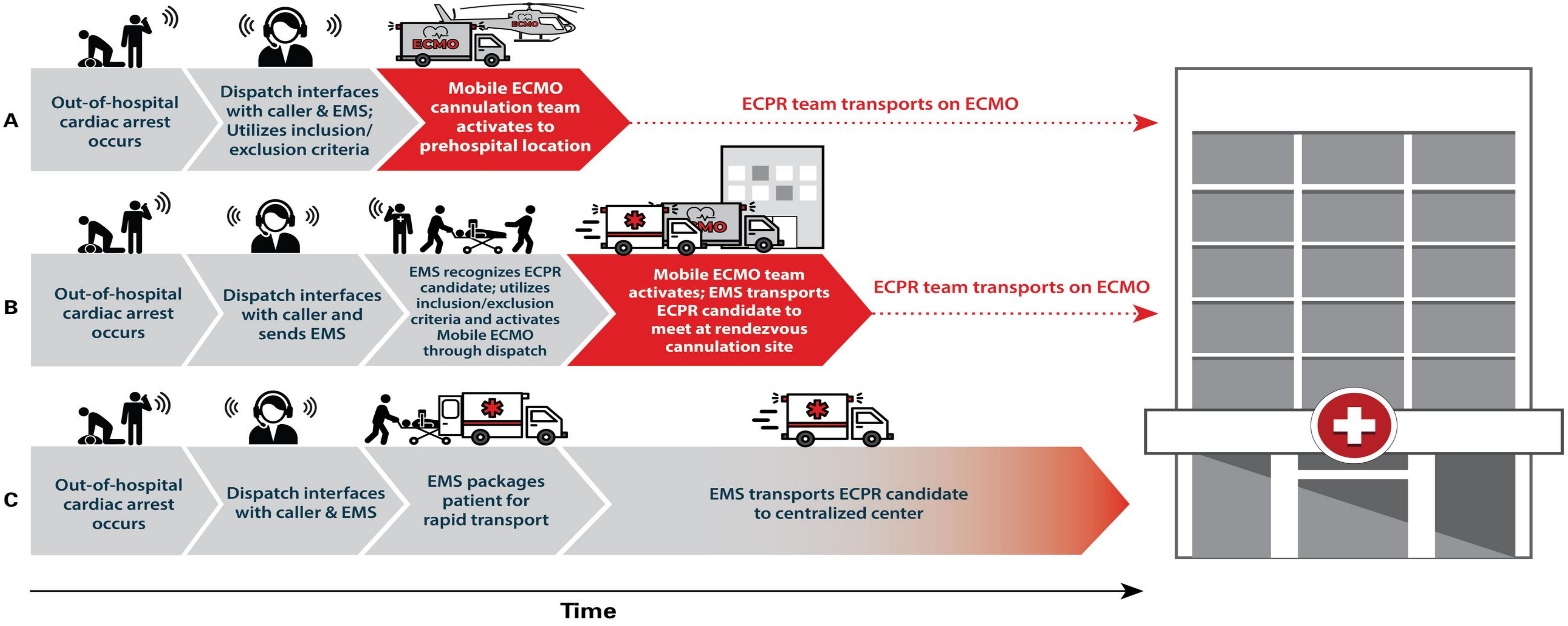
Team brought to scene; cannulation under ongoing mCPR.

ECMO Hub Model

Regional hubs extend geographic access to ECMO-ready care.

Compressing the Time to Reperfusion

60-minute timeline: hospital-based vs. ground vs. HEMS prehospital ECPR



No-flow and low-flow time strongly influence neurologic outcome. HEMS-based systems reach the patient fastest where ground transport time is prohibitive.

Gottula AL, et al. Prehosp Emerg Care. 2024

Compressing the Time to Reperfusion

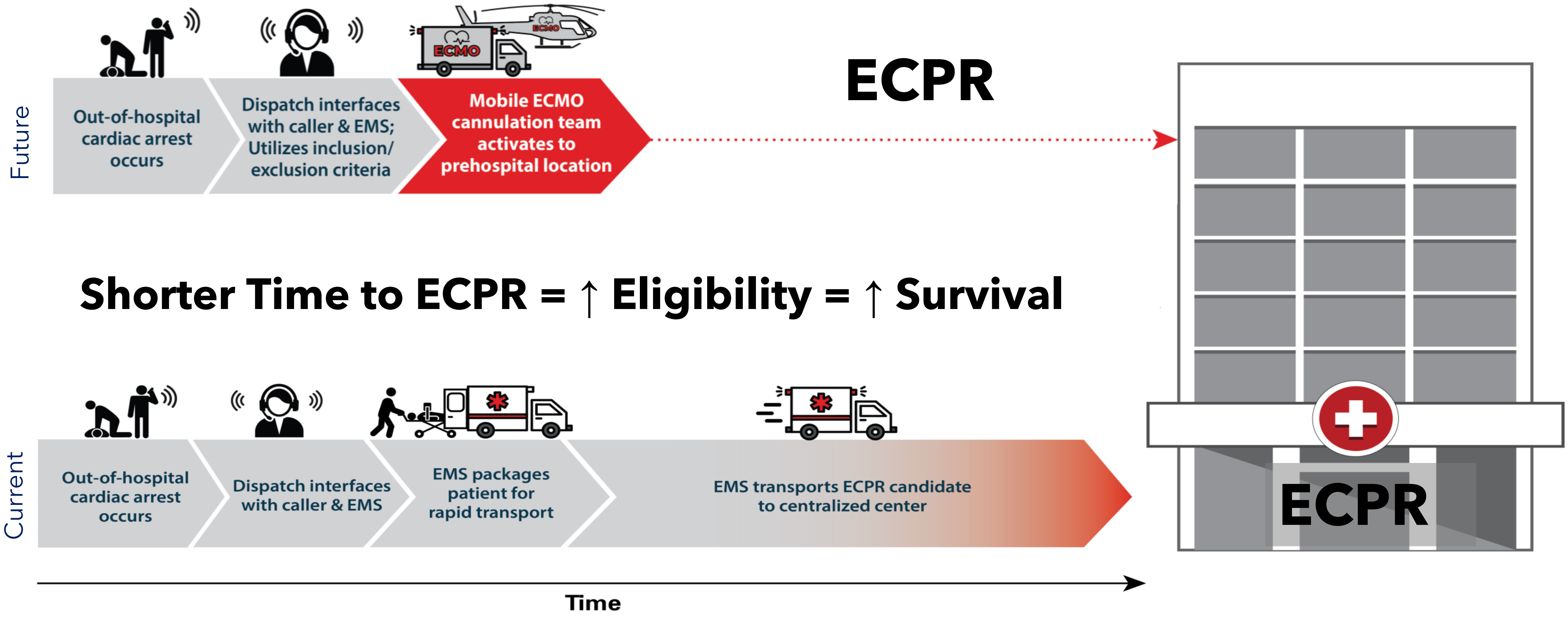


Figure 1: Sixty-Minute Timeline for Hospital-Based and Prehospital ECPR Systems of Care

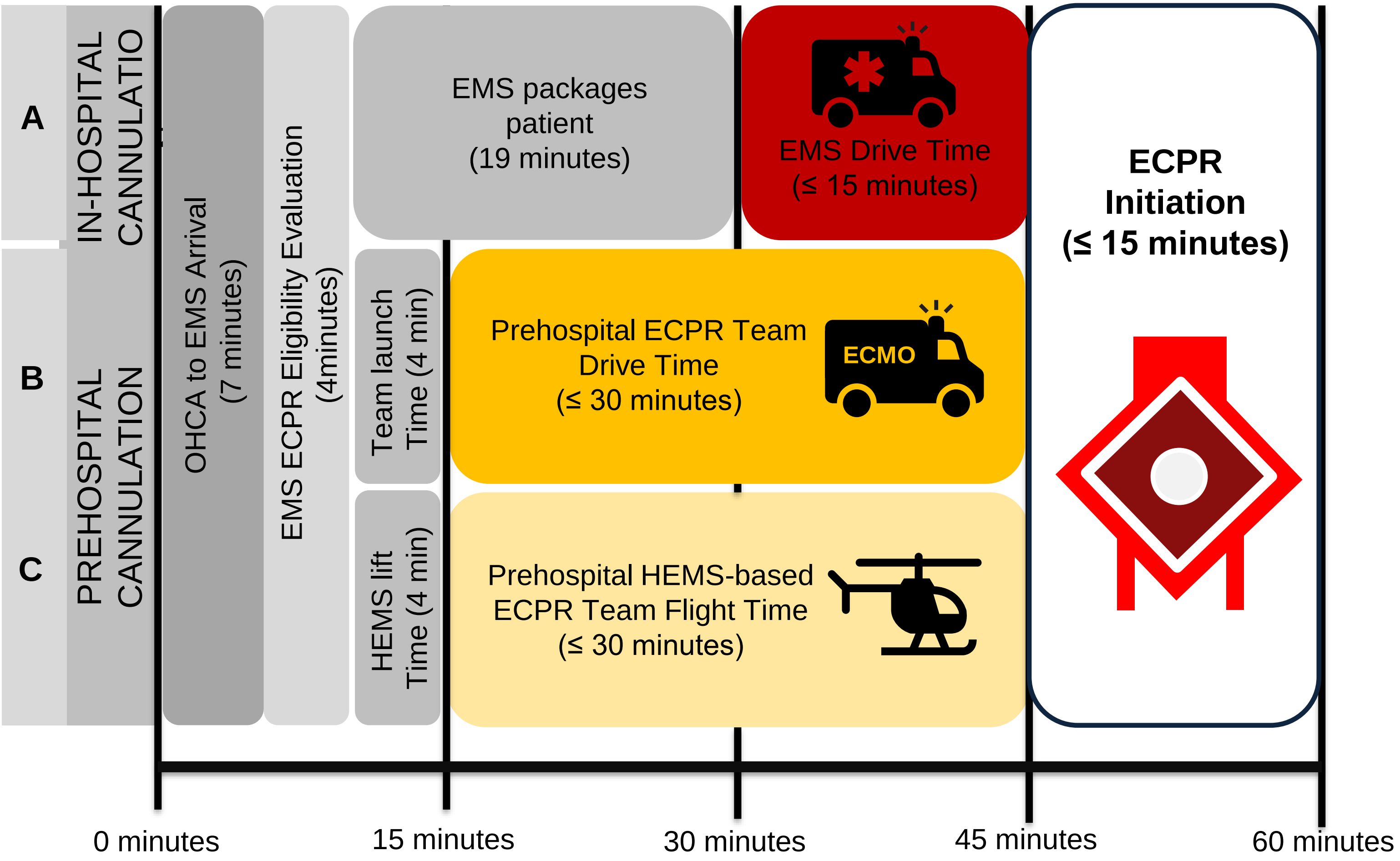


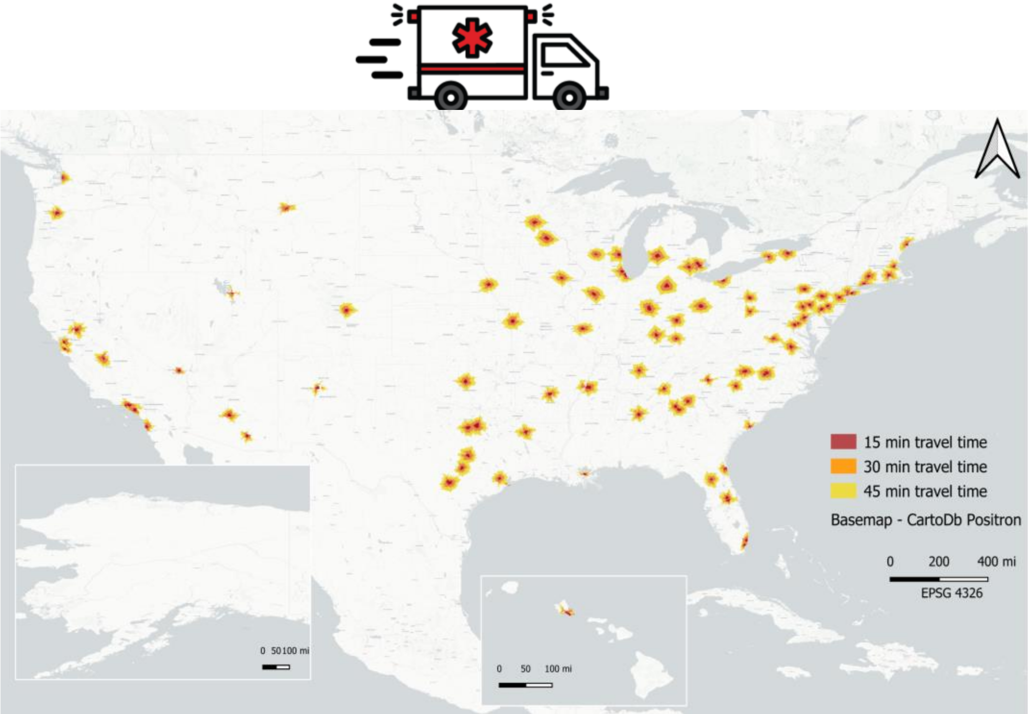
Figure 1: Sixty-Minute Timeline from OHCA to ECPR Initiation for (A) In-Hospital Ground-Based ECPR System, (B) Prehospital Ground-Based ECPR System, (C) Prehospital HEMS-Based ECPR System

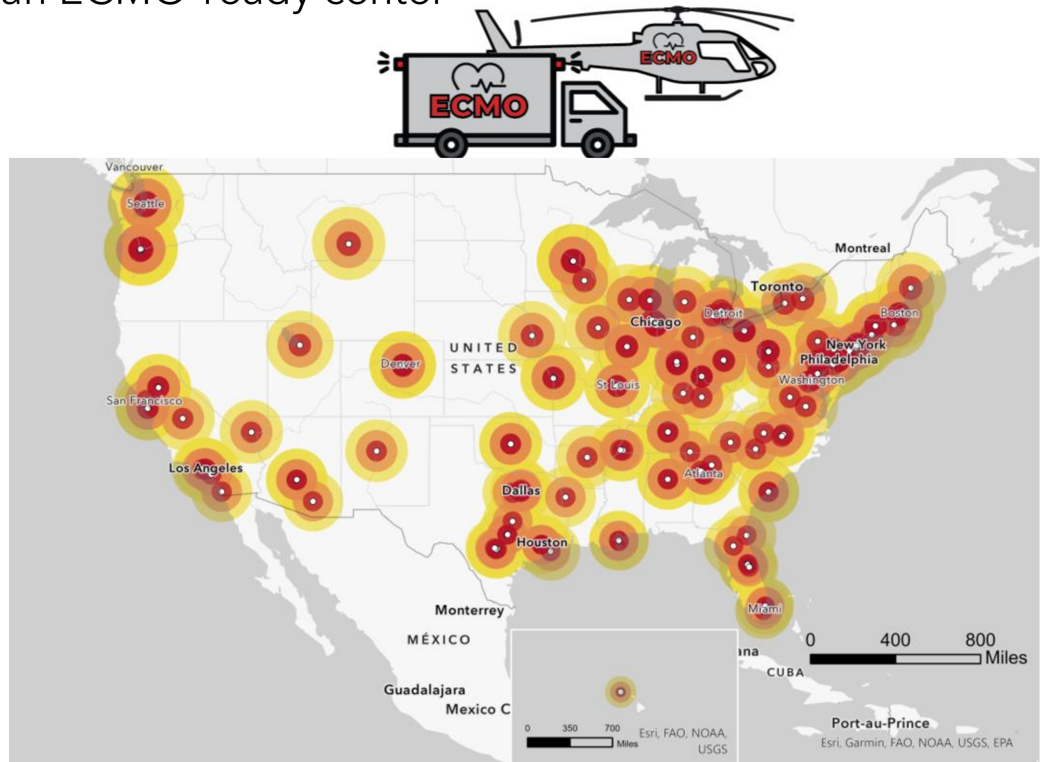
ECMO: Extracorporeal Membrane Oxygenation, ECPR: Extracorporeal Cardiopulmonary Resuscitation, EMS: Emergency Medical Services, HEMS: Helicopter Emergency Medical Services, OHCA: Out of hospital Cardiac Arrest

Gottula AL et. al. Prehosp Emerg Care. 2024 .

HEMS Transforms Geographic Access

Clinically eligible patients within a 45-minute transport time of an ECMO-ready center





44.7%

91.2%

Clinically eligible patients within 45-minute transport time of ECMO-ready centers

Gottula AL et. al. Prehosp Emerg Care. 2024 .

Current Hospital-Based

12%

7,539 patients

Prehospital ECPR Ground-Based

28%

17,595 patients

Prehospital ECPR HEMS-Based

49%

30,784 patients

THE FOCUS

Helicopter-EMS Prehospital ECPR

The MMRC is one of only three programs in the world offering HEMS-based prehospital ECPR – and the only U.S. program.

Auto-launch HEMS carries the mobile ECMO team to the patient, compressing the ischemic interval that dominates neurologic outcome.

HEMS Prehospital-ECPR

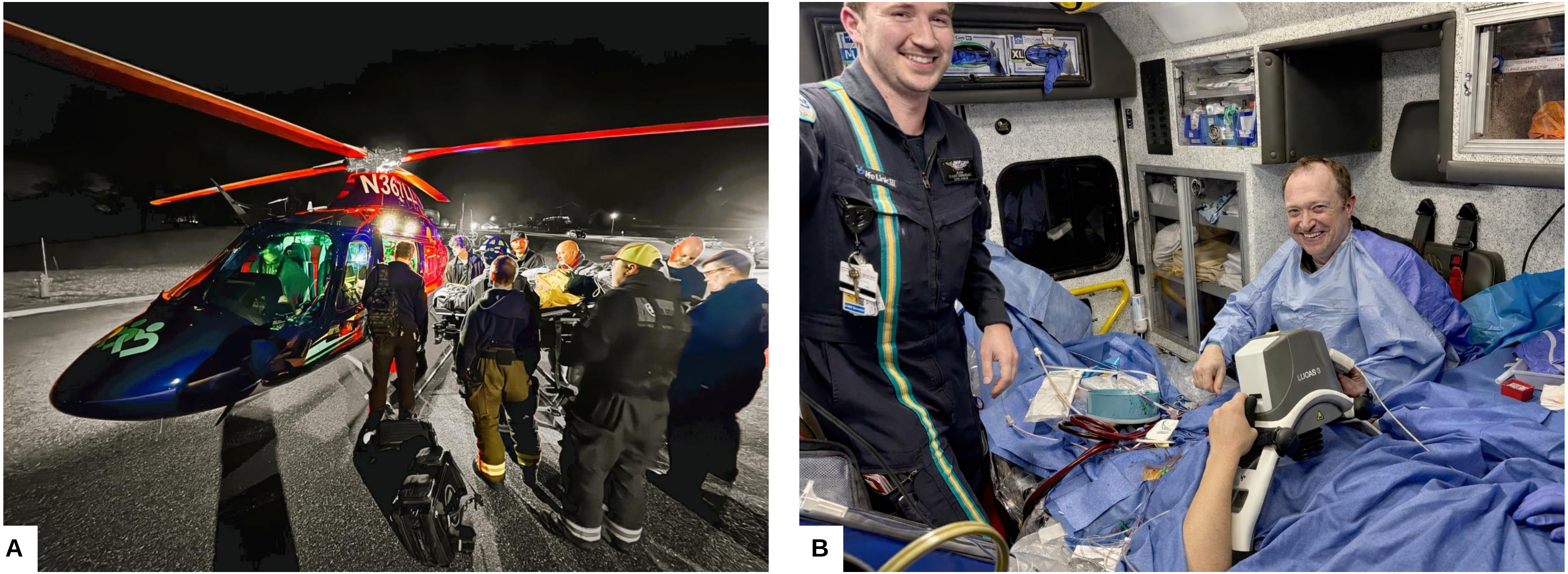
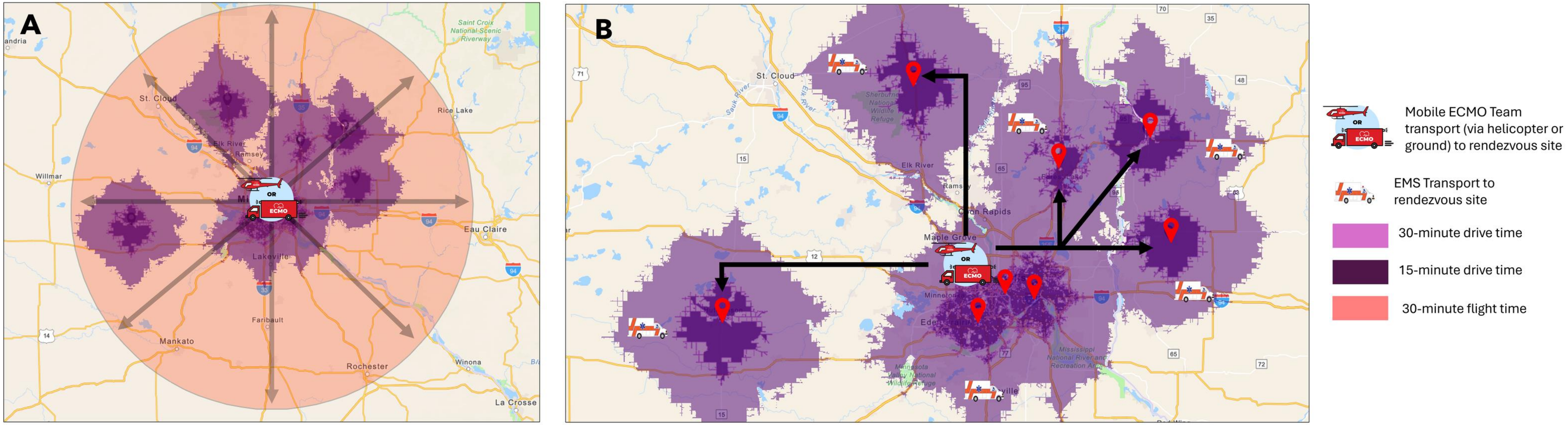


Fig. 7 – The Minnesota Mobile Resuscitation Consortium Prehospital HEMS-Based ECPR Program. (A) The patient being loaded in the Life Link III AW-119 after prehospital ECPR cannulation. (B) Interior view of an ambulance where a patient is being cannulated for ECPR by the prehospital HEMS-based ECPR team.

Geographic Coverage of HEMS ECPR

Modeled access expansion across the rural United States



Geospatial modeling shows HEMS-based systems dramatically expand ECPR access for rural and access-limited populations – the same problem set FORTRESS confronts in denied-evacuation theaters.

Gottula AL, et al. Crit Care Med. 2025

Field ECMO Kit – Exterior, Assembled

Backpack-style field cannulation bag; exterior-mounted cannulation kit

❶ Top section (zippered lid)
Sterile gloves, sizes 6.5 / 7 / 7.5 / 8 (4 pairs each)

❷ Main compartment (rear)
Heart Pack, emergency wire pouch, paperwork binder

❸ Point-of-care pocket
iStat + CG4+, heparin, contrast, butterfly probe, trauma shears

❹ Side compartments (x2)
Post-cannulation kits; Arrow introducer pouch (6–7 Fr)

❺ Cannulation Kit – exterior mount
Front quick-release strap for immediate access on arrival


Empty – front


Harness – rear

Field ECMO Kit – Step 1 Cannulation Pack

All equipment for percutaneous ECMO cannulation, organized by pocket

1 Top left pocket
18G 7 cm entry needles (x2); 3 mL luer-lock syringes (x2)

2 Top right pocket
18G 9 cm percutaneous entry thinwall needles (x2)

3 Top middle pocket
US probe cover + gel; 50–60 mL syringe; ECMO clamps (x2)

4 Sterile instrument set
Bandage scissors, tubing clamps (4-pack), sterile wrap

5 Bottom pocket – dilators
Maquet dilator kit; iodine and 4x4 gauze below

6 Side pouch
500 mL – 1 L normal saline bottle

7 Guidewires
Amplatz extra-stiff wire guides, 0.035 in, 180 cm (x2)

Field ECMO Kit – Opened

Clamshell opening exposes all packs in sequence of use

❶ Top section
Sterile gloves (6.5–8), accessed without opening main bag

❷ Post-Cannulation Pack
2x post-cannulation kits; Heart Pack + binder behind

❸ Side pouch (in wall)
Arrow Super-Arrow-Flex sets: 6 & 7 Fr, 11 & 24 cm

❹ Cannulation Kit
Primary kit; duplicate rides on exterior front velcro

❺ Front-side pouches
Emergency wire + emergency circuit component pouches

Packed configuration

Specific Aim 1 – Force Design & Doctrine

Define far-forward advanced-resuscitation team structure, training, and equipment

Doctrine development. Stakeholder engagement (JTS, JSOC, NATO, DHA) translates civilian prehospital and rural ECPR into a Clinical Practice Guideline for team structure, training, and readiness standards. Assess whether existing ARSC teams can be scaled into a FORTRESS team.

Field ECMO Kit prototype. Determine FEK contents by weight and volume, and develop a Long-Range Medical Backpack to carry the kit in the field.

Method. Mixed-methods, evidence-informed Delphi consensus – grounded in >800 MMRC ECPR cases – yields force composition, credentialing, activation criteria, and platform limits.

DELIVERABLES

- **FORTRESS Clinical Practice Guideline**
- **Force design + readiness metrics**
- **Credentialing & sustainment models**
- **Validated FEK configuration**
- **Long-Range Medical Backpack**

Specific Aim 2 – Arctic & Transport Testing

Quantify environment–transport–physiology interactions in austere conditions

Testing environment

Minnesota's Arctic-like climate (~30 days/yr below 0°F / -18°C) – a natural laboratory for human and mechanical performance under thermal stress.

Transport modality

Vibration, spatial limitation, acoustics, and power variability across ground and HEMS platforms analyzed for procedural and physiologic impact.

Equipment resilience

Cold- and motion-induced vulnerabilities in pumps, circuits, and monitoring inform requirements for future field use.

Hypothermia mitigation

Transport heater–cooler configurations quantified for rewarming capacity and normothermia maintenance during prolonged transport.

Key Performance Metrics

Pre-specified operational, procedural, and outcome targets (Table 1, excerpt)

Operational & Time-Based

Landing → patient contact	**<2 min**
Scene arrival → needle stick	**<5 min**
Total low-flow time	**<60 min**
Activation → flow (composite)	**<45 min**

Technical & Procedural

Successful femoral cannulation	**>95%**
Time to successful cannulation	**<15 min**
Achieved flow rate	**>3.5 L/min**
A-line waveform confirmation	**<5 min**

Patient-Centered Outcomes

Survival to hospital admission	**>80%**
Survival to discharge	**>35%**
Neuro-intact survival (CPC 1–2)	**>30%**
Circuit clot / air entrainment	**<5% / 0%**

STRATEGIC IMPACT

A Deployable Force Multiplier for Prolonged Casualty Care

1 **Preserve combat power**

Stabilize casualties far forward without risking premature evacuation.

2 **Physiology over timelines**

Shift casualty care from rigid evacuation windows to risk-informed command decisions.

3 **Cross-Service & NATO-ready**

Generalizable across Army PCC, Air Force en route care, and allied forces.

4 **Counter emerging threats**

Direct answer to chemical-warfare and hypothermic refractory arrest.

FORTRESS translates a proven civilian ECPR system into DoW doctrine – extending lifesaving capability to the point of need where evacuation cannot be assumed.

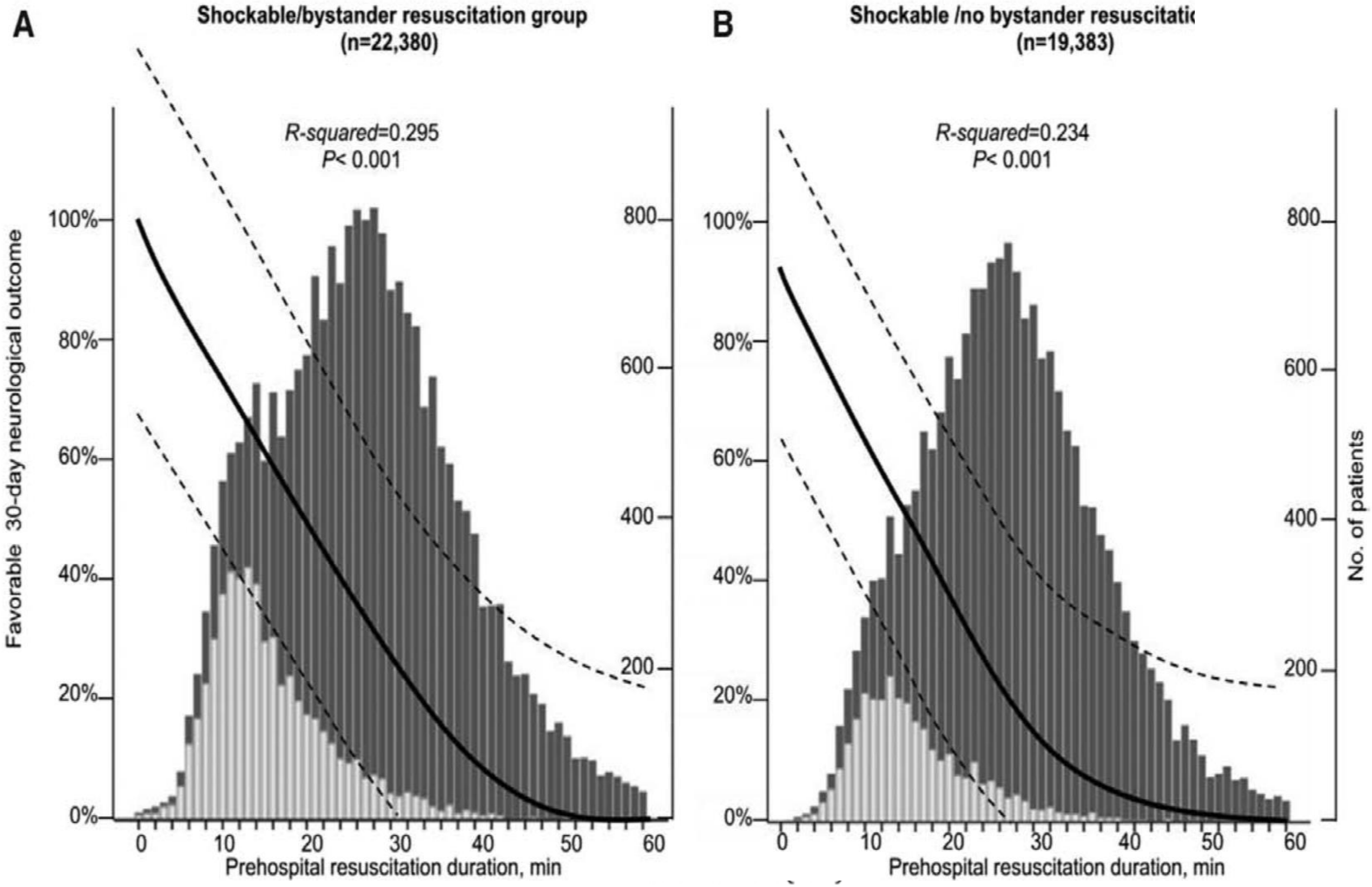
THANK YOU

APPENDIX

Introduction

350,000
OHCA Patients

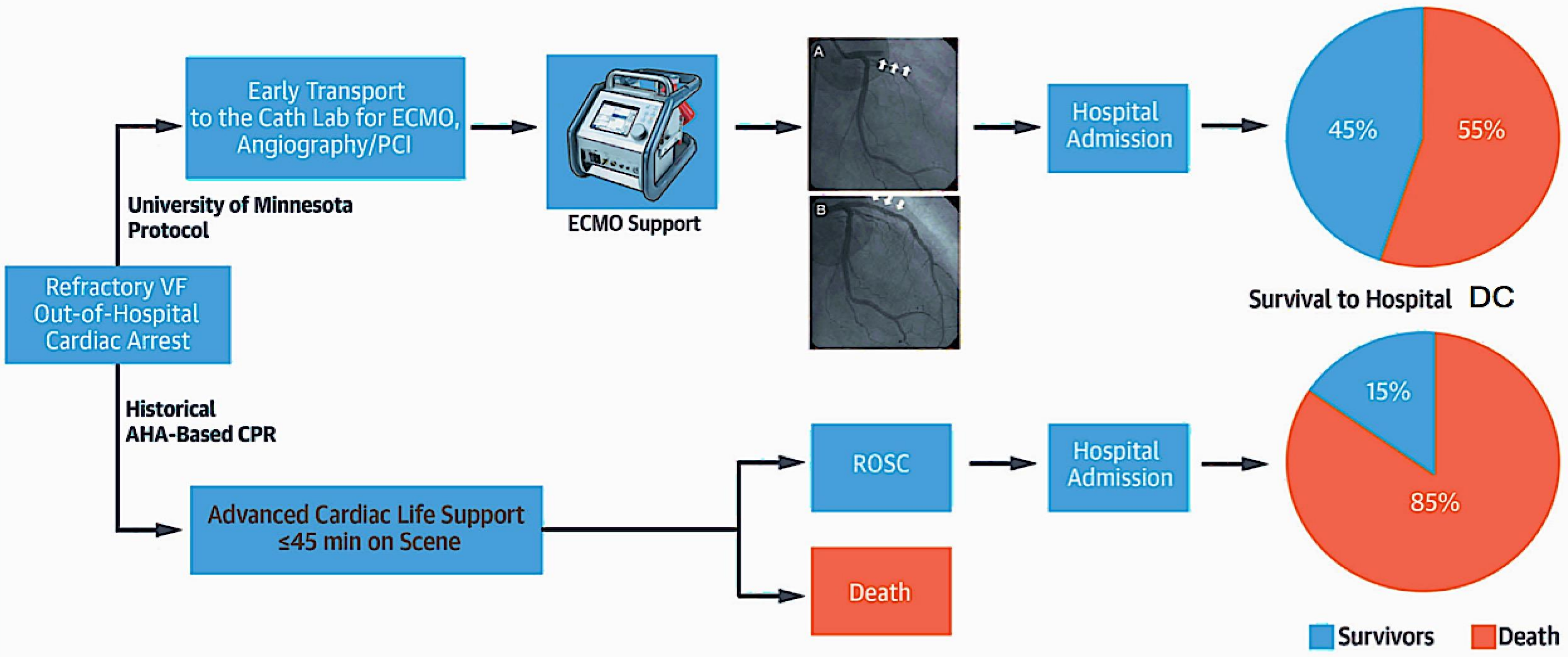
9.3%
OHCA Survival to Discharge



9.3%

OHCA Survival to Discharge

CENTRAL ILLUSTRATION Refractory Cardiac Arrest Due to VF/VT and the University of Minnesota ECLS/PCI Protocol



Yannopoulos, D. et al. J Am Coll Cardiol. 2017;70(9):1109-17.

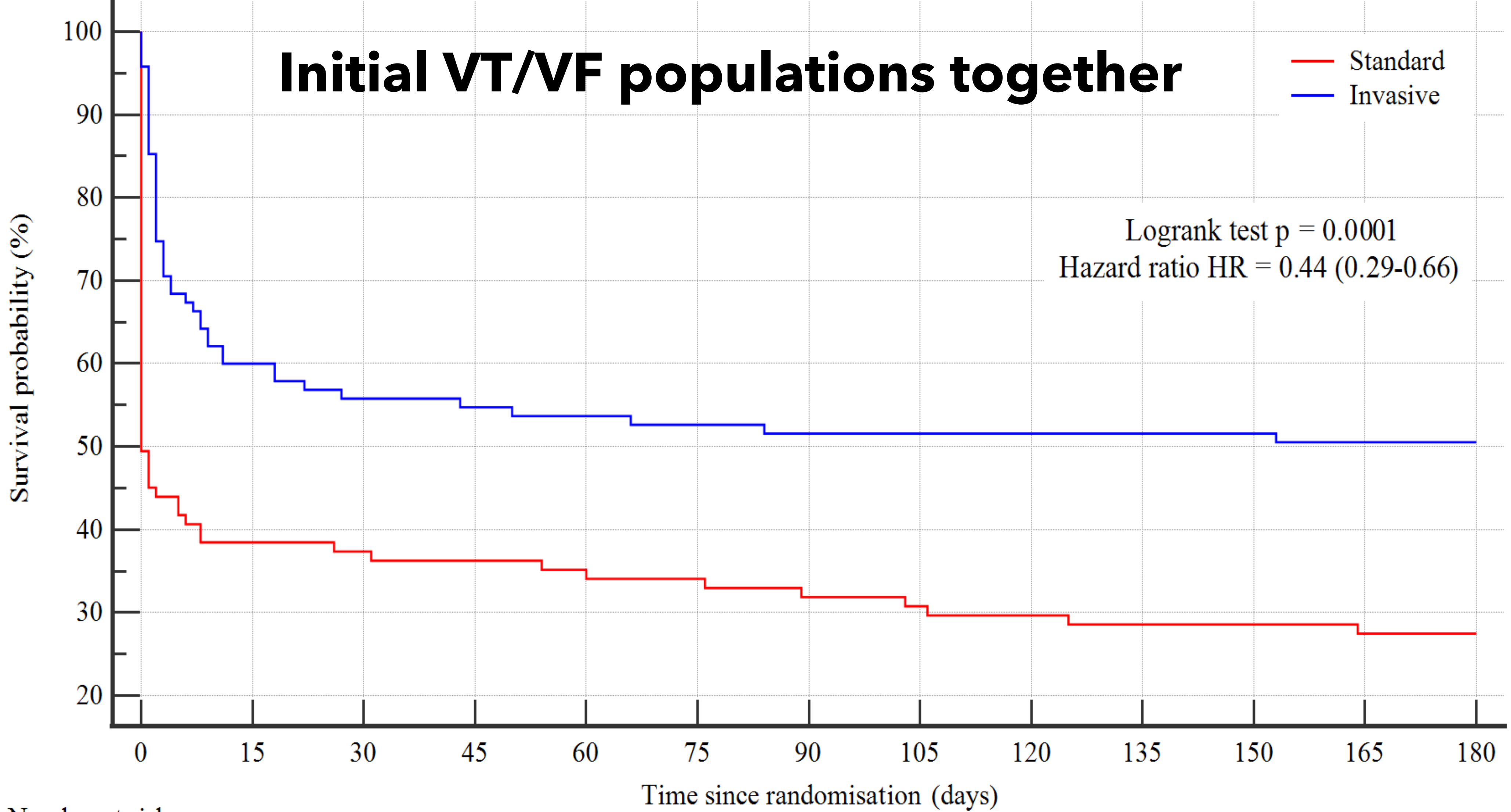
Intraarrest transport, extracorporeal cardiopulmonary resuscitation, and early invasive management in refractory out-of-hospital cardiac arrest: an individual patient data pooled analysis of two randomised trials

Check for updates

Jan Belohlavek,[a,g,*] Demetris Yannopoulos,[b,g] Jana Smalcova,[a] Daniel Rob,[a] Jason Bartos,[b] Michal Huptych,[c] Petra Kavalkova,[a] Rajat Kalra,[b] Brian Grunau,[d] Fabio Silvio Taccone,[e] and Tom P. Aufderheide[f]

oa OPEN ACCESS

Initial VT/VF populations together



Number at risk

	0	15	30	45	60	75	90	105	120	135	150	165	180
Group: Standard	91	35	34	33	31	31	29	28	27	26	26	25	25
Group: Invasive	95	57	53	52	51	50	49	49	49	49	49	48	48

Consistent effect is shown regardless of the time to implement

2023 American Heart Association Focused

EXTRACORPOREAL CPR

ECPR		
COR	**LOE**	**Recommendation**
2a	B-R	1. Use of ECPR for patients with cardiac arrest refractory to standard ACLS is reasonable in select patients when provided within an appropriately trained and equipped system of care.

on the use of medications, temperature management, percutaneous coronary angiography, extracorporeal cardiopulmonary resuscitation, and seizure management in this population. We discuss the lack of data in recent cardiac arrest literature that limits our ability to evaluate diversity, equity, and inclusion in this population. Last, we consider how the cardiac arrest population may make up an important pool of organ donors for those awaiting organ transplantation.

Key Words: AHA Scientific Statements ■ advanced cardiac life support ■ angiography ■ heart arrest ■ resuscitation

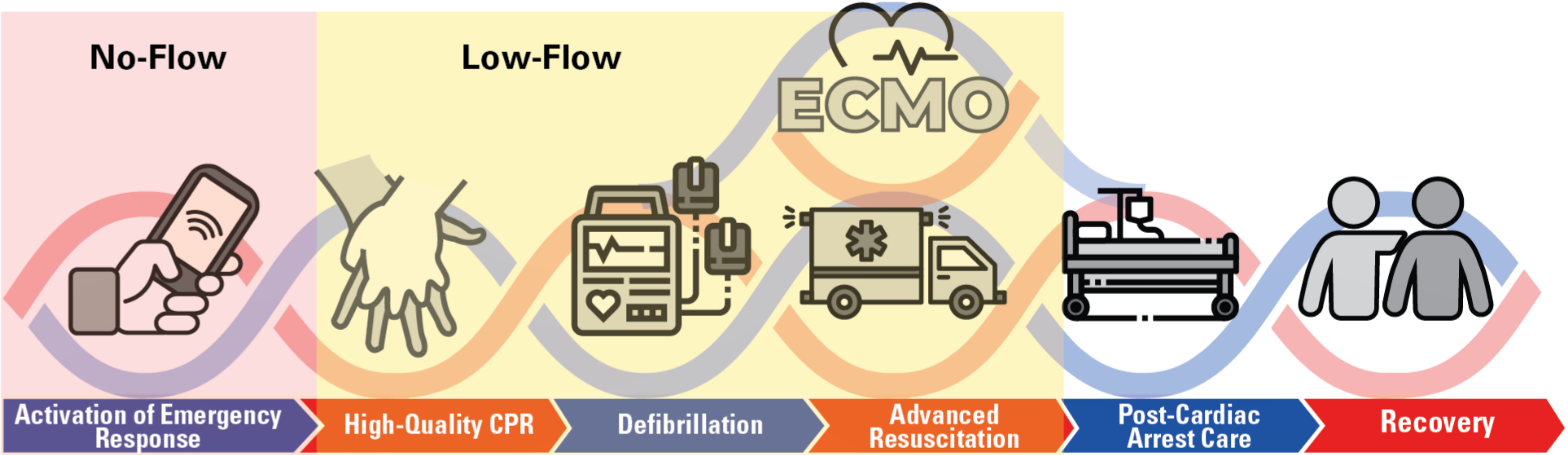
More Than a Machine

…appropriately trained and equipped systems of care

- ECMO is often described as a device, but ECPR is a systems intervention.
- Outcomes start with *research* and depend on bystander action, dispatch, EMS, transport, cannulation, reperfusion, and ICU care.
- The University of Minnesota model shows that the machine is only the final step in a larger chain

[PMID: 33437949] [PMID: 27412906].

ECMO as a System of Care



[PMID: 33627592] [PMID: 33437949] [PMID: 35653248]

Time Is the Dominant Variable

- No-flow time and low-flow time strongly influence neurologic outcome.
- Shorter time to reperfusion (ECMO flow) is associated with better survival.
- ECPR systems are designed to compress the ischemic interval.

[PMID: 32108267] [PMID: 32205336] [PMID: 40012345]

American Heart Association.

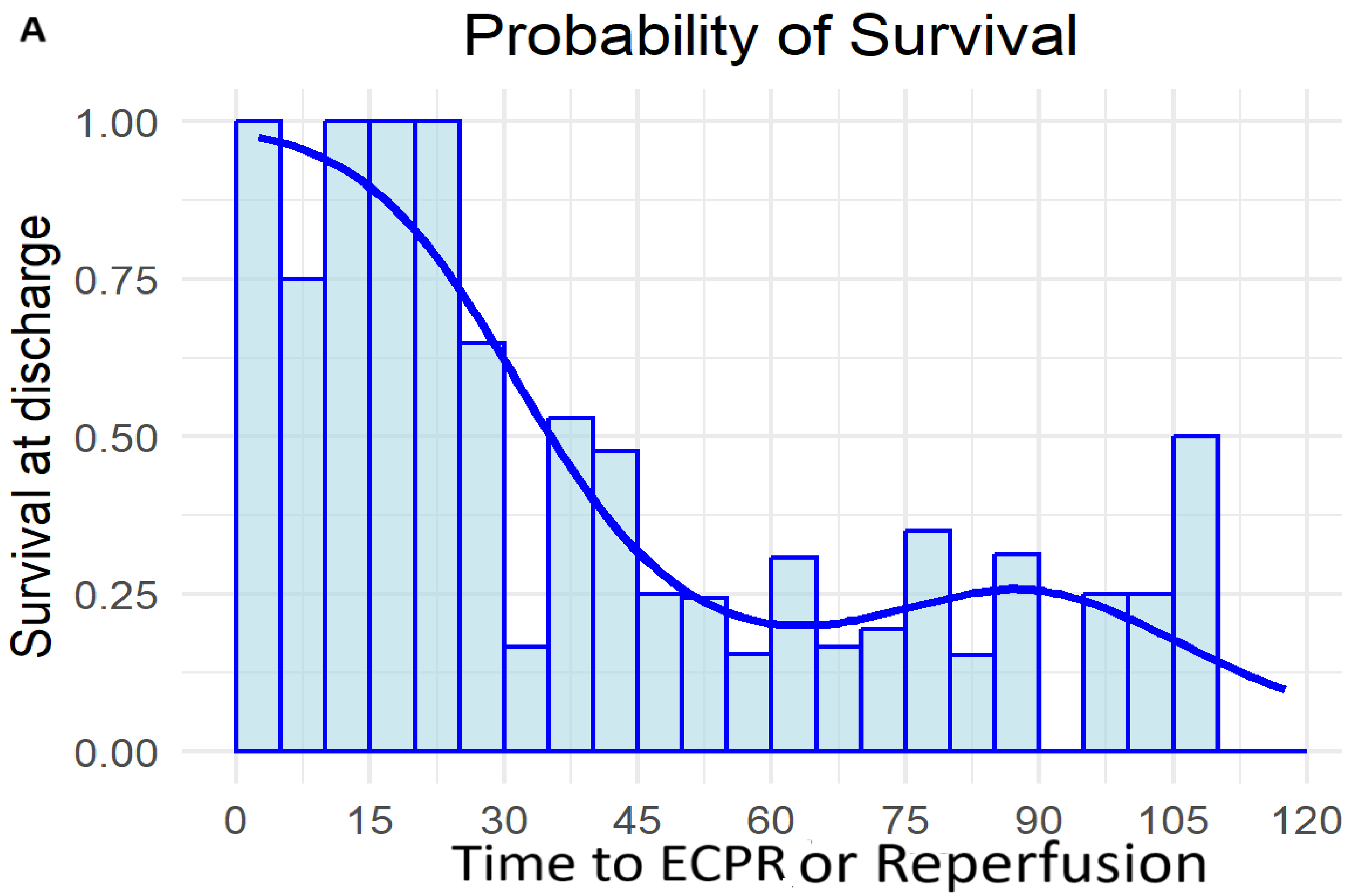
Circulation

The Association of VA-ECMO Cannulation Time with Survival of Patients with Refractory Out of Hospital Cardiac Arrest

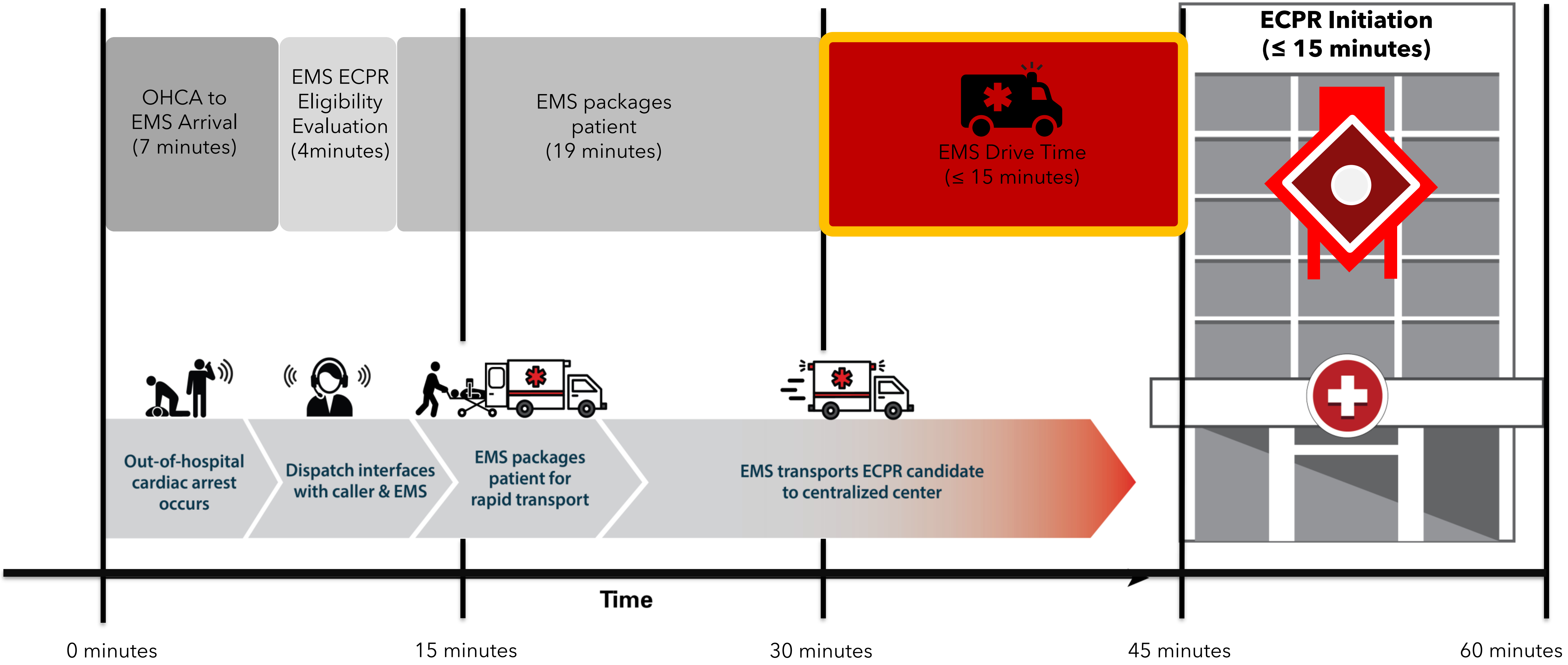
Kosmopoulos M[1], Koukousaki D[2], Yannopoulou E[2], Sebastian P[3], Monti C[4], Kalra R[2], Burnett A[5], Bruen C[5], Tanghe P[6], Peterson B[5], Alexy T[2], Bartos JA[2], Gurevich S[2], Raveendran G[2], Halperin H[1], Aufderheide T[4], Yannopoulos D[2]

1. Johns Hopkins University School of Medicine, Department of Medicine, Division of Cardiology
2. University of Minnesota Medical School, Department of Medicine, Division of Cardiology, Center for Resuscitation Medicine
3. University of California of San Francisco, Department of Medicine
4. Medical College of Wisconsin, Medical School
5. St Paul Fire EMS, St. Paul, MN, USA
6. North Memorial EMS, Robbinsdale, MN, USA

Short Title: Time to ECPR and survival after cardiac arrest


A
Probability of Survival
Survival at discharge
1.00
0.75
0.50
0.25
0.00
0
15
30
45
60
75
90
105
120
Time to ECPR or Reperfusion

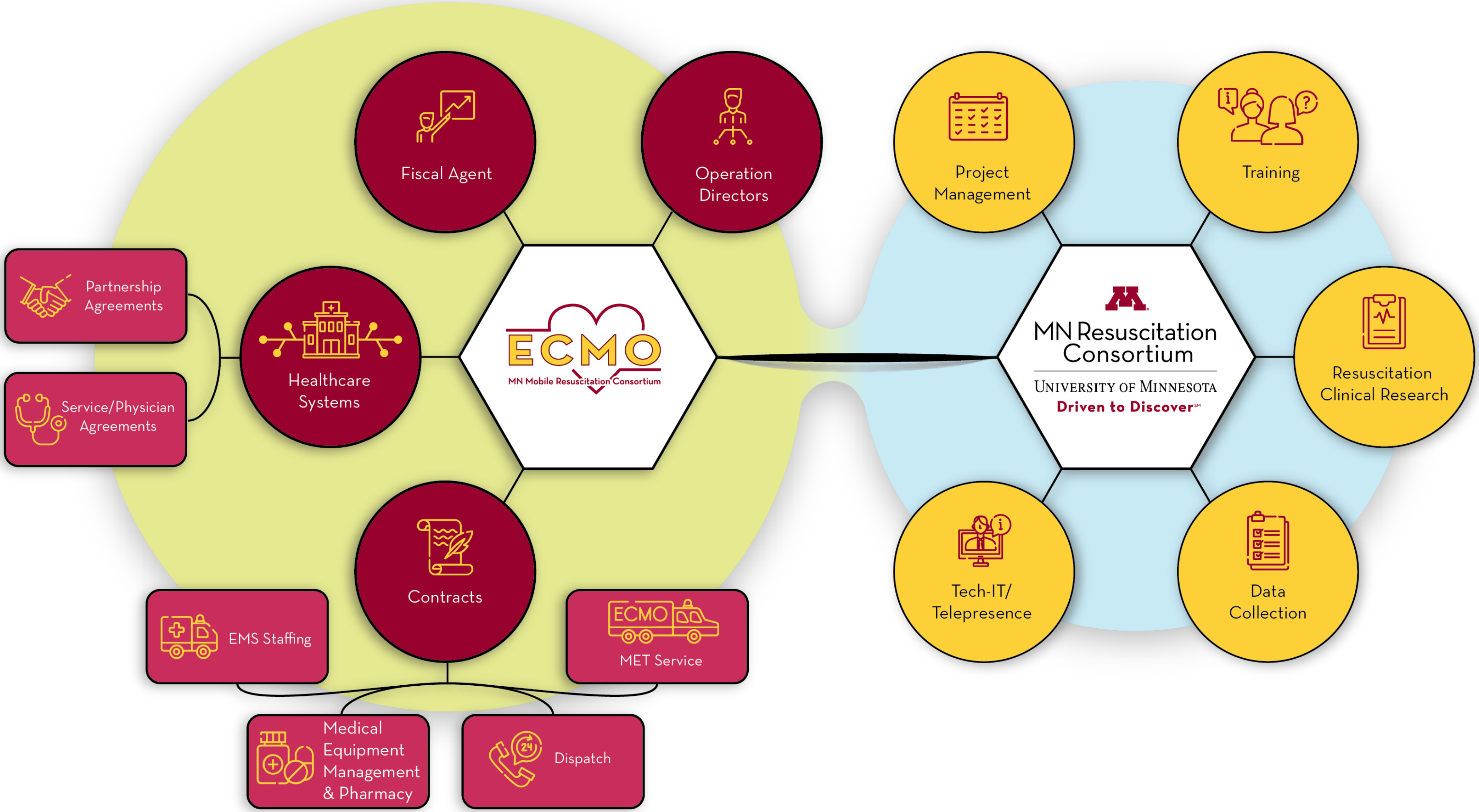
The *Current* Timeline: OHCA to ECPR



MMRC Program Description

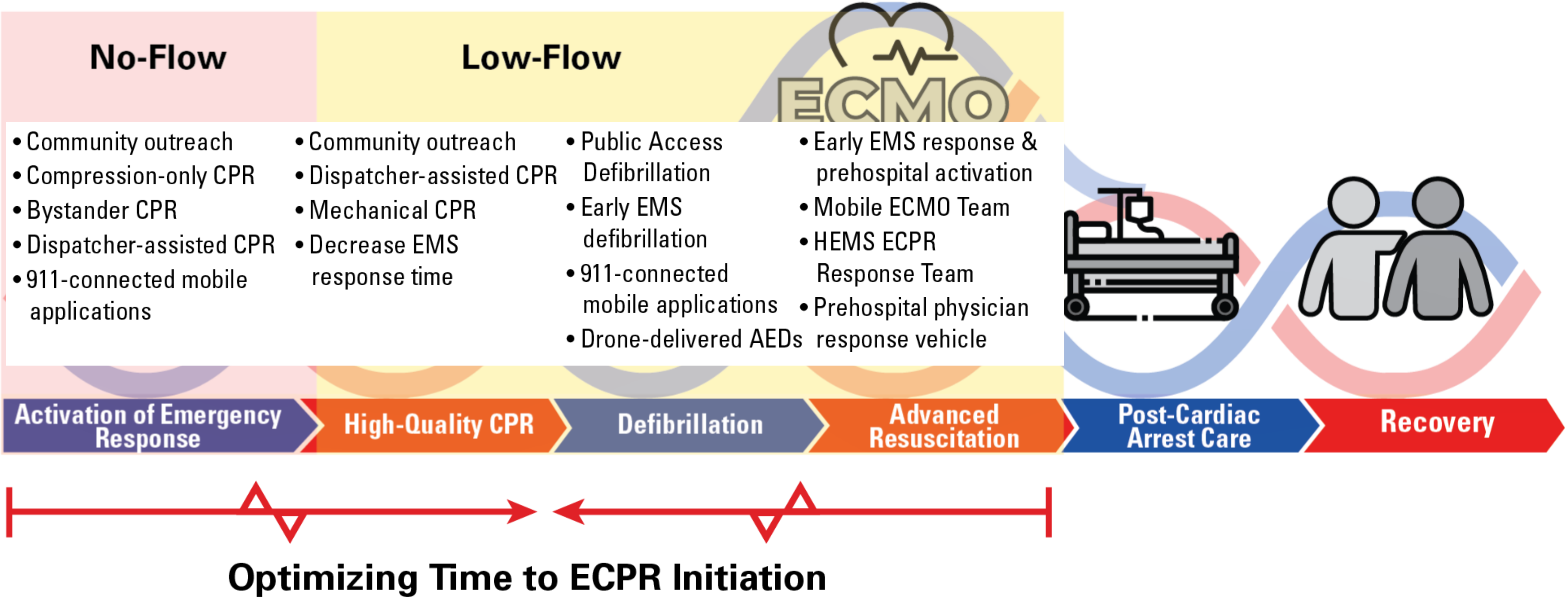
- The MMRC is a community-wide mobile ECMO-facilitated resuscitation program.
- It includes EMS, dispatch, multiple ECMO initiation hospitals, a mobile cannulation team, and a centralized ICU.
- It has worked to optimize every link in the chair of survival.
- The system was built to make ECPR available across a metropolitan region.

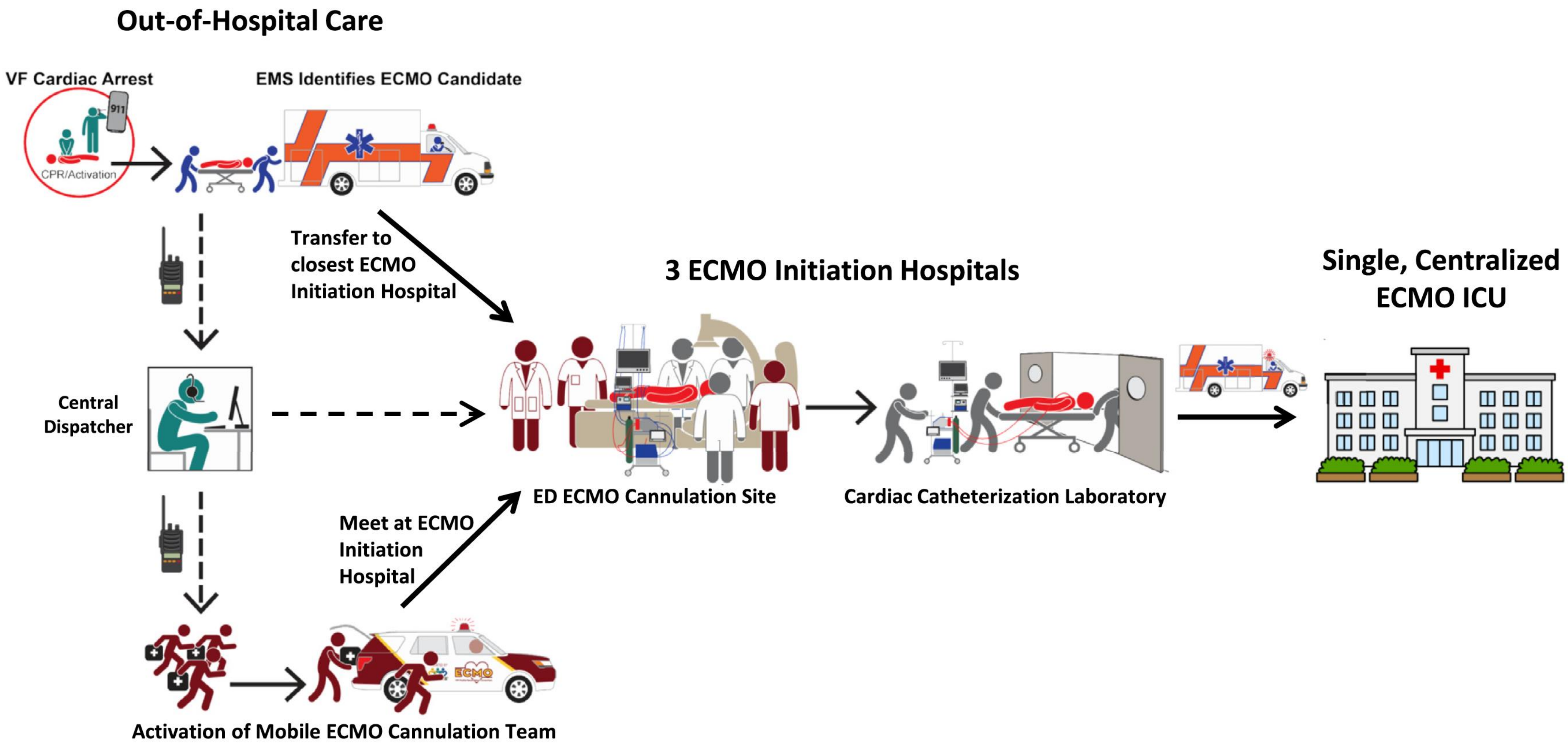
[PMID: 33437949]



Fiscal Agent
Operation Directors
Partnership Agreements
Service/Physician Agreements
Healthcare Systems
ECMO
MN Mobile Resuscitation Consortium
Contracts
EMS Staffing
ECMO
MET Service
Medical Equipment Management & Pharmacy
Dispatch
Project Management
Training
MN Resuscitation Consortium
University of Minnesota
Driven to Discover℠
Resuscitation Clinical Research
Tech-IT/ Telepresence
Data Collection

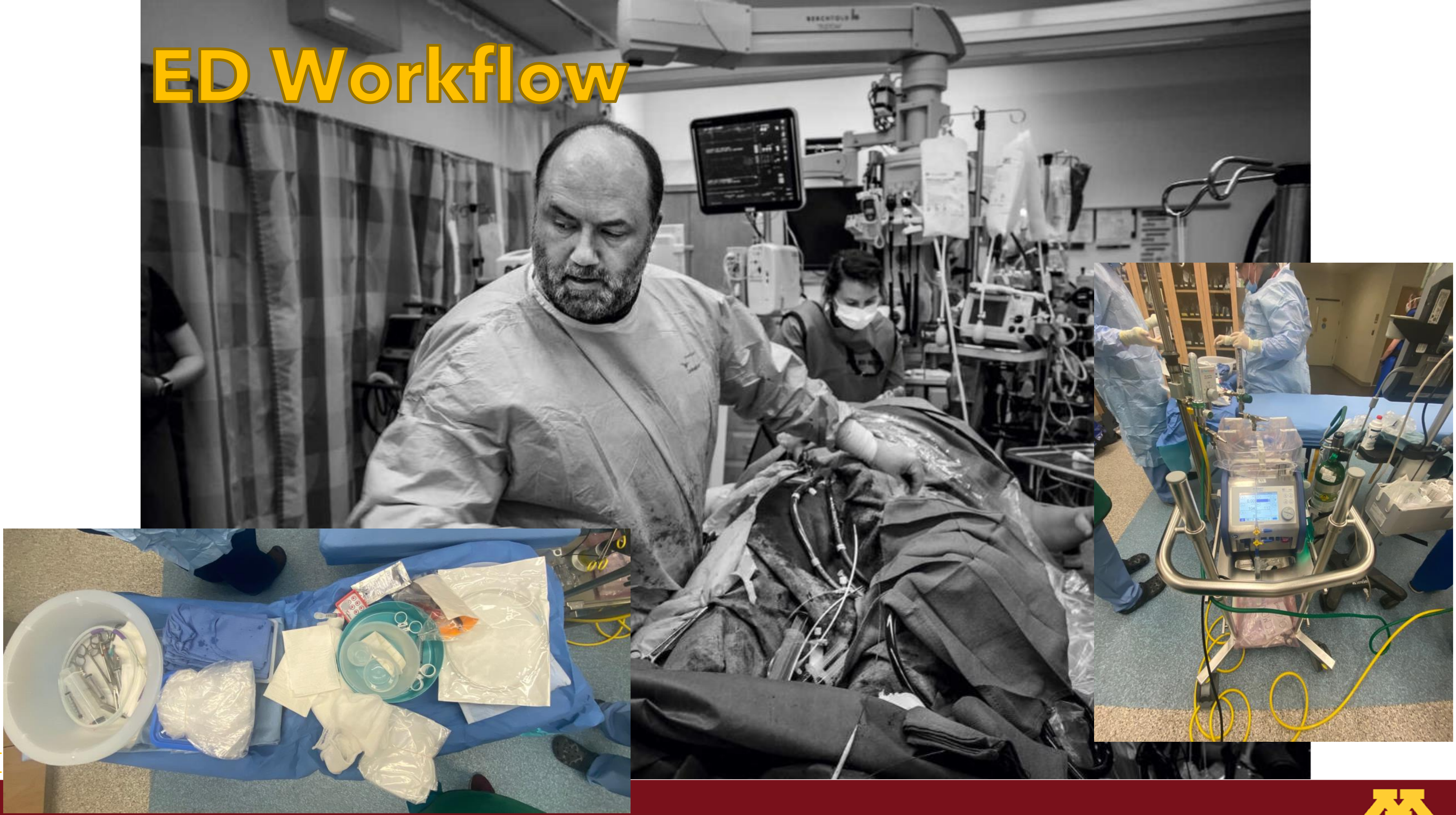
MMRC: Optimize Every Link



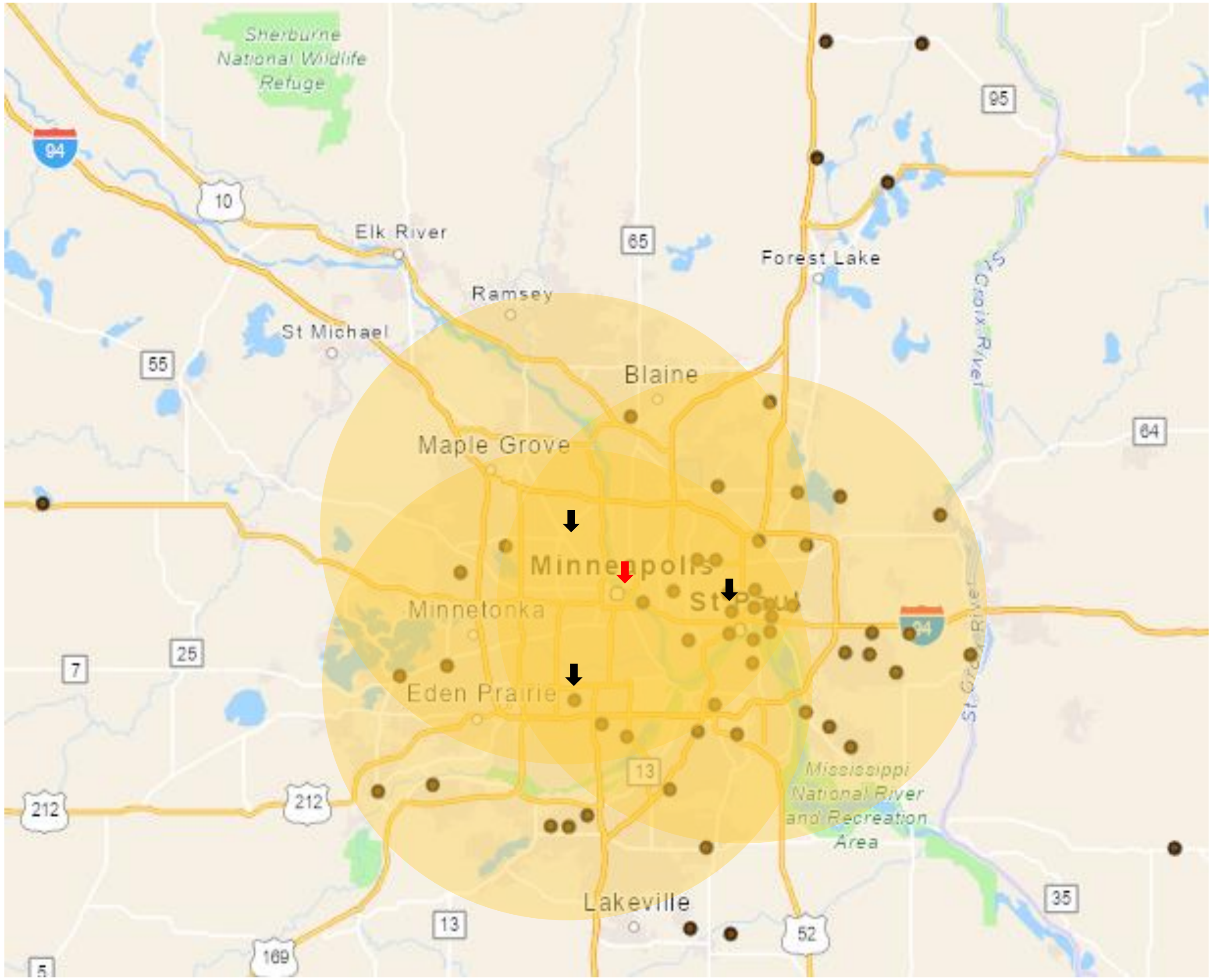


Out-of-Hospital Care
VF Cardiac Arrest
911
CPR/Activation
EMS Identifies ECMO Candidate
Transfer to closest ECMO Initiation Hospital
Central Dispatcher
Meet at ECMO Initiation Hospital
Activation of Mobile ECMO Cannulation Team
ECMO
3 ECMO Initiation Hospitals
ED ECMO Cannulation Site
Cardiac Catheterization Laboratory
Single, Centralized ECMO ICU

ED Workflow



First 4 Months: 12/2019 – 3/2020



[PMID: 33437949]

58 patients aged 18-75 transported with CPR by EMS to a Cannulation Center

13/58 (22%) met ≥2 resuscitation discontinuation criteria

45/58 (78%) patients received full resuscitation efforts

4/58 (7%) declared dead prior to transfer due to refractory shock or failure to achieve an organized rhythm

41/58 (71%) patients transferred to the ECMO Center

Survival
Survival to Hospital Discharge: 27/58 (47%)
Survival with CPC 1 or 2: 25/58 (43%)

Timeline of ECPR in the Twin Cities

12/2014 UMMC ECPR

12/2019 Mobile ECMO at Southdale and Regions

4/2020 – 5/2022
Intermittent COVID
Closures

5/2022
Reopen Mobile ECMO
at Southdale and
Regions

7/2022 Mobile ECMO Truck

02/2024 North Memorial

10/2025 Northland, Lakes, and Hutchinson

5/2026 Ridges & Methodist Hospital

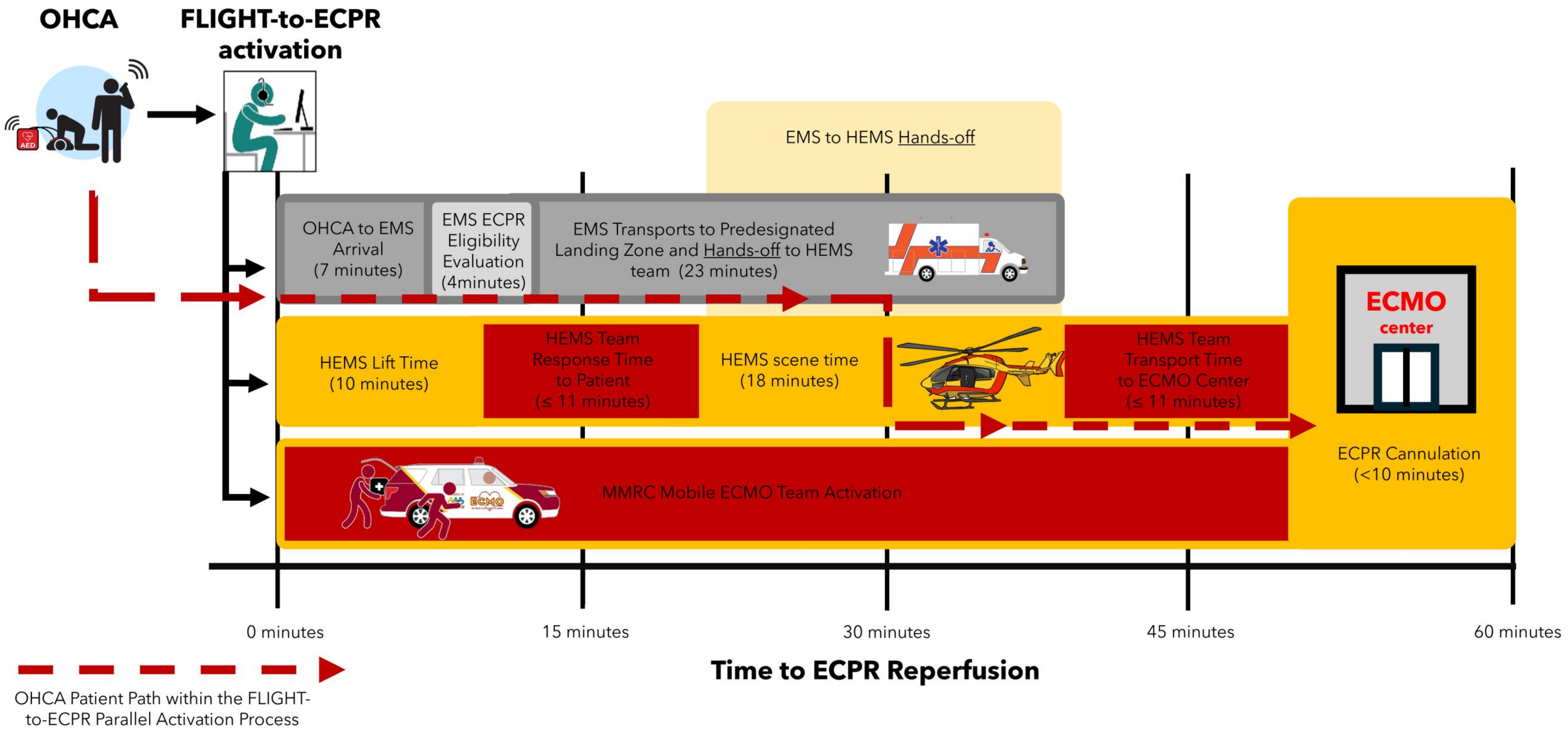
Mobile ECMO Team

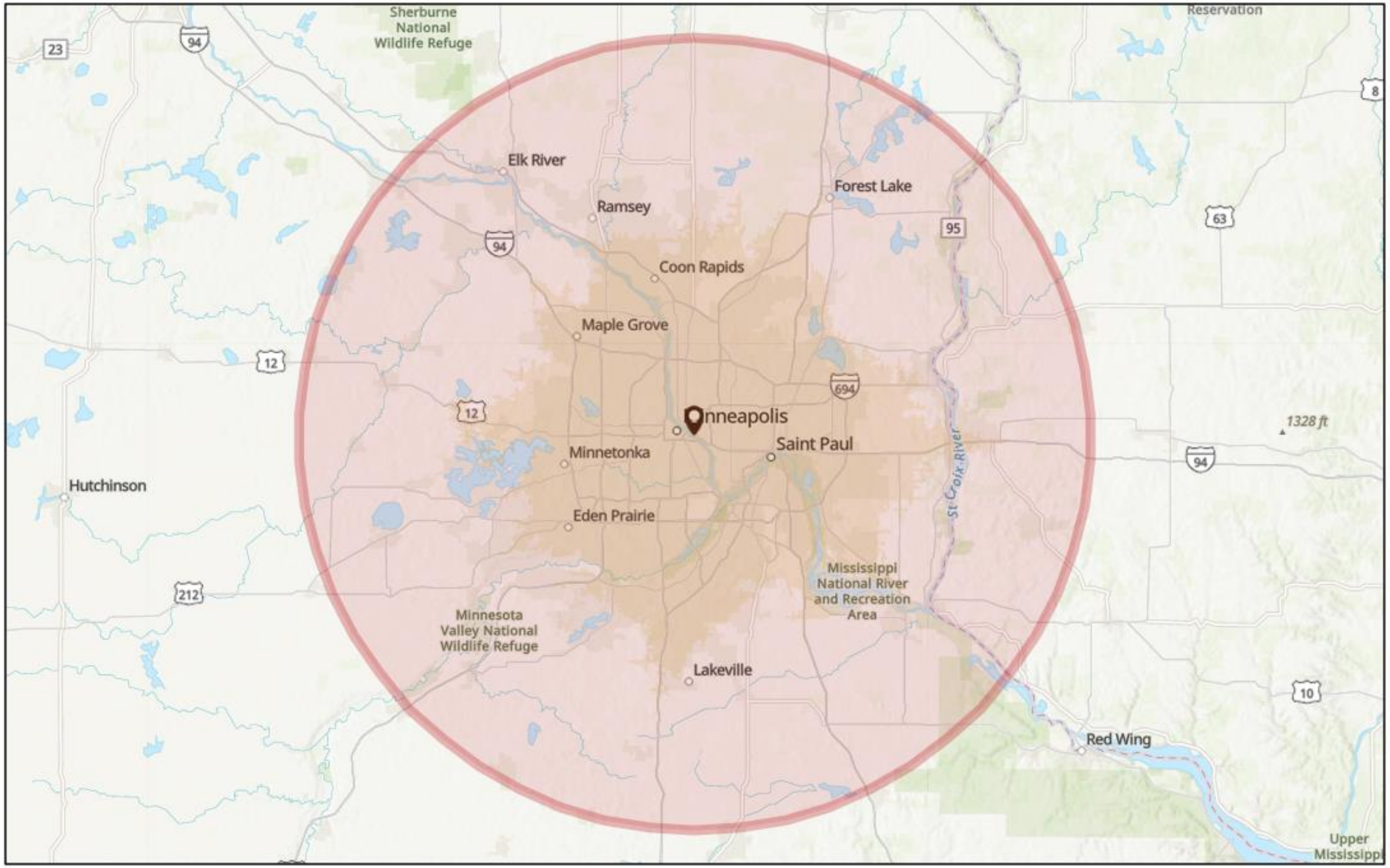
- The mobile team brings expertise to the patient rather than waiting for transfer to a fixed center.
- The cannulating physician and ECMO clinicians respond to the site of care.

[PMID: 33437949]

Expanding the Geographic Reach of the ECMO Hub Model

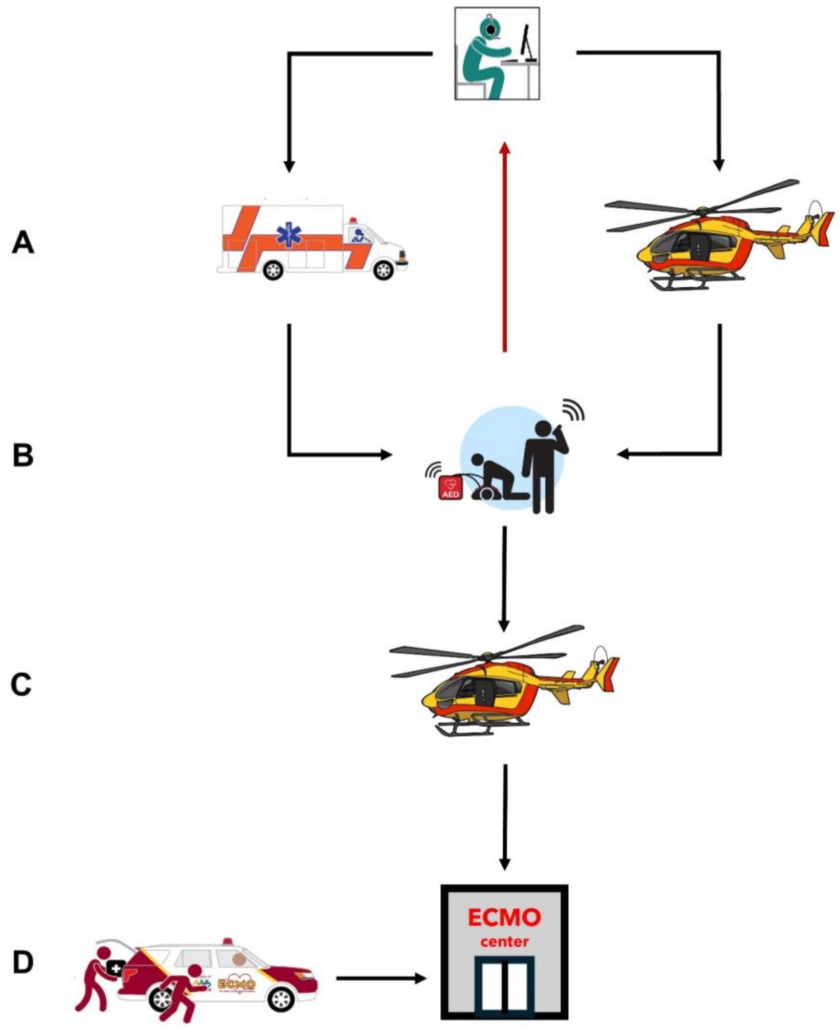
FLIGHT to ECPR System




Sherburne National Wildlife Refuge
Reservation
23
94
8
Elk River
Ramsey
Forest Lake
95
63
Coon Rapids
Maple Grove
12
694
Minneapolis
Saint Paul
1328 ft
Minnetonka
St Croix River
94
Hutchinson
Eden Prairie
212
Mississippi National River and Recreation Area
Minnesota Valley National Wildlife Refuge
Lakeville
10
Red Wing
Upper Mississippi

FLIGHT-to-ECPR Study

- Single-center prospective cohort
- Aug 2021 – Dec 2025 | Adults 18–75 with refractory VF/VT OHCA
- Parallel EMS + auto-launch HEMS activation
- Intra-arrest mCPR transport to ECMO center
- 1:1 matched comparison to standard ground-transport ECPR



Available online at ScienceDirect
Resuscitation
journal homepage: www.elsevier.com/locate/resuscitation
EUROPEAN RESUSCITATION COUNCIL

Original paper

The FaciLItated hospital-based ECPR via Helicopter Transport (FLIGHT-to-ECPR) study

Adam L. Gottula[a,b,c,*,†], Alexander Wilcox[a,d,†], Kevin Sipprell[e], Pierre Sebastian[a,f], Kevin Rixmann[a,b], Paul Rees[a,f], Rajat Kalra[a,f], Charles Bruen[a], Josh Weiner[a,b], Peter Tanghe[g], Bjorn Peterson[b], Josh Howell[b], Kim Harkins[a], Jason Bartos[a,f], Demetris Yannopoulos[a,f]

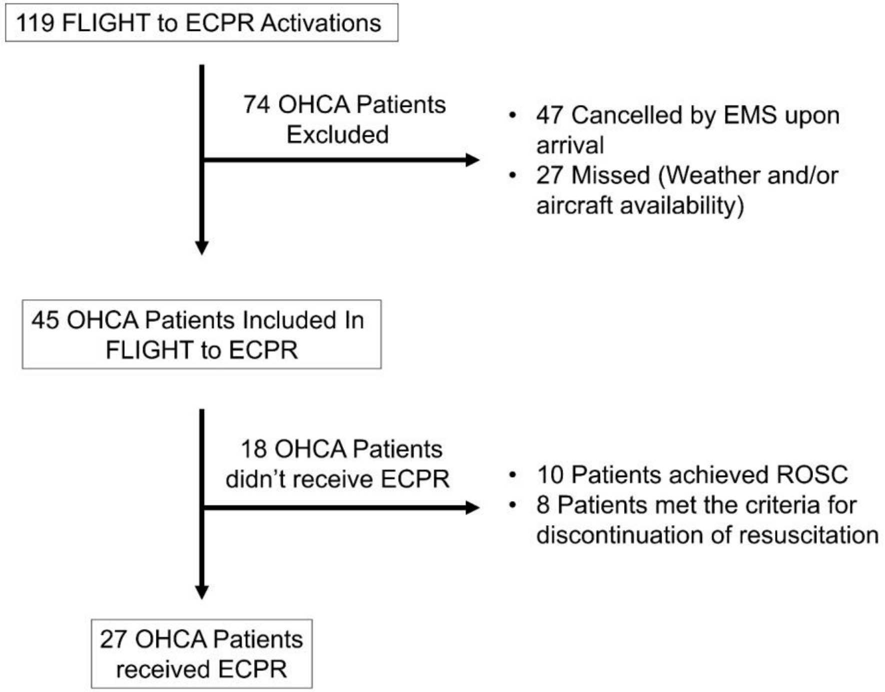


Table 1 – All patients treated with the MMRC FLIGHT-to-ECPR study protocol.

	All patients	Patients cannulated for ECPR	Patients not cannulated for ECPR	P-value (cannulated for ECPR vs. not cannulated for ECPR)
Total number	*45*	*27*	*18*	
Demographics				
Age, mean (SD)	55.2 (15.0)	57.4 (14.7)	51.7 (15.2)	0.242
Sex, % male	34 (75.6%)	21 (77.8%)	13 (72.2%)	0.732
Race, % White	41 (97.6%)	25 (96.2%)	16 (100.0%)	>0.99
Race, % African American	0 (0.0%)	0 (0.0%)	0 (0.0%)	–
Time intervals				
9-1-1 call to hospital arrival time (min), mean (SD)	70.3 (18.5)	69.7 (20.8)	71.1 (14.8)	0.811
HEMS launch time (min), mean (SD)	12.2 (5.8)	11.9 (3.9)	12.6 (8.0)	0.538
HEMS scene time (min), mean (SD)	18.0 (11.6)	20.1 (11.7)	15.0 (11.0)	0.106
HEMS flight time (min), mean (SD)	18.6 (6.3)	19.4 (6.6)	17.7 (5.9)	0.424
Needle stick to ECMO time (min), mean (SD)	N/A	5.8 (3.2)	N/A	–
Cardiac arrest characteristics				
VT/VF, *n* (%)	36 (81.8%)	20 (74.8%)	15 (88.2%)	0.445
Witnessed cardiac arrest, *n* (%)	36 (83.7%)	23 (85.2%)	13 (81.2%)	>0.99
Bystander CPR, *n* (%)	29 (69.0%)	17 (63.0%)	12 (80.0%)	0.314
LUCAS placed, *n* (%)	42 (93.3%)	27 (100.0%)	15 (83.3%)	0.058
Field intubation, *n* (%)	40 (88.9%)	27 (100.0%)	13 (72.2%)	0.007
Number of shocks, mean (SD)	3.5 (3.3)	4.1 (3.8)	2.5 (1.9)	0.214
Lactate, mean (SD)	13.1 (4.8)	13.1 (4.8)	12.7 (5.5)	0.875
pH, mean (SD)	7.0 (0.2)	7.0 (0.2)	7.0 (0.3)	–
Low flow time (min), mean (SD)	77.6 (33.4)	85.9 (29.3)	40.2 (25.2)	0.001
Outcomes				
Days on V-A ECMO, mean (SD)	N/A	3.1 (2.5)	N/A	–
Hospital LOS (days), mean (SD)	9.1 (10.0)	7.0 (8.4)	14.6 (12.2)	0.105
Alive at discharge, CPC 1–2, *n* (%)	15 (33.3%)	7 (25.9%)	8 (44.4%)	0.218

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EUROPEAN RESUSCITATION COUNCIL

Original paper

The FaciLItated hospital-based ECPR via Helicopter Transport (FLIGHT-to-ECPR) study

Adam L. Gottula [a,b,c,*,†], *Alexander Wilcox* [a,d,†], *Kevin Sipprell* [e], *Pierre Sebastian* [a,f], *Kevin Rixmann* [a,b], *Paul Rees* [a,f], *Rajat Kalra* [a,f], *Charles Bruen* [a], *Josh Weiner* [a,b], *Peter Tanghe* [g], *Bjorn Peterson* [b], *Josh Howell* [b], *Kim Harkins* [a], *Jason Bartos* [a,f], *Demetris Yannopoulos* [a,f]

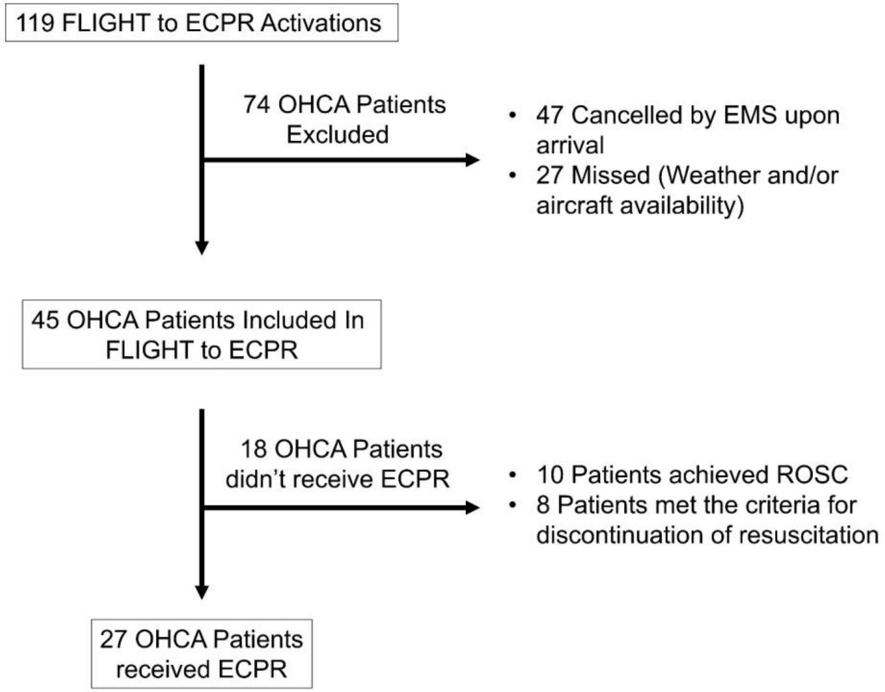


Table 2 – Matched comparison of patients undergoing ECPR cannulation in the FLIGHT-to-ECPR study vs. standard MMRC ECPR protocol.

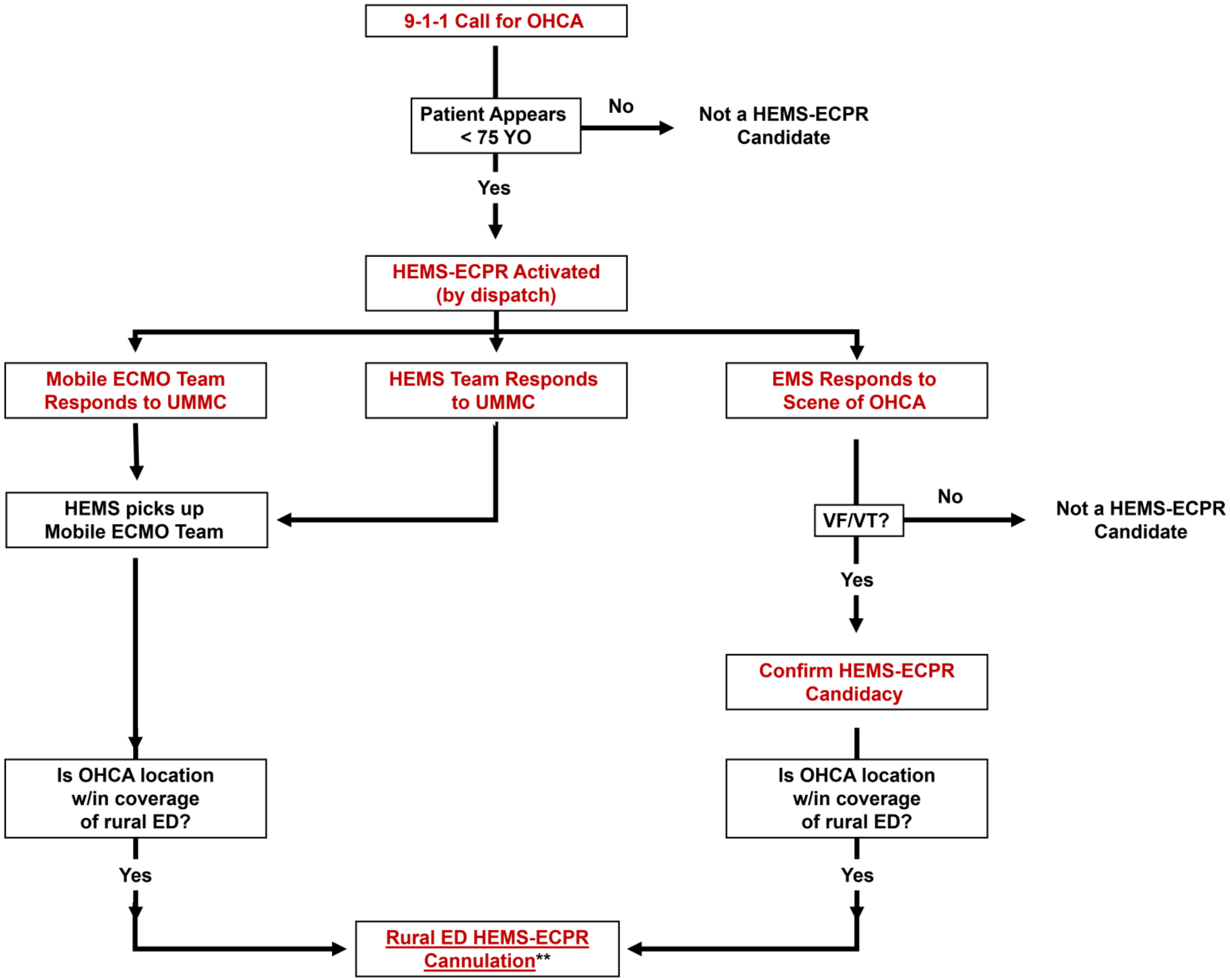
	MMRC FLIGHT-to-ECPR protocol	Standard MMRC ECPR protocol	p-value
Total number	27	27	
Demographics			
Age, mean (SD)	57.4 (14.7)	56.9 (11.1)	0.666
Sex, % male	21 (77.8%)	19 (79.2%)	>0.99
Race, % White	25 (96.2%)	21 (87.5%)	0.340
Race, % African American	0 (0.0%)	1 (4.2%)	0.480
Time intervals			
9-1-1 call to ECMO cannulation hospital arrival time (min), mean (SD)	69.7 (20.8)	N/A	N/A
HEMS launch time (min), mean (SD)	11.9 (3.9)	N/A	N/A
HEMS scene time (min), mean (SD)	20.1 (11.7)	N/A	N/A
HEMS flight time (min), mean (SD)	19.4 (6.6)	N/A	N/A
Needle stick to ECMO time (min), mean (SD)	5.8 (3.2)	8.2 (6.4)	0.118
Cardiac arrest characteristics			
VT/VF, *n* (%)	20 (74.1%)	23 (85.2%)	0.501
Witnessed cardiac arrest, *n* (%)	23 (85.2%)	19 (70.4%)	0.327
Bystander CPR, *n* (%)	17 (63.0%)	16 (61.5%)	>0.99
LUCAS placed, *n* (%)	27 (100.0%)	25 (92.6%)	0.491
Intubated with ETT, *n* (%)	27 (100.0%)	24 (88.9%)	0.236
Number of shocks, mean (SD)	4.1 (3.8)	3.4 (3.5)	0.463
Lactate, mean (SD)	13.1 (4.8)	11.4 (4.2)	0.231
pH, mean (SD)	7.0 (0.2)	7.0 (0.2)	0.661
Low flow time (min), mean (SD)	85.9 (29.3)	87.1 (29.2)	>0.99
Outcomes			
Days on V-A ECMO, mean (SD)	3.1 (2.5)	4.6 (7.9)	0.913
Hospital LOS (days), mean (SD)	7.0 (8.4)	8.9 (11.4)	0.745
Survival to discharge, *n* (%)	7 (25.9%)	7 (25.9%)	>0.99

ECMO Takes Flight: Expanding the Rendezvous Model

HEMS-Rendezvous Model

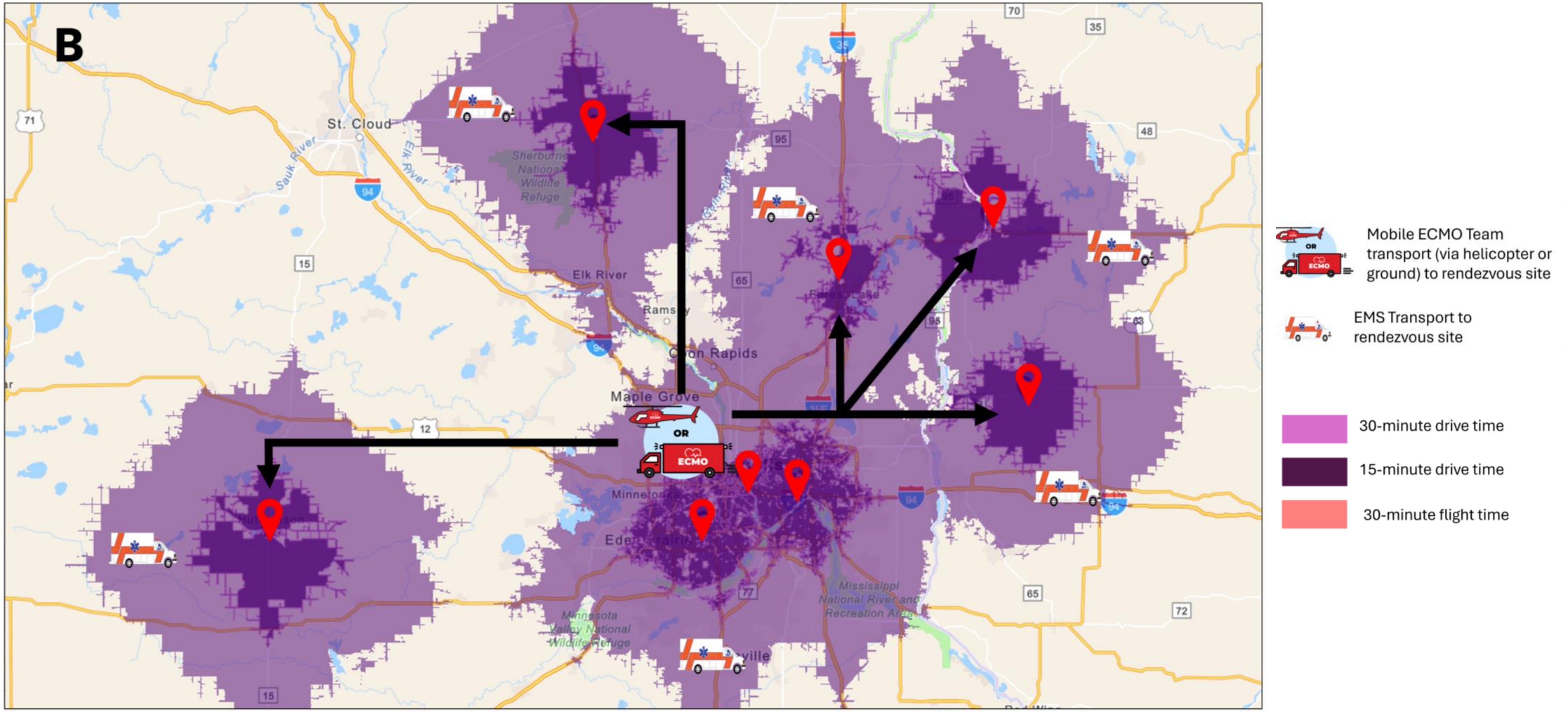
Fig. 1 – The Minnesota Mobile Resuscitation Consortium HEMS-Rendezvous Model. (A) MMRC Mobile ECMO Team is leaving to rendezvous with a patient at a rural emergency department. (B) MMRC Mobile ECMO Team following a successful HEMS-rendezvous ECPR.

Minnesota's Mobile Resuscitation Consortium (MMRC) HEMS-ECPR Activation Pathway



*EMS (1) moves OHCA Patient into the ambulance, (2) establishes a landing zone, and (3) HEMS-ECPR team responds to scene
**EMS (1) loads OHCA patient into the ambulance and (2) completes intra-arrest transport to rural ED.
ECMO: extracorporeal membrane oxygenation, ECPR: Extracorporeal cardiopulmonary resuscitation, ED: emergency department, EMS: emergency medical services, HEMS: helicopter emergency medical services, OHCA: out-of-hospital cardiac arrest, UMMC: University of Minnesota Medical Center, VF/VT: ventricular fibrillation/ventricular tachycardia, YO: years old

HEMS Rendezvous Model



The Prehospital ECPR Model

Mobile ECMO Truck

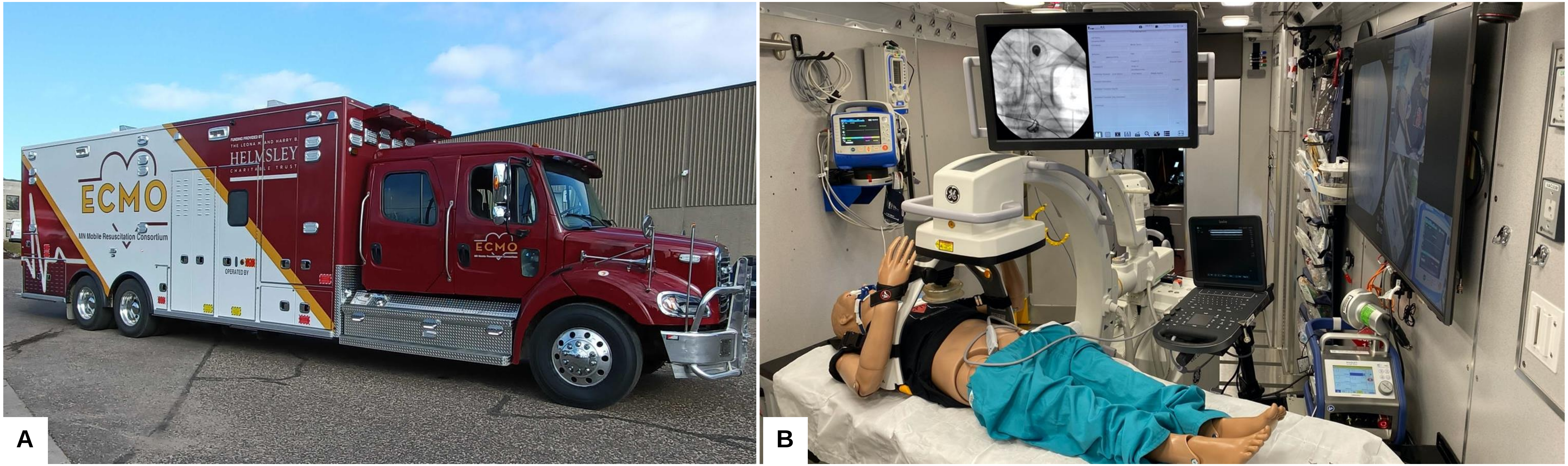


Fig. 2 – The Minnesota Mobile Resuscitation Consortium ECMO truck platform (ECMO99). (A) Exterior view of the purpose-built mobile ECMO unit designed for rapid deployment to rendezvous sites of scene for refractory out-of-hospital cardiac arrest. The vehicle houses a dedicated extracorporeal life support team and full resuscitation capabilities, enabling scene-based initiation of ECPR. (B) Interior view of the ECMO truck demonstrating the integrated fluoroscopy system and procedural workspace configured for ultrasound- and fluoroscopy-guided percutaneous veno-arterial ECMO cannulation under ongoing mechanical CPR. The platform is engineered to replicate the functionality of a cardiac catheterization laboratory within a mobile environment.

Mobile ECMO Truck

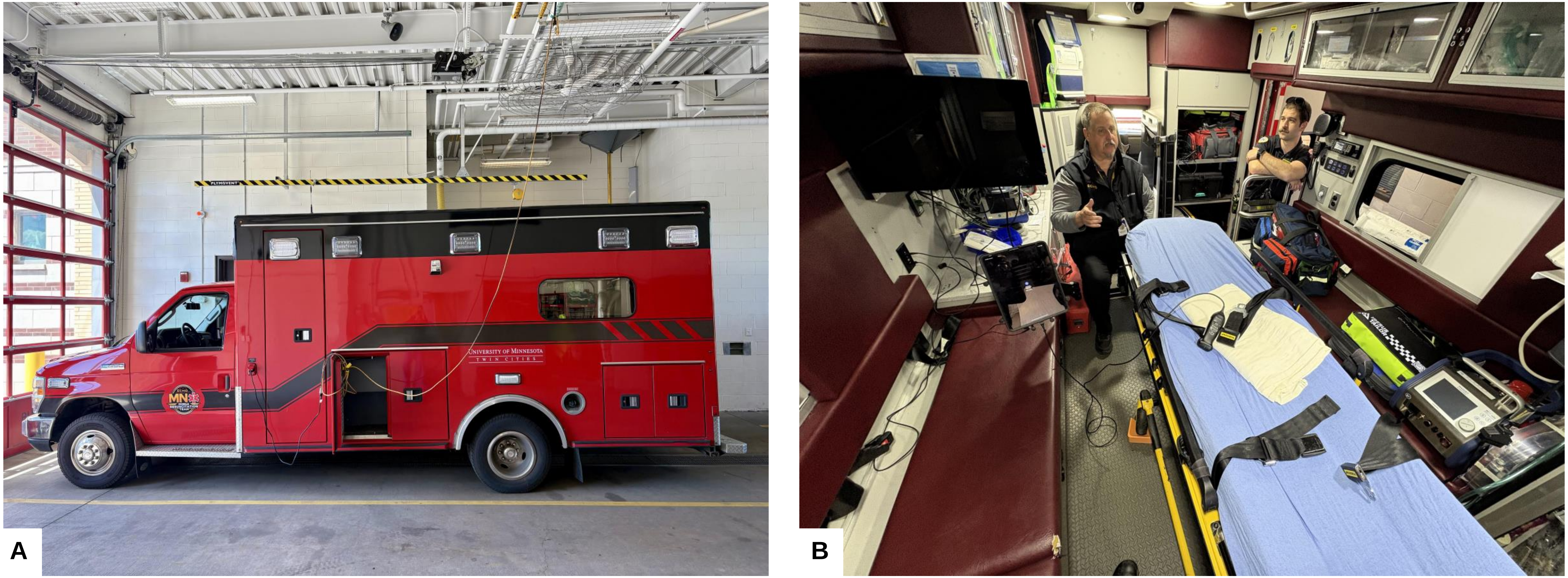


Fig. 3 – The Minnesota Mobile Resuscitation Consortium compact ECMO truck platform (ECMO50). (A) Exterior view of the purpose-built compact mobile ECMO unit designed for rapid deployment to rendezvous sites of scene for refractory out-of-hospital cardiac arrest. (B) Interior view of the ECMO truck demonstrating the procedural workspace configured for ultrasound-guided percutaneous veno-arterial ECMO cannulation under ongoing mechanical CPR.

Mobile ECMO Truck

Fig. 4 – The Minnesota Mobile Resuscitation Consortium compact ECMO truck platform (ECMO50). (A) Driver-side interior view of the purpose-built compact mobile ECMO unit. (B) Passenger-side interior view of the purpose-built compact mobile ECMO unit.

Mobile ECMO Truck

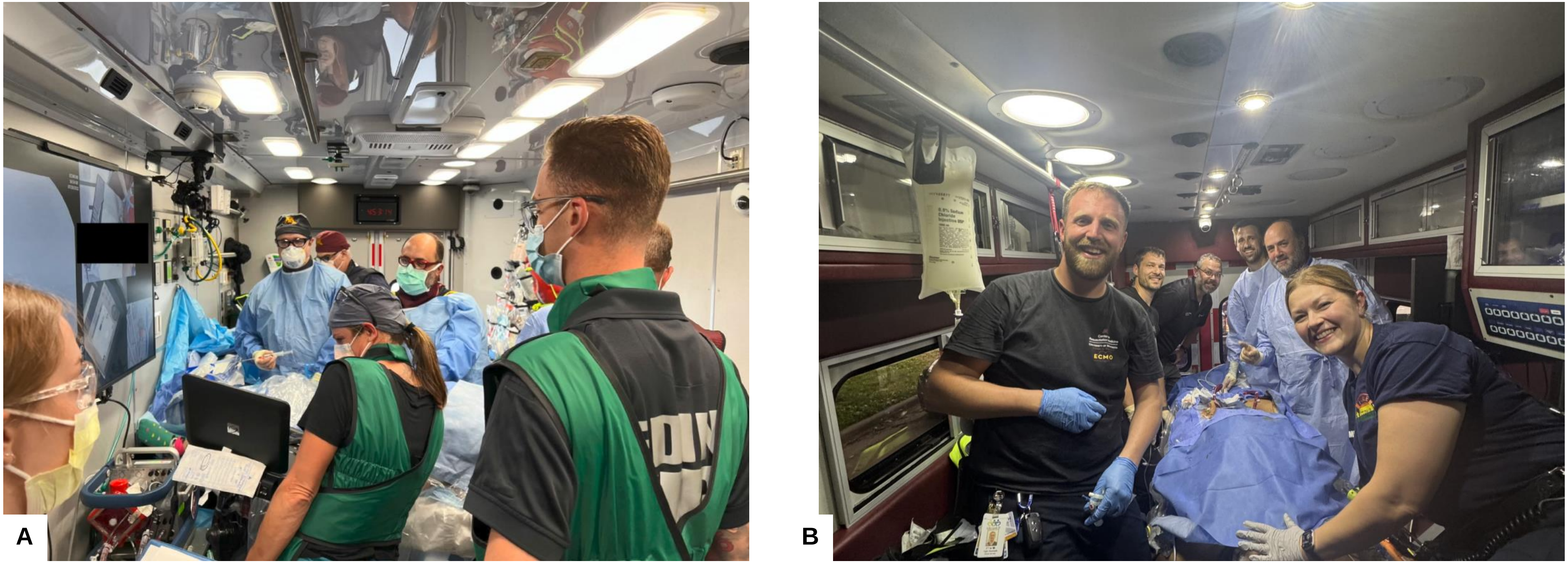


Fig. 5 – The first cannulations in the Minnesota Mobile Resuscitation Consortium (A) ECMO truck (ECMO99) and (B) compact ECMO truck platform (ECMO50).

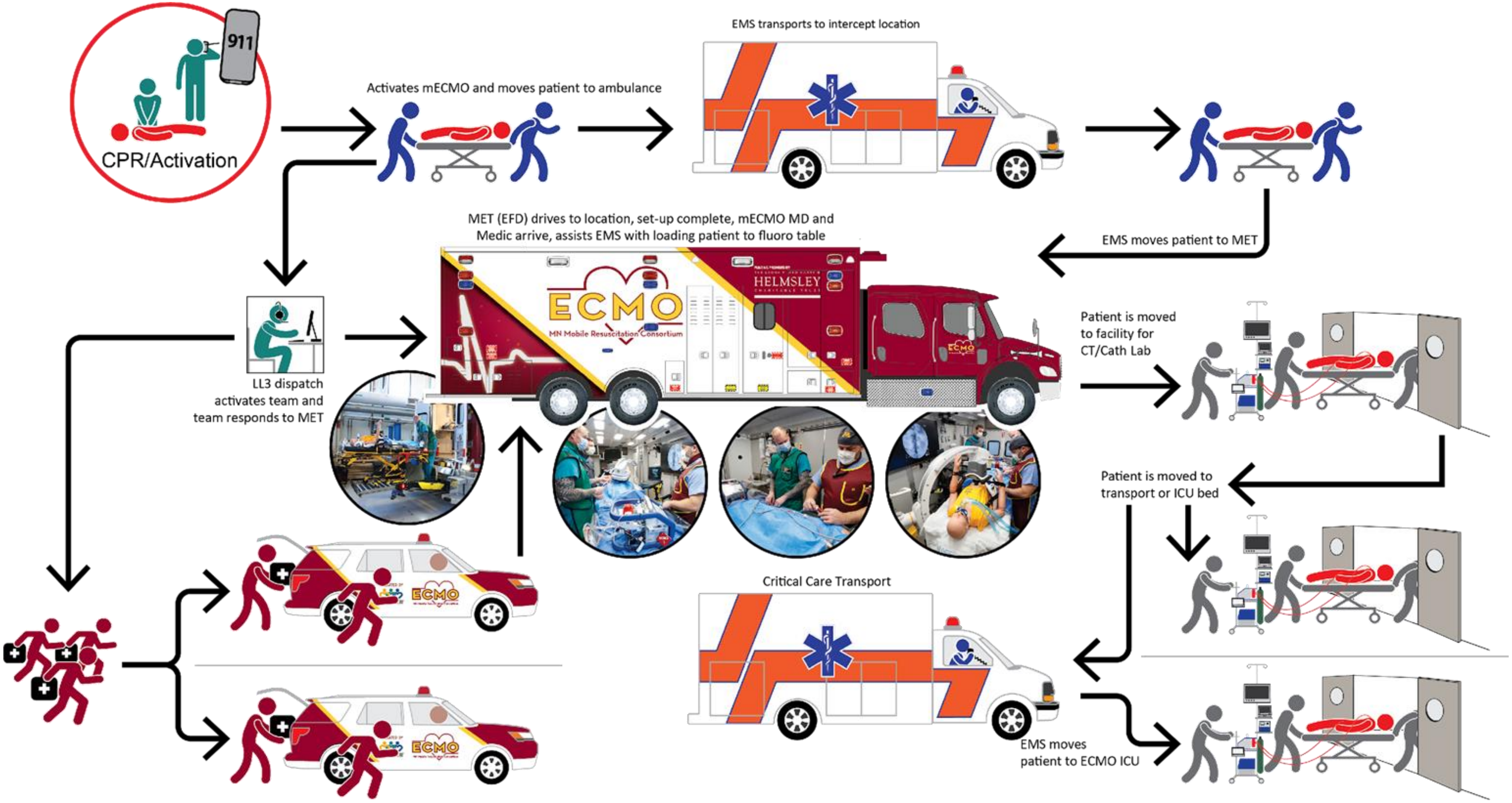


Fig. 6 – The Minnesota Mobile Resuscitation Consortium (MMRC) ECMO truck protocol for refractory ventricular fibrillation/ ventricular tachycardia out-of-hospital cardiac arrest.

Mobile ECMO Truck

- Single-center prospective cohort
- Aug 2022 – April 2024 | Adults 18–75 with refractory VF/VT OHCA
- Parallel EMS + ECMO Truck Activation
- Intra-arrest mCPR transport to ECMO Truck
- 1:1 matched comparison to standard ground-transport ECPR

RESUSCITATION 223 (2026) 111089

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EUROPEAN RESUSCITATION COUNCIL

Original paper

The Minnesota Mobile Resuscitation Consortium ECMO truck: a feasibility study for ECPR in refractory out-of-hospital cardiac arrest

Kevin Rixmann [a,†], *Adam L. Gottula* [a,*,†], *Alexander Wilcox* [a], *Kevin Sipprell* [c], *Josh Weiner* [a], *Paul Rees* [a], *Rajat Kalra* [a], *Charles Bruen* [a], *Alexandra Schick* [a], *Bjorn Peterson* [b], *Kobly Kolbet* [b], *Kim Harkins* [a], *Jason Bartos* [a], *Demetris Yannopoulos* [a]

Abstract

Background: Refractory ventricular fibrillation/ventricular tachycardia (VF/VT) out-of-hospital cardiac arrest (OHCA) carries poor survival with conventional resuscitation. Extracorporeal cardiopulmonary resuscitation (ECPR) improves outcomes in selected patients; however, time to reperfusion is the dominant determinant of neurologically intact survival, and geographic distance excludes many otherwise eligible patients.

Research question/hypothesis: We hypothesized that a purpose-built, fluoroscopy-enabled mobile ECMO truck delivering scene-based ECPR would be feasible and achieve neurologically favorable survival comparable to a mature in-hospital ECPR system when matched on low-flow time.

Goals/aims: To evaluate the feasibility, procedural performance, and clinical outcomes of a sustained prehospital ECPR program integrated within a regional cardiac arrest system of care.

Methods: We performed a single-center retrospective analysis of a prospectively collected registry within the Minnesota Mobile Resuscitation Consortium. Adults (18–75 years) with refractory VF/VT OHCA treated under the ECMO truck protocol were compared with a matched cohort treated under the standard in-hospital ECPR pathway, matched on low-flow time. Baseline characteristics, laboratory values, time intervals, cannulation metrics, and outcomes were compared. The primary outcome was survival to hospital discharge with a favorable neurological status.

Results: A total of eight patients underwent ECMO truck activation and were matched to eight in-hospital controls. Baseline characteristics were similar between groups. Total low-flow time was 74.8 [standard deviation (SD) 19.8] min in the ECMO truck group and 73.0 (SD 22.9) min in controls ($p = 0.87$). Needle-stick–to–ECMO flow times were 7.5 (SD 3.1) min versus 12.0 (SD 10.8) min, respectively ($p = 0.71$). Neurologically favorable survival was 25% in the ECMO truck cohort versus 25% in matched controls ($p \geq 0.99$).

Conclusions: A sustained, protocolized prehospital ECPR program using a purpose-built ECMO truck is feasible and achieves outcomes comparable to an established in-hospital ECPR system when matched on low-flow time. This single-center feasibility study demonstrates that a mobile ECPR program using a purpose-built Mobile ECMO Truck can be implemented safely and with acceptable procedural performance.

Keywords: Extracorporeal cardiopulmonary resuscitation, Out-of-hospital cardiac arrest, Mobile ECMO truck, Prehospital ECPR

Introduction

Out-of-hospital cardiac arrest (OHCA) affects nearly 400,000 people each year in the United States, yet survival remains poor, with variation, when treated with standard cardiopulmonary resuscitation (CPR) by emergency medical services (EMS).[1–3] For patients with refractory ventricular fibrillation or ventricular tachycardia (VF/VT), extracorporeal cardiopulmonary resuscitation (ECPR) has been shown to substantially improve survival.[4–6] The Minnesota Mobile Resuscitation Consortium (MMRC) established the first organized ECPR system in the U.S. dedicated to treating refractory VF/VT

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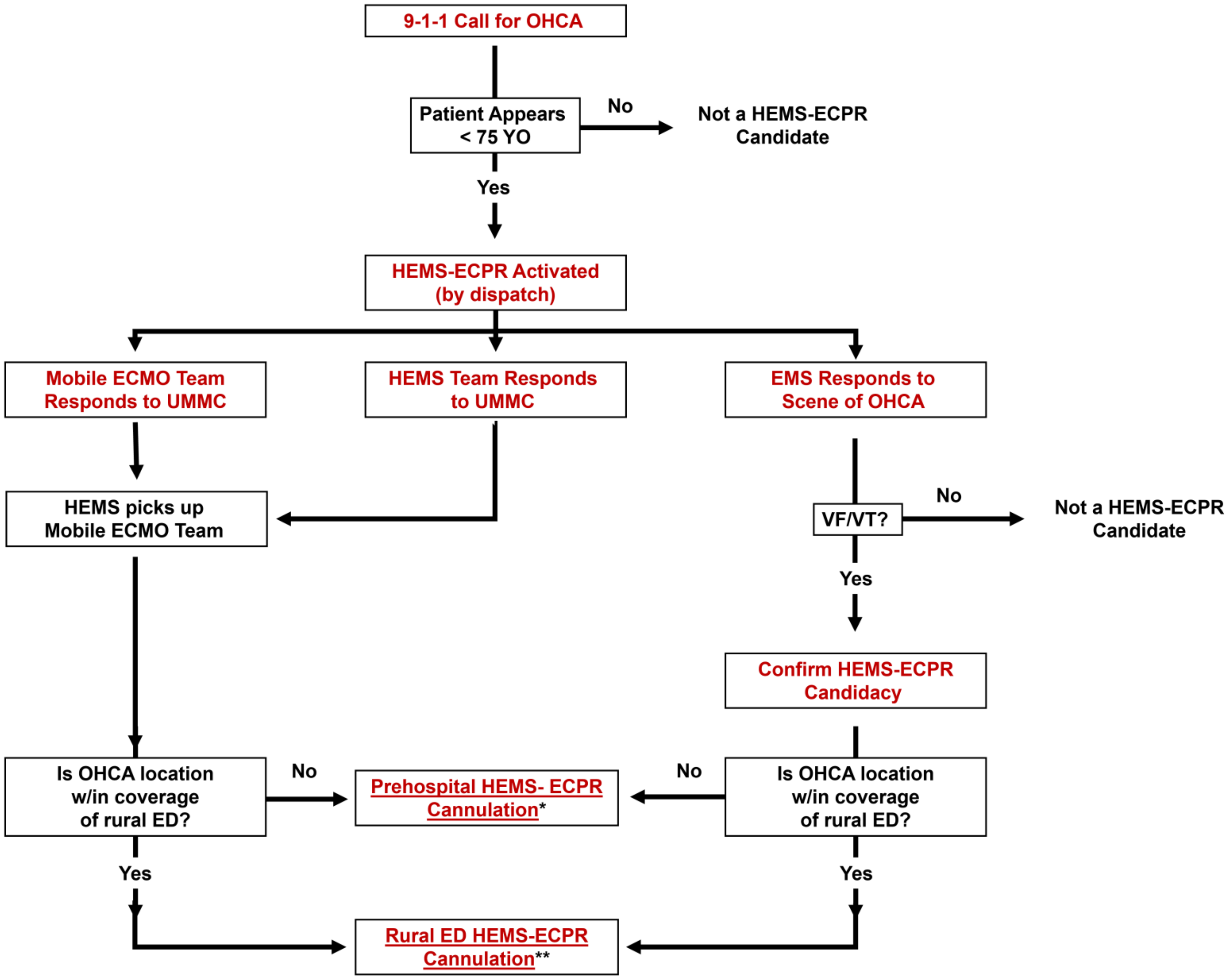
https://doi.org/10.1016/j.resuscitation.2026.111089
Received 27 February 2026; Received in Revised form 31 March 2026; Accepted 2 April 2026

Table 1 – Matched comparison of patients undergoing ECPR cannulation in the MMRC ECMO truck vs. MMRC standard.

	ECMO truck protocol	Standard MMRC ECPR protocol	*p*-value
Total number	8	8	–
Demographics			
Age, mean (SD)	57 (11.6)	58.9 (9.7)	0.752
Sex, % male	8 (100%)	6 (85.7%)	0.467
Race, % White	7 (87.5%)	5 (71.4%)	0.569
Race, % African American	1 (12.5%)	1 (12.5%)	>0.99
Time intervals			
9-1-1 call to ECMO cannulation hospital arrival time (min), mean (SD)	62.1 (27)	48.4 (9.3)	0.344
Low flow time (min), mean (SD)	74.8 (19.8)	73 (22.9)	0.872
Needle stick to ECMO time (min), mean (SD)	7.5 (3.1)	12.0 (10.8)	0.711
Cardiac arrest characteristics			
VF/VT, *n* (%)	7 (87.5%)	7 (87.5%)	>0.99
Witnessed cardiac arrest, *n* (%)	7 (87.5%)	6 (75%)	0.467
Bystander CPR, *n* (%)	8 (100%)	6 (75%)	0.468
LUCAS placed, *n* (%)	8 (100%)	8 (100%)	>0.99
Intubated with ETT, *n* (%)	8 (100%)	7 (87.5)	>0.99
Number of shocks, mean (SD)	3.4 (3)	3.6 (3.6)	0.873
Lactate, mean (SD)	8.1 (2.2)	10.5 (4.3)	0.193
pH, mean (SD)	7.2 (0.2)	7.0 (0.2)	0.080
Outcomes			
Days on V-A ECMO, mean (SD)	2 (0)	3.5 (3.7)	0.37
Hospital LOS (days), mean (SD)	6.5 (4.6)	6.0 (4.7)	0.833
Survival to discharge, *n* (%)	2 (25%)	2 (25%)	>0.99

Minnesota's Mobile Resuscitation Consortium (MMRC) HEMS-ECPR Activation Pathway



*EMS (1) moves OHCA Patient into the ambulance, (2) establishes a landing zone, and (3) HEMS-ECPR team responds to scene
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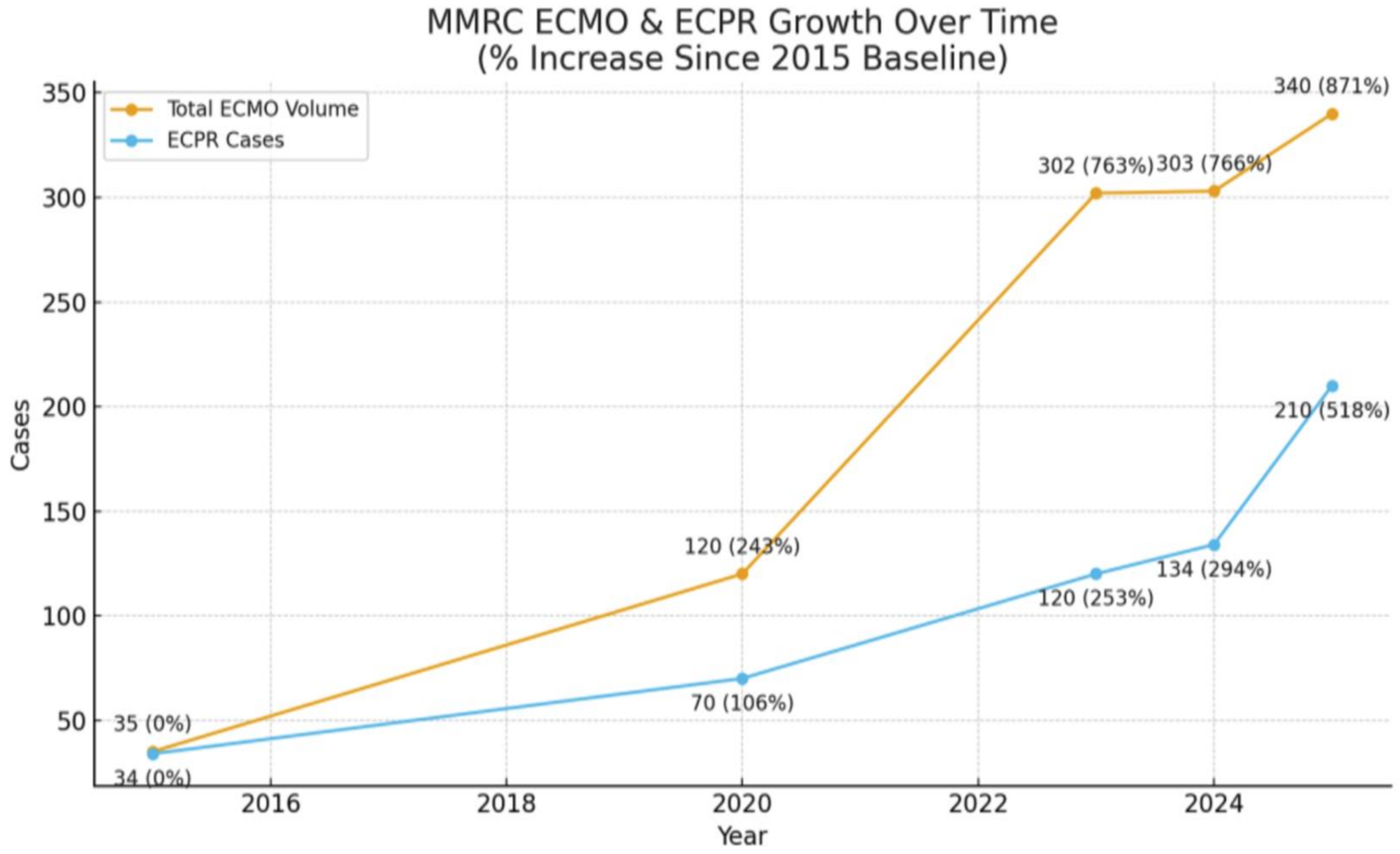
ECMO: extracorporeal membrane oxygenation, ECPR: Extracorporeal cardiopulmonary resuscitation, ED: emergency department, EMS: emergency medical services, HEMS: helicopter emergency medical services, OHCA: out-of-hospital cardiac arrest, UMMC: University of Minnesota Medical Center, VF/VT: ventricular fibrillation/ventricular tachycardia, YO: years old



MMRC ECMO & ECPR Growth Over Time
(% Increase Since 2015 Baseline)
Total ECMO Volume
ECPR Cases
Cases
Year
350
300
250
200
150
100
50
2016
2018
2020
2022
2024
35 (0%)
34 (0%)
120 (243%)
70 (106%)
302 (763%)
303 (766%)
340 (871%)
120 (253%)
134 (294%)
210 (518%)

Mobile ECMO Team