Salvage the Survivable: Rethinking Prehospital Trauma Triage with Rapid Ultrasound Identification of Hemorrhage and Tension Pneumothorax

Terence Byrne MD, LT, MC, USN (NREMT/SOCM)
Mark Piehl MD, MPH, David Rayburn MD, MPH

Disclosures

LCDR Byrne: None

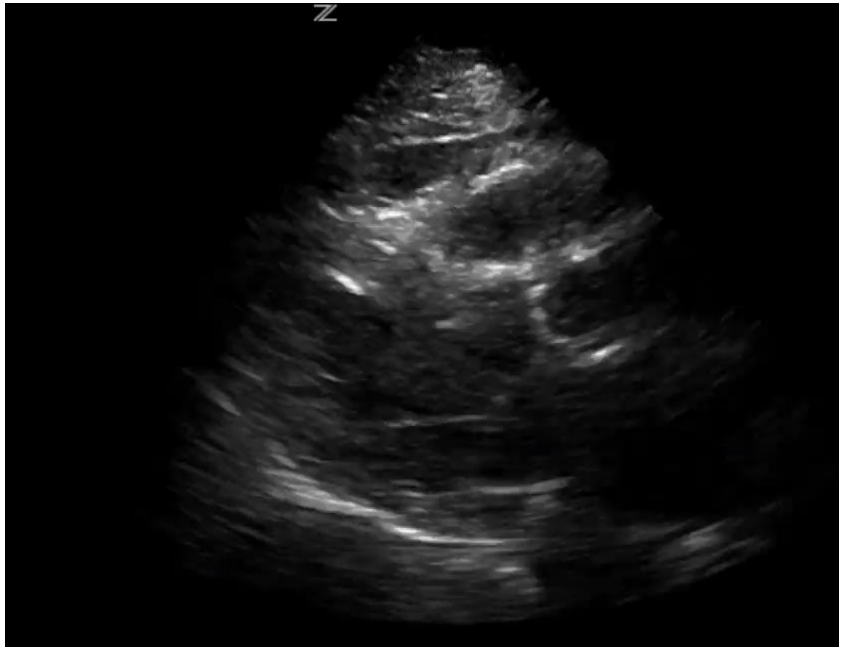
Piehl: Founder & CMO 410 Medical, Inventor of LifeFlow

DoW grants:

- USSOCOM W81XWH-22-C-0002
- USAF SBIR AF212-CSO1 Phase II, F2-15653
- USAF SBIR AF211-CSO1 Phase II, F2-15254
- USAF SBIR AFX246-DPCSO1 Phase II, F2D-12663
- USAF STTR AFX23E-TPCSO1 Phase II, F2-17944
- USAF SBIR AX255-PCSO1 Phase I, FX-0833

Rayburn: FujiFilm / Sonosite - Consultant

Can POCUS Augment Trauma & MASCAL Triage?



Who is survivable?

Who to transfuse?

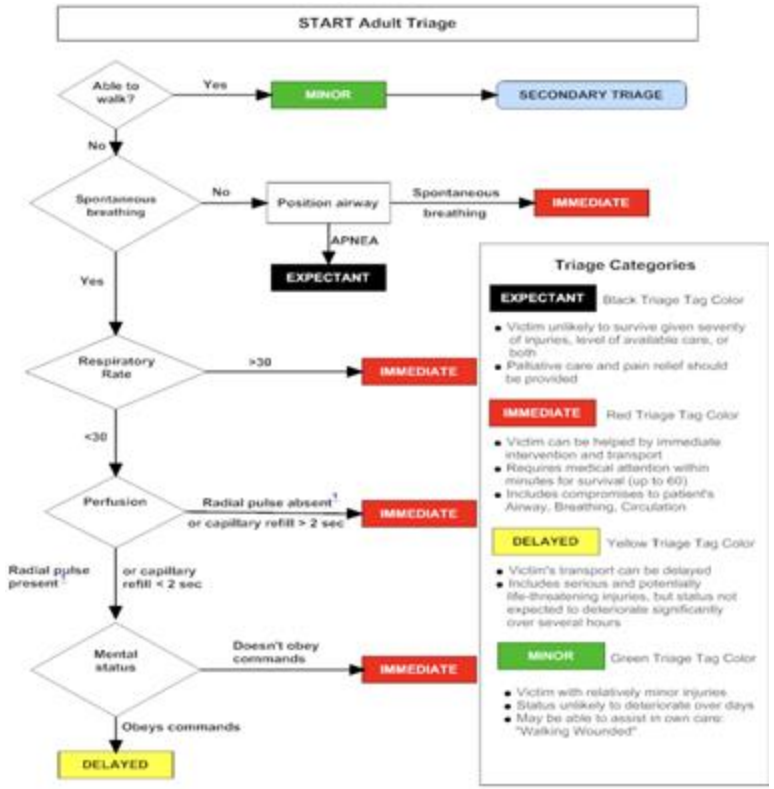
Who needs thoracostomy?

Triage in Actual MASCALs

- Formal triage systems aren't being used
- Subjective judgment preferred
- Binary decision tree: urgent vs non-urgent, survivable vs not

Rush et al. (JSOM 2024):

Key lessons from Rush et al.:



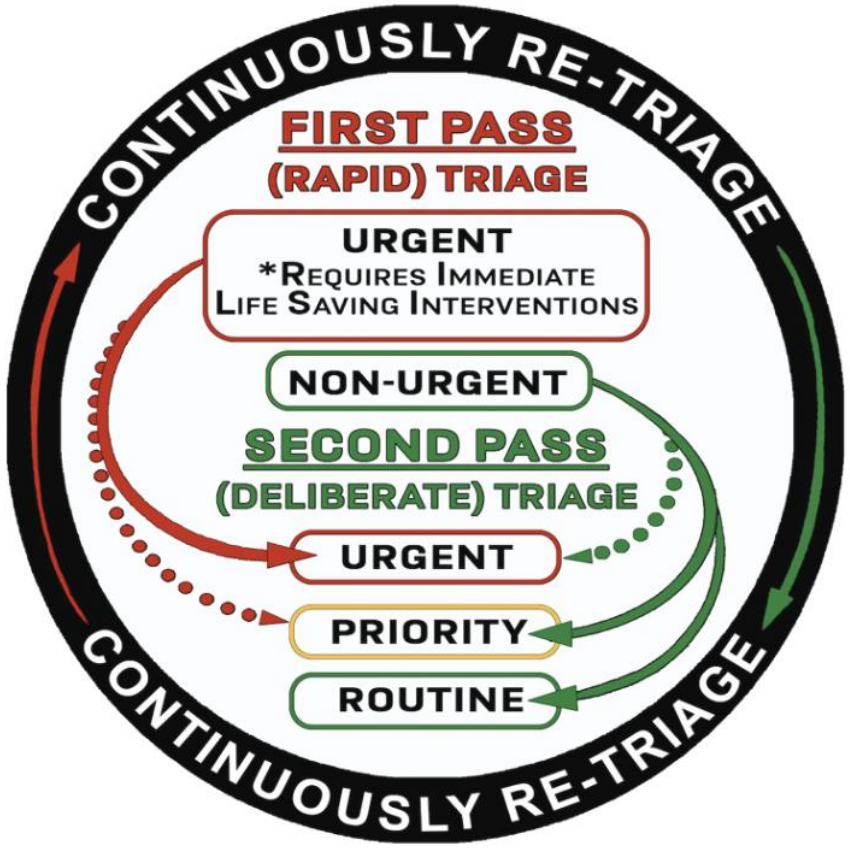
Triage in Actual MASCALs

- Formal triage systems aren't being used
- Subjective judgment preferred
- Binary decision tree: urgent vs non-urgent, survivable vs not

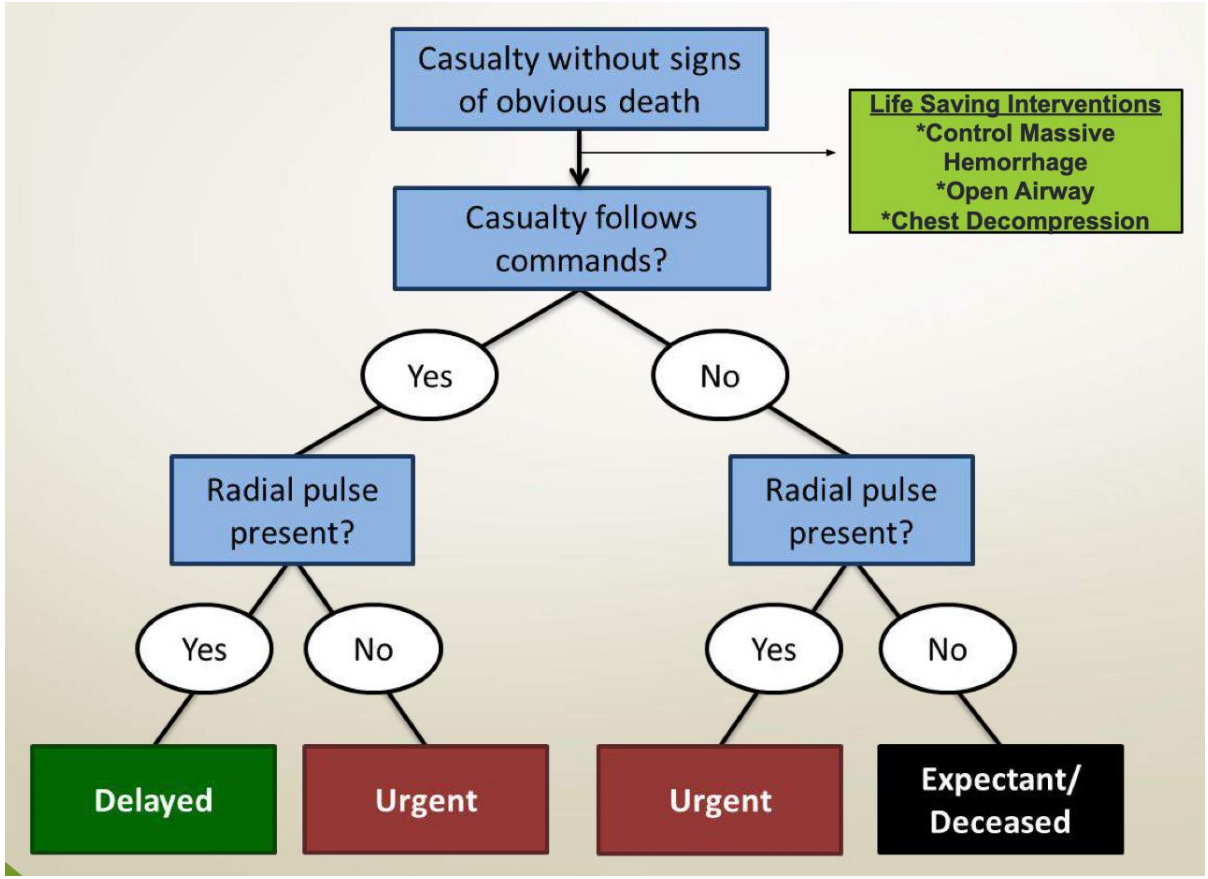
Rush et al. (JSOM 2024):

Key lessons from Rush et al.:

MASCAL Triage - 2 Tier

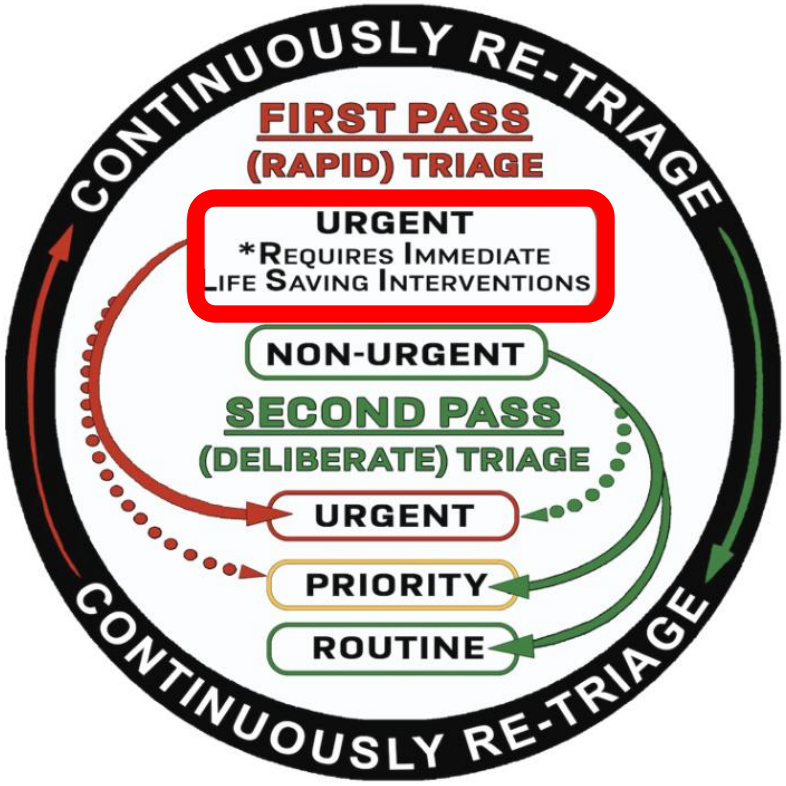


Remley et al. (JSOM 2025)
TCCC 2026



Ramp Triage

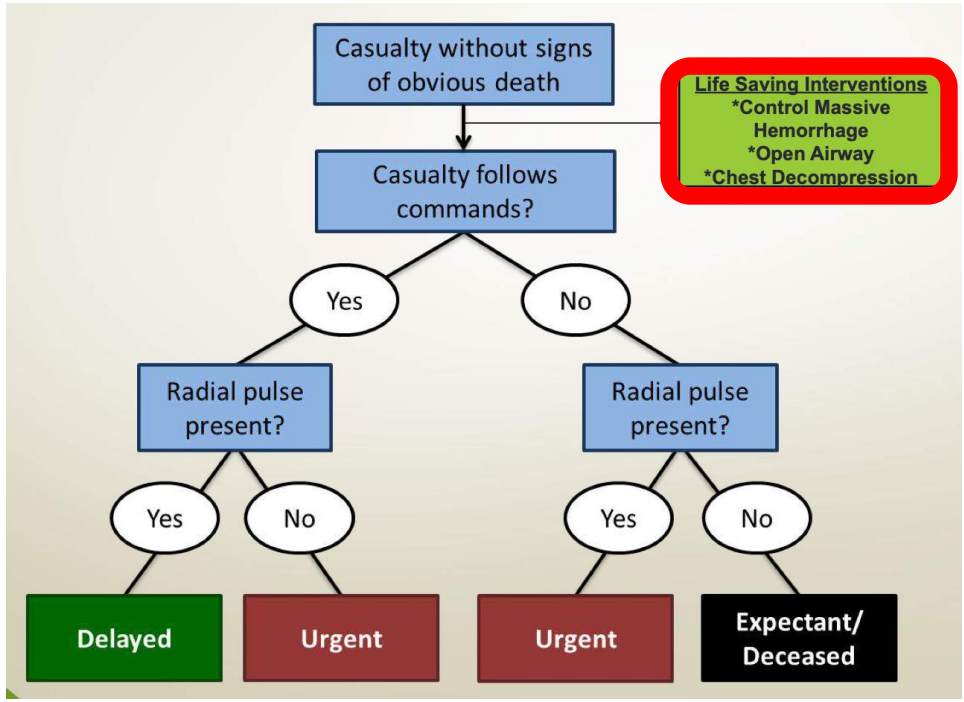
MASCAL Triage - 2 Tier



TCCC 2026

LSI's:

- Hemorrhage control
- Basic airway
- Chest decompression



Ramp Triage

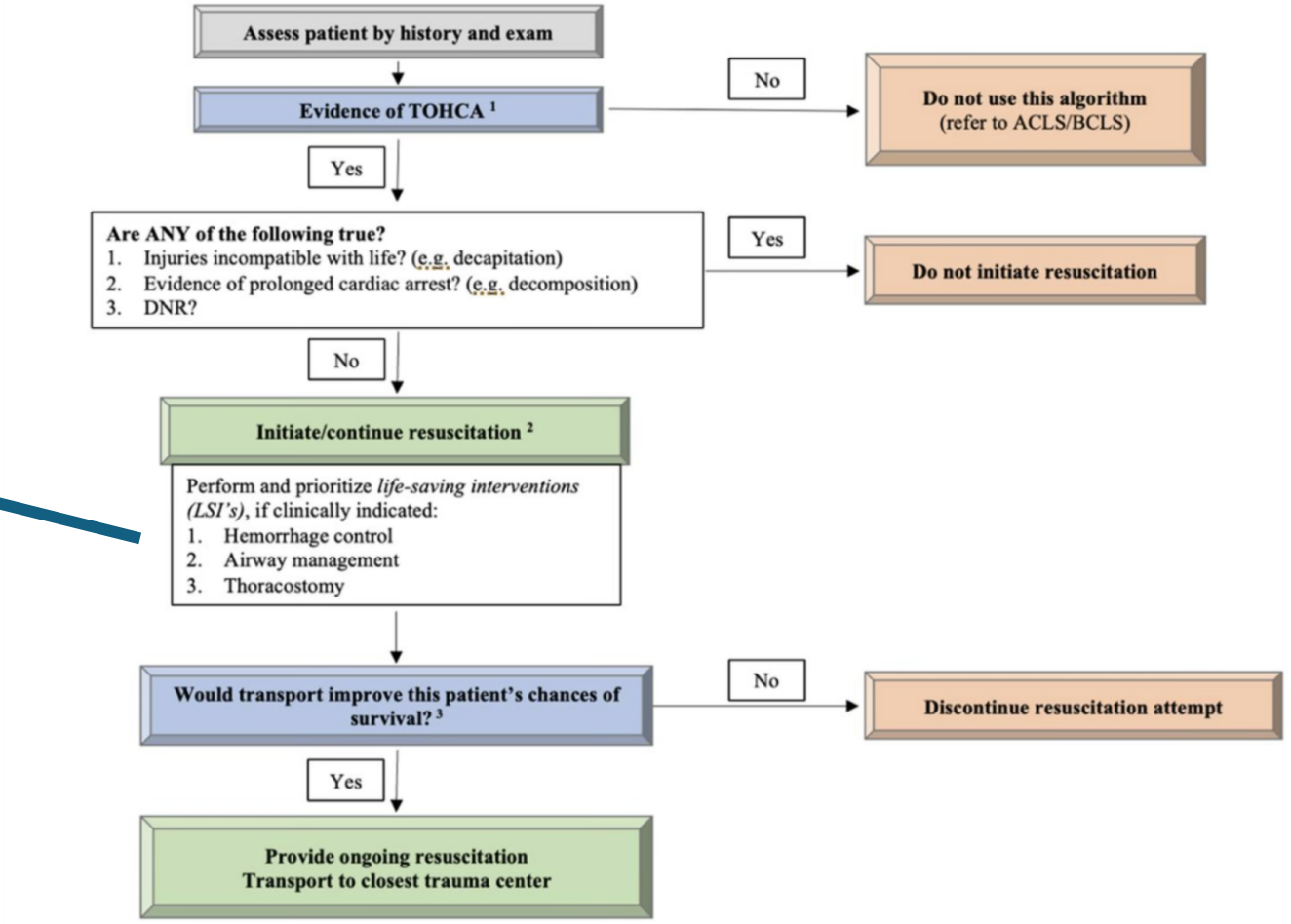
Traumatic Circulatory Arrest

LSI's:

- Hemorrhage control
- Basic airway
- Chest decompression

PREHOSPITAL EMERGENCY CARE
https://doi.org/10.1080/10903127.2024.2428668

Prehospital Trauma Compendium: Prehospital Management of Adults with Traumatic Out-of-Hospital Circulatory Arrest – A Joint Position Statement and Resource Document of NAEMSP, ACS-COT, and ACEP



Traumatic Circulatory Arrest

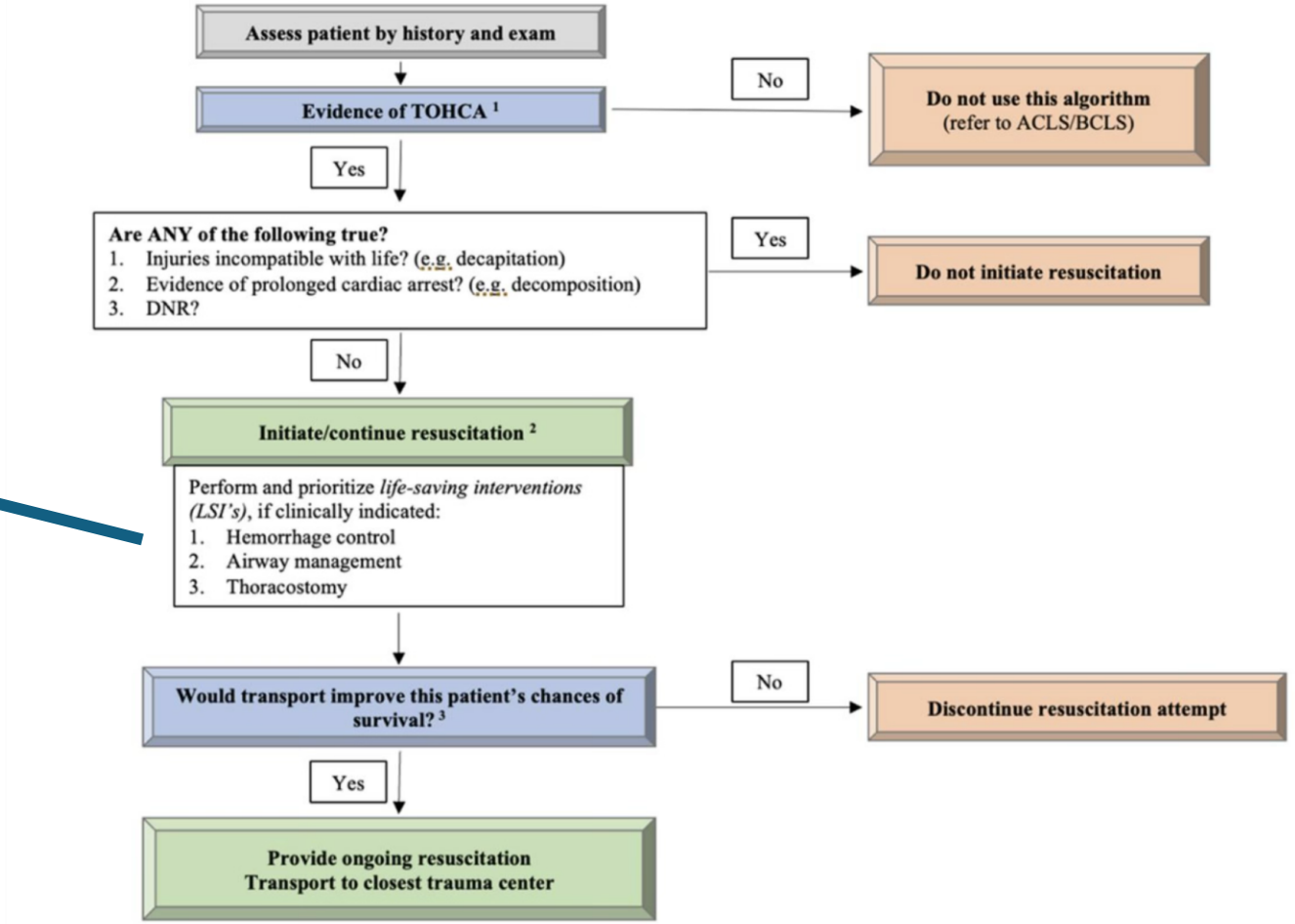
LSI's:

- Hemorrhage control
- Basic airway
- Chest decompression

?  ?

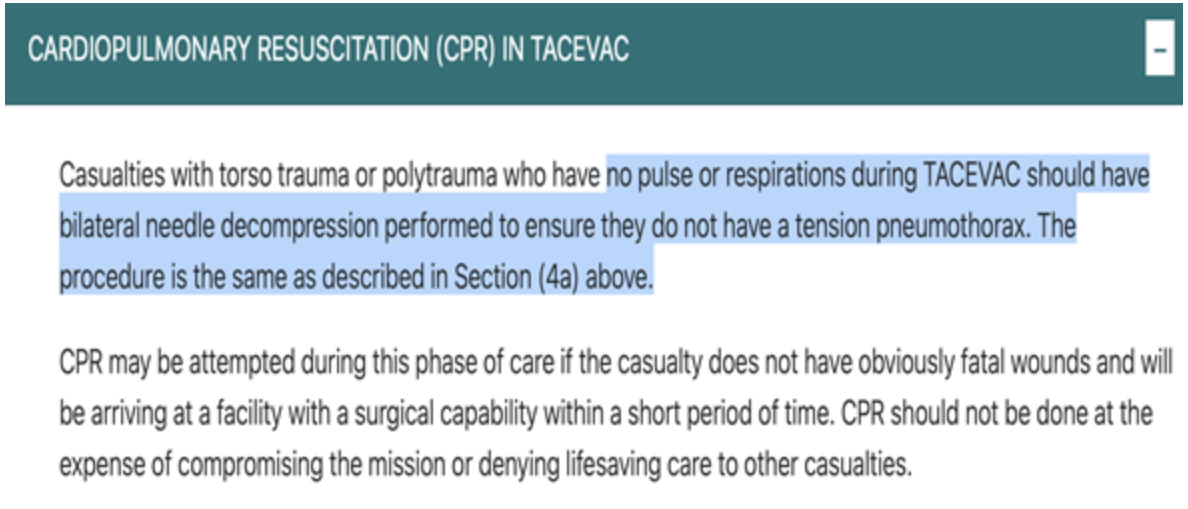
PREHOSPITAL EMERGENCY CARE
https://doi.org/10.1080/10903127.2024.2428668

Prehospital Trauma Compendium: Prehospital Management of Adults with Traumatic Out-of-Hospital Circulatory Arrest – A Joint Position Statement and Resource Document of NAEMSP, ACS-COT, and ACEP



TCCC approach to pneumothorax

- Suspected tension pneumothorax → needle decompression
- Pulseless torso trauma casualty → bilateral needle decompression empirically



CARDIOPULMONARY RESUSCITATION (CPR) IN TACEVAC

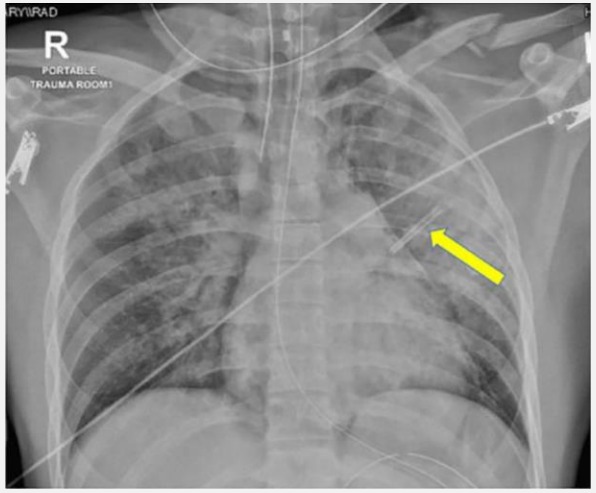
Casualties with torso trauma or polytrauma who have no pulse or respirations during TACEVAC should have bilateral needle decompression performed to ensure they do not have a tension pneumothorax. The procedure is the same as described in Section (4a) above.

CPR may be attempted during this phase of care if the casualty does not have obviously fatal wounds and will be arriving at a facility with a surgical capability within a short period of time. CPR should not be done at the expense of compromising the mission or denying lifesaving care to other casualties.

2. Initial treatment of suspected tension pneumothorax:
    1. If the casualty has a chest seal in place, burp or remove the chest seal.
    2. Establish pulse oximetry monitoring.
    3. Place the casualty in the supine or recovery position unless he or she is conscious and needs to sit up to help keep the airway clear as a result of maxillofacial trauma.
    4. Decompress the chest on the side of the injury with a 14-gauge or a 10-gauge, 3.25-inch needle/catheter unit.
    5. If a casualty has significant torso trauma or primary blast injury and is in traumatic cardiac arrest (no pulse, no respirations, no response to painful stimuli, no other signs of life), decompress both sides of the chest before discontinuing treatment.

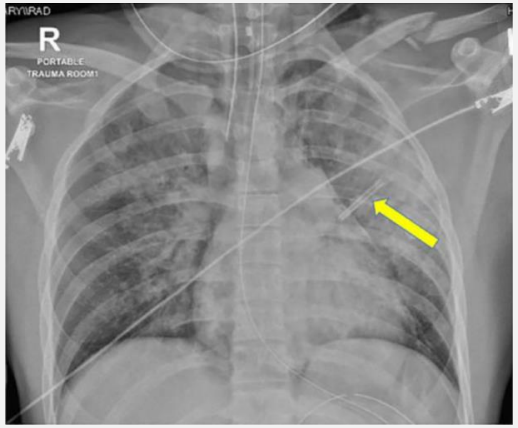
Evidence For This Approach

1. Boever et al. (Injury 2025, n=214) Level 1 Trauma Centers:
   - **55%** triggered by subjective "absent breath sounds" alone
   - Only **30% overall response rate**
   - **14% complication rate**
2. Muchnok et al. (JAMASurg 2022, n=8,469) prehospital trauma
   - Needle decompression infrequently performed (0.2-0.5% of patients)
   - **Wide variation in decompression rates** among EMS agencies
3. Talmy et al. (Transfusion 2025, n=224**)** IDF Trauma Registry
   - Only **1.3% showed vital sign improvement after decompression**
   - 0 survivors among patients with traumatic circulatory arrest
   - 15% did not meet IDF criteria for the procedure



Evidence For This Approach

1. Boever et al. (2025, n=214) Level 1 Trauma Centers:
   - **55%** triggered by subjective "absent breath sounds" alone
   - Only **30% overall response rate**
   - **14% complication rate**
2. Muchnok et al. (JAMASurg 2022, n=8,469) prehospital trauma
   - Needle decompression infrequently performed (0.2-0.5% of patients)
   - **Wide variation in decompression rates** among EMS agencies
3. Talmy et al. (Transfusion 2025, n=224**)** IDF Trauma Registry
   - Only **1.3% showed vital sign improvement after decompression**
   - 0 survivors among patients with traumatic circulatory arrest
   - 15% did not meet IDF criteria for the procedure



Conclusion: We are performing procedures on patients who don’t need them, and missing those who do

The Bigger Problem: No Objective Tool

- Blood products must go to salvageable casualties
- Thoracostomy should only be performed when truly necessary
- Rush et al.: "**formal systems are too complex**" *but the **current alternative** (**subjective judgment + blanket interventions**) wastes resources and causes harm*
- Shackelford et al. (J Trauma 2022): "**massive casualty triage has changed little in 200 years**"; a *modified approach is needed for large-scale combat operations*

> J Trauma Acute Care Surg. 2022 Aug 1;93(2S Suppl 1):S160-S164.
doi: 10.1097/TA.0000000000003699. Epub 2022 May 23.

Evidence-based principles of time, triage and treatment: Refining the initial medical response to massive casualty incidents

Stacy A Shackelford [1], Michael A Remley, Sean Keenan, Russ S Kotwal, Jay B Baker, Jennifer Gurney, Stephen Rush, Paul Friedrichs

Affiliations + expand

PMID: 35583968 DOI: 10.1097/TA.0000000000003699

Limitations of Current Triage

Vernon et al., Mil Med 2024

- 12,268 combat casualties
- Vital sign-based triage tools predict 24-hour mortality & massive transfusion, AUROC 0.83–0.91
- none distinguish beating heart from cardiac standstill in pulseless patient
- Conclusions:
  1. Subjective **clinical judgment alone** is **insufficient**
  2. No objective tool to distinguish **salvageable vs. non-survivable** in the field
  3. O**bjective, rapid, field-deployable diagnostic tool** could improve triage

MASCAL Triage - Role for POCUS?

MASCAL

Move, Treat, and Transport

Manage the Incident
- Security and safety
- Resources: tactical, medical, evacuation
- Maintain accountability

TRIAGE
STABLE / UNSTABLE / DEAD
(Repeat in all phases)

MOVE
Out of Danger

- Move directly to higher level of care if situation/resources allow
- Find/move UNSTABLE casualties first *or* move all live casualties at same time if time & tactics do not permit field triage

TREAT
as Able

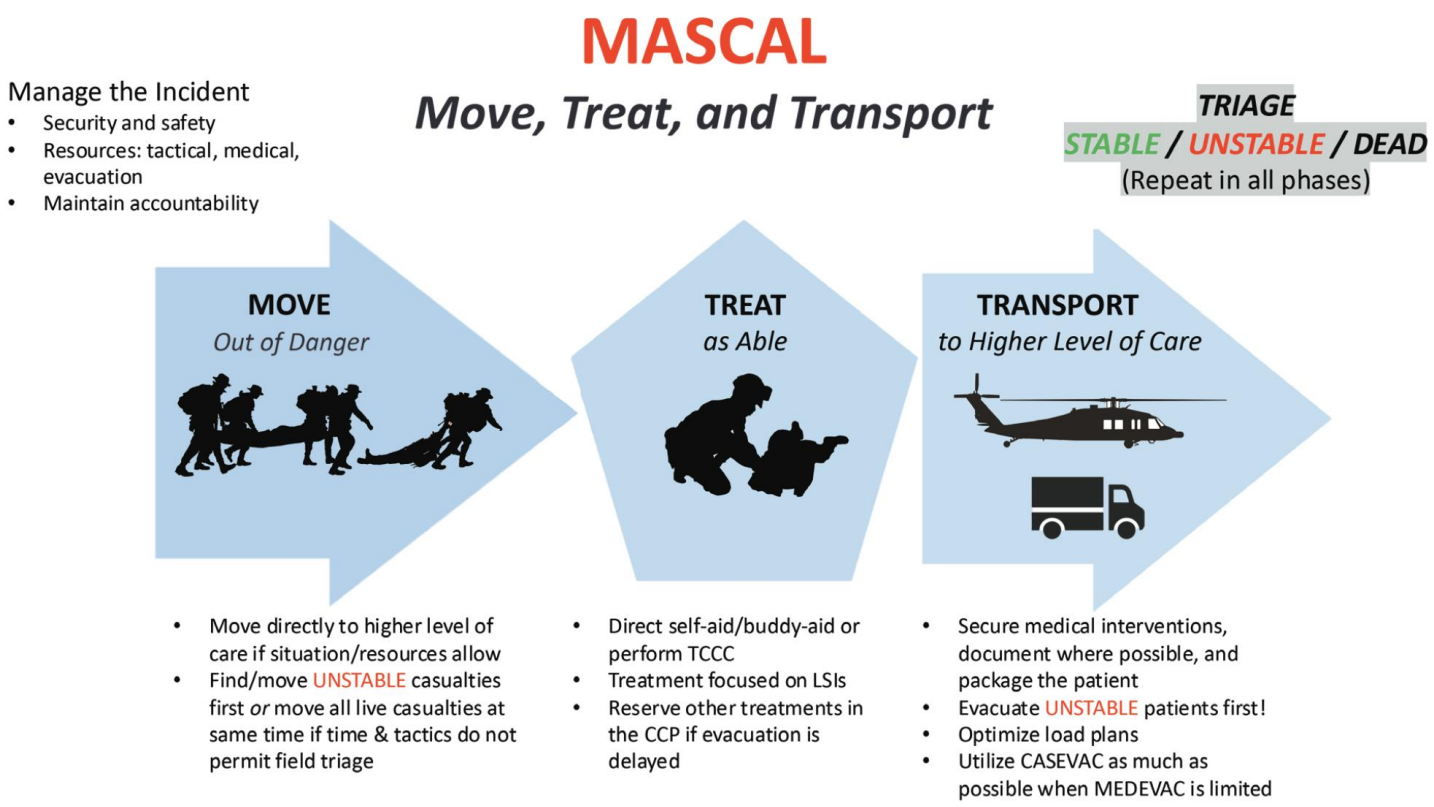
- Direct self-aid/buddy-aid or perform TCCC
- Treatment focused on LSIs
- Reserve other treatments in the CCP if evacuation is delayed

TRANSPORT
to Higher Level of Care

- Secure medical interventions, document where possible, and package the patient
- Evacuate UNSTABLE patients first!
- Optimize load plans
- Utilize CASEVAC as much as possible when MEDEVAC is limited

Rush et al. (JSOM 2024)

MASCAL Triage - Role for POCUS?



Rush et al. (JSOM 2024)

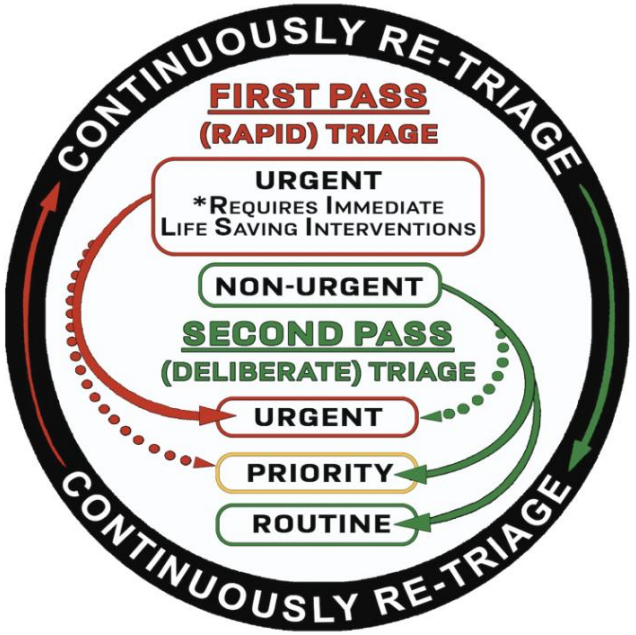
Phase III: Resuscitate, Package Casualties, Set Conditions for Evacuation

Make rapid decisions on appropriate distribution of medical support and supplies. The appropriate distribution of these supplies and choosing which casualties on which to use them is critical to **"doing the most good for the most people"**.

Two-pass System with POCUS

First Pass

- MARCH framework
- Binary: urgent vs non-urgent



Second Pass

- For urgent
- POCUS protocol:

Three binary questions

1. **Cardiac motion?** → blood
2. **Tamponade?** → EDT
3. **Pneumothorax?** → decompression

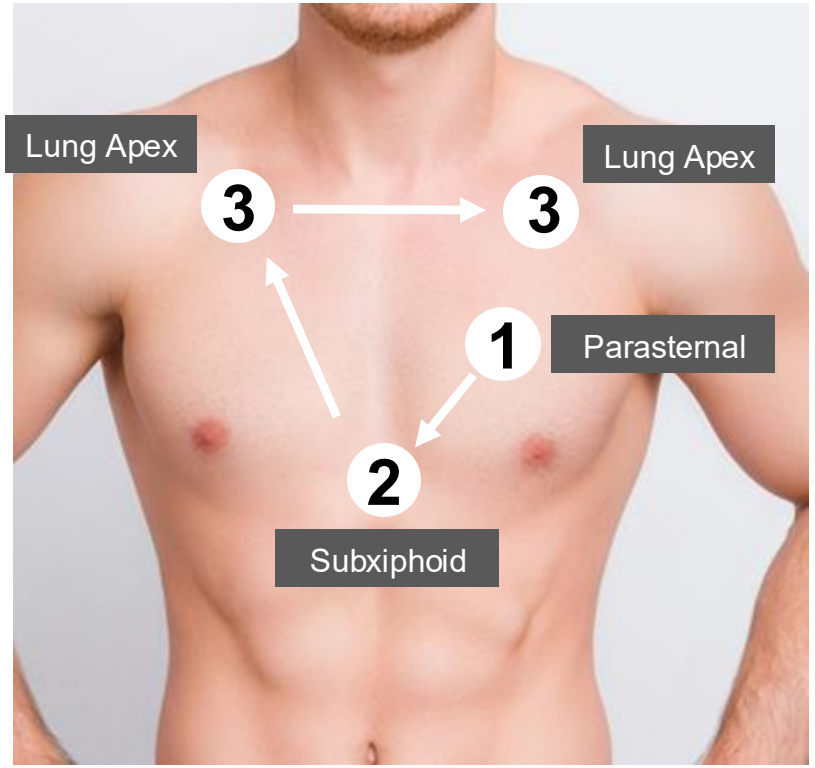
Rapid 3-View POCUS Triage Protocol

3 views: parasternal long axis, subxiphoid, bilateral apical lung

3 key decision points:

1) Cardiac motion present?
2) Pericardial effusion/tamponade?
3) Pneumothorax?

Target: <**30 seconds** to complet

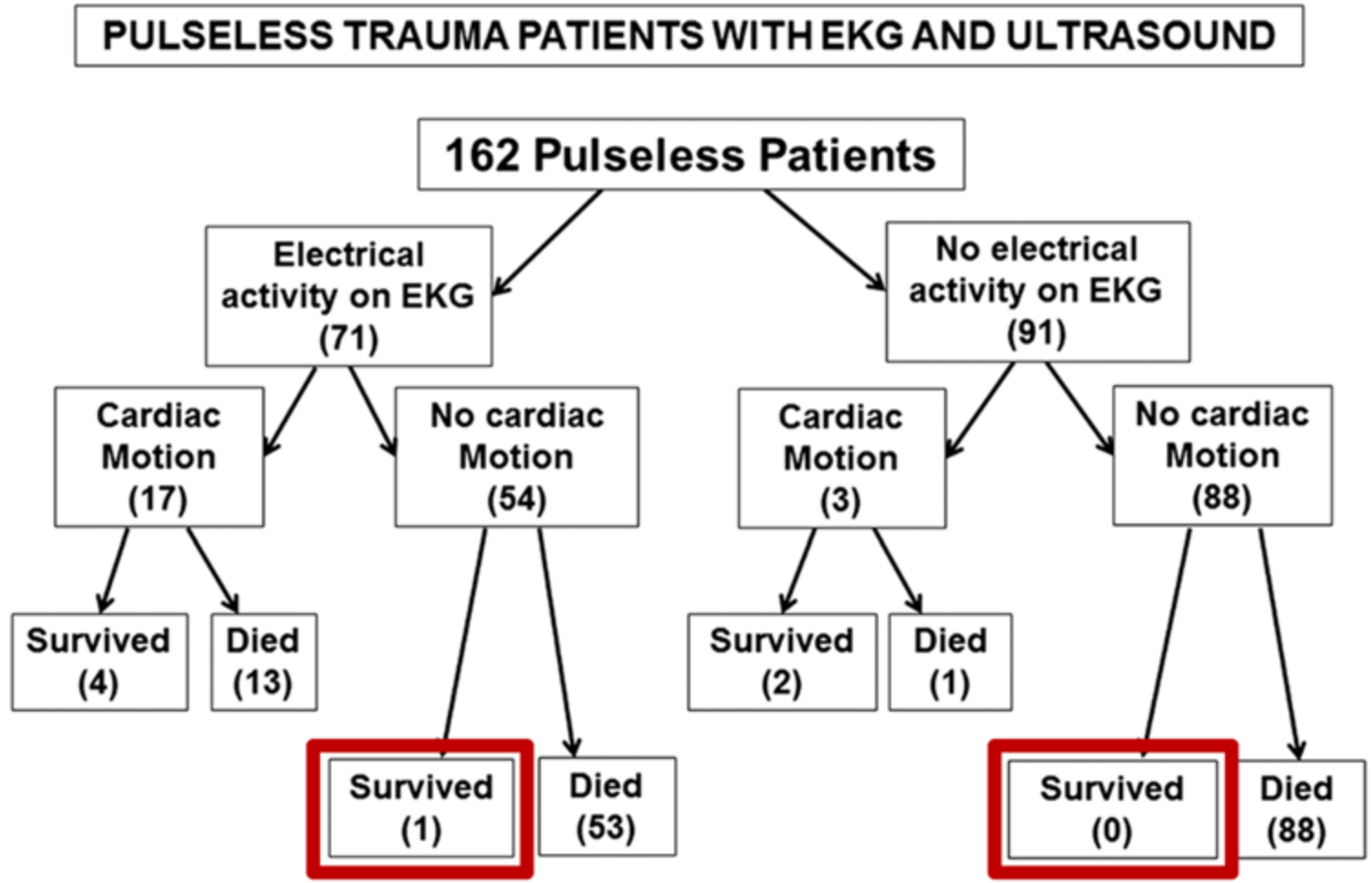


Cardiac Standstill as a Prognostic Marker

162 pulseless patients

Survival:

- 23.5% with cardiac motion
- 1.9% without cardiac motion
- 0% no US motion + no EKG



Cureton et al, J Trauma 2012

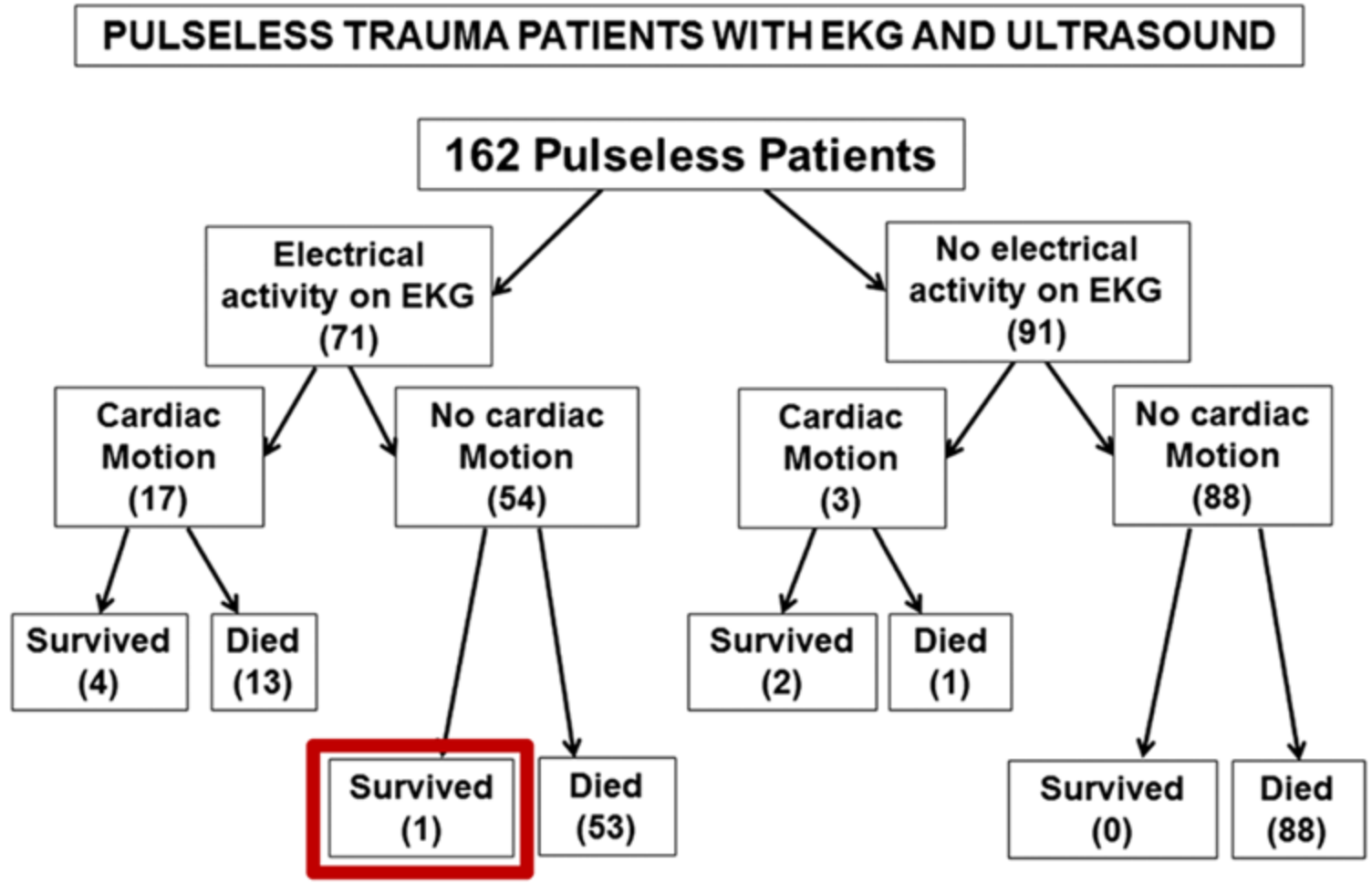
Cardiac Standstill as a Prognostic Marker

All survivors had electrical activity, cardiac motion, or both

100% of patients without cardiac motion and electrical activity died

1 patient survived to discharge:

- Pulseless, +EKG, no US
- Brachial artery injury
- Resuscitated, injury repaired



Cureton et al, J Trauma 2012

FAST and Resuscitative Thoracotomy

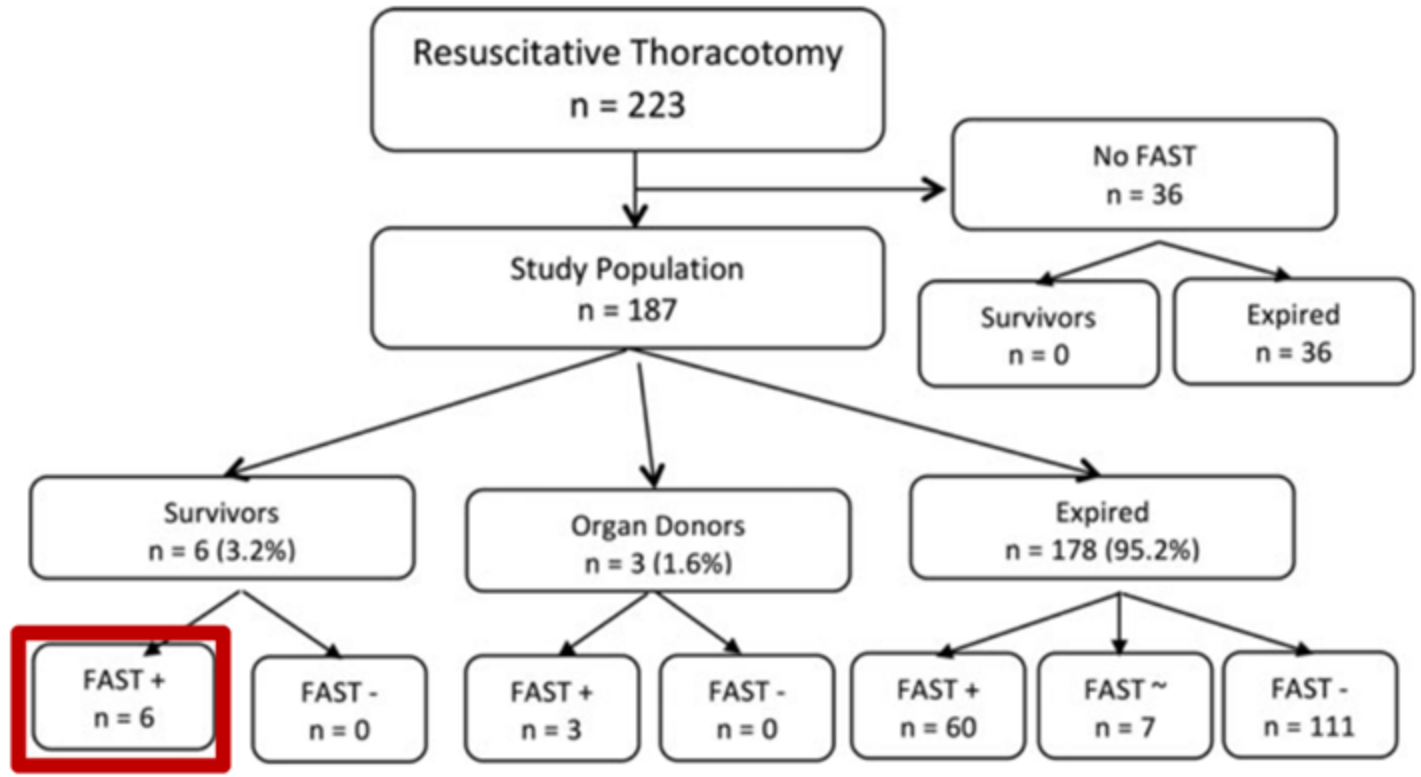
- FAST sensitivity 100%, NPV 100% for identifying survivors of EDT
- All survivors had cardiac motion on US
- 0% survival with no cardiac motion

FAST Ultrasound Examination as a Predictor of Outcomes After Resuscitative Thoracotomy

A Prospective Evaluation

Kenji Inaba, MD, Konstantinos Chouliaras, MD,* Scott Zakaluzny, MD,* Stuart Swadron, MD,†*

Annals of Surgery • Volume 262, Number 3, September 2015



Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Outcomes following military traumatic cardiorespiratory arrest: A prospective observational study☆

Nicholas T. Tarmey[a,*], Claire L. Park[a], Oliver J. Bartels[a], Thomas C. Konig[a], Peter F. Mahoney[a], Adrian J. Mellor[b]

[a] Department of Military Anaesthesia and Critical Care, Royal Centre for Defence Medicine, Birmingham Research Park, Vincent Drive, Edgbaston, Birmingham B15 2SQ, United Kingdom
[b] Ministry of Defence Hospital Unit Northallerton, MDHU Northallerton, Friarage Hospital, Northallerton, North Yorkshire DL6 1JG, United Kingdom

- 2 Years in Helmand
- 54 patients in Trauma Arrest
- 4 neuro intact survivors (8%)
- All suffered massive exsanguination
- All survivors had cardiac activity on ECHO
- **None of the patients in asystole survived**

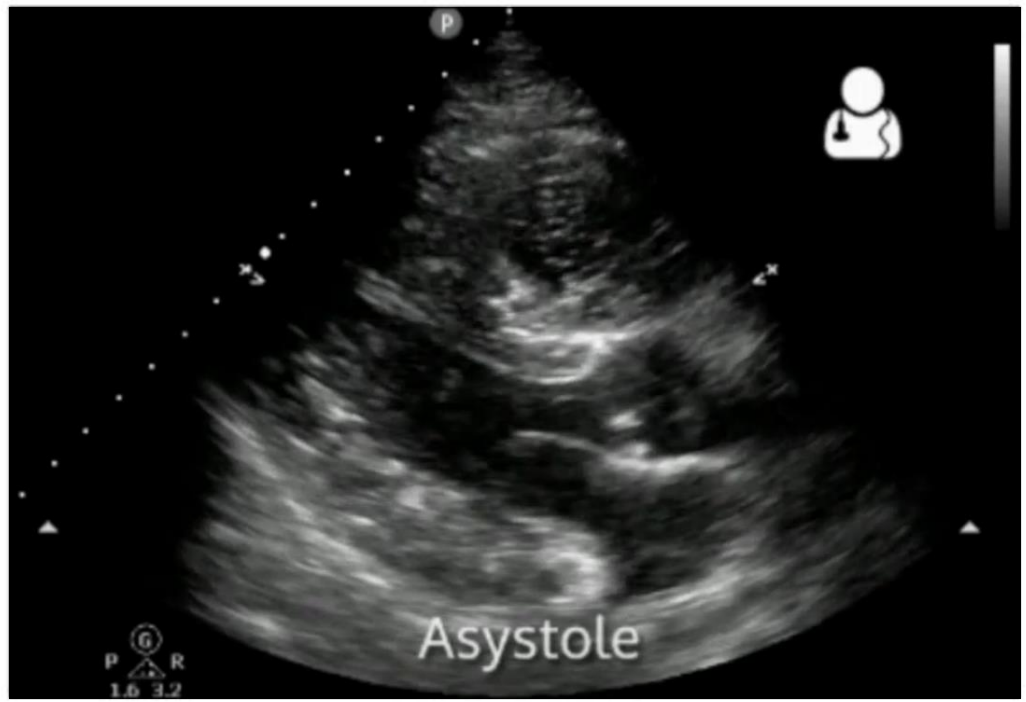
Factors associated with survival:

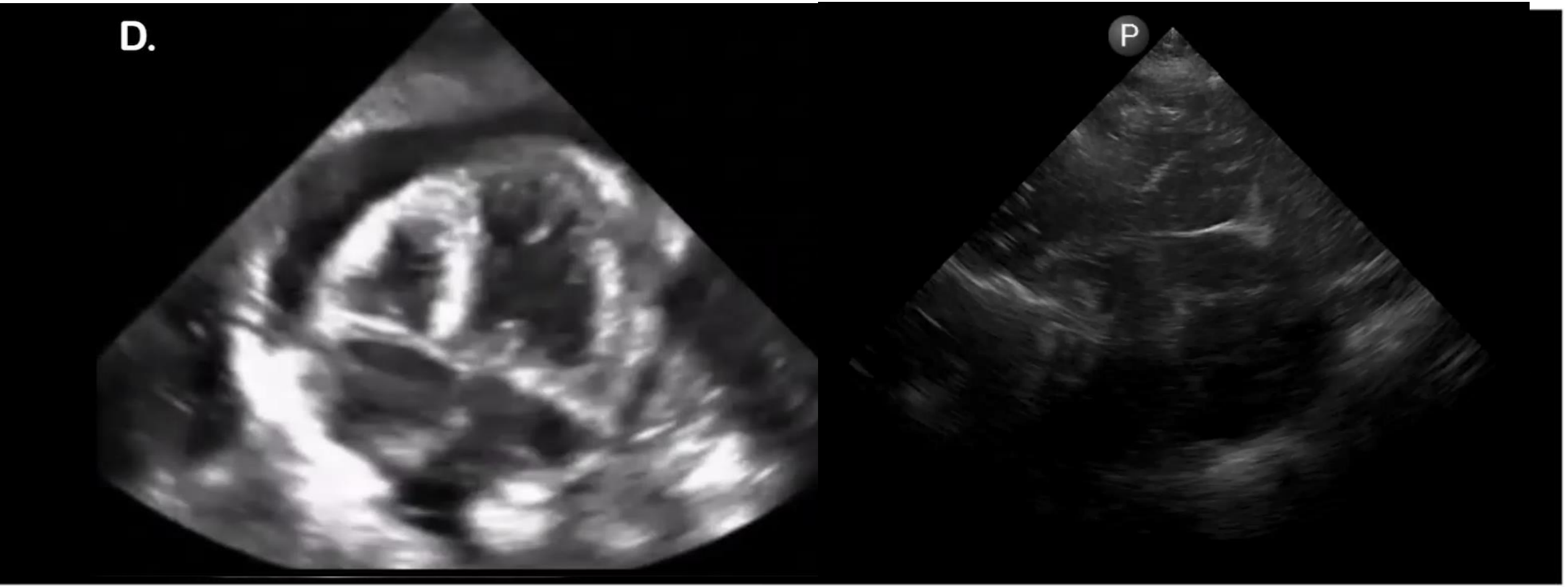
- Witnessed arrest in transport
- Electrical activity on EKG
- Cardiac motion on US

Hemorrhagic Shock Decision Algorithm

- No pulse + cardiac motion on POCUS → blood + prioritize evacuation

- No pulse + no cardiac activity → expectant/move to next patient





Tamponade

Standstill

Summary: How POCUS Can Change Triage

- Current triage:
  - may lead to unnecessary procedures
  - misses potential survivors
- POCUS triage:
  - Cardiac activity = prioritized resources (blood) + best hope for survival
  - Asystole = non-survivable -> conserve resources
  - Lung slide = no pneumothorax -> no procedure
  - Asystole + pericardial tamponade = ?salvageable if EDT available

TRAINING, IMPLEMENTATION FUTURE How Do We Get There?

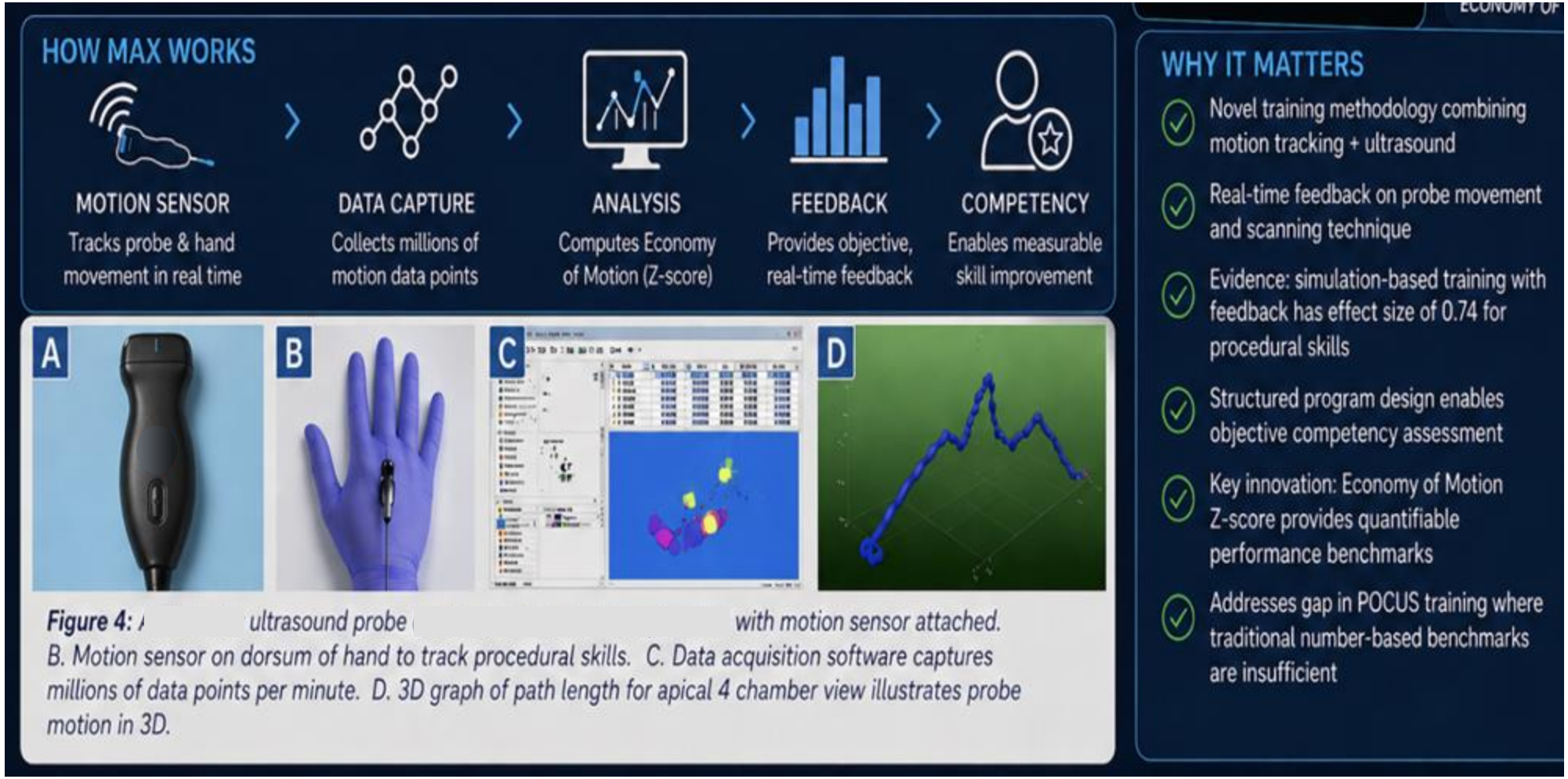
Two parallel training pathways

1) SOF (MAX POCUS)
2) Civilian EMS (New Orleans)

"Can non-physician providers learn this rapidly and perform it accurately?”

- The Naysayers

Motion Augmented eXperience (MAX) POCUS

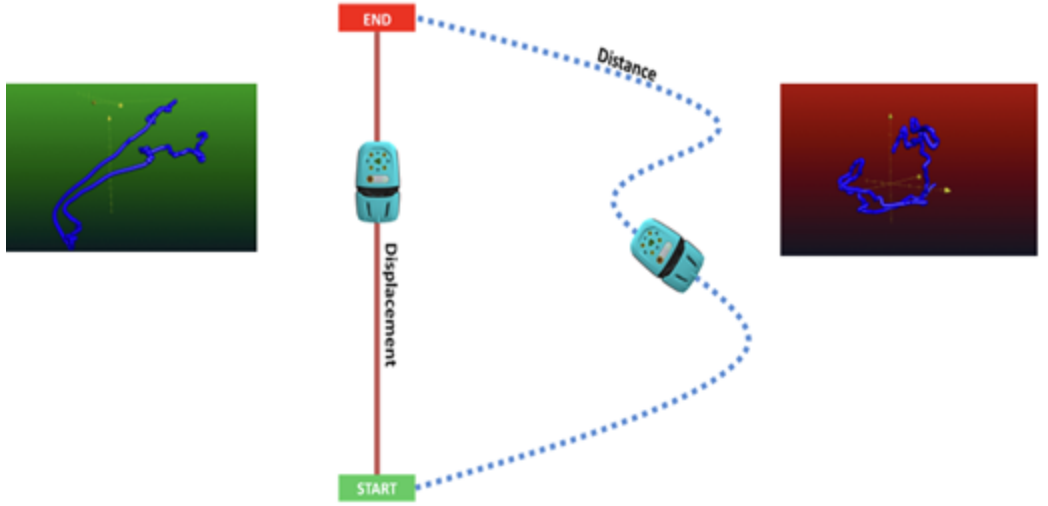


Daher, et al. Anesthesia & Analgesia 2024

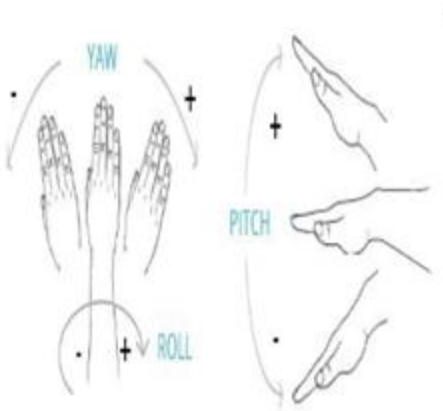
MAX POCUS

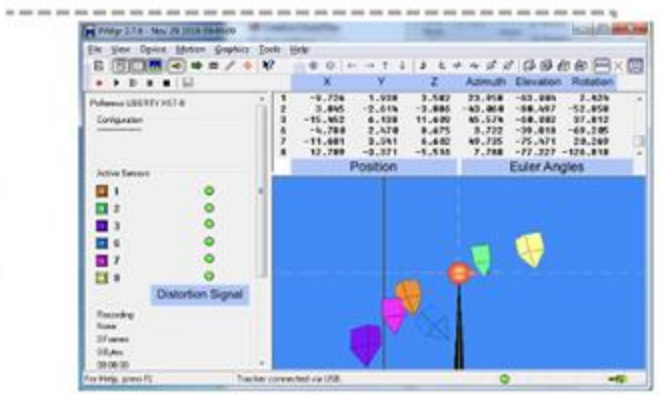
HENRY FORD HEALTH

Path Length- Gross Motor Movement



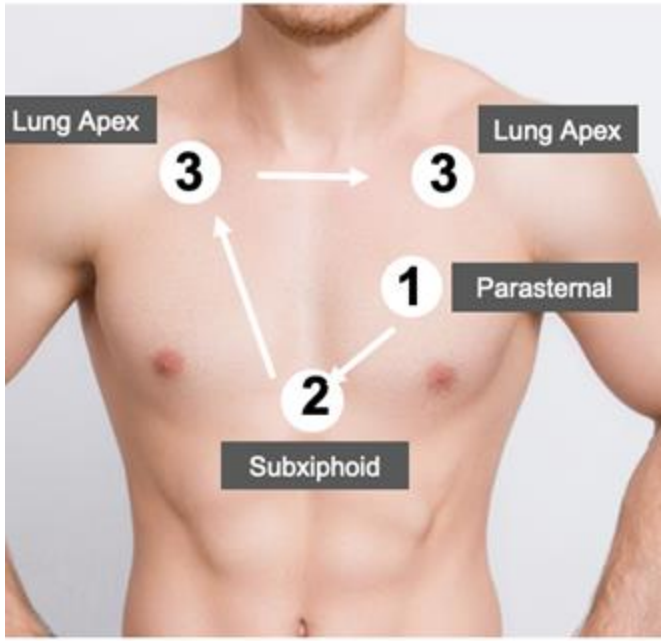
Rotational Motion- Fine Motor Movement





Millions of data points

SOF Medic Study Design



STUDY DESIGN
Retrospective Analysis
(IRB Approved)

TRAINEE COHORT
- 36 SOF Medics
- 72 Warmed-Up Trials

EXPERT COHORT
(Gold Standard Baseline)
- 12 Practicing Experts
- 19 Practiced Trials

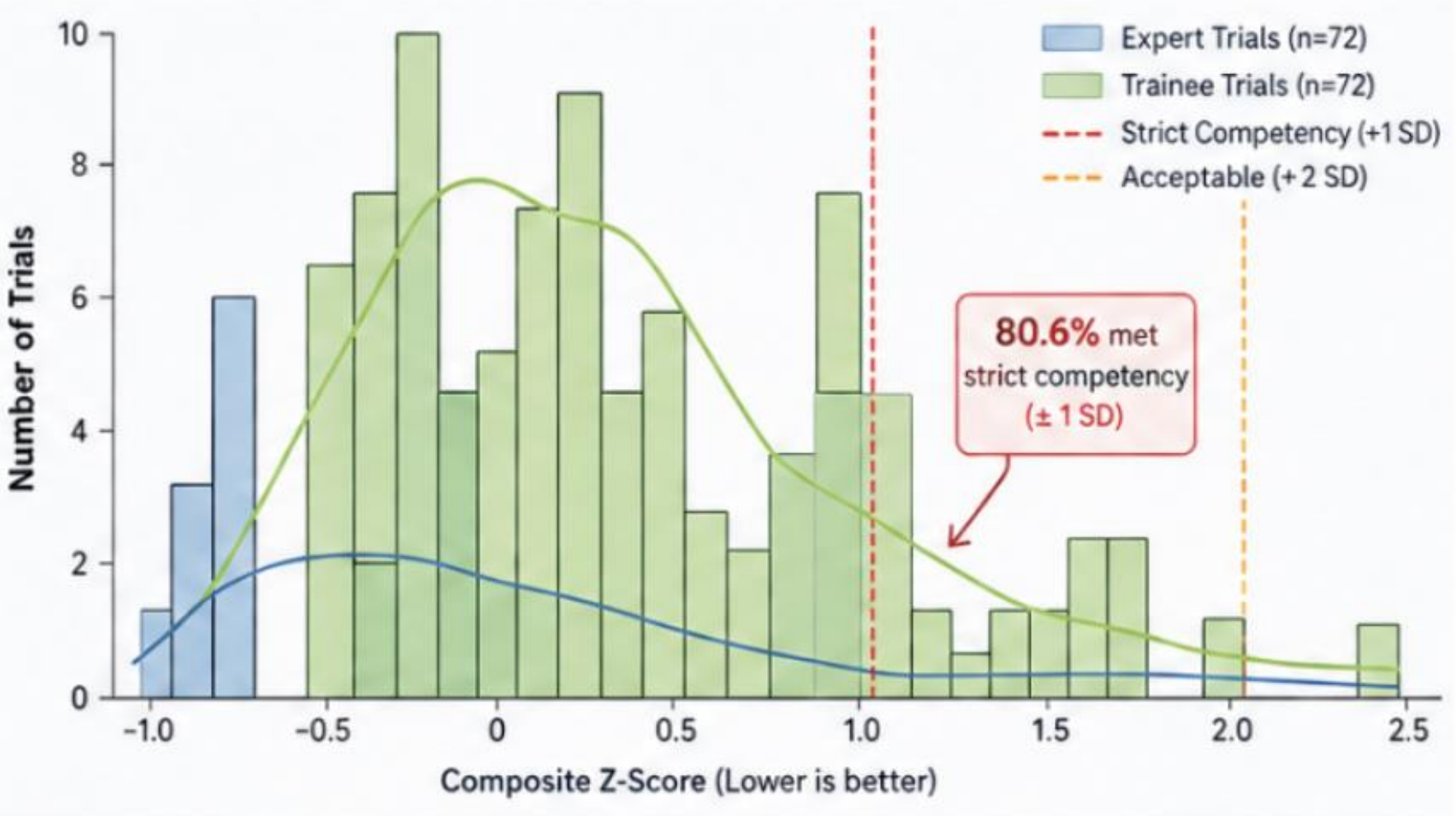
EVALUATION METRICS
- Procedural Time
- Composite 'Economy of Motion' Z-Score
(Aggregating Time, Path Length, Rotations, TM)

COMPETENCY THRESHOLDS
(Relative to Expert Mean)
- Strict Competency: ≤ +1.0 SD
- Acceptable Competency: ≤ +2.0 SD


00:00:00

FOCUSED 3-VIEW POCUS IN MASS CASUALTY EVENTS

Can medics rapidly identify life-threatening conditions within 30 seconds?



Procedural Time Trainees under 30 s

28.7 s

(p=0.297)

Strict Competency (≤ +1.0 SD)

80.6%

Acceptable Competency (≤ +2.0 SD)

98.6%

★ Consistent with literature showing paramedics can learn POCUS in 4–13 hours of structured training

Prospective Testing vs Predicted

Metric	Original Trainee Approx (n=72)Mean (SD)	Actual Trainee Day 5 (n=10)Mean (SD)	P-Value (MWU)
Time (seconds)	27.8 (11.2)	25.1 (4.9)	**0.739** (No difference)
Starts/Stops (Accels/TM)	65.4 (23.3)	56.3 (14.7)	**0.281** (No difference)
Path Length	622.4 (420.7)	564.4 (115.3)	**0.605** (No difference)
Rotations	2878.4° (1291.8)	3562.1° (1391.0)	**0.128** (No difference)

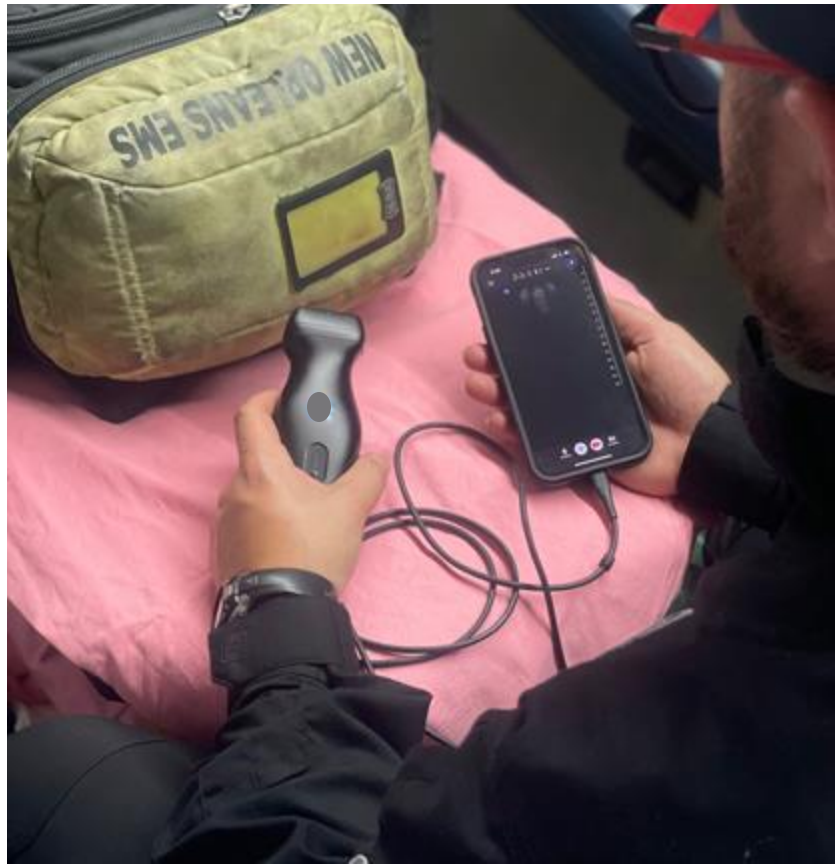
- ★ **Primary finding: 27.8 s predicted vs 25.1 s Actual exam time**
- ★ **SOF medics achieved 30 second target for complete exam in prospective trials**
- ★ No Difference between any predicted metric and the actual metrics
  - Can model different exam sequences
- ★ Preliminary Results, Data Collection ongoing

New Orleans EMS Experience

- Program started 2023
- 4-hour training program
- 50+ Paramedic/AEMTs trained

- Curriculum progression: Lung → Cardiac → EFAST

- Less training time than SOF pathway, yet successful field implementation

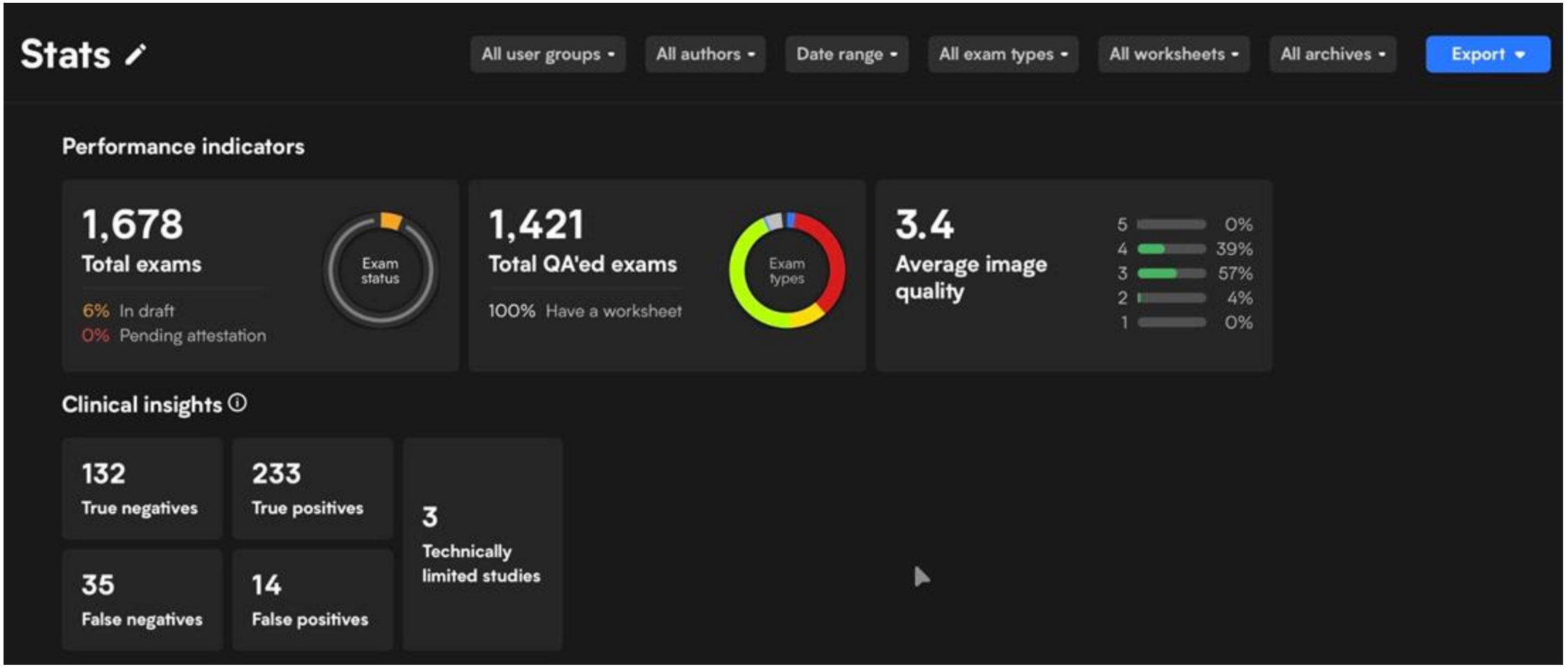


Civilian EMS experience

- Field Identification
  - Pneumothorax
  - Hemothorax
  - Cardiac motion
  - Hemopericardium
  - Abdominal/Pelvic Free Fluid
  - Doppler pulse after reduction of pulseless extremity

- 8-hour simulation-based POCUS course improved EMS provider knowledge scores from 67.6% to 89.0%
- 4-hour hands-on curriculum with microlearning adjunct improved scores from 46% to 78%

Diagnostic Accuracy: NOEMS QA Data



Overall diagnostic accuracy: 87.9% sensitive, 90.4% specific

Evidence

Boehm, et al

- Evaluation of paramedic-performed POCUS exams
- Diagnostic Accuracy- 89.7% sensitive, 92.7% specific
- Lung- 91% sensitive, 100% specific
- EFAST-100% sensitive, 96.5% specific
- Frequently resulted in change in clinical decsions

Clinical Impact: Putting It All Together

- Operational workflow recap:
  - First pass: MARCH — standard life-saving interventions
  - Second pass: POCUS protocol → cardiac motion? → pericardial effusion? → pneumothorax? → treatment decisions based on findings
- Direct scarce resources (blood products) go to salvageable casualties with objective data
- Prevent unnecessary interventions
- Prioritize casualties who will survive

Conclusions

1. Rapid POCUS protocol is **feasible and trainable for both SOF and civilian paramedics**
2. SOF medics achieve **expert-level speed** AND t**echnical competency**
3. Civilian paramedics achieve **~90% sensitivity** in real-world and external validation data
4. POCUS provides objective triage data that current TCCC practice lacks:
    a. Cardiac activity → prioritize resources and blood products
    b. Cardiac standstill without tamponade → expectant/conserve resources
    c. Cardiac standstill with pericardial tamponade → EDT if available (the only potentially survivable asystole scenario)

Bottom Line

"Salvage the Survivable"

POCUS offers medics an objective tool to make key decisions in <**30 seconds**

References