

Survival after Severe Penetrating Brain Injury in Modern Warfare: Lessons from High-Volume Wartime Neurosurgical Center in Ukraine

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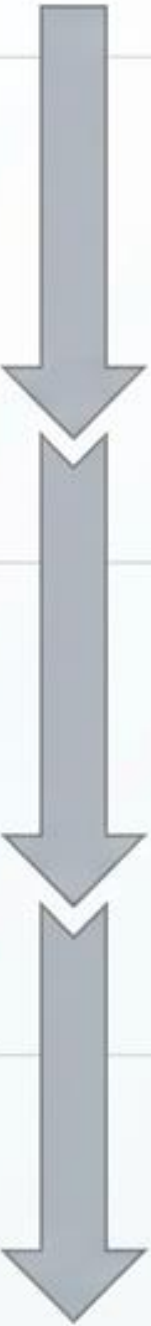
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Non-Disclosure

**Alex Valadka, MD,
Andrii Sirko, MD, PhD,
and Rocco Armonda, MD
have no conflicts to
report.**



Strategic Learning Objectives



Blast vs. GSW Point of Injury (Epidemiology)

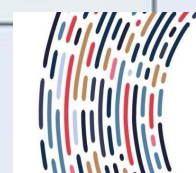
Describe the epidemiology and mechanisms of penetrating brain injury (PBI) in modern peer-to-peer conflicts, emphasizing the predominance of blast trauma.

Clinical & Radiological Markers Treatment & Outcomes (Predictors)

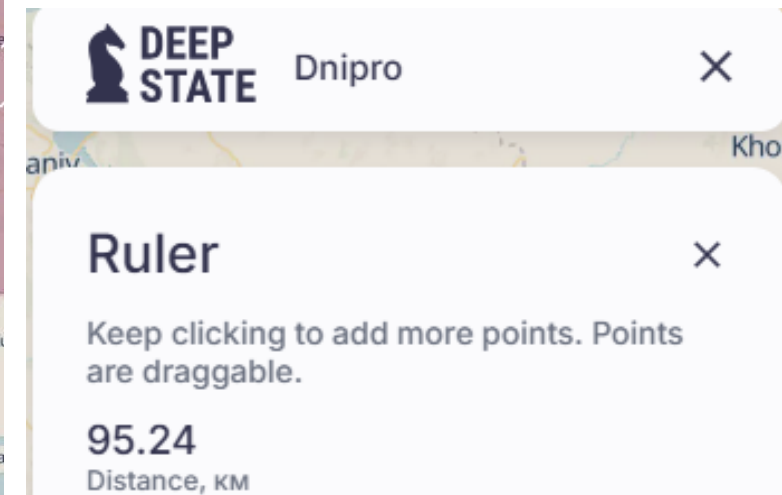
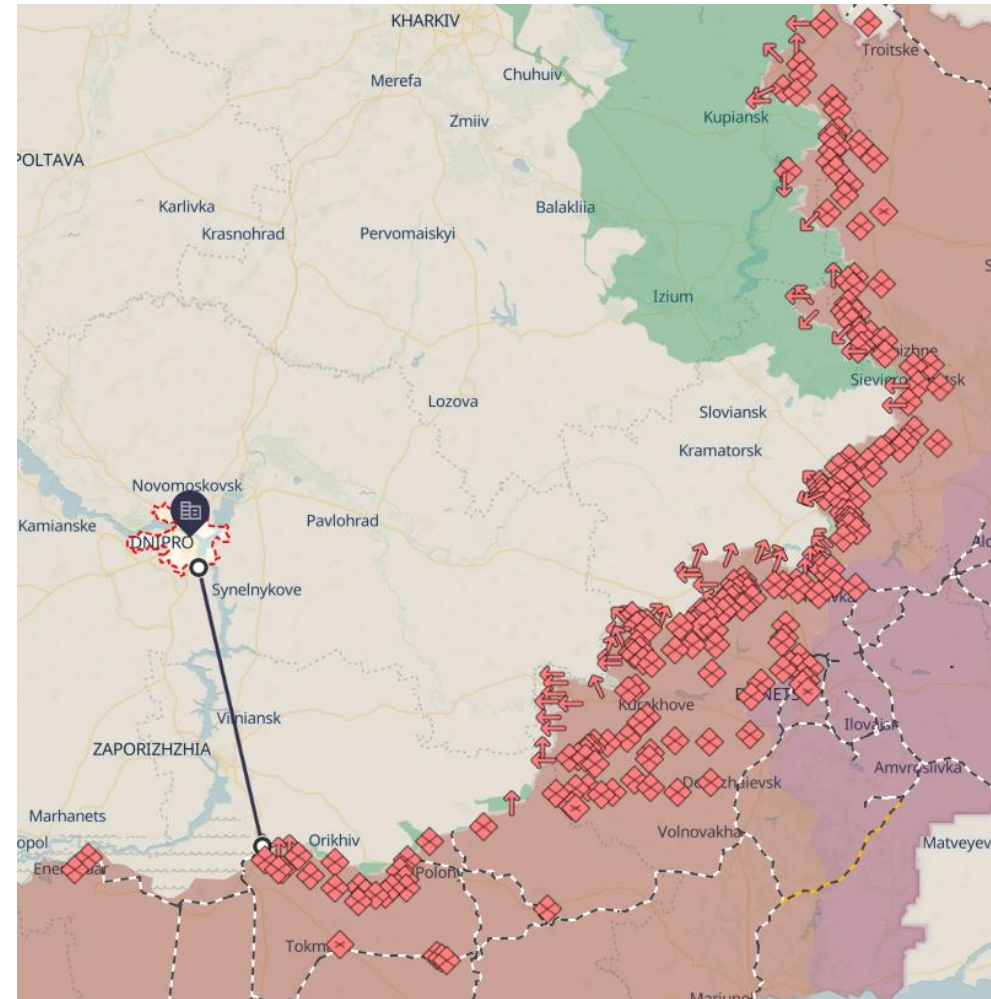
Analyze predictors of mortality and functional outcomes in combat PBI, including GCS, hemorriage, venous sinus injury, and infections.

Evacuation & Integration System-Level Synthesis (Operations)

Discuss operational lessons for military trauma systems, including evacuation timelines and the critical integration of civilian tertiary centers.



Single Frontline Medical Center

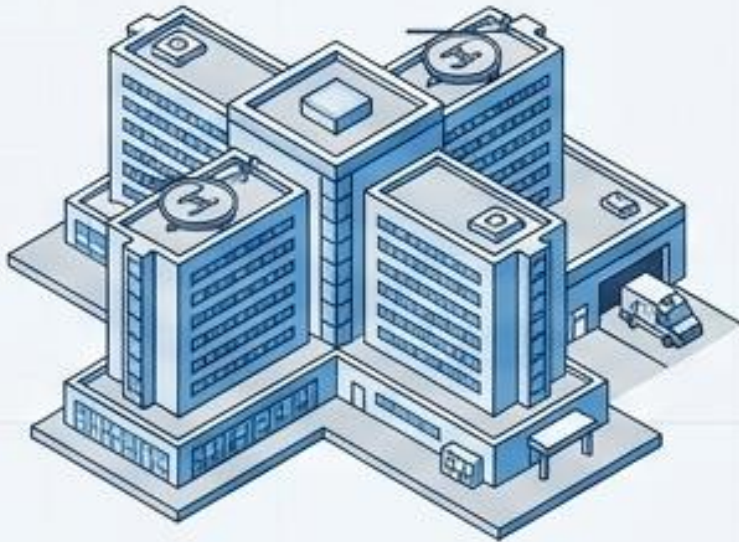


My native Mechnikov regional clinical hospital
in Dnipro,
which has a 227-year history

The distance from the Dnipro to the front
line (enemy positions)
is less than 60 miles

The Cohort Context: Mechnikov Regional Clinical Hospital

High-Volume Civilian Tertiary Center



- **24/7** multidisciplinary facility
- **1,200** beds total
- **42 ICU** beds
- **3** dedicated neurosurgical departments

Context: Situated to receive casualties evacuated from forward military medical facilities in Eastern Ukraine.

Date Range

**May 2014 –
Dec 2017**

Study Size

**N = 121 (subset
of 184 total)**

Demographic

**100% Male
Soldiers**

Mean Age

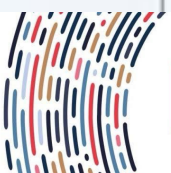
34.1 years

Primary Mechanism

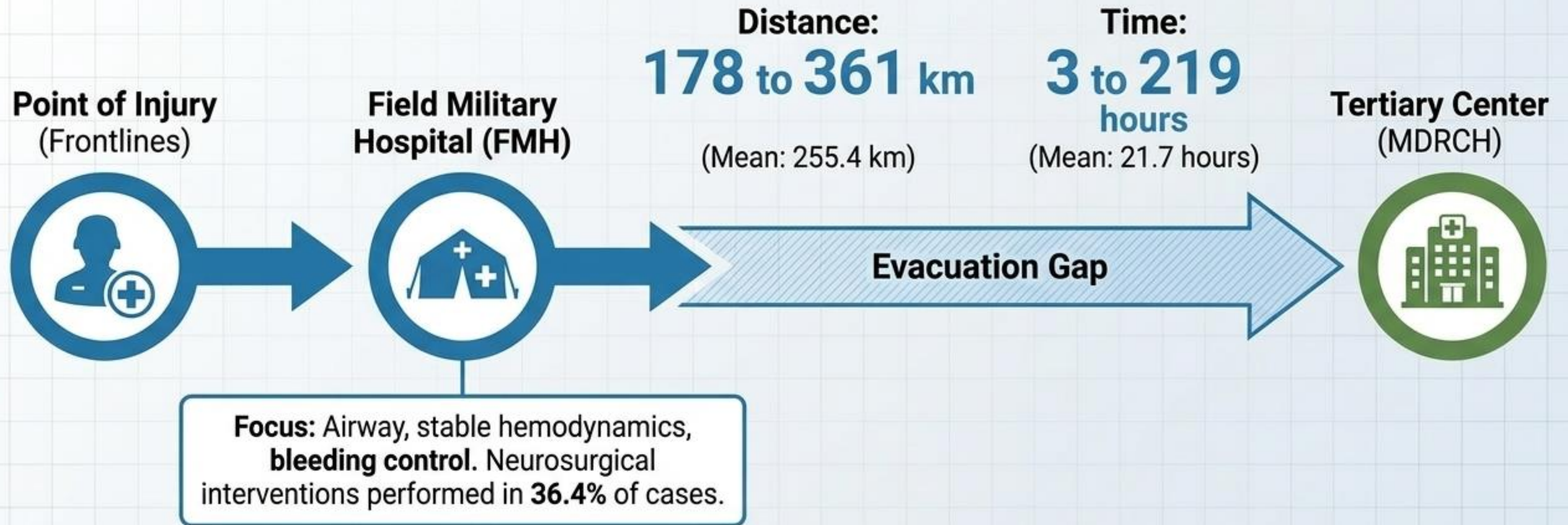
**Combat-related
Penetrating Brain
Injury**

Evacuation Profile

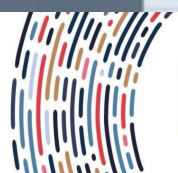
**From forward
military facilities**



The Evacuation Gap: Operating Beyond the “Golden Hour”



Civilian trauma relies on the ‘Golden Hour.’ Combat trauma survivability here was achieved despite an average evacuation time of nearly 22 hours, demanding robust prolonged field care and seamless civil-military routing.



Point of Injury: The Shift from Bullets to Blasts

Modern peer-to-peer combat dramatically shifts the primary mechanism of PBI compared to civilian environments.

Gunshot Wounds (GSW)  16.5%		Blast Fragments  83.5%	
 Kinetic Pathology	High velocity, massive primary tract destruction.	 Kinetic Pathology	Multifocal, non-perforating, ricochet, and complex fragment ingress.
 1-Month Mortality	50.0%	 1-Month Mortality	14.9%

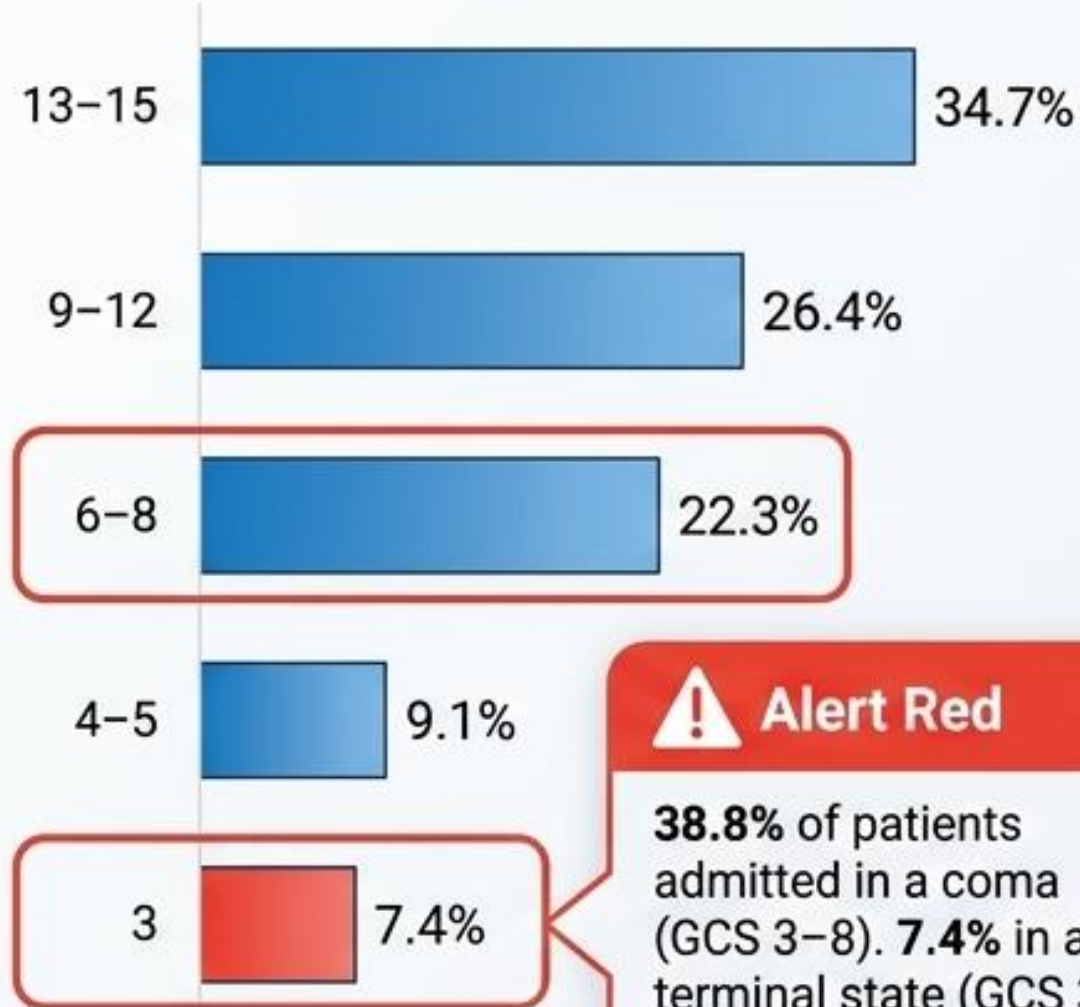
Unlike civilian environments dominated by GSWs, modern battlefield PBIs are overwhelmingly caused by artillery, rockets, and improvised explosive devices—resulting in lower raw kinetic energy but infinitely more complex multifragmentary damage.

Clinical Triage: A Severely Compromised Population

Baseline admission metrics demonstrate the extreme severity of the surviving cohort.

Neurological State (GCS)

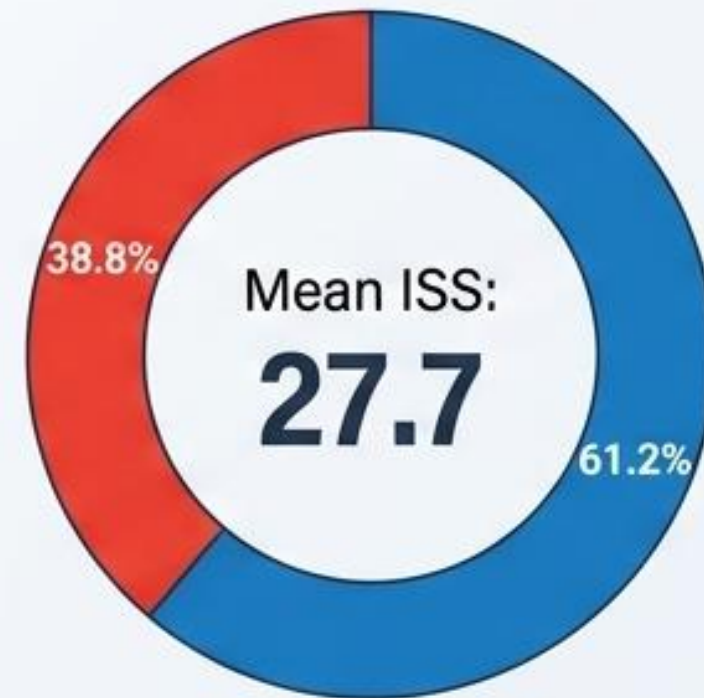
Mean Admission GCS: 10



Alert Red

38.8% of patients admitted in a coma (GCS 3-8). **7.4%** in a terminal state (GCS 3).

Systemic Trauma (ISS)

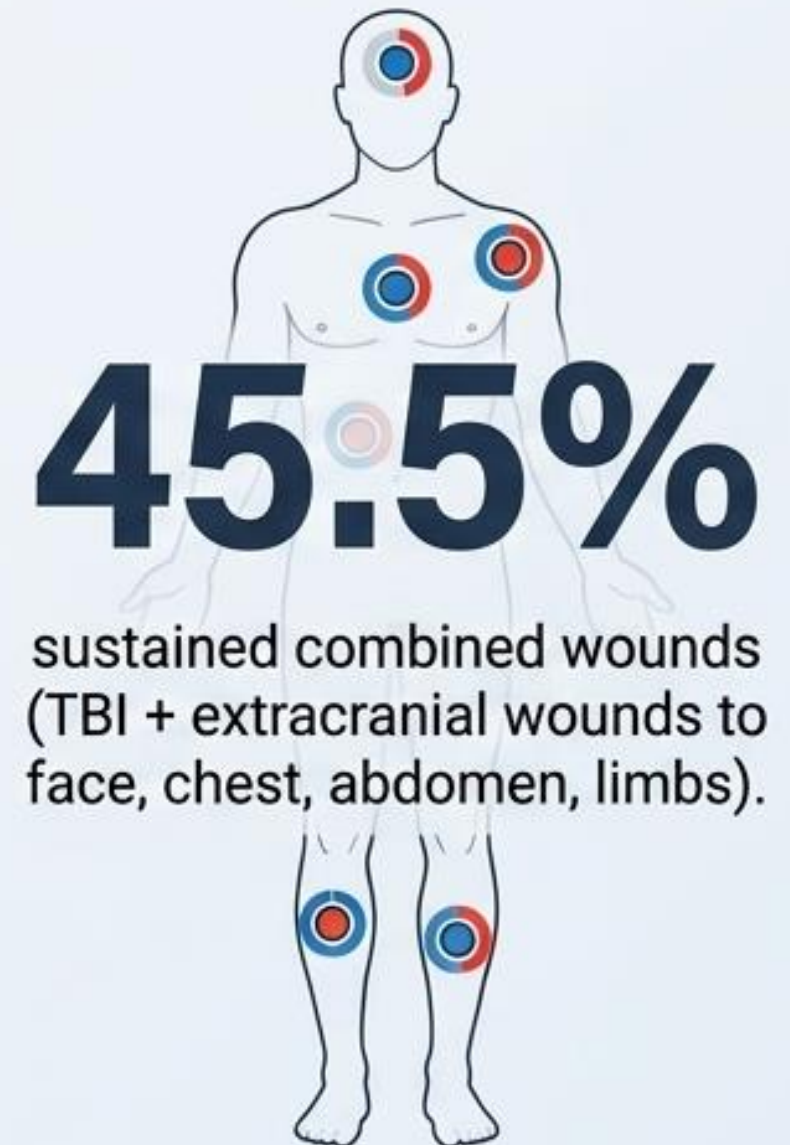


■ Severe to critical, ISS ≥ 26

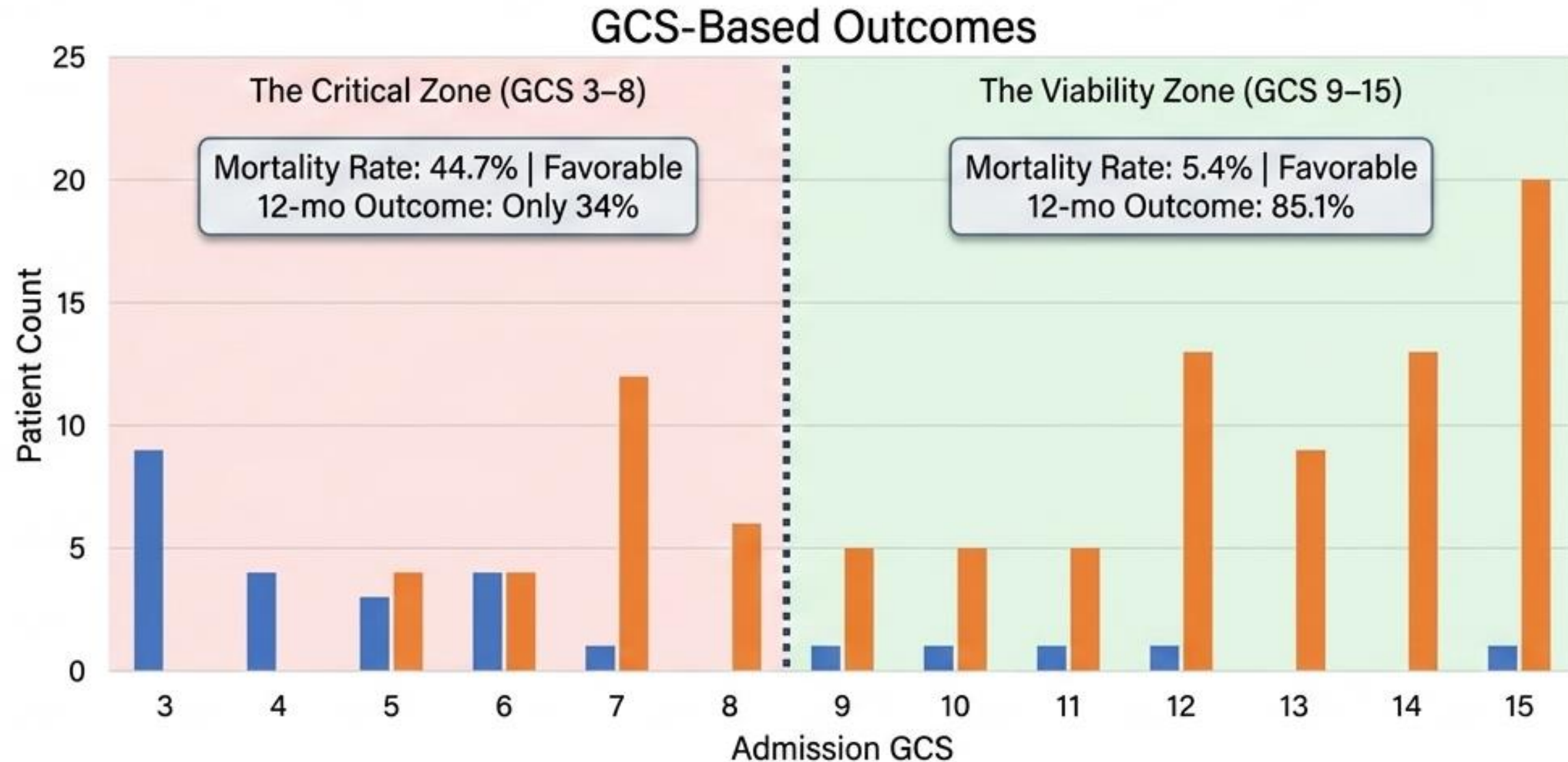
■ Mild to moderate, ISS ≤ 25

38.8% of patients had **Severe to Critical** systemic trauma (ISS ≥ 26).

Combined Injuries



The Triage Inflection Point: Admission GCS



An admission GCS of 8 or below serves as the absolute tipping point for mortality risk. Patients arriving with $\text{GCS} \geq 9$ achieved favorable long-term outcomes 11 times more frequently than those in a comatose state.



Overarching Outcomes: Defying the Baseline Odds

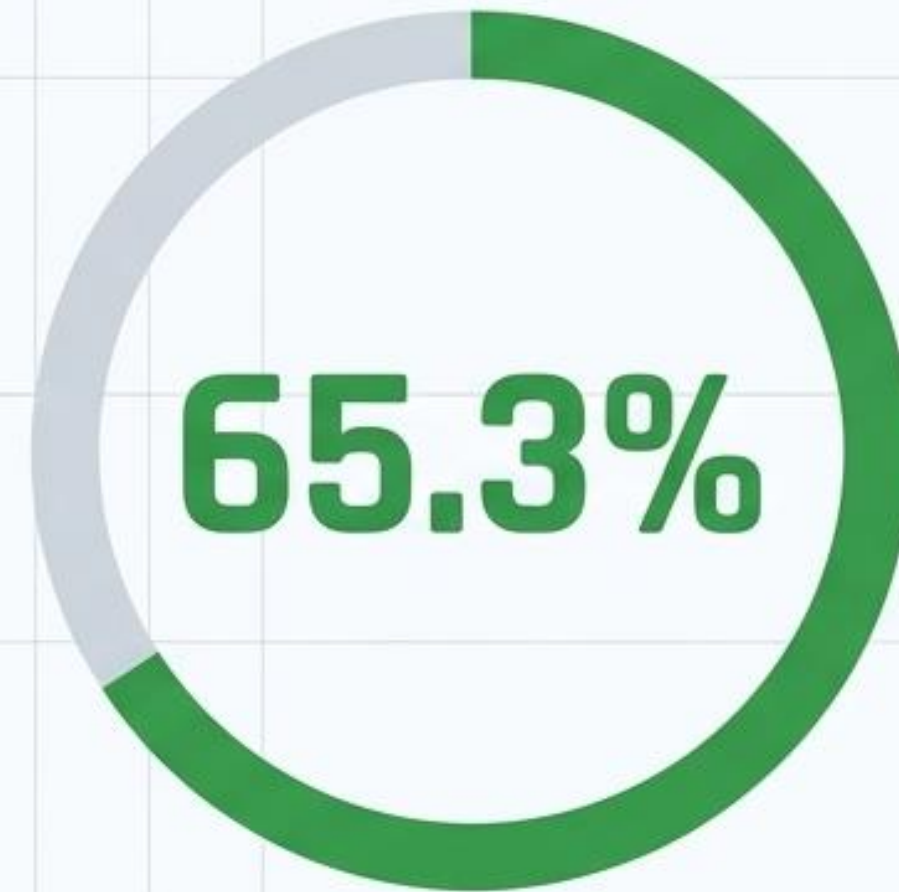
Despite prolonged evacuation and severe injury profiles, aggressive high-volume care yielded high survivability.

1-Month Mortality



- 25 patients died.
- Primary causes: Uncontrolled diffuse brain swelling (48%), Intracranial infection (28%), Brain stem damage (12%).

12-Month Functional Outcome



- Achieved 'Favorable Outcome' (Glasgow Outcome Scale 4 or 5: Good recovery or moderate disability).

These outcomes are significantly better than historical peacetime PBI metrics, proving the efficacy of integrated military-civilian trauma networks.

The Lethality Matrix: Multipliers for Poor Functional Outcome

Odds Ratios (OR) for unfavorable outcomes at 1 year (GOS 1-3).

Clinical

Admission GCS ≤ 8 :

11.1x Risk

Gunshot Wound Mechanism
(vs Blast): **3.6x Risk**

Radiological

Axial Dislocation (Herniation):

12.2x Risk Highest anatomical predictor

Intraventricular Hemorrhage:

9.1x Risk

Subarachnoid Hemorrhage:

8.4x Risk

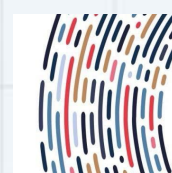
Dural Venous Sinus Injury:

4.0x Risk

Complications

Purulent-Septic Complications:

10.1x Risk



The Secondary Front: Purulent-Septic Complications

11.6%

(14 patients) developed intracranial purulent-septic complications despite protocol adherence.

Pathogen Breakdown

Acinetobacter baumannii
(5 of 12 positive CSF cultures)

Klebsiella pneumoniae

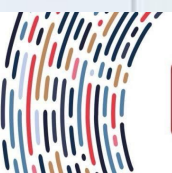
Staphylococcus epidermidis

Pseudomonas aeruginosa

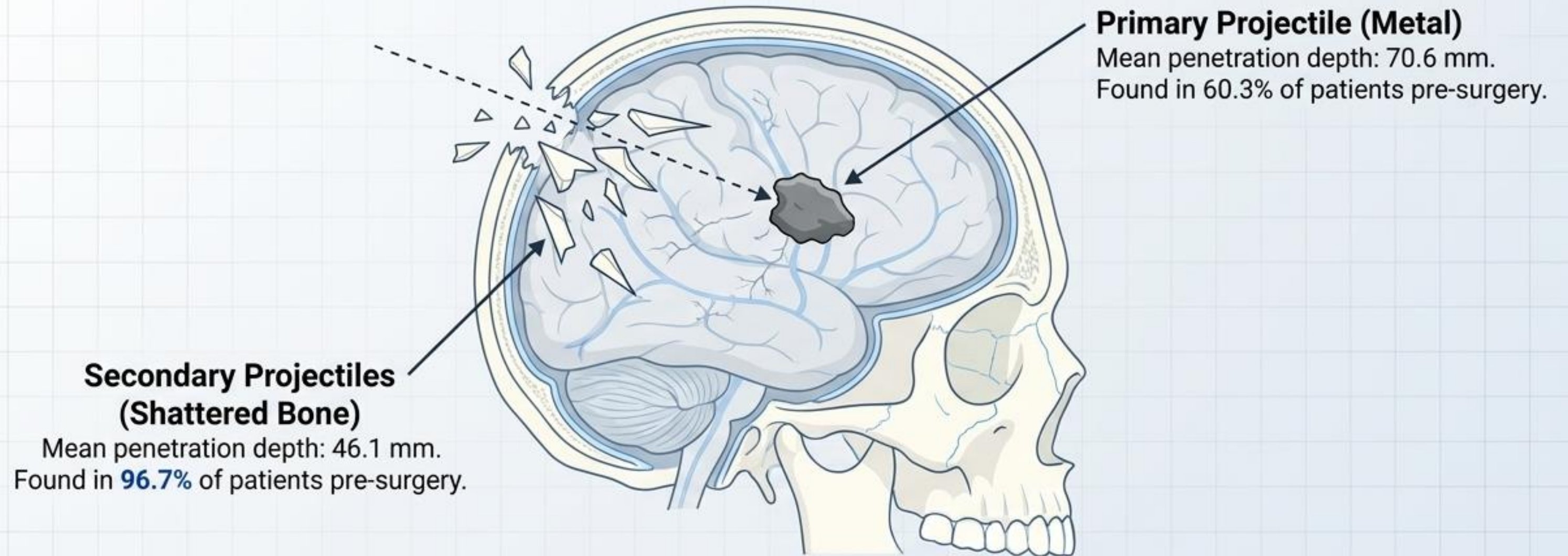


Postoperative infections act as a massive **force multiplier** for mortality and severe **morbidity**.

With rising GCS on admission, infectious complications replace initial brain destruction as the **leading cause of death**.

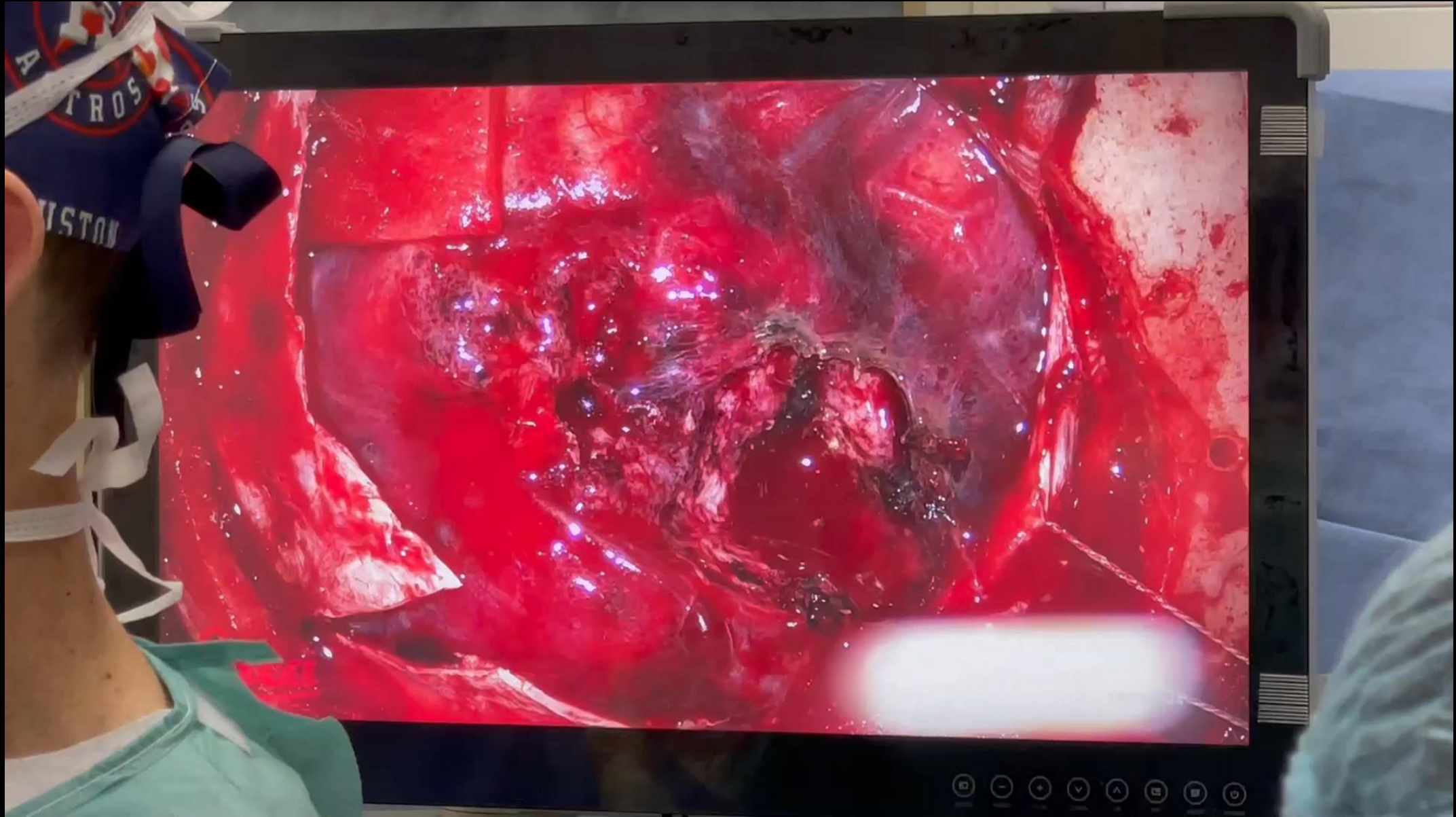


The Pathology of the “Secondary Projectile”



Key Insight: Bone fragments act as **secondary injuring projectiles**, driving **traumatic brain damage in 96.7% of patients**. Treating modern combat PBI is not just about the shrapnel—it is about managing **massive, diffuse bone ingress**.





Aggressive Intervention Protocol at the High-Volume Center



Neuro-Intensive Targets

- Systolic BP $\geq$ 100-110 mmHg (age-dependent)
- Avoid Hypoxia (PaO₂ < 60 or SatO₂ < 90%)
- Cerebral Perfusion Pressure: 60-70 mmHg
- ICP Adjustment: $\leq$ 22 mmHg



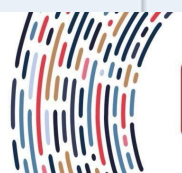
Surgical Imperatives

- 63.6% underwent immediate operations upon stabilization.
- Resection trepanation (47.9%)
- Inflow-outflow drainage (48.9%)



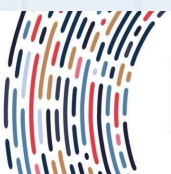
Intracranial Debridement

- Bone fragments removed in 84.3% of operated patients.
- Metal fragments removed in 36.3%.



Strategic Synthesis: The High-Volume Survival Blueprint

How a 75%+ survival rate is achieved in peer-to-peer warfare.



Final Directives for Future Military Trauma Systems

1

Redefine Triage Expectations

Blast mechanisms now dominate, causing massive secondary bone-fragment ingress. Prepare neuro-teams for complex, diffuse debridement rather than standard GSW single-tract repair.

2

Embrace the Evacuation Reality

The “Golden Hour” is dead in peer-to-peer combat. Trauma systems must adapt to extreme evacuation delays (averaging 21+ hours) by massively expanding Prolonged Field Care capabilities.

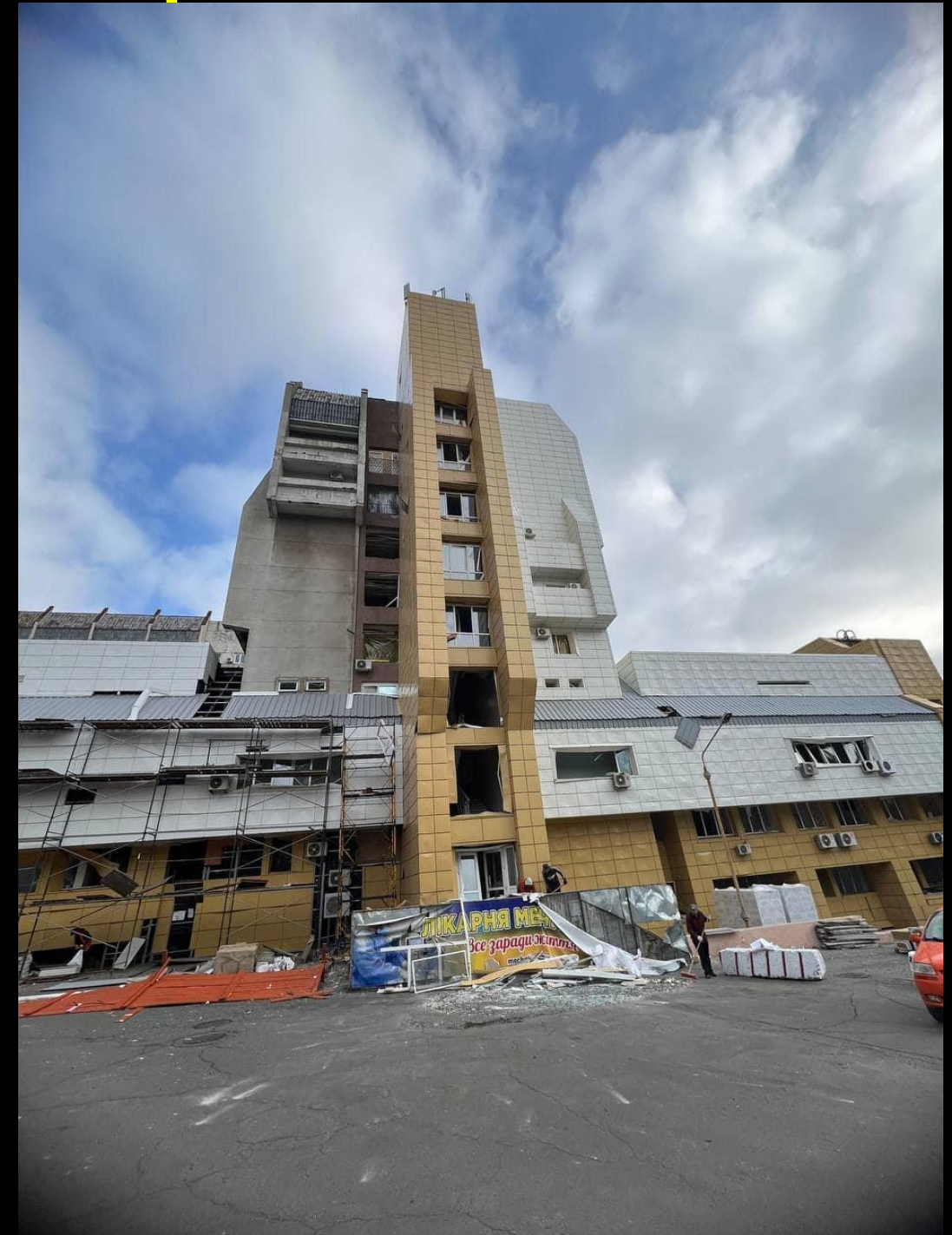
3

Integrate Civilian Infrastructure

Military field hospitals cannot manage high-volume complex neurotrauma alone. National defense strategies must seamlessly integrate civilian tertiary centers into the combat evacuation chain to achieve meaningful survival rates.



Russian ballistic missile attack on Dnipro, October 25, 2024 Mechnikov Hospital



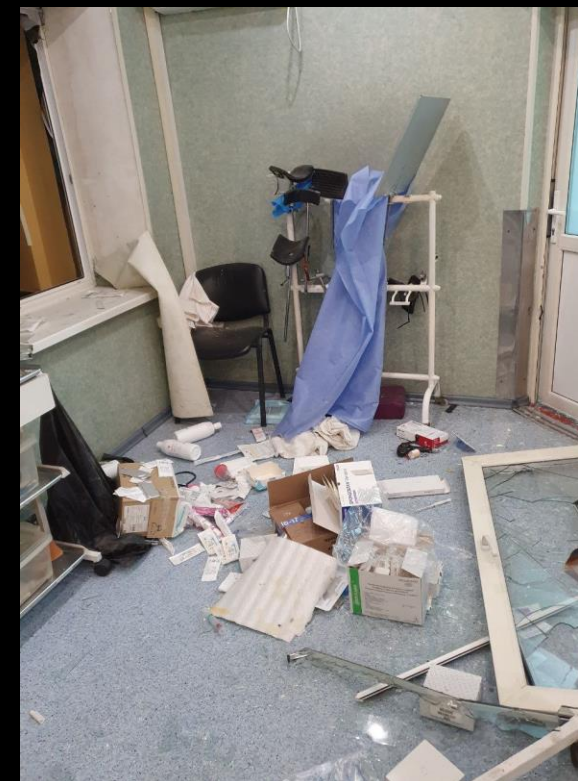


➤ **Mechnikov Hospital.**

October 25, 2024
time 23.00-23.50.

Urgent neurosurgical
operating room.

Neurosurgeon
Bohdan Sirko and
team perform the
removal
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An aerial photograph of a wide river. A large, multi-arched bridge spans the river in the background. In the foreground, a small, tree-covered island is situated in the river. On the island, there is a small white church with a golden dome and a red roof. A road with a guardrail runs along the right bank of the river. The sky is overcast.

*Thank you for your help and support
during the war*

GLORY TO UKRAINE!



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