Reframing neurotrauma research for LSCO: lessons from Ukraine for the UK Defence Medical Services

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INTRODUCTION

Recent operational experience from the full-scale invasion of Ukraine by Russia highlights the challenges UK Defence Medical Services may face in a future Large-Scale Combat Operation (LSCO) against a near-peer adversary. These environments are characterised by contested airspace, persistent drone surveillance, delayed casualty evacuation, overwhelmed medical facilities and frequent civilian casualties. The 2025 Strategic Defence Review[1] acknowledges the need to move to warfighting readiness without guaranteed air superiority or protected evacuation corridors.

These realities necessitate a shift in the military medical research agenda, from models shaped by counterinsurgency and air evacuation to one designed for prolonged field care, massive casualty surges and forward surgical intervention under threat.

INJURY PATTERNS IN LSCO

Neurotrauma, which includes blunt and penetrating traumatic brain injury (TBI) and spinal injuries, is emerging as a disproportionately represented injury category in LSCO. Reports from Ukrainian medical centres suggest that head, face and cervical spine injuries constitute nearly one-third of all serious battlefield trauma.[2–4] In Iraq and Afghanistan, TBIs were most often non-penetrating and associated with the primary blast wave from improvised explosive devices, typically among vehicle occupants wearing personal protective equipment (PPE). Primary blast brain injury emerged as one of the signature injuries of those conflicts.[5] In Ukraine, by contrast, the predominant mechanism is penetrating TBI caused by secondary blast fragments from artillery, drones and top-down munitions.[6] It is also likely that primary blast brain injury is occurring in Ukraine but remains under-recognised and under-reported amidst the overwhelming volume of penetrating trauma. These fragments, especially from first person-view drones or cluster munitions, are the primary mechanism of injury, both for military personnel and unprotected civilians.[7]

Prospectively collected data from the beginning of the full-scale invasion on 24 February 2022–1 October 2025 shows that 2284 patients with penetrating craniocerebral injuries underwent primary surgery at Mechnikov Hospital, Ukraine. An additional 543 patients, who initially underwent surgery in mobile field hospitals, received further treatment there. This is a ninefold increase on the numbers treated between 2014 and 2022.[8] Prior to the 2022 invasion, 12.9% of penetrating TBI was secondary to gunshot wounds; this percentage has fallen to 3.5% while the percentage caused by shrapnel injuries from secondary blast has risen from 87.1% to 96.5%.[7] Importantly, frontal, orbital and sinus-region injuries are prevalent, often resulting in cerebrospinal fluid (CSF) leaks, dural defects or communication with air-containing structures. In these cases, violation of the frontal sinus increases the risk of intracranial infection. Timely surgical management is required to prevent meningitis, brain abscess or persistent CSF leak. Delayed secondary injuries, including cerebral vasospasm, infection, CSF leak, hydrocephalus and seizures are a significant and serious source of subsequent deterioration.

OPERATIONAL CHALLENGES

Neurotrauma care in LSCO presents unique systemic and tactical constraints.

PPE design

Multiple types of PPE may potentially protect against brain injury and are determined by the trajectory of the causative mechanism; these include the combat helmet, eye protection, visor, nape guard and neck collar. With the exception of the helmet, these protect only against the energised fragments of secondary blast. There has been a move towards 'high cut' helmets with reduced weight and interoperability with hearing protection, regardless of the reduced coverage to penetrating TBI.[9] The desire for reductions in the helmet has also resulted in shells becoming thinner regardless of the materials used, but little medical evidence exists as to the increased risks.

Care on the battlefield

The UK has historically relied on advanced medical retrieval platforms to provide far-forward and early neuroprotection following neurotrauma, including anaesthesia, controlled ventilation, blood products, vasopressors, hypertonic saline and direct conveyance to a neurosurgical facility.[10] However, contested airspace is likely to result in denial of this previous model of care. Clear guidelines should be developed to train and deliver bundles of care far-forward by the lowest levels of providers to reduce morbidity and mortality.

Delayed evacuation and medical survivability

With uncrewed aerial systems (UAS) surveillance and glide bombs targeting ambulances and field hospitals, evacuation windows are unpredictable and often delayed until twilight periods (where the UAS threat is reduced). Therefore, patients may remain in Role 1 or forward Role 2 facilities for extended periods. Furthermore, the deliberate targeting of medical assets, so called 'double tap' tactics, may compound the reduced capacity and capability of medical systems.

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Overwhelmed Intensive Care capacity

Severe TBI patients often require ventilatory support and intracranial pressure (ICP) management. However, the field intensive care capacity (scarce ventilators, limited medical gases and no routine ICP monitoring) is limited, and nurse-to-patient ratios may fall to 5:1.[3 11]

Lack of early specialist neurosurgical intervention

Unlike Ukraine, which has increasingly deployed neurosurgical teams forward, NATO systems often rely on evacuation to rearward echelons before neurosurgical care can be delivered. Survival after TBI improves with the forward deployment of military neurosurgeons.[12] In Ukraine, patients with TBI are most often initially managed by emergency physicians, anaesthetists, general and orthopaedic surgeons who play a critical role in early stabilisation. Given the complexity of penetrating injury patterns now seen in Ukraine, which challenge even experienced neurosurgeons, there is a clear need to better support these frontline clinicians with protocols, targeted training and decision support tools. Penetrating TBI patterns (anterior skull base, orbit, frontal sinus and posterior fossa) demand clear forward algorithms for debridement, CSF-leak control and infection prevention which may not be deliverable in the absence of specialist neurosurgeons.

High civilian casualty burden

Most military medical treatment facilities will almost inevitably treat civilian casualties. Mass casualties involving civilians challenge standard triage, resource allocation and ethical frameworks. These policies should anticipate high numbers of unsalvageable penetrating TBI while safeguarding resources for salvageable cases. These thresholds are complex and context dependent.

These constraints raise an urgent need to re-evaluate triage systems, forward surgical capabilities and preventative strategies.

RESEARCH PRIORITIES FOR DEFENCE

In response to these realities, we propose the following research themes and questions, summarised in table 1. These are expert opinions based on collaborative discussions between UK, Ukrainian and US military clinicians.

The core aim of military neurotrauma care is to improve survival, preserve neurological function, prevent infection and enable return to duty or quality long-term recovery. Achieving this under LSCO conditions requires a major adaptation in research focus and operational delivery.

LSCO will often deny rotary retrieval; neuroprotection must therefore be delivered from the point of injury through the echelons of care and maintained during potentially long evacuation time lines. The organising principle is that simple, auditable targets preserve brain function. Future conflict will not wait for us to adapt. A research agenda that reflects the true scale, tempo and complexity of neurotrauma in LSCO will help to ensure our personnel receive care that is not only immediate but optimally informed by evidence.

Current UK research frameworks are not structured to respond dynamically to battlefield requirements. We recommend expanding the Combat Casualty Care research programme to include a Defence Neurotrauma Innovation Consortium as part of the proposed Defence Brain Health Initiative, co-led by military clinicians, academics and scientists. This body should focus on the priorities summarised in box 1.

CONCLUSION

The purpose of military neurotrauma care is to ensure survival with preserved function, but LSCO demands we deliver it without guaranteed air superiority, with significantly longer prehospital times and currently, without neurosurgeons near the front lines of the conflict. The UK should pivot from retrieval-centric models to distributed, standards-driven neuroprotection from the point of wounding, sustained through ground or maritime evacuation, developed in forward R2 and completed in R3/4 through rehabilitation.

Table 1 Proposed research questions and rationale

Theme	Research question	Rationale
Triage and evacuation	How can neurosurgical triage and capacity be scaled for high-volume trauma in LSCO?	Mass-casualty neurotrauma requires models beyond traditional single-patient neurosurgical planning.
Forward care	What is the impact of prolonged evacuation on TBI outcomes, and which interventions (or bundle of interventions) mitigate deterioration?	Delayed evacuation may worsen secondary brain injury; battlefield imaging, oxygenation and neurosurgical reach back may help.
Surgical access	Does forward deployment of neurosurgeons improve survival and functional outcomes in penetrating TBI?	Ukraine's use of mobile neurosurgical teams may support earlier definitive care.
ICU capacity	What neurocritical care models are viable with limited intensive care beds and staff?	Role 2 settings must support moderate-to-severe TBI care without 1:1 staffing or neuromonitoring.
Injury patterns	What unique neurotrauma patterns result from drone-delivered fragmentation and thermobaric weapons?	Fragmentation to anterior skull base and orbit should lead to investigation of optimised PPE and surgical algorithms.
Polytrauma	How should resuscitation protocols adapt to penetrating TBI with multisystem injuries?	Whole blood appears to reduce coagulopathy in penetrating TBI; damage-control algorithms must reflect brain physiology.[11–13]
Infection prevention	What is the optimal early surgical approach to skull base or sinus-involved penetrating TBI?	Prompt debridement and dural repair with flap closure reduces cerebrospinal fluid (CSF) leaks and infections.[4 14]
Vascular injury	How should vascular TBI (eg, pseudoaneurysms) be identified and treated forward?	Early angiography and hybrid interventions may reduce fatal secondary haemorrhage.
Musculoskeletal health	What is the impact of mobilising civilians on spinal degeneration and injury?	High rates of lumbar disc disease in recruits suggest need for ergonomic and screening strategies.[15]
Rehabilitation	What are the long-term neurological and psychiatric outcomes in TBI survivors?	Chronic impairment, post-traumatic stress disorder (PTSD) and functional deficits must inform rehabilitation services.[16 17]
Contextual survivability	What injury patterns can be recognised, on the battlefield, during evacuation and in medical facilities, as futile in the context of LSCO?	Systems will require adaptation to reduce the risk to battlefield medical providers and medical assets, and to preserve capability for salvageable cases.

LSCO, Large-Scale Combat Operation; PPE, personal protective equipment; TBI, traumatic brain injury.

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Box 1 Neurotrauma research for Large-Scale Combat Operation

- ⇒ Medical research into personal protective equipment design to prevent against traumatic brain injury.
- ⇒ Fieldable neurotrauma diagnostic tools (including CT, transcranial near infrared spectroscopy (NIRS) and doppler, angiographic tools and biomarkers)
- ⇒ Decision-support tools using lightweight artificial intelligence (AI) for triage and to guide futility decision making.
- ⇒ Shared trauma registries with allied partners.

A focused consortium advancing PPE, field imaging, decision support and shared registries, while running real-world trials of forward care bundles, will ensure that care is immediate, resilient and evidence led.

Contributors All listed authors contributed substantially to the development of the work, critically revised the manuscript for important intellectual content and approved the final submitted version. DB is the guarantor of this paper. Grammarly was used for grammar and spell checking. OpenEvidence was used for some of the literature review. ChatGPT was used to put references into the Vancouver format. All ideas are the authors' own.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; internally peer reviewed.

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Check for updates

To cite Baxter D, Armonda R, Valadka A, *et al*. *BMJ Mil Health* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/military-2025-003102

Accepted 27 April 2026

BMJ Mil Health 2026;**0**:1–3. doi:10.1136/military-2025-003102

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