

ORIGINAL RESEARCH

Damage Control Surgery for Wartime Carotid Artery Injuries: Interaction Between Role 2 and Role 3 Facilities in Ukraine and a Clinical Case Series Analysis

Ihor Rusanov ^{b,c}, Dmytro Mialkovskyi ^b, Iurii Mikheiev ^{b,c}, Roman Kuziv ^b, Kostiantyn Gumeniuk ^a, Serhii Machuskyi ^{b,*}, Alex Valadka ^d, Rocco A. Armonda ^e

^a The Command of the Medical Forces of the Armed Forces of Ukraine, Ukraine

^b Zaporizhzhia Military Hospital, Zaporizhzhia, Ukraine

^c Zaporizhzhia State Medical and Pharmaceutical University, Zaporizhzhia, Ukraine

^d Department of Neurological Surgery, University of Texas Southwestern Medical Center, Dallas, TX, USA

^e Department of Neurosurgery, MedStar Georgetown University Hospital, Washington, DC, USA

Introduction: This case report aimed to describe patterns of combat related carotid artery injury in Ukrainian military personnel and to evaluate outcomes of damage control surgery (DCS) at Role2 facilities followed by definitive management at Role 3 facilities.

Method: A retrospective, observational analysis was conducted over a 12 month period at military Role 2–3 facilities. Medical records, operation reports, imaging studies, and evacuation data were reviewed for patients with penetrating neck trauma and confirmed extracranial carotid artery injury. All patients received individualised surgical management at Role 2 and Role 3 facilities according to DCS principles, tailored to clinical severity, associated injuries, and available resources.

Results: Ten male patients with penetrating carotid artery injuries were identified. Six patients presented at Role 2 facilities with hard signs of vascular injury, including active arterial bleeding in four cases and expanding neck haematoma in two cases. Temporary intravascular shunts were used as a DCS measure at Role 2 facilities in four patients (40%). Definitive management included primary arterial repair in four patients (40%), carotid ligation in two patients (20%), and reconstruction with interposition grafts following shunting or ligation in four patients (40%). Shunt thrombosis occurred in two of four shunted patients, both involving improvised temporary shunts. The overall stroke rate was 30% (three of ten), including one non-disabling stroke and two disabling stroke, one of which was fatal. Peri-operative mortality was 10% (one of ten). Among patients with available follow up, most demonstrated favourable neurological outcomes, particularly after primary repair.

Conclusion: Combat related carotid artery injuries are life threatening and require rapid application of DCS principles. Temporary shunting at Role 2 facilities can be lifesaving but carries risks, particularly when improvised shunts are used. Primary repair at Role 3 facilities provides favourable neurological outcomes when feasible. Close coordination between Role 2 and Role 3 facilities is essential to optimise survival and neurological outcomes in modern warfare.

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INTRODUCTION

The lack of air superiority in the current Russia–Ukraine war has markedly limited rapid aeromedical evacuation of combat casualties, increasing the importance of timely

surgical decision making at every stage of care. Carotid artery injuries are among the most lethal wartime vascular injuries and may be rapidly fatal even when managed by experienced surgeons.^{1,2}

Effective treatment requires prompt haemorrhage control, maintenance of cerebral perfusion, and structured evacuation to higher levels of care. Damage control surgery (DCS) prioritises immediate lifesaving interventions while deferring definitive reconstruction until physiological stabilisation is achieved.³ This approach shortens operation time, limits blood loss, and reduces hypothermia and acidosis, making it particularly suitable for austere combat

* Corresponding author. Department of Vascular Surgery, Zaporizhzhia Military Hospital, 2 Poshtova St, Zaporizhzhia, 69063, Ukraine.

E-mail address: senia.334@gmail.com (Serhii Machuskyi).

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environments where advanced resources may be unavailable or evacuation delayed.^{3,4}

This study aimed to characterise combat related carotid artery injuries encountered in modern warfare and to evaluate outcomes of DCS performed at Role 2 facilities followed by definitive management at Role 3 facilities, with particular focus on mortality, neurological complications, and shunt related outcomes. The study was exempted from ethical approval by the institution.

STUDY DESIGN

This retrospective, observational study was conducted at Zaporizhzhia Military Hospital, a Role2 and 3 referral facility within the Ukrainian military medical evacuation system. The study period included 12 consecutive months (January – December 2024). Patients were eligible if they had sustained penetrating neck trauma, undergone open surgical neck exploration at a Role 2 or Role 3 facility, and had a confirmed extracranial carotid artery injury.

METHODS

Data were collected from electronic medical records, operation reports, intra-operative photo documentation, duplex ultrasonography, computed tomography angiography (CTA), and evacuation records. Variables included patient demographics, mechanism of injury, clinical

presentation, vessels injured, associated trauma, treatment at a Role 2 facility, evacuation time, imaging findings at a Role 3 facility, surgical management, and clinical outcomes.

The Ukrainian military medical system follows the NATO Medical Treatment Role framework: Role 1 provides immediate point of injury care and triage; Role 2 delivers resuscitation and DCS by forward surgical teams; Role 3 offers multidisciplinary surgical care with advanced imaging and vascular expertise; and Role 4 represents tertiary referral facilities outside the combat zone.^{5,6}

Primary outcomes were peri-operative death, stroke (disabling or non-disabling), shunt thrombosis, and neurological outcome at follow up. Secondary outcomes included patterns of surgical management and complications related to shunt use or vessel ligation.

Only descriptive statistics were applied due to the small sample size. Continuous variables are reported as medians and ranges, and categorical variables as counts and percentages. Statistical calculations were performed using Microsoft Excel (Microsoft, Seattle, USA).

RESULTS

Ten patients were included, all male, with a median age of 41 years (range 29–56 years); all had sustained penetrating neck trauma. Seven patients had a common carotid artery (CCA) injury, three had an internal carotid artery (ICA)

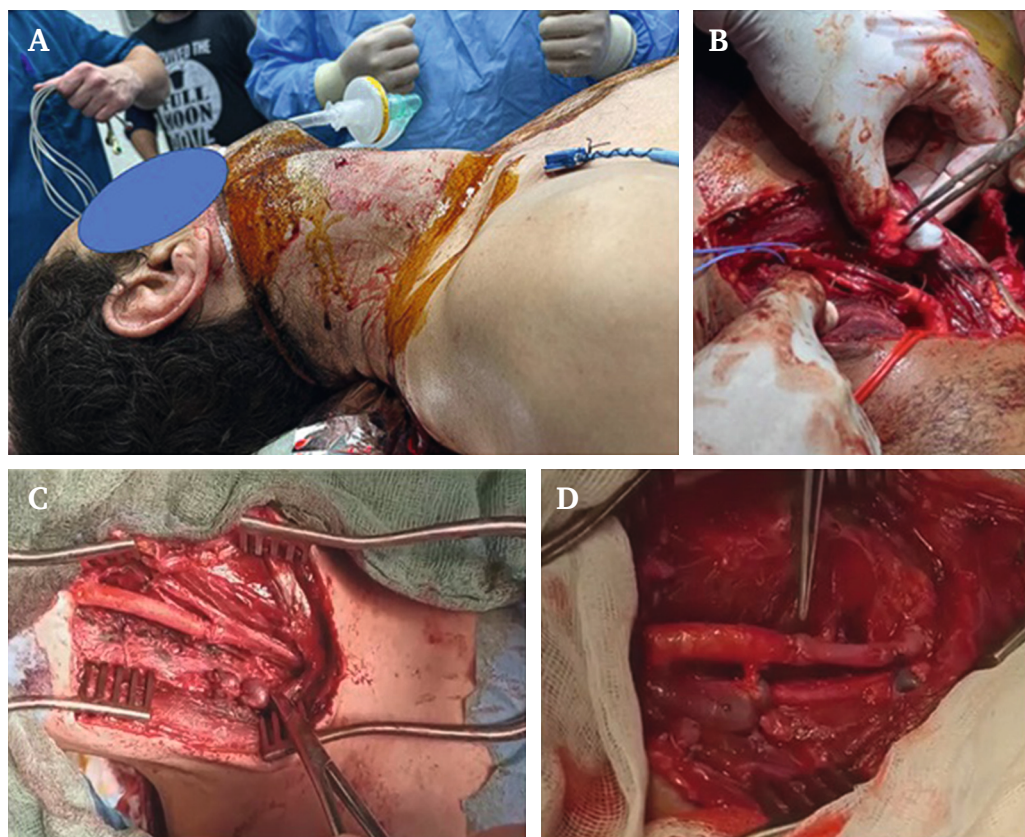


Figure 1. Images showing: (A) Extensive haematoma of the neck at a Role 2 facility; (B) Temporary shunt (Argyle) in the area of the common carotid artery (case 1); Reconstruction of the common carotid artery with a synthetic 6mm PTFE graft in Case 1 (C) and an autologous venous graft with a section of the reversed great saphenous vein in Case 3(D).

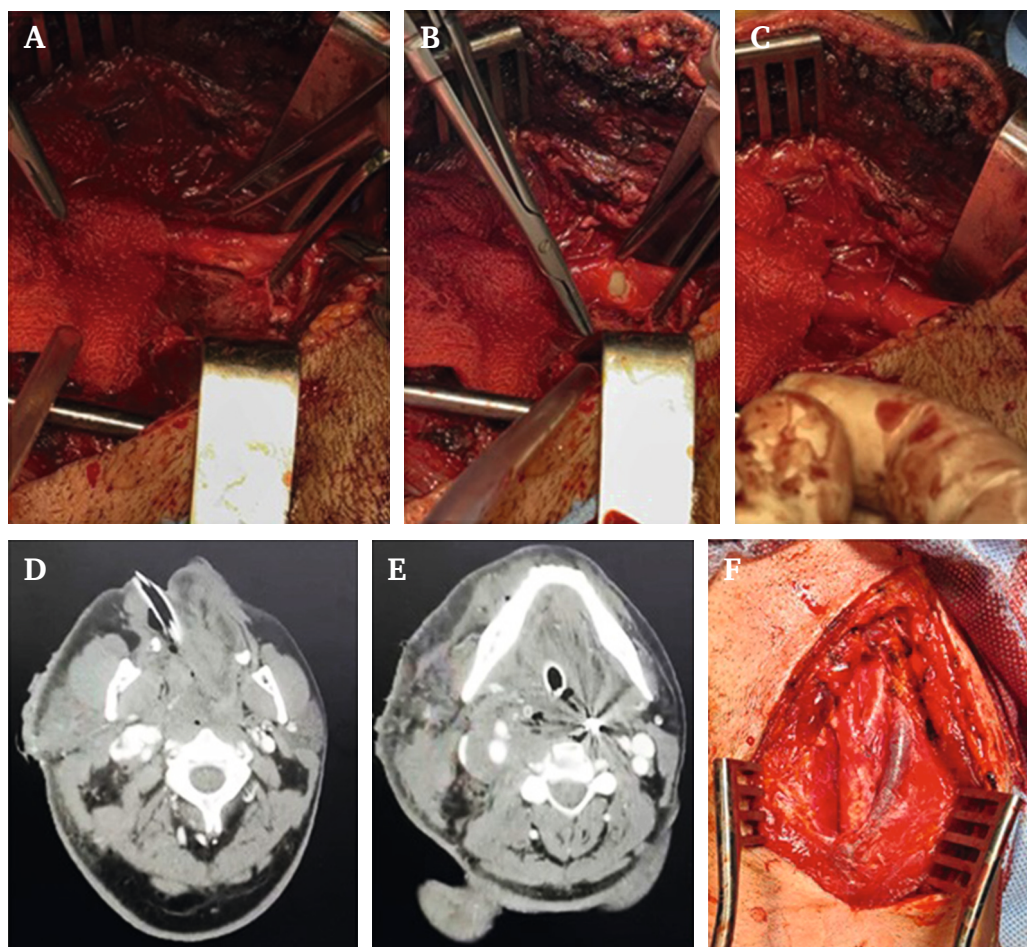


Figure 2. Images showing: (A–C) Common carotid artery injury and primary repair with lateral vascular suture using 6/0 Prolene (case 5). (D and E) Computed tomography angiography images demonstrating internal carotid artery injury, contrast extravasation, and metallic shrapnel that caused the arterial injury (case 8); (F). End to end primary repair of internal carotid artery injury (case 8).

injury, and five had a concomitant internal jugular vein (IJV) injury. None presented with isolated neck trauma, and all had associated injuries.

The mechanism of injury was drone related in eight cases, including six first person view (FPV) drone strikes. Six patients presented at a Role 2 facility with hard signs of vascular injury, including active arterial bleeding in four cases and expanding neck haematoma in two (Fig. 1A). Four patients presented with soft signs only.

Immediate neck exploration at a Role 2 facility as part of DCS was required in five patients. Temporary intravascular shunts were placed in four patients (40%) (Fig. 1B). The remaining patients were initially managed conservatively at a Role 2 facility and underwent delayed exploration at a Role 3 facility after CTA demonstrated active contrast extravasation.

Definitive management included primary arterial repair in four patients, carotid artery ligation in two, and arterial reconstruction with interposition grafts following shunting or ligation in four (Fig. 1C,D, Fig. 2A–F, Fig. 3A, B). No endovascular techniques were available at either Role 2 or Role 3 facilities.

Temporary shunt thrombosis occurred in two of four shunted patients, both involving improvised temporary shunts. Overall, three patients experienced stroke (30%): one non-disabling and two disabling, including one fatal hemispheric infarction (Fig. 3C, D). The peri-operative mortality rate was 10% (one patient).

Follow up data were available for six patients (range six to twelve months). Among these, no late graft related complications, infections, or pseudoaneurysms were observed. One patient had a persistent non-disabling neurological deficit, while the remaining patients demonstrated favourable long term neurological outcomes. A summary of individual patient characteristics and management is provided in Table 1 and the outcomes are summarised in Table 2.

Follow up data were available for six of the ten patients (cases one, two, three, five, six, and seven). All patients who underwent primary carotid repair with lateral sutures (cases five to seven) had favourable long term outcomes without neurological deficits. Owing to wartime evacuation patterns, complete follow up was not possible in four cases, representing a study limitation. One patient had sustained

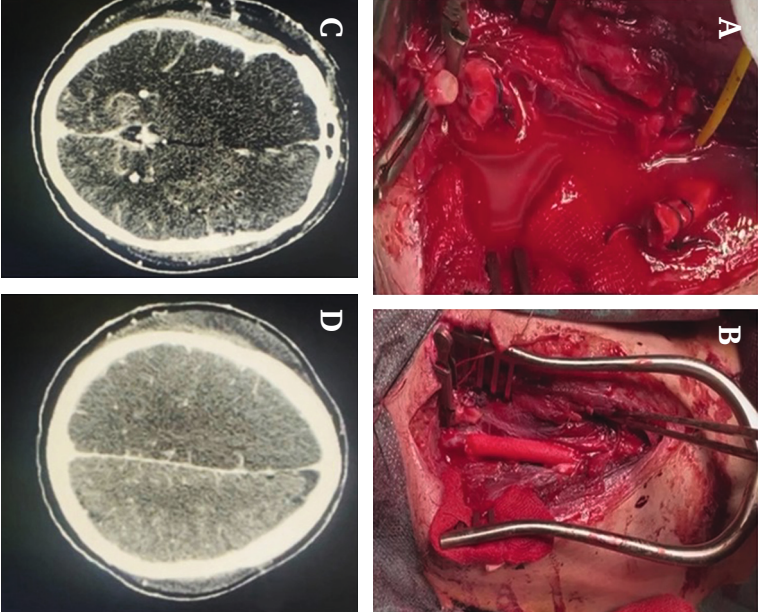


Figure 3. Images showing: (A and B) The ends of the common carotid artery were ligated at a Role 2 facility. The artery was repaired with a synthetic PTFE graft (case 9). (C and D) Catastrophic ipsilateral hemisphere stroke after right internal carotid artery ligation (case 10).

a severe ischaemic stroke before evacuation, one patient died on post-operative day five, and outcome data were unavailable for two transferred patients. Among patients with available follow up (range six to twelve months), no late graft related complications were observed, and only one patient had a persistent non-disabling neurological deficit. The 10% peri-operative mortality rate was limited to a single patient after internal carotid artery ligation for a zone III injury.

DISCUSSION

Although this series included a limited number of cases, it reflects the spectrum of vascular neck injuries and clinical scenarios encountered in modern warfare and highlights the importance of coordinated care between Role 2 and Role 3 facilities. The predominance of drone related mechanisms mirrors recent observations from the war in Ukraine and is associated with polytrauma and delayed evacuation.⁶

Urgent neck exploration remains mandatory in the presence of hard signs of vascular injury, as emphasised in contemporary trauma guidelines.^{3,5} In this cohort, DCS at a Role 2 facility was essential for haemorrhage control in unstable patients, enabling survival to definitive care.

Temporary intravascular shunts, widely used in Iraq and Afghanistan,⁴ preserve cerebral blood flow until definitive

Table 1. Summary of patient (*n* = 10) characteristics, surgery performed, and outcomes.

Patient identifier number	1	2	3	4	5	6	7	8	9	10
Age – y and sex	38 male	44 male	35 male	45 male	29 male	52 male	39 male	45 male	35 male	56 male
Vital signs on admission (HR – bpm and systolic BP – mmHg)	HR 97 BP 97	HR 85 BP 102	HR 90 BP 111	HR 119 BP 82	HR 97 BP 104	HR 84 BP 110	HR 88 BP 115	HR 90 BP 107	HR 89 BP 98	HR 127 BP 75
Glasgow Coma Scale on admission	13	14	11	7	14	13	14	12	12	3
Type and mechanism of the neck trauma	Penetrating (FPV-drone)	Penetrating (explosive device from drone)	Penetrating (FPV-drone)	Penetrating (grenade from drone)	Explosive device (mine)	Penetrating (FPV-drone)	Penetrating (artillery fire)	Penetrating (FPV-drone)	Penetrating (FPV-drone)	Penetrating (FPV-drone)
Clinical presentation	Arterial neck bleeding and extensive haematoma (Role 2)	Arterial neck bleeding (Role 2)	Expanding neck haematoma (Role 2)	Arterial bleeding (Role 2)	Neck haematoma (Role 2) extensive neck haematoma (Role3)	Stable haematoma (Role 2)	Stable haematoma (Role 2)	Stable haematoma (Role 2)	Bleeding (Role 2)	Neck haematoma (Role 2) extensive haematoma (Role 3)

Vessels affected	CCA and IJV	CCA	CCA and IJV	ICA	CCA and IJV	CCA	CCA	CCA	CCA and IJV	ICA (high injury) and IJV
Concomitant trauma	Multiple soft tissue injuries to the upper extremities, face and chest (non-penetrating)	Eye injury and facial skull fracture, mild TBI	Oesophagus injury	Multiple injuries (left axillary artery and vein), penetrating wound to the abdominal cavity	Traumatic amputation of the right foot	Eye injury and non-penetrating TBI	Facial soft tissues, mild TBI	Tracheal injury, gunshot humeral fracture	Multiple soft tissue injuries of the head, mild TBI	Multiple eye injuries, TBI, a penetrating chest wound (tension pneumothorax), and injuries to both lower extremities
Treatment approach (Role 2)	Temporary shunt CCA (Argyl shunt), IJV ligation	Temporary shunt CCA (Pruitt F3 shunt)	Temporary shunt CCA, IJV ligation (non-specialised shunt)	Temporary shunt ICA (non-specialised shunt)	Pressure bandage	Pressure bandage	Pressure bandage	Pressure bandage	CCA and IJV ligation	Pressure bandage, bilateral thoracostomy
Approximate evacuation time – min	100	30	120	120	30	100	100	120	30	120
CT scan data (Role 3)	No signs of brain ischaemia	No signs of brain ischaemia	Minor ipsilateral ischaemic focus	Focus of ischaemia (6 h) after stabilisation)	Neck haematoma, contrast extravasation, with shrapnel near CCA	Neck haematoma, contrast extravasation near ICA	Neck haematoma, contrast extravasation	Neck haematoma with shrapnel near CCA, contrast extravasation	No signs of brain ischaemia	Extensive neck haematoma, ICA injury
Surgical approach at Role 3	Interposition PTFE graft of CCA	Interposition PTFE graft of CCA	Interposition vein greater saphenous vein graft of CCA	Thrombosed temporary shunt removal, ICA ligation	Lateral CCA suture, IJV ligation	Lateral CCA sutures	Lateral CCA sutures	ICA end to end anastomosis	CCA repair with PTFE graft	ICA ligation
Clinical outcomes	No neurological complications	No neurological complications	Ipsilateral stroke (non-disabling)	Ipsilateral severe stroke. Patient evacuated, further follow up unknown	No neurological complications	No neurological complications	No neurological complications	No neurological complications	No neurological complications	Catastrophic hemispheric stroke; death on the 5th post-operative day

HR = heart rate; BP = blood pressure; bpm = beats per minute; FPV = first person view; CCA = common carotid artery; IJV = internal jugular vein; TBI = traumatic brain injury; CT = computed tomography; ICA = internal carotid artery; PTFE = polytetrafluoroethylene.

Table 2. Shunt use, stroke patterns, and death.

Variable	n (%)	Comments
Temporary shunt use (total)	4 (40)	Cases 1, 2, 3, 4
Standard commercially available shunts	2 (20)	Both maintained patency; no intra-operative thrombosis
Improvised shunts	2 (20)	Both thrombosed; constructed from available tubing
Total stroke	3 (30)	Cases 3, 4, and 10
Non-disabling stroke	1 (10)	Case 3
Disabling stroke (survived)	1 (10)	Case 4 (severe stroke before loss to follow up)
Fatal stroke	1 (10)	Case 10
Peri-operative death	1 (10)	Catastrophic hemispheric stroke (Case 10)

Data are presented as n (%).

repair and align with DCS principles. However, they pose risks of thrombosis, embolism, and intimal trauma, especially when improvised devices are used under austere conditions. In this series, improvised shunts were associated with ischaemic stroke, while standard Argyl (Cardinal Health, Dublin, OH, USA) and Pruitt-F3 (LeMaitre Vascular, Burlington, MA, USA) shunts placed by trained surgeons yielded better outcomes.⁷ This underlines the need to standardise shunt use, train surgeons in atraumatic insertion, and ensure supply of specialised devices with antithrombotic coatings. Although some reports suggest high stroke rates with shunts,⁸ current joint trauma system guidelines still emphasise their utility.³ The conflicting data highlight a major knowledge gap requiring further study, particularly under wartime conditions.

Primary repair remains the optimal treatment when feasible. Four patients in this cohort underwent direct repair without ischaemic complications. Yet this approach requires time and patient stability, conditions not always achievable at Role 2 facilities. In minor vessel wall injuries, lateral suturing is often possible, whereas severe wall defects demand shunting or ligation. Definitive repair is therefore more suitable at Role 3 facilities with vascular expertise and resources.⁵

Zone I and III injuries remain the most challenging due to limited exposure. White *et al.* reported that ICA ligation in modern combat is three times more frequent than CCA ligation, with near universal stroke.² Carotid ligation was unavoidable in selected cases, particularly for severe ICA injuries or in profoundly unstable patients. This pattern was confirmed in this case report, including one fatal hemispheric infarction following ICA ligation. Endovascular techniques, including stent grafting, are promising alternatives for inaccessible lesions⁹ but are still unavailable at most Ukrainian Role 2–3 facilities. Expanding endovascular capability is a key goal for the future.

The Ukrainian experience underscores the operational relevance of DCS principles and structured evacuation within the NATO Medical Treatment Role system. Forward surgical teams operate under austere conditions yet must make complex vascular decisions with limited resources. Close coordination with receiving Role 3 facilities is therefore critical to optimise timing of evacuation and definitive repair.

Modern warfare in Ukraine has introduced new mechanisms of carotid trauma. While historical series have mainly described gunshot and shrapnel wounds,¹⁰ most of the current patients were injured by FPV drones or explosive devices dropped from drones. These weapons produce combined blast and penetrating trauma, often with poly-trauma, including burns, limb amputations, and traumatic brain injury. Such injuries complicate management and delay evacuation, as drones also threaten medical personnel during casualty transport. Indeed, none of these patients had isolated neck trauma.

These findings reinforce several key points. Firstly, DCS principles are critical in carotid trauma, particularly at Role 2 facilities where decisions must be rapid and simple. Secondly, primary repair is ideal but not always feasible; shunts provide a valuable bridge but require standardisation and resources. Thirdly, ligation, although sometimes unavoidable, carries high risks, especially in ICA injuries. Fourthly, the evolution of modern weapons, especially FPV drones, is reshaping the epidemiology of vascular injuries and complicating evacuation logistics. Finally, effective coordination between Role 2 and Role 3 facilities remains essential for optimising outcomes.

Limitations of this case series include small sample size, lack of long term follow up in some cases, and restricted access to advanced endovascular therapies. Nevertheless, these cases provide unique insights into the realities of carotid injury management in today's warfare. Future efforts should focus on improving shunt technology, expanding endovascular options, and refining guidelines tailored to austere combat environments.

Conclusion

The choice of strategy for carotid artery trauma depends on injury location, collateral circulation, and available resources. In unstable patients, ligation may be the only lifesaving option, while temporary shunting at Role 2 facilities remains the preferred DCS technique when feasible, as it preserves cerebral perfusion until definitive repair. Primary reconstruction is optimal for stable patients at Role 3 facilities, where expertise and equipment allow for safer vessel restoration. These findings highlight the need for

improved availability of specialised shunts, standardised training for Role 2 teams, and streamlined communication between medical echelons to maximise survival in austere combat settings.

CONFLICTS OF INTEREST

None.

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