Neurosurgical Forum LETTERS TO THE EDITOR

Early decompressive craniectomy and limited tract debridement: a proven strategy?

TO THE EDITOR: I read with interest the editorial by Wolfe¹² and the article by Larkin and coauthors⁷ in the December issue of *Neurosurgical Focus* (Wolfe SQ: Editorial. Developing systems of care: association of time to craniectomy with survival in patients with severe combat-related brain injuries. *Neurosurg Focus* 45(6):E3, December 2018; and Larkin MB, Graves EKM, Boulter JH, et al: Two-year mortality and functional outcomes in combat-related penetrating brain injury: battlefield through rehabilitation. *Neurosurg Focus* 45(6):E4, December 2018).

Wolfe¹² in her editorial states “military doctrine over the past decade has shown that emergency craniectomy significantly improves outcome in these patients.” As an aging veteran (and with the assistance of Jim Goodrich, a consumer of military neurosurgical history), I’m unsure that this contention is justified, and concerned that a remarkable body of historical literature has been forgotten by our generation of military surgeons.

“Each war brings great respect and recognition to individual neurosurgeons who have done an exemplary job in impossible situations. Each war involves neurosurgeons who are inexperienced for the tasks at hand. Each war involves relearning principals [sic] that were useful in the past but which have been forgotten.” (Slater J: *Neurosurgery at war. Presidential Address, Western Neurosurgical Society Annual Meeting, Lake Tahoe, CA, September, 2005.*)

Long-Term Neurological Outcomes From Combat-Related Penetrating Brain Injury

Larkin and coauthors⁷ present data on an 80-patient cohort of US service members out of a 908-patient population treated in Kandahar, Afghanistan, between January 2010 and March 2013. Their cohort mortality was 21%. Although comparison of data between conflicts is understandably challenging based on differing data collection and methodology, the reader should be aware of available historical data. Cushing’s mortality for his last 45-patient cohort in World War I (WWI) was 28%.⁵ Estimated mortality for craniocervical wounds in World War II (WWII) was 25% of patients reaching an evacuation hospital and

13% of those receiving surgery.⁸ In Korea, in a cohort of 1105 casualties with penetrating head injuries reaching an Army neurosurgical installation between September 1950 and August 1952, fewer than 8% of patients died.⁹ In Hammon’s analysis of 2187 consecutive penetrating injuries to the brain in Vietnam over a 26-month period, an in-hospital mortality rate of 9.7% was reported for US casualties who received surgical intervention.⁶ Assuming a post-hospitalization mortality rate on par with the 6%–8% reported by Carey et al.⁴ in a follow-up study of 103 soldiers followed up at 1 year, survivability in Vietnam appears to have been similar, if not better than that reported in the Iraq and Afghanistan conflicts.

In conversation with colleagues, I’ve heard comparisons of data between conflicts dismissed based on immortal time bias, different mechanism of injury, and/or more rapid casualty evacuation during the Iraq and Afghanistan conflicts. I see little validation for such concerns. The proportion of blast and gunshot wounds between Vietnam and the current conflicts are similar. Blast injuries comprised 80% of injuries in Larkin et al.’s study,⁷ essentially identical to the 80% (1170 fragmentation vs 247 gunshot wounds) among US personnel reported in Hammon’s series.⁶

As to the contention that patients with more severe injuries are surviving to receive care, resulting in higher overall mortality? The recognition that forward neurosurgical care results in improved outcomes is hardly new. Surgeons learned and relearned this principle in each war of the 20th century. Matson⁸ raised similar concerns regarding casualty care during WWII: “When a neurosurgical team functioned close to the scene of combat and received casualties very early (2–6 hours post injury) head wounds were operated on that would not have survived to reach a hospital further in the rear (6–24 hours after injury). The operative mortality in the former group was naturally higher.” Based on the best information available, the contention that the change in the treatment paradigm from limited craniectomy, aggressive tract debridement, and watertight dural closure to one of decompressive craniectomy with limited debridement has resulted in improved outcomes is not supported.

Complications Related to Surgical Approach

The strategy of aggressive debridement, limited craniectomy, and watertight dural closure developed during WWI/WWII/Korea and perfected in Vietnam was hard

earned through the treatment of thousands of casualties. Beginning with Brandvold et al. in the 1980s,² a new strategy of minimal debridement was advanced that has influenced management in the Iraq and Afghanistan conflicts. Carey in 2003 cautioned against limited debridement strategies based on literature review, highlighting a profound increase in the need for further debridement, CSF leakage, and fatal meningitis in minimalist strategies compared to Vietnam data.³ Again referencing Hammon's series,⁶ the incidence of CSF fistula (0.63%) and meningitis (0.63%) were quite low. The only long-term outcome study performed to date on patients from the Iraq and Afghanistan conflicts that included these variables (Weisbrod et al.¹¹) reported a 10.2% rate of CSF leakage and a 29.9% rate of meningitis/ventriculitis. Whereas the surgical strategy used in the Iraq and Afghanistan conflicts has achieved excellent outcomes for many US service members as demonstrated by Larkin, it is sobering to consider the potential impact of higher rates of CSF leakage and meningitis on non-US casualties, who comprised the largest fraction of Larkin's study population (828 of 908 casualties) and on whom long-term follow-up could not be obtained. At the very least, strong consideration should be given to a strategy of aggressive tract debridement and watertight dural closure for non-US casualties who will probably remain in austere medical conditions by US standards.

Operational Considerations on the Treatment of Penetrating Brain Injuries

This is not to say that decompressive craniectomy has not played an important role in the Iraq and Afghanistan conflicts. It has played an essential role¹ based on the small medical footprint and limited in-theater holding system used during this conflict. In comparison to the 7.2 days patients with penetrating head injuries spent at evacuation hospitals in Vietnam, critically injured US casualties were typically evacuated from theater less than 24 hours after initial resuscitative surgery. Critical Care Air Transport Teams (CCATT) provided outstanding in-flight critical care to US casualties, albeit usually without direct neurosurgical oversight. Decompressive craniectomy allowed for safe transportation of casualties during this critical time period. The favored technique¹⁰ included "large craniectomies to prevent brain strangulation over bone edges, minimal brain debridement, adequate brainstem decompression, and dural onlay substitutes for dural closure." Preliminary data suggest that this technique has achieved good long-term outcomes for US soldiers fighting an insurgency with clear air superiority over the enemy, low casualty burden, with immediate critical care air transport out of the theater within 24 hours of injury. How the same strategy would perform in a conventional war absent air superiority and rapid casualty evacuation to the rear is an open question. In many circumstances, a single definitive operation capable of providing the highest likelihood of survival for an individual casualty is preferable. This is particularly true for a casualty who is unlikely to be rapidly evacuated from the battlefield. I would argue there are few data to suggest that the strategy used (by this author as well) during the heaviest casualty periods of the Iraq

and Afghanistan wars is preferable to methods developed during 20th-century conflicts in the absence of a plan for rapid evacuation from theater.

I applaud the continued efforts of my colleagues in uniform to continue to pursue outcome data on our experience in Iraq and Afghanistan. They face considerable challenges in assembling these data. I offer the above comments as a reminder of the words of George Santayana that those who cannot remember the past are condemned to repeat it.

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References

1. Bell RS, Mossop CM, Dirks MS, Stephens FL, Mulligan L, Ecker R, et al: Early decompressive craniectomy for severe penetrating and closed head injury during wartime. **Neurosurg Focus** 28(5):E1, 2010
2. Brandvold B, Levi L, Feinsod M, George ED: Penetrating craniocerebral injuries in the Israeli involvement in the Lebanese conflict, 1982–1985. **J Neurosurg** 72:15–21, 1990
3. Carey ME: The treatment of wartime brain wounds: traditional versus minimal debridement. **Surg Neurol** 60:112–119, 2003
4. Carey ME, Young HF, Rish BL, Mathis JL: Follow-up study of 103 American soldiers who sustained a brain wound in Vietnam. **J Neurosurg** 41:542–549, 1974
5. Cushing H: A study of a series of wounds involving the brain and its enveloping structures. **Br J Surg** 5:558–684, 1918
6. Hammon WM: Analysis of 2187 consecutive penetrating wounds of the brain from Vietnam. **J Neurosurg** 34:127–131, 1971
7. Larkin MB, Graves EKM, Boulter JH, Szuflita NS, Meyer RM, Porambo ME, et al: Two-year mortality and functional outcomes in combat-related penetrating brain injury: battlefield through rehabilitation. **Neurosurg Focus** 45(6):E4, 2018
8. Matson DD: **The Treatment of Acute Craniocerebral Injuries Due to Missiles**. Springfield, IL: Charles C Thomas, 1948, pp 83–85
9. Meierowsky AM: General considerations and preoperative measures, in Meierowsky AM (ed): **Neurological Surgery of Trauma**. Washington, DC: Office of the Surgeon General, Department of the Army, 1965, pp 67–74
10. Ragel BT, Klimo P Jr, Martin JE, Teff RJ, Bakken HE, Armonda RA: Wartime decompressive craniectomy: technique and lessons learned. **Neurosurg Focus** 28(5):E2, 2010
11. Weisbrod AB, Rodriguez C, Bell R, Neal C, Armonda R, Dorlac W, et al: Long-term outcomes of combat casualties sustaining penetrating traumatic brain injury. **J Trauma Acute Care Surg** 73:1525–1530, 2012
12. Wolfe SQ: Editorial. Developing systems of care: association of time to craniectomy with survival in patients with severe combat-related brain injuries. **Neurosurg Focus** 45(6):E3, 2018

Disclosures

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Response

We thank Dr. Jonathan Martin for his military service and for his comments regarding the most recent Military Neurosurgery edition of *Neurosurgical Focus*. We agree that there is a large body of historical neurosurgical literature relating to military neurotrauma and lessons learned. Readers should refer to the paper by Agarwalla et al. from the 2010 Military Neurosurgery edition of *Neurosurgical Focus* for additional military neurosurgery historical context.¹ Saying that nearly everything we do today as neurosurgeons is founded upon the principles developed by the giants who preceded us understates the value of their contributions. We are and remain humbled by their service and innovation.

As noted by Dr. Martin, comparing data between conflicts is difficult for a variety of reasons, but not without value. Dismissing specific lessons learned from prior experiences is certainly ill advised, but continuing surgical practices based solely on what was done before is probably worse. The following will provide agreement with balance to some of Dr. Martin's assertions, and where appropriate disagree based on available data.

The mortality in our selected cohort was 21% and accounted for all casualties who reached neurosurgical care. If those who died prior to evacuation to higher levels of care are excluded, the resultant mortality is 6%. This is less than the postevacuation mortality of 12% reported by Carey et al. and similar to the 5.8% by Weisbrod et al.^{6,14} In his editorial, Dr. Martin has succeeded in defining why comparing specific outcomes/survival data between military conflicts is of limited value, and why the conclusions drawn are often specious. The conclusions asserted by the studies Dr. Martin references must be viewed through the prism of immortal time bias, and the outcomes achieved are what you would expect if the patient survived to reach someone with neurosurgical expertise. In Cushing's series,⁷ the majority of casualties who survived to surgery were not received until more than 24 hours after injury. The increasing time from wounding to admission as the war progressed may have inadvertently improved the reported mortality. Meierowsky¹¹ and Hammon¹⁰ excluded KIA (killed in action) and 455 "expectant" casualties, respectively, in their results. Last, the 12% mortality, deemed atypical, from Carey et al. only included patients who were operated on and then evacuated, asserting that a "more selective triage would have eliminated these individuals from neurosurgical consideration."⁶

Given that neurosurgical technique, diagnostic and surgical technology, antibiotics, field resuscitation, pre- and postoperative critical care, transport methodologies, and personal protective gear have all advanced significantly with time (even from Carey's time in many respects), perhaps the only conclusion that can be drawn from an outcomes comparison between conflicts is that a higher proportion of patients in previous conflicts probably died before reaching neurosurgical care. A simple comparison of conflict casualty rates would allow a similar conclusion.

"Blast" injury proportions in recent conflicts may mirror prior campaigns, but they are not identical. Penetrating brain injuries in conflicts prior to the most recent (Op-

eration Iraqi Freedom and Operation Enduring Freedom) campaigns were mostly the result of fragmentation from smaller artillery munitions, which are different from penetrating brain injuries resulting from the blast injuries inflicted by currently used improvised explosive devices that cause significant multitrauma injuries from one or all of the mechanisms of blast injury.⁸ The severe edema and hyperemia seen in these injuries, in combination with the requirement for long evacuation distances, led military neurosurgeons to use a strategy of wide cranial decompression, CSF diversion, superficial debridement of necrotic tissue, and watertight scalp closure.^{3,4,8,14} Dr. Martin's comments elucidate this well, and we agree.

The continued debate over the need for aggressive debridement remains largely unfounded. Retained bone and metal fragments in the brain were previously implicated in posttraumatic seizures and abscess formation, which led to continued use of aggressive wound debridement during the Vietnam conflict.⁸ A retrospective review by Rish et al. demonstrated that only one-third of patients with abscesses had retained fragments, and analysis by the Vietnam Head Injury Study failed to show any statistically significant association.^{8,9,12} This was further supported by Brandvold et al., Taha et al., and Amirjamshidi et al. from data collected during the Israeli-Lebanese and Iran-Iraq conflicts, respectively.^{2,5,13} We maintain that the forward-deployed neurosurgeon should decompress, debride where appropriate, and avoid causing additional injury by aggressive debridement.

Although the data suggest that the outcomes in this conflict have been very good, and with overall survival higher than in any other conflict in history, there have been, as yet, no head-to-head trials comparing surgical techniques from previous conflicts with those commonly used today. There will never be. As previously stated and commensurate with the immortal time bias seen in previous studies, it is possible to assert that the patients who survived to reach a neurosurgeon and intervention in today's modern conflicts were more likely to survive than those who did not. This should not detract from the fact that techniques used in these conflicts maximized survival in the setting of long transport times where no neurosurgeon was available. It is therefore equally unjustified to imply that surgical techniques from previous conflicts had value outside of the populations they described. These historical studies are worth reviewing, honoring, and using as a means of advancing the current care with modern resources.

"History never repeats itself but it rhymes." – Mark Twain

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References

1. Agarwalla PK, Dunn GP, Laws ER: An historical context of

- modern principles in the management of intracranial injury from projectiles. **Neurosurg Focus** 28(5):E23, 2010
2. Amirjamshidi A, Abbassioun K, Rahmat H: Minimal debridement or simple wound closure as the only surgical treatment in war victims with low-velocity penetrating head injuries. Indications and management protocol based upon more than 8 years follow-up of 99 cases from Iran-Iraq conflict. **Surg Neurol** 60:105–111, 2003
  3. Bell RS, Mossop CM, Dirks MS, Stephens FL, Mulligan L, Ecker R, et al: Early decompressive craniectomy for severe penetrating and closed head injury during wartime. **Neurosurg Focus** 28(5):E1, 2010
  4. Bell RS, Vo AH, Neal CJ, Tigno J, Roberts R, Mossop C, et al: Military traumatic brain and spinal column injury: a 5-year study of the impact blast and other military grade weaponry on the central nervous system. **J Trauma** 66 (4 Suppl):S104–S111, 2009
  5. Brandvold B, Levi L, Feinsod M, George ED: Penetrating craniocerebral injuries in the Israeli involvement in the Lebanese conflict, 1982–1985. Analysis of a less aggressive surgical approach. **J Neurosurg** 72:15–21, 1990
  6. Carey ME, Young HF, Rish BL, Mathis JL: Follow-up study of 103 American soldiers who sustained a brain wound in Vietnam. **J Neurosurg** 41:542–549, 1974
  7. Cushing H: A study of a series of wounds involving the brain and its enveloping structures. **Br J Surg** 5:558–684, 1918
  8. Ecklund JM: The impact of military conflict in modern-day neurosurgical management. **World Neurosurg** 79:264–266, 2013
  9. George ED, Dagi TF: Military penetrating craniocerebral injuries. Applications to civilian triage and management. **Neurosurg Clin N Am** 6:753–759, 1995
  10. Hammon WM: Analysis of 2187 consecutive penetrating wounds of the brain from Vietnam. **J Neurosurg** 34:127–131, 1971
  11. Meierowsky AM: General considerations and preoperative measures, in Meierowsky AM (ed): **Neurological Surgery of Trauma**. Washington, DC: Office of the Surgeon General, Department of the Army, 1965, pp 67–74
  12. Rish BL, Caveness WF, Dillon JD, Kistler PJ, Mohr JP, Weiss GH: Analysis of brain abscess after penetrating craniocerebral injuries in Vietnam. **Neurosurgery** 9:535–541, 1981
  13. Taha JM, Saba MI, Brown JA: Missile injuries to the brain treated by simple wound closure: results of a protocol during the Lebanese conflict. **Neurosurgery** 29:380–384, 1991
  14. Weisbrod AB, Rodriguez C, Bell R, Neal C, Armonda R, Dorlac W, et al: Long-term outcomes of combat casualties sustaining penetrating traumatic brain injury. **J Trauma Acute Care Surg** 73:1525–1530, 2012

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