

JOINT TRAUMA SYSTEM CLINICAL PRACTICE GUIDELINE (JTS CPG)



Neurosurgery and Severe Head Injury (CPG ID:30)

Provides guidelines and recommendations for the treatment and medical management of casualties with moderate to severe head injuries in an environment where personnel, resources and follow-on care may be limited.

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TABLE OF CONTENTS

Purpose.....	2
Background.....	2
Trends	2
Classification	2
Eligibility for Neurosurgical Care of Role 3 Facilities	2
Coalition	3
Host Nationals.....	3
Early Evaluation and Treatment.....	3
Transporting Patient.....	4
Sedation	4
Intracranial Hypertension	4
Antiepileptic Medications	5
Other Precautions	5
Aeromedical Evacuation Considerations.....	5
Intracranial Pressure	5
Drains	6
Pneumocephallus.....	6
Risk of Venous Thrombosis	6
Surgical Management of Moderate to Severe Head Injuries	6
Intracranial Pressure Monitoring	6
Operative Care: Evacuation of Hematoma	7
Subdural Hematoma	7
Performance Improvement Monitoring.....	9
Population of Interest	9
Intent (Expected Outcomes)	9
Performance/Adherence Metrics	9
Data Source.....	10
System Reporting & Frequency.....	10
Responsibilities	10
References.....	10
Appendix A: General Indications	13
Appendix B: 3% Saline Protocol.....	16
Appendix C: Additional Information Regarding Off-Label Uses in CPGs.....	17

PURPOSE

These guidelines are not intended to supplant physician judgment. Rather, these guidelines are intended to provide a basic framework for those less experienced with the delivery of care in this setting to the brain injured patient, as well as to educate and provide insight to others on the delivery of care in a restrictive environment.

BACKGROUND

TRENDS

Significant head trauma presents as a complicating injury in at least a third of all trauma related deaths in the United States.¹ In the combat environment, multiple trends have been observed in the management of traumatic brain injury (TBI) since 2003, warranting the standardization of care for these casualties.

- Positive outcomes are achieved through rapid evacuation from the battlefield, far forward medical management, timely neurosurgical intervention, meticulous critical care, and a dedicated rehabilitative effort.²⁻⁷
- In recent U.S. military experience, a large percentage of patients who have presented with severe head injury are Host Nationals.
- There is a sizable body of foundational literature from military trauma centers confirming that patients with severe closed and penetrating brain injuries who received timely and aggressive neurosurgical and neuro-critical care interventions had favorable outcomes.²⁻⁴
- Following Role 3 theater hospital treatment, transfer of the patient will occur to a hospital serving patients of their national origin. Experience has demonstrated that often patients who fail to quickly recover to independent or minimally assisted living have typically not been treated aggressively thereafter by some national healthcare systems. Decisions made for the care of these patients are to be made in light of the available continuum of care for the patient in their nation of origin.

CLASSIFICATION

The classification of head injury has prognostic and care eligibility implications in the combat environment. Head injured patients are classified according to their Glasgow Coma Score (GCS).

- Mild: GCS 13-15
- Moderate: GCS 9-12
- Severe: GCS 3-8

Currently, neurosurgical care is available at Role 3 facilities.

ELIGIBILITY FOR NEUROSURGICAL CARE OF ROLE 3 FACILITIES

Given the restrictive nature of neurosurgical resources in the combat environment, the following guidance is provided for determining eligibility for neurosurgical care. A subsequent independent study confirmed the validity of the previously observed favorable outcomes by comparing combat casualties with isolated severe brain injuries to matched civilian counterparts.⁴

COALITION

- Coalition forces with **mild head injuries** that do not clear within 24 hours may require transfer for formal evaluation by Computed Tomography (CT) and/or a neurosurgeon.
- All Coalition casualties with any **penetrating head injury, open skull fracture, or moderate or severe head injury** should be referred for neurosurgical evaluation.
- Patients with head trauma and unexplained neurologic deficits should be referred for neurosurgical evaluation.

HOST NATIONALS

- Management of host nationals should be in accordance with medical rules of eligibility established for that AOR.
- Host National patients with **mild head injury** should be managed locally and should not be transferred to Role 3 facilities unless transfer is first discussed and coordinated with the receiving neurosurgeon or Chief of Trauma.
- **Moderate head injury** may be referred to Role 3 facilities with neurosurgical capability for definitive care.
- Transfer of Host Nationals with a **severe head injury** is based on mission, tactical situation, and resource availability and must be preceded by direct communication and discussion with the neurosurgeon, as these casualties may need to be managed expectantly.

EARLY EVALUATION AND TREATMENT

The initial management of the patient with significant head trauma begins with addressing life-threatening injuries and resuscitation in accordance with published Advanced Trauma Life Support (ATLS) protocols.⁸

- **Blood products** are preferred over albumin or Hespan if colloids are needed.⁹
- For those **patients not requiring massive transfusion protocol or other blood products**, normal saline is the preferred crystalloid solution, avoiding hypotonic fluids.
- **Normoventilation** with a goal PaCO₂ of 35-40 mmHg should be maintained.
- **Prophylactic hyperventilation** is not recommended, but may be used as a temporizing measure to reduce intracranial pressure in the setting of suspected herniation.¹⁰
- Routine prophylactic antibiotics are unnecessary for isolated closed head injuries, but penetrating injuries, open skull fractures, or pre-operative patients should be placed on antibiotics.¹¹ **Antibiotic recommendations** for the first level of surgical care include use of either cefazolin 2 gm IV every 6-8 hours or clindamycin 600 mg IV every 8 hours. If a penetrating head injury appears grossly contaminated with organic debris, consider addition of metronidazole 500 mg IV every 8-12 hours.¹¹
- **Monitor glucose** every 6 hours. Goal is to maintain glucose < 180 mg/dl but avoid hypoglycemia.¹²
- **Steroids** should be **avoided** in head injured patients as they have not shown outcome benefit and increase mortality in patients with severe head injury.^{10,13}

- **Manage hypotension** maintaining SBP at ≥ 110 mm Hg in patients with suspected TBI's to decrease mortality and improve outcomes.¹⁴ A systolic blood pressure of less than 90mm Hg is the single risk factor most highly associated with mortality in brain trauma.¹⁵
- A common strategy for **management of hypoxemia** has been goal of SaO₂ >90% and PaO₂ >60 mmHg.¹⁰ However, in the recent combat experience, given frequent handoffs, equipment challenges, varying levels of provider experience, etc., SaO₂ and PaO₂ have been managed with goals of >93-95 and >80, respectively.
- Document **serial neurological exam** findings, including:
 - **Glasgow Coma Score**
 - **Pupil size and reactivity**
 - Presence of **gross focal neurologic signs and/or deficit**.

TRANSPORTING PATIENT

Due to the requirement to move the coalition patient with severe head trauma to Role 4 facilities usually out of theater, early and safe transport of these patients should involve consideration of several factors.

SEDATION

For casualties transferring to Role 3 facilities with neurosurgical capability, avoid long-lasting sedation or paralysis. However, at no time should medication selection override the need to safely transport the casualty.

- **Vecuronium is preferred for paralysis** because it is readily available in the far forward environment and does not require refrigeration. Bolus dosing is preferred over continuous infusion.
- **Propofol is preferred for sedation.**¹⁰
- Pain management with **intermittent narcotics is preferred over continuous infusion**.

INTRACRANIAL HYPERTENSION

Despite recent controversy in terms of placement of invasive monitors to measure intracranial pressure, treatment of known or suspected intracranial hypertension remains a cornerstone of therapy in patients with severe brain injury.¹⁶

If treatment for intracranial hypertension is needed prior to transfer, then initiate hyperosmotic therapy with one of the following:

1. **3% Saline**¹⁷ ([Appendix B](#))
 - a. Consider 250ml bolus of 3% saline and then infuse 3% saline at 50-100ml/hr for resuscitation Enroute to the Role 3 facility.
 - b. Goal serum Na level is 150-160. Caution is advised if patient presents in a hyponatremic state.
 - c. Place central venous access to administer hypertonic saline and vasoactive medications particularly if it is anticipated to be needed long term.

2. **Mannitol.** Consider using mannitol if there is further deterioration in neurological status or as an alternative to 3% NaCl.
 - a. Mannitol 1g/kg bolus IV followed by 0.25g/kg IV push q4 hrs.¹⁰
 - b. In the trauma population, replace brisk urine output following mannitol administration with isotonic fluids.
 - c. Avoid mannitol in hypotensive or under-resuscitated casualties
 - d. When treating patients with osmotic agents, monitor serum sodium on a frequent basis.

ANTIEPILEPTIC MEDICATIONS

- Seizures are not uncommon after severe brain trauma. **Anticonvulsant prophylaxis** should be administered to avoid the hemodynamic changes and increased cerebral metabolic activity associated with seizure activity.
- Give antiepileptic medication for **seizure prophylaxis** for the first 7 days after a moderate or severe TBI.¹⁰ Reasonable options include phenytoin, fosphenytoin, or levetiracetam.¹⁸ ([Appendix A](#))

OTHER PRECAUTIONS

1. Avoid and treat **hyperthermia**
2. Elevate head of bed to 30-45° or use reverse Trendelenburg position for suspected concomitant **spine/spinal cord injuries**.
3. **Gastric ulcer prevention** should be provided.
4. Consider **enteral nutrition** according to *Nutritional Support Using Enteral and Parenteral Methods*.¹⁹

AEROMEDICAL EVACUATION CONSIDERATIONS

INTRACRANIAL PRESSURE

1. Observation in theater may be warranted for **patients with borderline ICP measurements due to stresses of flight** including vibration, temperature, noise, movement, light, hypoxia, and altitude.²⁰
2. **ICP monitoring** is recommended during aeromedical evacuation for patients who would meet the requirements as stated above.
3. **Do not remove a functional ICP monitor** in the immediate period prior to aeromedical evacuation. This provides information to the CCAT team that can direct in flight treatment. Furthermore, it offers a level of safety in terms of stable ICP in patients who may otherwise require sedation or not have a reliable neurological exam.
4. In addition, patients who have ongoing resuscitative requirements and an intracranial lesion or the potential for development of cerebral edema may require **delayed evacuation**. For example, this is seen with patients who have significant burns requiring resuscitation by the JTS Burn CPG²¹ and have an intracranial mass lesion or cerebral edema.

DRAINS

Do not remove drains in the immediate period prior to aeromedical evacuation.

PNEUMOCEPHALLUS

- The effect of increasing altitude on contained air within the body, including the cranium, will potentially result in expansion of the pneumocephalus. This factor should be considered carefully by the treating neurosurgeon and coordinated with CCATT to discuss the potential risk; this is particularly true for those who have not undergone a decompressive craniectomy prior to the flight.
- All patients should be transported with head of bed elevation or reverse Trendelenberg at 30-45°. Typically USAF doctrine is to load all patient's feet first into the aircraft.²² In a patient with TBI, the aeromedical transport physician may consider loading head first, to maintain head elevation.

RISK OF VENOUS THROMBOSIS

- Starting DVT chemoprophylaxis on a US/Coalition patient with a moderate to severe head injury should be done in consultation with the theater neurosurgeon.
- Patients with moderate or severe head injury require routine DVT prophylaxis (i.e. sequential compression device).
- Enoxaparin 30mg sq BID or SQ heparin may be used as chemoprophylaxis providing patient does not have potential hemorrhagic issues.^{10,23,24}

SURGICAL MANAGEMENT OF MODERATE TO SEVERE HEAD INJURIES

Non-operative management of intracranial hematomas should be followed with serial imaging and clinical examinations.

Surgical intervention is often indicated in the management of patients with severe brain trauma. This includes operative care such as evacuation of space-occupying hematomas via craniectomy or craniotomy, as well as placement of intracranial monitors.

INTRACRANIAL PRESSURE MONITORING

1. Management of severe TBI patients using information from ICP monitoring is recommended to reduce in-hospital and two-week post-injury mortality.¹⁴
2. Intracranial pressure (ICP) monitoring should be considered in all salvageable patients with a severe brain injury and an abnormal CT showing one or more of the following: Hematomas, contusions, swelling, herniation, or compressed basal cisterns.¹⁰
3. ICP monitoring is indicated in patients with severe TBI and a normal CT if 2 or more of the following are noted: Age >40, unilateral or bilateral posturing, systolic blood pressure <90 mm Hg.¹⁰
4. Options for ICP monitoring.¹⁰
 - External Ventricular Drain

- Parenchymal ICP monitors. Currently Codman ICP monitors are the only device with aeromedical certification approved for USAF aircraft.
5. Goal ICP is <22 mmHg.¹⁰
 6. Target Cerebral Perfusion Pressure (CPP) for survival and favorable outcomes is between 60-70 mm Hg. Whether 60 or 70 mmHg is the minimum optimal CPP is unclear and may depend on the auto regulator status of the patient.¹⁴

OPERATIVE CARE: EVACUATION OF HEMATOMA

Epidural Hematoma²⁵

1. All epidural hematomas > 30cc should be surgically evacuated regardless of the patients GCS
2. EDH <30cc and with less than 15mm thickness and less than 5 mm midline shift with a GCS >8 without a focal deficit may be managed non-operatively with appropriate monitoring in the ICU setting.

Subdural Hematoma²⁵

1. Craniotomy for evacuation of an acute SDH with a thickness >10mm or midline shift > 5mm regardless of the patient's GCS. Give consideration for expectant management with Host Nationals who present with a GCS of <8.
2. Craniotomy for evacuation of acute SDH with a thickness <10mm and shift <5 mm if there is a decrease in GCS of 2 or more, worsening pupillary exam, and/or and ICP greater than 20mm Hg.

Traumatic Parenchymal Lesion²⁵

1. Craniotomy with evacuation of a hematoma in a patient with a GCS of 6-8 with frontal or temporal contusions greater than 20 cc in volume with midline shift or at least 5mm and/or cisternal compression on CT
2. Patients with lesions greater than 50 cc in volume in a salvageable patient.

Posterior Fossa Mass Lesion²⁵

Mass effect on non-contrast CT or with neurological dysfunction or deterioration referable to the lesion should undergo operative intervention as soon as possible.

Exploratory Burr Holes

Exploratory burr holes have limited practical utility. They should only be performed after consultation with a neurosurgeon if possible and at a location where CT scan is not available to better guide management.

1. Indications for consideration of burr holes²⁶
 - a. No immediate neurosurgical capabilities
 - b. No CT scan available
 - c. Deteriorating neurological exam that can be localized
 - d. Unilateral pupillary changes

Traumatic Aneurysms

High index of suspicion is required for penetrating injuries at the skull base or across known major vascular territories.⁷

Debridement

Removal of devitalized brain tissue is an option in penetrating head injuries and in select cases of open skull fractures.²⁶

Foreign Body Removal

The routine pursuit of individual foreign bodies (e.g. bullets, metallic fragments, bone) within the brain is not advisable, but should be left to the discretion of the neurosurgeon. Removal of fragments from the sensory, motor, or language cortex may reduce the risk of posttraumatic epilepsy.²⁷

Dural Management

Primary dural closure or limited duroplasty should be done cautiously at initial operation as ongoing edema progresses after penetrating or severe blunt trauma. Dura can be reconstructed with temporalis fascia or fascia lata.²⁶

Decompression

Surgical decompression, or craniectomy, should be strongly considered following penetrating combat brain trauma.^{3, 28, 29}

- The kinematics of combat trauma can be very different from that seen in the civilian setting. The muzzle velocities of military rifles are much higher than civilian hand guns which may lead to cavitation and surrounding devitalized tissue. Additionally, blasts can create four to five different classes of injury to the brain and other organ systems complicating management.³⁰
 - Primary Blast Injury- Blast overpressure from pressure waves.
 - Secondary Blast Injury- Penetrating fragmentation injuries.
 - Tertiary Blast Injury- Displacement of the casualty or debris that falls on the casualty from the blast.
 - Quaternary Blast Injury- Injury from the thermal effect or release of toxins from the blast.
 - Quinary Blast Injury- Hyperinflammatory state after blast trauma.
- Patients will require aeromedical evacuation within and out of theater. During transportation, significant intervention for intracranial hypertension is limited. Consider pre-transport decompressive techniques and Enroute monitoring devices to address these operational needs.

NOTE: Craniectomy also facilitates early Critical Care Air Transport Team (CCATT) transport of patients out of theater.

Skull Flap Management

For US and Coalition forces:

1. Those who have **penetrating brain trauma**: Do not save or send the calvarium as alloplastic reconstruction techniques are used for these casualties.

2. Those who have **blunt trauma**: Consider abdominal subcutaneous implantation of the calvarial flap for later reconstruction if it can be done in a sterile fashion.

For Host Nationals:

1. Clean and replace.
2. Clean and replace with hinge craniectomy. This involves partial fixation of the superior aspect of the bone flap, allowing it to “hinge” outward to accommodate swelling.³¹
3. Craniectomy with potentially limited chances for cranioplasty in the future, depending on local rules of eligibility.

ICP Monitoring and Surgical Intervention

ICP monitoring and/or surgical intervention is not advised for those patients with a GCS 3-5 and evidence of CT scan findings and history suggestive of diffuse anoxic injury if long term continuing care and rehabilitative capabilities are not available in the nation of origin.

PERFORMANCE IMPROVEMENT MONITORING

POPULATION OF INTEREST

1. All patients with a diagnosis of traumatic brain injury and an initial GCS of 3-8.
2. All patients who receive a cranial procedure (ICP monitor, craniectomy, craniotomy).

INTENT (EXPECTED OUTCOMES)

1. All patients in population of interest avoid hypotension and hypoxia: SBP never < 100 mmHg, MAP never < 60, SaO₂ never < 93%.
2. All patients in population of interest have PaCO₂ monitored at every role of care.
3. All patients in population of interest have a head CT performed within 4 hours of injury.
4. All patients with a ventriculostomy have hourly documentation of ICP/ CPP and ventriculostomy output.
5. Patients in population of interest unable to be monitored clinically (e.g., unable to hold sedation for Q1 hour neuro exam) have an ICP monitor or ventriculostomy placed prior to transport out of theater.

PERFORMANCE/ADHERENCE METRICS

1. Number and percentage of patients in the population of interest with lowest SBP<100 within first 3 days after injury.
2. Number and percentage of patients in the population of interest with MAP<60 within first 3 days after injury.
3. Number and percentage of patients in the population of interest with SaO₂<93% within first 3 days after injury.

4. Number and percentage of patients in population of interest who have PaCO₂ documented at every role of care (POI, POI MEDEVAC, ROLE 2-4, interfacility MEDEVAC).
5. Number and percentage of patients in the population of interest who maintain PaCO₂=35-40
6. Number and percentage of patients who had a head CT performed within 4 hours of injury.
7. Number and percentage of patients with a ventriculostomy who had hourly documentation of ICP/ CPP and ventriculostomy output.
8. Number and percentage of patients in the population of interest unable to be monitored clinically (eg. unable to hold sedation for Q1 hour neuro exam) who have an ICP monitor or ventriculostomy placed prior to transport out of theater.

DATA SOURCE

- Patient Record
- Department of Defense Trauma Registry (DoDTR)
- ICU flow sheet
- Neurologic assessment flow sheet

SYSTEM REPORTING & FREQUENCY

The above constitutes the minimum criteria for PI monitoring of this CPG. System reporting will be performed annually; additional PI monitoring and system reporting may be performed as needed.

The system review and data analysis will be performed by the Joint Trauma System (JTS) Director and the JTS Performance Improvement Branch.

RESPONSIBILITIES

It is the trauma team leader's responsibility to ensure familiarity, appropriate compliance and PI monitoring at the local level with this CPG.

REFERENCES

1. National Vital Statistics System (NVSS), 2006–2010. CDC National Center for Health Statistics. https://www.cdc.gov/nchs/nvss/about_nvss.htm Nov 15, 2016.
2. Bell RS, Vo AH, Neal CJ, 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. 2009;66(4 suppl):S104-S111.
3. Bell RS, Mossop CM, Dirks MS, et al. Early decompressive craniectomy for severe penetrating and closed head injury during wartime. Neurosurg Focus. 2010;28:E1.
4. Dubose J, Bamparas G, Inaba K, Stein DM, Scalea T, Cancio LC, Cole J, Eastridge B, Blackbourne L. Isolated severe traumatic brain injuries sustained during combat operations: demographics, mortality outcomes, and lessons to be learned from contrasts to civilian counterparts. J Trauma. 2011;70(1):11-16.

5. Weisbrod A, Rodriguez C, Bell R, et al. Long-term outcomes of combat casualties sustaining penetrating traumatic brain injury. *J Trauma Acute Care Surg.* 2012;73(6):1525-1530.
6. Nakase-Richardson R, McNamee S, Howe LL, Massengale J, Peterson M, Barnett SD, Harris O, McCarthy M, Tran J, Scott S, Cifu DX. Descriptive Characteristics and Rehabilitation Outcomes in Active Duty Military Personnel and Veterans with Disorders of Consciousness with Combat and Non-Combat Related Brain Injury. *Arch Phys Med Rehabil.* 2013;94(10):1861-1869.
7. Bell R, Vo AH, Roberts R, Wanebo J, Armonda RA. Wartime traumatic aneurysms: acute presentation, diagnosis, and multimodal treatment of 64 craniocervical arterial injuries. *Neurosurgery.* 2010;66(1):66-79.
8. Chapple W, Al-khatib J, Haskin D, et al. *Advanced Trauma Life Support Manual, Ed. 9, Chicago, American College of Surgeons, 2012.*
9. Cooper D, Myburgh J, Heritier S, Finfer S, Bellomo R, Billot L, Murray L, Vallance S; SAFE-TBI Investigators; Australian and New Zealand Intensive Care Society Clinical Trials Group. Albumin resuscitation for traumatic brain injury: is intracranial hypertension the cause of increased mortality? *J Neurotrauma.* 2013;30(7):512-518.
10. Bratton SL, Chestnut RM, Ghajar J, et al. Guidelines for the management of severe traumatic brain injury. *J Neurotrauma.* 2007;24(supl 1):S1-S106.
11. Joint Trauma System, Infection Prevention in Combat Related Injuries CPG, 08 Aug 2016. https://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs Accessed Mar 2018.
12. Finfer S, Chittock DR, Su SY, Blair D, Foster D, Dhingra V, Bellomo R, Cook D, Dodek P, Henderson WR, Hébert PC, Heritier S, Heyland DK, McArthur C, McDonald E, Mitchell I, Myburgh JA, Norton R, Potter J, Robinson BG, Ronco JJ. Intensive versus conventional glucose control in critically ill patients. *N Engl J Med.* 2009;360(13):1283-1297.
13. Edwards P, Arango M, Balica L, Cottingham R, El-Sayed H, Farrell B, Fernandes J, Gogichaisvili T, Golden N, Hartzenberg B, Husain M, Ulloa MI, Jerbi Z, Khamis H, Komolafe E, Laloë V, Lomas G, Ludwig S, Mazairac G, Muñoz Sánchez Mde L, Nasi L, Ollidashi F, Plunkett P, Roberts I, Sandercock P, Shakur H, Soler C, Stocker R, Svoboda P, Trenkler S, Venkataramana NK, Wasserberg J, Yates D, Yutthakasemsunt S; CRASH trial collaborators. Final results of MRC CRASH, a randomised placebo-controlled trial of intravenous corticosteroid in adults with head injury-outcomes at 6 months. *Lancet.* 2005;365(9475):1957-1959.
14. Carney N, Totten A, O'Reilly C, Ullman J, Hawryluk G, Bell M, Bratton S, Chesnut R, Harris O, Kisson N, Rubiano A, Shutter L, Tasker R, Vavilala M, Wilberger J, Wright D, Ghajar J. *Guidelines for the Management of Severe Traumatic Brain Injury, Fourth Edition. Neurosurgery 0: 2016. 1-10.*
15. Schreiber MA, Aoki N, Scott BG, et al. Determinants of mortality in patients with severe blunt head injury. *Arch Surg.* 2002;137:285-290.
16. Chesnut R, Temkin N, Carney N, Dikmen S, Rondina C, Videtta W, Petroni G, Lujan S, Pridgeon J, Barber J, Machamer J, Chaddock K, Celix JM, Cherner M, Hendrix T. A Trial of Intracranial-Pressure Monitoring in Traumatic Brain Injury. *N Engl J Med.* 2012;367(26):2471-2481.
17. Qureshi A, Suarez JJ. Use of hypertonic saline solutions in treatment of cerebral edema and intracranial hypertension. *Crit Care Med.* 2000;28(9):3301-3313.
18. Szaflarski JP, Sangha KS, Lindsell CJ, Shutter LA. Prospective, randomized, single-blinded comparative trial of intravenous levetiracetam versus phenytoin for seizure prophylaxis. *Neurocrit Care.* 2010;12(2):165-172.

19. Joint Trauma System, Nutritional Support Using Enteral and Parenteral Methods CPG, 04 Aug 2016. https://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs Accessed Mar 2018.
20. Goodman M, Makley AT, Lentsch AB, Barnes SL, Dorlac GR, Dorlac WC, Johannigman JA, Pritts TA. Traumatic brain injury and aeromedical evacuation: when is the brain fit to fly? *J Surg Res.* 2009;164(2):286-293.
21. Joint Trauma System, Burn Care CPG, 11 May 2016. https://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs Accessed Mar 2018.
22. Johannigman J, Zonies D, Dubose J, Blakeman TC, Hanseman D, Branson RD. Reducing secondary insults in traumatic brain injury. *Military Medicine.* 2015;18D(3 Suppl).
23. Latronico N, Berardino, M. Thromboembolic prophylaxis in head trauma and multiple-trauma patients. *Minerva Anesthesiol.* 2008;74(10):543-548.
24. Meyer R, Larkin M, Szufliata N, Neal C, Tomlin J, Armonda R, Bailey J, Bell R. Early venous thromboembolism chemoprophylaxis in combat-related penetrating brain injury. *Journal of Neurosurgery.* Published online June 17, 2016.
25. Brain Trauma Foundation. Guidelines for the Surgical Management of Traumatic Brain Injury, 4th Ed, Sept 2016. <https://braintrauma.org/guidelines/guidelines-for-the-management-of-severe-tbi-4th-ed#/> Mar 02 2017.
26. Giannou C, Baldan M, Molde A: Chapter 26: Cranio-cerebral Injuries. *War Surgery: Working with limited resources in armed conflict and other situation of violence, Vol. 2, Geneva, Switzerland, 2013.*
27. Salazar A, Jabbari B, Vance SC, Grafman J, Amin D, Dillon JD. Epilepsy after penetrating head injury. Clinical correlates: a report of the Vietnam Head Injury Study. *Neurology.* 1985;35(10):1406-1414.
28. Ecker R, Mulligan LP, Dirks M, Bell RS, Severson MA, Howard RS, Armonda RA. Outcomes of 33 patients from the wars in Iraq and Afghanistan undergoing bilateral or bicompartamental craniectomy. *J Neurosurg.* 2011;115(1):124-129.
29. Ragel B, Klimo P Jr, Martin JE, Teff RJ, Bakken HE, Armonda RA. Wartime decompressive craniectomy; technique and lessons learned. *Neurosurg Focus.* 2010;28(5):E2.
30. Wolf SJ, Bebartha VS, Bonnett CJ, Pons PT, Cantrill SV. Blast Injuries. *Lancet.* 2009; 374(9687):405-15.
31. Schmidt JH 3rd, Reyes BJ, Fischer R, Flaherty SK. *J Neurosurg.* 2007; 107(3):678-82.

APPENDIX A: GENERAL INDICATIONS

MONITORING & LABS	GENERAL INDICATIONS*
INTRACRANIAL PRESSURE (ICP)	Glasgow Coma Score of 3-8 with an abnormal CT scan (hematomas, contusions, edema, or compressed basal cisterns) or 2 or more of the following adverse features are present in a patient with severe head injury and a normal head CT scan: (Age > 40 years, Unilateral or bilateral motor posturing, systolic blood pressure, < 90 mmHg).
ARTERIAL LINE	Any head trauma that requires tracheal intubation and/or for other medical indications.
CENTRAL VENOUS PRESSURE	When ICP or CPP management requires anything beyond simple measures and/or for other medical indications. Trendelenburg position will raise ICP. Line site of choice is SCV.
EXHALED CO2	Desirable when active measures are required to control ICP. Correlate to PaCO ₂ initially/periodically.
NEUROIMAGING	Non-contrast head CT upon admission then within 24 hours after admission (or earlier to document stability of the bleed). Additional scans obtained as indicated (e.g. clinical deterioration).
LABS	ABG, CBC, Chem 10, TEG, PT, PTT, and INR at least q8 hrs during the acute phase.
GENERAL MANAGEMENT PRINCIPLES*	
PHILOSOPHY	<ul style="list-style-type: none"> ▪ Maintain continuous communication between the care teams. ▪ Maintain the patient in a “hyperosmolar-but-euvolemic” state with adequate oxygen carrying capacity and a constant substrate delivery via adequate cerebral perfusion pressure (CPP) of >60mm Hg. ▪ Aggressively avoid hypotension, hypoxemia, fever (>99 F), hyponatremia and other CNS insults. ▪ The longer the ICP is elevated (> 20), and the MAP & CPP are low (< 60), the worse the outcome! ▪ Brain injury is heterogeneous amongst patients and the process is dynamic: Treatment and management goals must be tailored accordingly
RESUSCITATION FLUID	Normal or 3% saline.
MAINTENANCE FLUID	Normal saline
SEDATION	Propofol 1 st choice up to 72h. Other short-acting agents (Fentanyl, Versed) upon discretion of SICU or neurosurgical staff. Typical ICU Propofol sedation dose range: 20-75 mcg/kg/min
ULCER PROPHYLAXIS	All patients.
DVT PROPHYLAXIS	Recognize high DVT risk in traumatic brain injury patients. Intracranial neurosurgical procedures: Sequential Compression Device (SCD) with or without Graduated Compression Stocking (GCS); High Risk neurosurgery patients: SCD and/or GCS; OK to use Lovenox following stable CT scan in consultation with neurosurgeon.
SEIZURE PROPHYLAXIS	<ul style="list-style-type: none"> ▪ Prophylactic anti-epileptic treatment is optional and is maintained for 7 days if no seizure activity is documented. Phenytoin, fosphenytoin and levetiracetam may all be used as seizure prophylaxis. ▪ Treat acute seizure with Lorazepam 1-2 mg IV or Midazolam 5-10 mg IV followed by loading dose of Phenytoin 20 mg/kg infused at <50 mg/min or Fosphenytoin 20 PE (Phenytoin equivalent)/kg infused at <150 PE/min. The daily dose thereafter is 300 mg Phenytoin or 300 PE Fosphenytoin q HS or may be divided TID. ▪ Keppra (Levetiracetam) can be considered in lieu of Phenytoin with 20 mg/kg loading dose followed by 500 mg IV BID.
ANTIBIOTICS	If using antibiotic impregnated ventriculostomy, then no IV prophylactic antibiotics required. Otherwise, Ancef 1 gm IV TID while ventriculostomy in place only (neurosurgeons’ discretion). For all penetrating head trauma, use cefazolin (see 3, a. 6) above.
NURSING	Hourly neurologic assessments. Document ICP/ CPP and ventriculostomy output. Notify physician of all pertinent changes.

STEROIDS	Steroids are not recommended for head or spine trauma and should not be used.		
NUTRITION	Enteral feeding should be begun as soon as it is safe to do so. Avoid agitation/ ICP during nasal or oral tube placement. Full enteral nutritional goal ≤ 7 days.		
GENERAL MANAGEMENT GOALS (Goals may be individualized / altered by faculty according to specific patient requirements)*			
NEUROLOGIC	ICP	< 22 mm Hg	See page 7.
	CPP	> 60 mm Hg	
HEMODYNAMIC	Mean BP	Maintain to avoid ∇ BP	<ul style="list-style-type: none"> ▪ Hypotension (SBP < 90mmHg) worsens mortality ▪ Provide a rapid physiologic resuscitation
	CVP	> 5 mm Hg	
PULMONARY	SpO ₂ %	> 93%	Aggressive avoidance of hypoxemia
	PaCO ₂	35 – 40 mmHg in first 24 hrs/	Avoid routine hyperventilation
HEMATOLOGIC	INR	≤ 1.3	Fresh frozen plasma
	Platelets	$\geq 100,000/\text{mm}^3$	Platelets
	TEG	Normalized values	As indicated by results
METABOLIC	Glucose	> 80 < 150 mg/dl	Have low threshold for insulin drip
RENAL	Serum Osmolarity	> 280 & < 320 mOsm	See Sodium Disorders, the bottom table in this general table.
	Serum Sodium	> 138 & < 165 meq/L	
INTRACRANIAL PRESSURE MANAGEMENT*			
GENERAL MEASURES	Head in midline position, avoidance of tight cervical collars and tight circumferential ETT ties; elevate the head of the bed to 30 degrees. (Consider reverse Trendelenburg)		
SEDATION	Propofol 1 st choice up to 72°. Other short-acting agents (Fentanyl, Versed) upon discretion of SICU or neurosurgical staff. Typical ICU Propofol sedation dose range: 20-75 mcg/kg/min.		
TEMPERATURE	Aggressive temperature management. Consider cooling measures (Tylenol, cooling blanket) even for modest temperature elevations (>98.6° F).		
INTRACRANIAL DYNAMICS	<ul style="list-style-type: none"> ▪ Treat sustained ICP elevations >22 ▪ Always consider an expanding mass lesion with ICP elevations refractory to therapy. 		
TREATMENT PARADIGM FOR THE TRAUMATIC BRAIN INJURY PATIENT*			
TITRATE TO EFFECT Goal of ICP < 20	Ensure sedation and analgesia are adequate	Titrate lowest possible dose to achieve desired RASS score and/or BIS 60-80. Avoid routine over sedation.	
	Initiate CSF drainage via ventriculostomy	Consider ventriculostomy drainage to control ICP to < 20 mm Hg	
	Initiate osmotic therapy Hold if [Na ⁺] is >159 and/or the S _{osm} is >329	<p><u>Hypertonic Saline (3%)</u>: Bolus therapy is 100-250 ml over 10 min and/or infusion rates range between 25-100 ml/hr. (See Appendix B). As optional or adjunctive therapy consider <u>Mannitol</u>: 0.25–1 gm/kg over < 20 minutes then 0.25 gm/kg q 6 h.</p> <p>23.4% HTS (Bolus 30 mL IV administered over 10-15 min) may also be considered as an alternative to Mannitol if available¹¹.</p>	
	Initiate paralysis	Vecuronium: 10 mg IVP or 0.1 mg/kg. Cisatracurium (if available): Loading dose 0.2 mg/kg/Maintain infusion rates: 1-3 mcg/kg/min	
	Titrate EtCO ₂	PaCO ₂ ≥ 35	
CEREBRAL PERFUSION PRESSURE MANAGEMENT (CPP = MAP – ICP)*			
	1. Ensure euvoemia	Utilize endpoints of resuscitation (exam, vitals, Art. Line, CVP, PAC)	

CPP GOAL >60 mm Hg	Control the ICP First line: 3% saline; Second line: Mannitol or 23.4% HTS. Do Not use Mannitol in hypovolemic patients.	
	2. Consider vasoactive drugs	Consider patient physiology. Vasopressin is agent of choice, followed by Phenlepherine or Norepinephrine.

ACUTE CLINICAL DETERIORATION
 (e.g., Acute mental status change, blown pupil or other obvious signs of cerebral herniation, new focal neurological symptoms, progressive and refractory ICP elevation)*

1. Verify oxygenation and ventilation 2. Hyperventilate (PaCO2 30-35 mmHg) to temporize only 3. Re-dose osmotic agent 4. Call Neurosurgery 5. Arrange for emergent CT scan	UNCAL HERNIATION SYNDROME <ul style="list-style-type: none"> ▪ Unilaterally dilating pupil ▪ Progression to fixed and dilated ▪ Progressive impairment of consciousness → comatose ▪ Contralateral Babinski → contralateral weakness → bilateral decerebrate rigidity
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GLASGOW COMA SCORE	EYE OPENING	BEST VERBAL EFFORT	BEST MOTOR EFFORT
1	None	None	Flaccid
2	To Pain	Nonspecific sounds	Decerebrates to pain
3	To verbal stimuli	Inappropriate words	Decorticates to pain
4	Spontaneous	Confused	Withdraws to pain
5	-	Oriented	Localizes to pain
6	-	-	Follows commands

COMMON SODIUM DISORDERS SEEN IN HEAD TRAUMA (Discuss therapy with staff prior to initiation.)

Disorder	Na+	Diagnostic clues	Treatment
SIADH	↓	Low Sosm, <u>usually euvolemic</u> , ↑ Uosm Low serum Uric acid level	Free water restriction, hypertonic saline if severe
Cerebral salt wasting	↓	Sosm may be nl, ↑ uop, <u>signs of volume depletion & hemoconcentration</u> , very high U _{Na} Normal serum uric acid level	Volume replacement with NS or hypertonic saline. Oral sodium. Beware of rapid Na+ correction.
Mannitol use	↑	Polyuria, ↑ [Na ⁺] & Sosm	Hold Mannitol if Sosm > 329 mosm / [Na+] > 159
Diabetes Insipidus	↑	Polyuria (>250cc/hr), ↑ [Na ⁺] & Sosm, U _{SpGr} <1.005	DDAVP 2-4 mcg SQ/IV BID as permitted by staff neurosurgeon

* Individualized patient management in consultation with Neurosurgeon

APPENDIX B: 3% SALINE PROTOCOL

Hypertonic (3% saline) may be delivered via peripheral IV or intraosseous access.

1. Give 250cc 3% NaCl bolus IV (children 5 cc/kg) over 10–15 minutes.
2. Follow bolus with infusion of 3% NaCl at 50 cc/hour.
3. If awaiting transport; check serum Na⁺ levels every hour:
 - If Na < 150 mEq/L re-bolus 150 cc over 1 hour then resume previous rate
 - If Na 150–154, increase NaCl infusion 10 cc/hour
 - If Na 155–160, continue infusion at current rate
 - If Na >160, hold infusion, recheck in 1 hour
4. Once Na is within the range- continue to follow the serum Na⁺ level every 6 hours
5. After cessation of 3% NaCl infusion, continue to monitor serum Na for 48 hours to monitor for rebound hyponatremia.

APPENDIX C: ADDITIONAL INFORMATION REGARDING OFF-LABEL USES IN CPGS

PURPOSE

The purpose of this Appendix is to ensure an understanding of DoD policy and practice regarding inclusion in CPGs of “off-label” uses of U.S. Food and Drug Administration (FDA)–approved products. This applies to off-label uses with patients who are armed forces members.

BACKGROUND

Unapproved (i.e. “off-label”) uses of FDA-approved products are extremely common in American medicine and are usually not subject to any special regulations. However, under Federal law, in some circumstances, unapproved uses of approved drugs are subject to FDA regulations governing “investigational new drugs.” These circumstances include such uses as part of clinical trials, and in the military context, command required, unapproved uses. Some command requested unapproved uses may also be subject to special regulations.

ADDITIONAL INFORMATION REGARDING OFF-LABEL USES IN CPGS

The inclusion in CPGs of off-label uses is not a clinical trial, nor is it a command request or requirement. Further, it does not imply that the Military Health System requires that use by DoD health care practitioners or considers it to be the “standard of care.” Rather, the inclusion in CPGs of off-label uses is to inform the clinical judgment of the responsible health care practitioner by providing information regarding potential risks and benefits of treatment alternatives. The decision is for the clinical judgment of the responsible health care practitioner within the practitioner-patient relationship.

ADDITIONAL PROCEDURES**Balanced Discussion**

Consistent with this purpose, CPG discussions of off-label uses specifically state that they are uses not approved by the FDA. Further, such discussions are balanced in the presentation of appropriate clinical study data, including any such data that suggest caution in the use of the product and specifically including any FDA-issued warnings.

Quality Assurance Monitoring

With respect to such off-label uses, DoD procedure is to maintain a regular system of quality assurance monitoring of outcomes and known potential adverse events. For this reason, the importance of accurate clinical records is underscored.

Information to Patients

Good clinical practice includes the provision of appropriate information to patients. Each CPG discussing an unusual off-label use will address the issue of information to patients. When practicable, consideration will be given to including in an appendix an appropriate information sheet for distribution to patients, whether before or after use of the product. Information to patients should address in plain language: a) that the use is not approved by the FDA; b) the reasons why a DoD health care practitioner would decide to use the product for this purpose; and c) the potential risks associated with such use.