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Spine Immobilization: Prehospitalization to Final Destination

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Care of the combat casualty with spinal column or spinal cord injury has not been previously described, particularly in regards to spinal immobilization. The ultimate goal of spinal immobilization in the combat casualty is to first ''do no further harm'' and then provide a stable, painless spine and an optimal neurologic recovery. The protocol for treatment of the combat casualty with suspected spinal column or spinal cord injury from the battlefield to final arrival at a definitive treatment center is discussed, and the special considerations for medical evacuation off the battlefield and for aeromedical transport are delineated. Selective prehospital spine immobilization, which involves spinal immobilization with backboard, semi-rigid cervical collar, lateral supports, and straps or tape, is recommended if there is suspicion of spinal column or spinal cord injury in the combat casualty and when conditions and resources permit. The authors do not recommend spinal immobilization for the combat casualty with isolated penetrating trauma. (Journal of Surgical Orthopaedic Advances 20(1):2–7, 2011)

Key words: aeromedical evacuation, cervical spine, combat, immobilization, spinal cord injury, spine fracture, trauma

Although standard protocols exist for spinal immobilization in the Emergency Response Systems (EMS) in the civilian sector, there exists only a clinical practice guideline for combat casualties with potential spinal column or spinal cord injury (SCI) (1). Like the civilian EMS, the goal on the battlefield is to preserve life and limb through the evacuation process from the point of injury/battalion aid stations (BAS) en-route to a level 3 medical treatment facility or combat support hospital where more definitive stabilization procedures and intensive care are able to be performed. However, during the evacuation process there are many challenges, namely functioning in an austere environment with the potential to be under enemy attack (2). At all times, safety of the individual and unit are of paramount importance. The goal of in-theater care is to maximize the potential for neurologic recovery from the moment of injury to the time of arrival at a level 4 or 5 medical treatment facility, where advanced medical and surgical resources are available. To date there have been no in-flight neurologic deteriorations from aeromedical transport to a level 4 or 5 medical center, and this is largely attributed to the comprehensive evaluation and treatment while in theater (3). The most important initial step in management of spinal column and spinal cord injury is recognition of the injury. Poor diagnostic acumen or suboptimally managed spinal column injury can result in a neurologic deficit and permanently impair a patient's function and quality of life and in some cases may lead to death (4). Thus comprehensive care starting with prehospital spine immobilization to evaluation and treatment at a level 3 medical treatment facility in theater requires vigilance by the multidisciplinary trauma team to ensure that patients with spinal column and spinal cord injury are appropriately identified, medically stabilized,

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and immobilized in preparation for aeromedical transport to a definitive treatment facility.

Approximately 40,000 American service members have been wounded during the current conflicts in Iraq and Afghanistan and have brought unique challenges in the treatment of spinal column injuries (5). The current pattern of war injury has changed due to young, healthy combatants subjected to high-energy blast trauma and increased survival due to improved personal protective equipment and vehicle armor, improved battlefield first-aid training, "far forward" placement of surgical teams, more sophisticated surgical care, improved intensive care techniques, and markedly decreased medical evacuation times (6, 7). During World War I, 80% of overseas American troops with SCI died before they could return to the United States (8). This improved during the Vietnam conflict with statistics showing 0.9% of those admitted to U.S. Army hospitals had sustained SCI and 3.8% of those patients died during initial hospitalization (8).

Combat casualties with spinal column and spinal cord injury are significantly different than those in civilian trauma centers because of an increased incidence of open and severely contaminated wounds, associated traumatic brain injury, thoracic and visceral injuries, and complex bone and soft tissue extremity injuries. As of December 31, 2008, 432 active-duty U.S. service members serving during Operation Enduring Freedom and Operation Iraqi Freedom sustained SCI and received treatment in Department of Veterans Affairs SCI units (9). As in civilian trauma centers, initial treatment of the polytrauma combat casualty focuses on the principles of advanced trauma life support with resuscitation and medical stabilization, with initial management of suspected spinal column and spinal cord injury focusing on immobilization and preventing further neurologic injury and deterioration. The ultimate goal after aeromedical transport of the combat casualty with a potential spinal column or spinal cord injury is to provide the patient with a stable, painless spine and an optimal neurologic recovery and, for those without neurologic deficit, to do no further harm until their return to the Continental United States.

Battlefield and Prehospital Spine Immobilization

Battlefield Extrication

The treatment principles of prehospital care of the combat casualty with suspected spinal column or spinal cord injury are similar to those of civilian trauma systems, with focus on adhering to the standards of the Advanced Trauma Life Support (ATLS) protocol (10). The most significant difference of combat casualty care compared to care in civilian trauma systems is performance under harsh, austere, and dangerous conditions. Casualty evacuation during combat involves rearward progression through echelons of care with increasing medical capabilities and resources and further away from the combat zone. Level 1 care is provided by the first responder on the battlefield, delivering care in the most dangerous environment. The first responder is typically another service member, combat medic, or corpsman with limited supplies and basic medical training to perform life-saving measures to control hemorrhage, administer basic life support procedures, and open an airway. The primary focus of the first responder is to expeditiously remove the wounded comrade from danger, rather than maintain spinal stability. On the battlefield, preservation of life of the combat casualty and of the combat medic takes precedence over spine immobilization.

Therefore, limited battlefield intervention of the polytrauma combat casualty is advocated, and spine immobilization is often not performed on the battlefield during extrication unless conditions permit. If spine immobilization is to be performed during extrication, movement of the patient is carried out by maintaining the patient's head aligned with the axis of the body in a neutral position. The patient should not be forced into a position that results in undue pain or results in deformity different from their primary posture (11, 12). There is also a growing body of evidence against the performance of prehospital procedures that may delay necessary surgical interventions for patients with potentially survivable injuries (13–15). The most effective treatment of the combat casualty in theater can be performed at a level 3 medical treatment facility, and the principal goal of prehospital and battlefield care is safe and rapid transport to a higher echelon of care. Battlefield extrication occurs through a helicopter or ground vehicle, and the combat casualty is taken to a level 2 BAS or forward surgical team, and not infrequently directly to a level 3 medical treatment facility. Level 2 care can be bypassed if the level 3 medical treatment facility is close or clinical status of the patient requires level 3 care (16).

Transport Immobilization Technique and Devices

Helicopters or ground vehicles used for extrication are often exposed to rough geographic terrain and weather; therefore, the combat casualty, regardless of injury, should always be secured to prevent further injury. When preparing the combat casualty with suspected spinal column or spinal cord injury for transport from the battlefield to a level 2 or 3 medical treatment facility, spinal immobilization is performed when equipment and resources are available. Recommendation of the American College of Surgeons consists of a hard backboard, semirigid cervical collar, lateral support devices, and tape or straps to secure the patient over the forehead, thorax, and

extremities and the lateral support devices to the backboard (17, 18). On the battlefield and during transport, these resources are often unavailable or limited, particularly in a situation with multiple casualties following blast trauma. It is essential for the medic or corpsman during the request for medical evacuation to specify special equipment and resources for spinal immobilization. The authors do not recommend using sandbags for improvised cervical spine immobilization, especially when a rigid cervical collar is not in place. Sandbags placed on a backboard require extreme care and attention during movement because the heavy sand bags can slide, even when taped, resulting in lateral displacement of the patient's head and neck with respect to the torso (17). Also, sandbags must be removed before obtaining lateral cervical spine radiographs, and thus radiolucent lateral support devices should be used if available.

During transfers and movement of the combat casualty with suspected spine or spinal cord injury, the authors do not recommend the traditional log roll maneuver, because significant lateral motion of the lumbar spine has been reported (17, 19, 20). The HAINES (high arm in endangered spine) method is recommended, in which the patient is placed supine with one arm abducted to 180°, the medic or corpsman is kneeling on the opposite side, and the near arm is placed across the patient's chest with both lower extremities flexed. Another medic or corpsman maintains in-line stabilization of the head and neck, while the person at the side gently rolls and scoops the patient away and a backboard or transfer device is placed (17, 21).

Selective Prehospital Spine Immoblization

The following clinical criteria increase suspicion of spine or spinal cord injury and indicate the need for prehospital spine immobilization in a combat casualty: pain or tenderness along the spine, the presence of focal neurologic deficit, an altered level of consciousness, suspected extremity fracture, or the presence of other significant distracting injuries. Domeier et al., in a civilian multicenter prospective study of 6500 trauma patients, found the previous mentioned criteria to be predictive of most patients with cervical spinal injuries that required immobilization (17, 22–24). Vaccaro et al. also reported that, although some patients after transient paralysis may appear to have a normal neurologic exam, they still may have an unstable cervical spine fracture or dislocation (11). Prehospital cervical spine immobilization should also be considered for trauma resulting in temporary amnesia or loss of consciousness, after a major explosive or blast injury, fall from height, ejection or fall from any motorized vehicle, or after a vehicle rollover. Thus, in the combat environment, the authors recommend selective prehospital spine immobilization, and any suspected spinal column or spinal cord injury should be immobilized before transport if the patient's clinical status, safety conditions, and resources are available. Spine immobilization is not recommended in the combat casualty with penetrating trauma, because this has been associated with higher mortality and may hide other life-threatening injuries (2, 25, 26).

A retrospective study by Haut et al. demonstrated that those who underwent prehospital immobilization had no survival benefit and were more than twice as likely to die. This study found that the number needed to treat with spine immobilization to potentially benefit one penetrating trauma patient was 1032, and the number needed to harm and contribute to one death was 66 (13).

Spinal immobilization of all trauma patients, regardless of the patient's clinical symptoms, is based on historical rather than scientific precedent, and there is no level 1 or level 2 evidence to support this practice. A Cochrane Review on spinal immobilization for trauma patients also found no level 1 evidence or randomized controlled trial evaluating the effect of spinal immobilization on mortality, neurologic injury, spinal stability, and adverse effects (27). There have been several level 3 studies that demonstrated neurologic worsening with failure of adequate spinal immobilization (22, 28–36). The most relevant study by Toscano in a retrospective case series reported that 32 (26%) of 123 trauma patients sustained major neurologic deterioration between time of injury and hospital admission (34). The author concluded that neurologic deterioration was due to patient mishandling and attributed lack of spine immobilization after traumatic injury as the primary cause (34). This finding was contradicted by a study out of New Mexico by Hauswald et al., which was a retrospective review of blunt spine or spinal cord injuries. The study found that neurologic deterioration after injury occurred less frequently in nonimmobilized patients, compared with those treated with spine immobilization during transport (31). The authors theorized that spinal cord injury and subsequent neurologic deficit was due to the initial tremendous force during the traumatic event, and additional movement of the spine during transport would be insufficient to cause further injury (27).

Most trauma patients do not have spinal instability and will not benefit from spine immobilization (37). There are risks involved with spinal immobilization, and observational studies have found that rigid collars can cause iatrogenic pain (38, 39), skin ulceration (40–42), aspiration and respiratory compromise (43–47), and increased intracranial pressure (48–50). While a neurologic injury caused by an improperly managed unstable spine fracture is feared because of the risk of death, devastating long-term disability, and the immense social burden of spinal

cord injury, the universal immobilization of all combat casualties is unnecessary and in some patients may be more harmful than beneficial. Selective spinal immobilization in combat casualties with suspected spinal column or spinal cord injury is recommended, and these patients should remain immobilized until injury has been excluded.

Combat Support Hospital (Level 3) Spine Injury Protocol

On arrival to a combat support hospital level 3 medical treatment facility, initial management of the polytrauma combat casualty should include primary survey, again focusing on the stepwise ATLS protocol. In the casualty with hemodynamic instability, lifesaving measures take precedence over the definitive diagnosis and management of spinal column and spinal cord injury. During resuscitation, initial management of suspected spine injury should focus on preventing secondary spinal cord injury from hypoxia, hypotension, hyperthermia, and edema. The secondary injury cascade of SCI appears to be the optimal target of opportunity for mitigating the effects of further neurologic deterioration. Every reasonable effort should be made to document as thorough a neurologic exam as possible using the American Spinal Injury Association guidelines and should include motor testing, dermatomal sensory testing, lumbar and sacral root evaluation, and rectal examination. Patients should be removed from the backboard within 2 hours of placement to prevent pressure sores (41, 42), and as part of the secondary survey the backboard should be routinely removed when performing inspection of the neck, back, and buttocks.

Definitive management of the combat casualty with spinal column and spinal cord injury can only begin with recognition of the injury. A combat casualty who is awake, with normal sensorium, no neck pain or tenderness, and no neurologic deficit, does not require further radiographic evaluation and is subsequently cleared from cervical spine precautions (51–53). In the past decade, computed tomography (CT) has supplanted plain radiographs as the primary screening modality for trauma patients. The use of a spiral CT traumagram is indicated in the combat casualty who is unconscious or unable to provide a reliable clinical exam because of altered mental status or distracting injuries. Spiral CT of the spine will identify 99% of all fractures of the cervical, thoracic, and lumbar spine and provides more accurate assessment of osseous abnormalities and spinal canal compromise, when compared to plain radiographs (54–56). If CT is unavailable, initial imaging should consist of a three-view cervical spine series (anteroposterior, lateral, and odontoid views). The combat casualty will remain in spinal immobilization if a fracture is identified on imaging studies, if there is an altered level of consciousness or distracting injuries, or if there is persistent spine pain or tenderness despite normal imaging studies, which may indicate a ligamentous spine injury. The first available magnetic resonance imaging capability is located at a level 4 medical treatment facility and is obtained to identify occult fracture or ligamentous spine injury. The authors do not recommend dynamic flexion and extension cervical spine radiographs in theater; these should be delayed until 2 weeks after injury when pain and spasm have sufficiently subsided. The role of halo immobilization in the combat theater setting is limited and not feasible because of the lack of equipment in theater and the variable ability to properly assess reduction and placement. The primary focus at a level 3 medical treatment facility, despite patient holding capacity and intensive care capabilities, is to rapidly prepare the combat casualty for aeromedical transport to a definitive treatment center. Once the combat casualty is medically stabilized, with spinal column or spinal cord injury identified and protected, and other injuries initially managed, he or she is transported out of theater to a level 4 or 5 medical treatment facility. Again, the multidisciplinary trauma team must maintain heightened vigilance throughout the aeromedical process. Prevention of neurologic deterioration during aeromedical transport is a result of the appropriate identification and protection of the combat casualty with spinal column or spinal cord injury.

Aeromedical Transport

In previous conflicts, transport off the battlefield to initial medical treatment took 12 to 15 hours during World War II, 4 to 6 hours during the Korean War, and 2 hours during the Vietnam conflict. In the current conflicts in Iraq and Afghanistan, casualty evacuation is possible to an unprecedented degree with respect to speed and distance, which is due to "far-forward" surgical teams who can be reached within 30 to 60 minutes, the rapid global reach of modern airframes, and the clinical advancements in critical care and medical stabilization of polytrauma combat casualties (3). Currently, most patients arrive in Germany for level 4 care within 12 to 48 hours after injury and arrive in the United States in 4 to 5 days. This is compared to the Vietnam era when return to the United States for definitive care took 45 days (6, 57, 58).

The optimal time of transfer is determined by weighing the benefit of additional medical and surgical resources at a higher echelon of care against the inherent risks in moving a critical combat casualty who requires ongoing resuscitative care. Clinical practice guidelines recommend the following clinical parameters be met before transfer of a patient on aeromedical transport: heart rate < 120 beats/min, systolic blood pressure > 90 mm Hg, hematocrit $> 24\%$, platelet count $> 50/mm^3$, INR < 2.0, pH

> 7.3, base deficit > 5 mEq/L, temperature > 35°C (59). During aeromedical transport out of theater, every effort must be made to maintain medical stability, limit unnecessary spinal motion, and preserve neurologic function (34). A unique stressor to aeromedical transport is hypoxia due to decreased oxygen pressure, and even in a pressurized aircraft cabin, the effective altitude is 8000 to 10,000 feet and can adversely affect the spinal column or spinal cord injured combat casualty. Other conditions unique to airlift include temperature shifts, vibration, noise, decreased humidity, and *g*-forces up to two to three times gravity (3). Propeller-driven airframes, such as the C-130, tend to have high-vibration loads and the combat casualty is subjected to total body vibration with generalized muscle stimulation, increased metabolism, and discomfort. However, air transport in the civilian literature has not reported adverse effects for the spine-injured patient when properly executed. Armitage et al. described four spine-injured patients who developed respiratory distress or failure during air transport, which was attributed to patients with cervical spinal cord injury with severely reduced pulmonary function before transfer (60). The authors recommended performing measures to optimize oxygenation, humidification, and pulmonary function during air transport (61). A combat casualty with potential unstable thoracolumbar injury should be transported using a vacuum spine board (VSB), which is preferable to supine transport in an external brace. Patients can be safely transported on a VSB for up to 10 hours, and if anticipated flight time is greater than 10 hours, the patient should have an appropriate turning schedule (1).

Conclusion

Care of the combat casualty with spinal column and spinal cord injury is often performed under dangerous and harsh conditions. While all combat casualties do not require spinal immobilization, they should be immobilized with backboard, semi-rigid cervical collar, lateral supports, and straps or tape if there is suspicion of spinal column or spinal cord injury and when conditions and resources permit. The ultimate goal in treating the combat casualty with spinal column or spinal cord injury is "to do no further harm" and to optimize the chance of neurologic recovery. Preparation for aeromedical transport is essential for prevention of adverse effects during flight. The combat casualty with spinal column or spinal cord injury should be appropriately identified, medically stabilized, and immobilized for aeromedical transport to a definitive treatment facility.

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