5 Clinical Evaluation: Prehospital Algorithm

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Gun control opponents like to say "guns don't kill people, people kill people." But people with guns kill people more often and efficiently than people without guns. Guns may not cause violence, but they make violence more severe, more likely to lead to death instead of just injury.

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(Gun control violence increasingly viewed as public health challenge. JAMA 267:1171–1174, 1992)

Introduction

One of the primary determinants of outcome in craniocerebral missile injuries (CMIs) is the initiation of timely care, both for maintenance of hemodynamic status and for keeping the airway patent. Immediate care rendered to a patient with CMI depends on the place of injury (roadside accident site or battlefield, rural or urban setup, etc.) and consequently the resources available at the nearest medical setup. A sniper or an assassin deliberately aims at the head so as to ensure death or at least permanent disablement. On the other hand, soldiers in the battlefield are likely to sustain CMI due to high-velocity missiles (HVMs) as well as low-velocity missiles (LVMs); here, the CMI is generally part of polytrauma involving the neck, chest, abdomen, pelvis, and limbs. Since HVM injuries are largely incompatible with life, survivors are few and those who do so would have sustained grazing injury. Most of the survivors would have sustained injury due to LVM. In the civilian CMIs, the missile is often a shotgun or a countrymade weapon (*katta*), and the injury is generally due to LVMs. Injury due to exploding devices are being seen more often in violence in urban areas or in areas with armed militancy. These devices generally inflict multiple missile injuries to the head and neck. The civilian prehospital care has evolved with availability of ground and aeromedical transportation networks, so that the patients are transported to the nearest, most appropriate facility.

Triage and Action at the Site of Injury: Dealing with Mass Casualties

The determinants of decision making for final destination for patients from the scene of injury are governed by protocols followed by first responders and triage decisions. This initial link of first responders and their decision is crucial to the outcome of CMIs. In a battlefield scenario, treatment of CMI begins at the site of injury, with basic first aid and application of shell dressing by the paramedics or other soldiers. The patient is then transported to the regimental aid post located close to the forward defended location, where he/she is evaluated first by a physician (**Table 5.1**). Airway should be cleared and respiration supported by mouth-to-mouth breathing if necessary. Immediate apnea may be reversible, and it is important that this fact is understood by paramedics, police, fire personnel, and other people capable of rendering first aid. Open wounds should be covered and the patient transported in three-quarters prone position, so that the oropharynx remains clear of secretions and tongue falling back. "Scoop and run" as a policy has much to recommend it in such a situation.

Table 5.1. Chain of evacuation in battlefield	
Level	**Role**
RAP	Expert first-aid
ADS	"ABC" of resuscitation
FSC	Life- and limb-saving surgical intervention
Base/command hospital	Neurosurgical care

Abbreviations: ADS, advanced dressing station; FSC, forward surgical section; RAP, regimental aid post.

During war and in a war-like scenario, casualties are multiple and there may be a delay of hours before medical aid can reach the injured depending on the intensity of the battle. Once there is a lull in the battle, the casualties are collected and prioritized. The term *triage* is derived from the French word *trier* (meaning "to sort") and was anglicized after the Napoleonic wars. The practice of triage creates a situation whereby the greatest good for the greatest number can be accomplished. The four-tiered triage system (**Table 5.2**) was evolved during the Korean War. This led to significant improvement in survival among the war-wounded soldiers.[1] Triage may be based on physiological parameters or on anatomical factors and mechanism of injury. Physiology-based triage systems manage patients with current clinical instability, while anatomy-based systems are used to identify those patients who have potential for deterioration and may require early surgery.[2] Various triage scoring systems used are summarized in **Table 5.3**. Garner et al[2] retrospectively reviewed four trauma classification schemes (CareFlight; Simple Triage and Rapid Treatment; Modified Rapid Triage and Rapid Treatment; Triage Sieve). They found that the motor component of Glasgow Coma Score (GCS) and systolic blood pressure were the strongest physiological predictors associated with critical injury.

Table 5.2. Priority in management	
Priority	**Description**
PI	Patient requiring immediate resuscitation
PII	Patients requiring early surgery
PIII	Walking wounded
PIV	Moribund patients, unlikely to survive

Table 5.3. Triage scoring systems

Scoring system	Parameters
Trauma Index	Injury type, respiratory, cardiovascular, and CNS
Triage Index	Respiratory expansion, capillary refill, GCS
Trauma Score	Respiratory effort/rate, systolic BP, capillary refill, GCS
Revised Trauma Score	GCS, systolic BP, respiratory rate
CRAMS Scale	Circulation, respiration, abdominal findings, motor/speech
Homebush Triage	Based on modified Simple Triage and Rapid Treatment
Prehospital Index	Respiratory rate and level of consciousness
CareFlight Triage	Walking, obeys commands, radial pulse, respiration present/absent
Trauma Triage Rule	Systolic BP < 85 mm Hg, GCS motor < 5, penetrating injury to neck, head, and trunk
Trauma Sieve	Walking, airway, respiratory rate, capillary refill
Simple Triage and Rapid Treatment (capillary refill) *and* Modified Simple Triage and Rapid Treatment (radial pulse)	Walking, breathing, respiratory rate, radial pulse, obeys commands
Neuropsychiatric triage	Loss of limb/functional cosmesis, mangled remains
Anatomical factors	Penetrating wounds to chest, abdomen, traumatic amputation, comorbid factors
Mechanisms of injury	Fall > 20 ft, ejection from vehicle, high-speed motor vehicle accident

Abbreviations: BP, blood pressure; CNS, central nervous system; GCS, Glasgow Coma Score.
Source: Adapted from Wiseman et al.[3]

Transportation of patients with CMI is usually carried out to predetermined appropriate centers. However, distance, geographical factors, and logistic requirements may modify the transport destination. It may be appropriate and lifesaving to have the patient stabilized hemodynamically at a smaller hospital or facility if direct transport to a major center is not readily available. After stabilization and resuscitation, the patient is evacuated to the next echelon in the chain of evacuation, the advanced dressing station (ADS), which can be bypassed in case of CMIs. Transfer to forward surgical section is effected by ambulances, where basic surgical care is rendered. Evacuation to neurosurgical center is undertaken by ambulances and helicopters. The intervention undertaken at each of these echelons depends on the resources of the military units they care for. Computed tomography (CT) scan and facilities for neurosurgical procedures are generally available at rear echelon facilities (Base/Command Hospitals). Unlike closed head injury due to roadside accident, CMI in civilian or services setup elicits panic and shocked disbelief among the people around, which leads to loss of vital moments when the patient is potentially salvageable during the period of apnea. Our resources in civil still do not match the recommended "golden hour" concept. Most of the civilian CMIs reach neurosurgical care between 16 and 24 hours after the injury; partly the delay is due to poor transportation facilities in the rural hinterland of India and partly to the medicolegal procedures involved.[4] In the services setup, there is progressive shortening of the period of evacuation to a neurosurgical center due to better transportation facilities including availability of helicopters when required.

Communication and Evacuation

A severely injured soldier on the battlefield needs fully equipped, state-of-the-art medical setup. This utopian requirement may prompt medical planners into "forward fixing" in which surgical teams are moved more and more forward, closer to the battlefield, even though this may severely limit their role to merely that of first-aid providers. Any system placed on the battlefield must be a compromise between what is best for the wounded soldier and what is best for the conduct of the battle. The concept of "forward fixing" is to reduce the time lag between the injury and surgical intervention, and in case of minor injuries, early return to the frontlines. In the case of CMI, however, there is no such thing as a minor injury, and each patient has to be evaluated in detail and management planned accordingly. Neurosurgical intervention would presuppose availability of certain equipment and facilities if meaningful neurological recovery is the aim. This would mean access to CT scan, ability to carry out craniotomy and debridement, facilities otherwise taken for granted such as suction, bright light, and ability to achieve hemostasis by bipolar coagulator, etc. Clearly, if the basic minimum medical facility for neurosurgical intervention cannot be brought to the wounded soldier, the soldier should be brought to it, and his/her physical condition should be maintained till he/she arrives. The medical system in battlefield is racing a biological clock, and deterioration of human being after being wounded is predictable and assured. It is for these reasons that emphasis is laid on timely, efficient, rapid evacuation, preferably by air, to a neurosurgical center, where early, definitive surgery can be carried out.

Communication with neurosurgical center is vital and advance warning can minimize the reaction time of the surgical team after the patient reaches the center. In the armed forces chain of surgical management, where armed militancy and enemy action has continued over the past several years, the neurosurgical center is informed immediately on telephone by the surgeons working in the advance medical units about the occurrence of casualties, their clinical and neurological status, and the likelihood of evacuation. In the civilian setup, similar chain of communication can be established starting from primary health centers/ district hospitals to tertiary referral centers or to neurosurgical centers in private/corporate setup. The police can ensure a “green corridor” for rapid surface transport of such patients. The medical resources of an entire city can be divided into zones with active participation of private nursing homes, where first aid can be rendered and correspondingly the salvageability improved. In the times to come, with explosion of information technology, telemedicine is going to play a major role in the early management of neurotrauma, especially missile injuries. The clinical status and imaging appearances of the patient can be transmitted to the neurosurgeon and advice sought for management or evacuation.

To improve outcome, it is imperative that the interval between injury and therapy be minimized.[5,6,7] Kaufman et al[5] noted that 52% of their patients were transferred from other hospitals and over 80% of the patients arrived within 2 hours of injury. Overall, 87% of patients arrived by helicopter. Evacuation of a stable patient is best achieved by helicopter. This was conclusively proved in the Korean conflict and the Vietnam War, where often the casualties were evacuated from the scene of action directly to neurosurgical center. Helicopters were used during Operation Vijay in Kargil in 1999, in which the evacuation time was reduced to nearly 1 hour. However, this assumes that air superiority exists and helicopters would be made available. Availability of air evacuation can bypass the intervening echelons and transport the patient directly to the neurosurgical center. In civilian CMIs, generally the distance involved is not much and patients can expect to reach a neurosurgical center within 2 to 6 hours, once a decision has been taken to that effect. Air evacuation for civilians is not yet possible in our country, and most of the patients are transported by road in ambulances. It has been established that patients with neurotrauma should be transported directly to neurotrauma center, and these patients have improved outcome in the form of reduced mortality.[8,9]

Examination of a Patient with CMI

CMIs should never be approached in isolation. They are often multiple, leading to multiorgan damage, and ideally, a trauma team should assess the patient. The patient is stripped and a general survey of the patient is done, often along with a general surgery colleague.

Examination of Head and Neck

External wounds are closely examined (**Fig. 5.1**). Bone fragments, pulped brain, blood clots, and cerebrospinal fluid (CSF) leakage will be visible in most of the cases. At times, tiny puncture wounds may not be readily visible and these are often unaccompanied by significant intracranial hemorrhage or contusion. In author's experience, these patients are often less

Fig. 5.1 Gunshot wound of entry in the left frontal eminence.

severely injured since the offending missile is one with low KE (**Fig. 5.2**). Orbitocranial and faciocranial missile injuries are often accompanied by gross swelling and discoloration due to accompanying skull base injury (**Fig. 5.3**). There may be CSF orbitorrhea, rhinorrhea, and bleeding from the ear. Battle's sign may be seen in petrous fractures (**Fig. 5.4**). Orbitocranial injuries usually have permanent loss of vision due to injury to the globe or to the optic nerve. The bullet may be seen lying impacted in the skull (**Fig. 5.5**). Trajectories through the sinuses are accompanied by facial swelling and subcutaneous emphysema, even though CSF leak may not be immediately evident.

The mouth and oropharynx are cleared and seen under good illumination with the help of a laryngoscope. Bleeding into the pharynx may be seen in faciocranial injuries and in skull base fractures; these patients often would have swallowed large quantity of blood.

Fig. 5.2 Low-velocity gunshot wound, right temporal.

Fig. 5.3 High-velocity cranial gunshot injury with skull base injury, proptosis, and CSF rhinorrhea.

Fig. 5.4 Battle's sign.

Fig. 5.5 Bullet lodged in the right fronto-orbital region.

Baseline Neurological Evaluation

Once the patient is received in a neurosurgical center, a baseline neurological evaluation is carried out (**Box 5.1**). The thoroughness of neurological evaluation is largely dictated by the neurological status of the patient. In an unconscious patient, this would mean that any abnormal posturing and GCS are noted on arrival, and pupillary reactions, oculocephalic reflex, facial asymmetry, obvious difference in limb movements, muscle tone, and tendon reflexes between right and left sides are noted and recorded. If the patient is able to follow commands, his/her visual status can be assessed by finger counting, and ocular movements and facial movements can be ascertained. Intact phonation and ability to cough usually give a fair idea of integrity of lower cranial nerves. The ability of the patient to correctly tell his/her personal number (a seven- or eight-digit numerical figure) and to follow commands to move his/her right/left limbs has been found to be a fairly accurate indicator of intact cortical function indicating less severe injury. While evaluating the severity of injury, GCS is useful for prospective grading, while retrospective grading can be accorded by indicators such as duration of coma and posttraumatic amnesia.[10] GCS description can further be combined

Box 5.1 Baseline Neurological Evaluation in CMI (to be recorded at every level in the evacuation chain)

- Glasgow Coma Score.
- Pupils and finger counting.
- Ocular movements.
- Facial asymmetry (?).
- Speech: normal/slurring/hoarseness.
- Ability to move both sides.
- Ability to distinguish right and left sides.

with terms such as akinetic mutism and persistently vegetative state to give a complete and accurate assessment of the neurological status. In the war zone, casualties more often suffer from polytrauma as compared with civilian injuries and closed head injuries; the War Head Injury Score (WHIS) that incorporates both the GCS and Injury Severity Score (ISS) is an accurate predictor of outcome in the presence of multisystem trauma and CMI.[11]

Action at Peripheral Medical Setup

Depending on the resources and expertise available, the aim at a peripheral medical setup should be to evacuate the patient to the nearest hospital in the shortest possible time with stable vital parameters. Attention is paid to airway, respiration, and circulation ("the ABC of resuscitation": **Table 5.4**). After ensuring an adequate airway by oropharyngeal suctioning, insertion of airway, intubation, etc., ventilation must be commenced in apneic patients. When ventilatory support is required, oral intubation should be performed. A short-acting nondepolarizing neuromuscular blocking agent (vecuronium 0.01 mg/kg every 15–30 minutes) and sedative agent (thiopental 4 mg/kg or midazolam 0.07 mg/kg intravenous) may be administered in semi-conscious patients to minimize rise in intracranial pressure. Pulse oximeters are becoming standard equipment on ambulances and can be used to optimize patient's ventilatory status. Intravenous drips that will not get dislodged during transit are inserted and external hemostasis is achieved. Fractures of long bones are splinted and open chest wounds are closed. Whether to subject the patient to CT at the nearest scanner at this stage will depend on his clinical condition. Severe head injuries are now routinely investigated by early CT, which visualizes most of the pathological lesions of immediate surgical importance. The initial clinical examination is still crucially important in triage and as a baseline in assessing progress. The prognosis depends to a large extent on the findings of the initial examination,

Table 5.4. Primary survey in cases of CMI

	Function assessed	Observation	Clinical parameters
A.	Airway	?Patent	
B.	Breathing	?Noisy ?Effective	Rate and depth
			Chest movements
			Air entry
			?Cyanosis
C.	Circulation	?Adequate	Pulse rate and volume
			Blood pressure
			Skin color
			?Cold clammy limbs
			Capillary return
			External/internal hemorrhage
D.	Disability	?Normal	Conscious level/GCS
			Pupils
			Limb movements
E.	Expose	?Other injuries	Limbs, neck
			Chest, abdomen, pelvis
			Back

Abbreviation: GCS, Glasgow Coma Score.

and neurological status at a specified time after injury is widely used as a measure of severity of head injury. However, modern strategies of severe head injury management have brought one very important change in the nature of clinical examination: because endotracheal intubation may have to be done as soon as possible, first neurological evaluation may never have been carried out. Hence, the paramedic should be aware of the need for recording the preliminary neurological findings for future reference (**Box 5.1**). Moreover, valuable as they are, the neuroradiological findings must be interpreted in the light of clinical findings. Broad-spectrum antibiotic which crosses into the CSF is administered and the head wound is covered with povidone-iodine-soaked gauze since infection is a major threat in these patients while they are being evacuated to neurosurgical center for definitive management. A decision is taken according to the priority of the case whether to evacuate the patient by ambulance or by air.

Preliminary Medical Management

Intravenous line is set up and antibiotics are administered in antimeningitic dosages soon after arrival in a medical unit, usually in the ADS in the military chain of evacuation. During the Vietnam conflict, penicillin and chloramphenicol were the most commonly used antibiotics for CMI.[12] In the recent times, third-generation cephalosporins, in conjunction with an aminoglycoside, nafcillin, or vancomycin in antimeningitic dosages, have been efficacious in preventing delayed meningitis and brain abscess. Antibiotics are usually continued for 10 to 14 days after the injury.[13] Currently, cephalosporins and an aminoglycoside for antimicrobial prophylaxis in CMI are routine. Since patients with CMIs are at risk for seizures, intravenous phenytoin is administered routinely to all such patients.[14] Intravenous levetiracetam is another option to prevent seizures. Intravenous mannitol and loop diuretic (frusemide) are administered once the patient is hemodynamically stable. Hypothermia is to be prevented proactively, and appropriate antishivering protocol should be followed.

Specific Prehospital Care

Central nervous system injury in a patient with polytrauma is the leading cause of mortality and morbidity. Hypoxemia and hypoperfusion are the principle factors that cause the secondary brain injury ("second injury"). For combat-related traumatic brain injury, attempt to minimize secondary brain injury by attention to specific interventions and application of the guidelines of the Brain Trauma Foundation have been associated with decreased mortality and better outcomes.[15,16] **Fig. 5.6** details the prehospital management algorithm.

Airway

Airway management is the single most important factor in the prehospital care of traumatic brain injury. If the patient is spontaneously breathing and SpO_2 is greater than 90%, only an oropharyngeal airway after clearing the oropharynx is recommended. Patients with GCS less than 8 will require prehospital rapid sequence intubation, preferably by a physician,

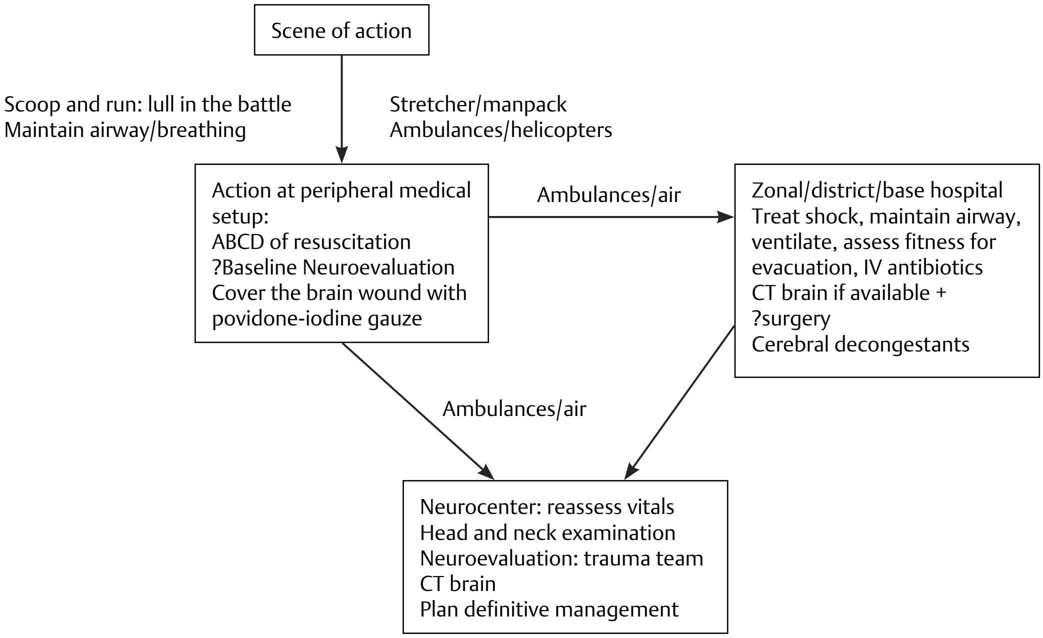

Fig. 5.6 Prehospital algorithm.

to improve outcome.[17] Alternative airway devices requiring less skills include laryngeal mask airway and Combitube (The Kendall Company, Mansfield, Massachusetts, United States). The paramedics earmarked for emergency prehospital care duties should have training and refresher course in the management of airway.

Breathing

Management of breathing implies attention to oxygenation and maintenance of carbon dioxide levels. Avoidance of hypoxia is intuitive in traumatic brain injury. In one study, SpO_2 levels more than 90% at the scene of injury were associated with 15% mortality, while levels less than 60% were associated with 50% mortality.[18] Ventilatory support may be required, and hyperventilation has specific indications to reduce raised intracranial pressure. However, in the event of systemic hypotension, increasing the intrathoracic pressure can aggravate hypoperfusion by reducing venous return, causing cerebral hypoxia, which can be aggravated by cerebral vasoconstriction caused by hyperventilation. Therapeutic hyperventilation should be considered only for patients with impending internal herniations. Typically, these patients will have GCS 8 or less, with anisocoria. The goal for end-tidal CO_2 should be around 35 mm Hg.[19] Development of portable capnography and ventilators and their utilization in prehospital care of severe traumatic brain injuries such as CMIs allow greater attention to details and specifics of ventilation of these patients.

Circulation

Systemic hypotension doubles the prehospital mortality in patients with traumatic brain injury.[20] Cerebral perfusion pressure (difference of mean arterial pressure and intracranial pressure) needs maintenance by attention to both these determining factors. Treatment with isotonic fluids is recommended, and there is no demonstrable benefit of utilization of hypertonic saline in the prehospital period.[21]

Illustrative Case

A 45-year-old army soldier sustained multiple splinter injuries to his face, neck, and chest walls in an IED explosion. He was airlifted to neurosurgical center within 6 hours of injury. On arrival, his GCS was 8/15, with dilatation of the right pupil and right orbital puncture wounds. He was tachypneic with SpO_2 of 75%. There was no intrathoracic injury. He was put on ventilator for 72 hours and then gradually weaned off. GCS was 15/15 after weaning off, and he was seen to have right-sided ocular injury. CT brain could be done on the fourth postinjury day, which showed three pellets embedded in the right frontal lobe and one lying in the posterior third ventricular region. He was managed conservatively, and was asymptomatic when reviewed 1 year later. His vision in the right eye was restored by intraocular lens implantation. The intracranial splinters had not moved from their initial location.

Military and Civilian Injuries

Most of the experience in the prehospital management, triage, evacuation, and surgical management of CMIs is derived from wartime series and experience; most of these principles can be extrapolated to be applied to civilian CMIs. Some of the contrasting features of injuries among the two groups are given in **Table 5.5**. Most of the survivors of CMIs in the battlefield and military operations would have sustained a shrapnel or low-velocity bullet injury, since high-velocity injuries due to bullets or shrapnel at close quarters are generally incompatible with life. Military personnel are more likely to sustain multiple, multiorgan injuries, unlike their civilian counterparts. Once they arrive in the hospital, the management of the two groups is essentially similar.

Table 5.5. Comparison between military and civilian CMIs		
Feature	**Military**	**Civilian**
Environment and circumstances	Military ops, hostile environment	Unexpected, in familiar environments. High percentage of CMIs are suicidal
Projectile velocity	High velocity	Low velocity
Projectile configuration	Splinters Bullet	Bullet
Triage	Likely mass casualties, hence triage	Usually solitary
Contamination	Likely	Unlikely
Associated injury to torso and limbs due to multiple missiles	High possibility	Low possibility
Prehospital care	Variable, dictated by battlefield conditions	Likely to be prompt
Imaging	Generally skull radiograph	Likely access to CT scanner
Evacuation	Dictated by battlefield conditions	Likely to have first responders within minutes of calling
Initial medical care	Nonspecialist doctor	Nonspecialist doctor

Conclusion

CMI management requires an integrated team approach. During war and antimilitancy operations, neurotrauma cannot be viewed in isolation since each patient potentially suffers from polytrauma. The evacuation from the scene of action to neurological center has to be quick and efficient, taking all due care to maintain airway, oxygenation, and circulation. Many lives can be gainfully saved if we can evolve a system of triage and timely evacuation of these patients to a neurosurgical center, where detailed evaluation can be carried out and management plan chalked out by a dedicated trauma team. Baseline neurological evaluation gives vital information for prognosis and for further comparison.

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