Treatment of cranial gunshot wounds

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Gunshot wounds of the head usually require special expertise. Priorities include attention to establishment of an airway, control of hemorrhage, maintenance of cardiovascular function, and determination of neurological status. We must know the principles of treatment based upon the pathology of central nervous system. Debridement and primary closure are indicated in management of such wounds. Perioperative intensive care is very important part of treatment.

Introduction

The early and adequate surgical treatment of the wounded constitutes one of the most potent factors in preserving the fighting morale of the troops and maintaining an Army up to strength. Wounds that are treated promptly and efficiently heal more quickly and leave a minimum of residual disability.

Management of vital functions

On-site therapy of cranial gunshot wounds may be best directed at maintaining systemic stability and preventing extracranial factors from worsening intracranial status.

In an unconscious patient when respiratory obstruction is present an efficient airway must be maintained by clearing the mouth and pharynx by extending the neck and by turning the patient into the Campbell coma position. If airway cannot be maintained in this fashion, then an oropharyngeal airway should be inserted. If this is not effective, then it would be necessary to pass an endotracheal tube with oral approach. To avoid the hyperextension of the neck intubate the patient with aid of muscle relaxants and to avoid increasing intracranial pressure during the intubation use sedation!

Tracheostomy should be necessary in case of direct laryngeal injury. The aims of ventilation (with or without sedation) are oxygenation and to keep carbon dioxide level normal to prevent hypoxia hypercarbia and brain edema. A respiratory rate between 14 and 20 breaths per minute and the pCO$_2$ between 25 and 30 Hgmm is ideal.
A rate faster than twenty breath per minute causes cerebral vasoconstriction to the degree that would reduce cerebral blood flow by 50% causing disruption of blood brain barrier and secondary brain swelling.

A pulse rate over 100 beats per minute means major blood loss and in a young trauma victim mild hypertension with tachycardia means the patient is in hemorrhagic shock. The presence of hypovolemic shock must alert and immediately to the probability of multisystem trauma. Internal hemorrhage from penetrating wound cannot be controlled without surgery. External hemorrhage can usually be controlled by direct pressure.

In shock without control of the bleeding and without fluid replacement, the estimated time of death is within the next ten minutes.

The only therapeutic modality in this limited 10-minute period is the placement of the military antishock trousers to start autotransfusion and the iv-s can be started en route. If the heart has stopped as an indirect result of injury then external cardiac compression must be initiated. This will often have to be carried out in conjunction with artificial respiration. Ideally head trauma patient should be kept dry with a minimum of iv. fluids on the other hand the perfusion to the brain must be maintained.

When isolated head injury is being managed the iv. should run at the slowest rate possible.

An orogastric sump tube is placed and connected to low constant suction. Ideally a short large-bore peripheral intravenous line on the urinary catheter will have already been placed while in the field. Place of central venous line is usually time consuming and carries an increased risk of further complication.

**Evacuation**

The patient’s condition should be stabilized before being evacuated! The speed and safety of evacuation and continuity of neurosurgical care are essential but this means not sheer physical speed. Casualties with brain wounds have to move by helicopter air ambulance from the Battalion Aid Station directly to neurotrauma center because the prompt neurosurgical intervention (six hours rule) may save casualties from the potentially catastrophic sequel of an expanding intracranial hematoma and reduce the incidence of infection.

In the trauma centers the operating room team is in the emergency room at the time of patient’s arrival. In the group “early death” we can best define the relationship between treatment delays and occurrence of prevalentable deaths.
In the first group the victims die primarily from extremely destructive injuries of the central nervous system and in the group “late deaths” from multisystem organ failure (MOF) and sepsis.

Physical examination

In combat zone the neurological surgeon cannot possibly spend a great deal of time with the preparation of records. Determination of vital signs blood pressure pulse and respiration permits the establishment of a baseline.

After stabilisation the vital function, the next step is the rapid precise neurologic examination includes removal of all clothing and inspection of the entrance and exit wound the extent of contusion of scalp. It is also necessary to note discharge of blood cerebrospinal fluid or pulped brain tissue from the wound.

A careful search must be undertaken for a possible entrance wound in face mastoid region or orbit because they are particularly prone to infection.

A wide area surrounding the site of penetration should be shaved and cleaned. Dry gauze squares and a gauze bandage can be applied. When brain tissue is fungating through the wound don’t apply the bandage too tightly!

The neurological examination should be sufficient thorough to render relevant information to all neurological system (Glasgow Coma Scale, brain stem reflexes, level of consciousness, cranial nerves, signs of meningeal irritation, motor function, tendon reflexes, sensory perception, coordination, vegetativ functions) and should be repeated at 5 to 10-minute intervals with careful recording. The Head Injury Form used during the War in Vietnam is the gold standard for military neurosurgeons.

Diagnostic tests

1. Blood is drawn for CBC, clotting studies, serum electrolytes and chemistry, toxycology screening as well as type and cross math for at least four units of packed red cells or whole blood. A urinanalysis is also sent as well as an arterial blood gas. Tetanus toxoid intramuscularly is given.

Mannitol may also be given intravenously unless there is obvious hypovolemic shock present.

Intravenous antibiotics – usually vancomycin – are begun and continued postoperatively.
2. Initial X-ray films are plain AP and lateral skull views must be obtained prior to neurosurgical intervention to render valuable information about the bony defect, about intracranial bone and metallic fragments. The radiograph of the cervical spine are mandatory to close out associated spinal injuries.

3. Computer tomographic scanning should be performed on all patients with missile wound of the head whenever a scanner is available unless the patient is dying or his condition deteriorating so rapidly that even a short delay of surgery would jeopardize chances of survival. The CT can demonstrate a defect major fractures of the skull and indriven bone fragments metallic fragments foreign bodies. CT is the only modality that can routinely visualize the missile track all types of intracranial hematoma and the destruction of the brain the edema and air.

4. However most gunshot injury involve non-ferromagnetic lead fragments, thus findings that are obvious by CT can be quite subtle or MR imaging. It should also be noted that intracranial ferromagnetic shrapnel fragments not only may cause significant artifacts but could lead to significant injury if they are able to torque in the magnetic field. Compared to CT, MR imaging is less sensitive in the detection of metallic and bone fragments, it is more sensitive in the detection of vasogenic edema and gliosis in the chronic state.

5. If cerebral agiography is performed, attention is paid to the location of vascular injury, especially traumatic arteriovenous fistulas, aneurisms.

6. Other testing such as evoked potentials or intracranial pressure monitoring may be of interest but the primary purpose of diagnostic testing in the determination of the size and location of the injury.

Surgery

As a role once the previously noted procedures and studies have been performed the patient is taken to surgery. However patients who enter flaccid and unresponsive and have remained so in spite of hyperventillation and Mannitol administration are an expection. They may be assumed to have irreversible widespread damage and are then maintained only with supportive therapy. They may suitable candidates for organ donation and the work-up for brain death declaration may be initiated at this time.

Upon transfer to the operating room general anaesthsia is administrated and an arterial line is placed. Under these more controlled circumstances as central venous or pulmonary artery catheter and a microsensor for monitoring intracranial pressure may be inserted.
The guiding principles of surgery are fourfold:

1. Evacuation of intracranial hematom(s) and arrest hemorrhage.
2. Debridement of necrotic and obviously devitalized brain along the track of the missile.
3. Debridement of clothing, hair, skin, bone and the missile fragments where accessible without obviously increasing the extent deficits.
4. Watertight dural and scalp closure and, later on, to restore the contour of the skull.

The first step is the shaving of hair cleaning preparation and draping of skin surrounding the entrance and exit wound. A wide craniectomy over the entrance site and a smaller but adequate craniectomy at the exit site provides the surgical approach of choice.

The wide exposure should provide visualization of sufficient brain tissue to identify the missile track as well as clots, necrotic tissue, hemorrhagic points and fragments and to provide the surgeon adequate working room for their removal.

The bone flap is usually left out, because of the contaminated nature of the wound. Macerated brain tissue is debrided by irrigation and suction. Bone and bullet fragments are removed if accessibles and if their removal is not expected to worsen the neurological deficit.

Intraoperative ultrasound has proven a valuable adjunct in localizing these fragments. There is no need for the use of a surgical microscope because the structures can be clearly identified with naked eye.

The employment of the microscope prolongs the operating time and seriously increases the danger of brain swelling and the risk of infection. Inspection of the missile track can best be accomplished by the use of a surgical head lamp. The wound is irrigated with copious of antibiotic solution. If associated depressed skull fracture exists the centripetal resection of periosteum covering intact bone surrounding site of fracture and en block resection of site of depression is the procedure of choice.

Dural sinus injuries are treated by direct repair with graft material if sinus occlusion is not possible that is with the posterior two thirds of the superior sagittal sinus. If the bony sinuses have been involved the mucosa is exenterated and the space packed with fat or fascia lata and covered with pericranium or dural graft. The essential factors responsive for the high morbidity and mortality of ventricular wounds are infection with resultant ventriculitis, hemorrhage into the ventricular system and associated damage to vital centers. The resection of choroid plexus is essential part of treatment after radical debridement of all layers of missile track.
After hemostasis is achieved a subdural intracranial pressure monitoring catheter is placed before final watertight dural closure and the scalp is closed in a watertight manner after placing epidural drain which is brought out a separate incision. Occasionally the scalp has been so severely damaged as to require the rotation of a flap to allow coverage. A sterile head dressing is placed again keeping it sufficiently bulky to cushion the craniectomy site but loose enough to prevent an iatrogenic increase in intracranial pressure.

If ventilatory support was necessary preoperatively if there was significant brain swelling noted at surgery or if the postoperative hyperventilated to maintain $pCO_2$ at 25 to 30 Hgmm.

**Postoperative care**

Mannitol is added every four hour if hyperventilation alone does not control the intracranial pressure.

Intravenous antibiotics are continued for 14 days and orally in additional 14 days.

The patient also receives a loading dose of phenytoin and is maintained on a daily dose to minimize the risk of seizures.

Routinely AP and lateral skull films are taken immediately postoperatively to obtain a better estimate of the number of fragments remaining, if any.

If the intracranial pressure stays below 20 Hgmm, a CT scan with contrast is performed on the 3rd and 7th postoperative day and weekly thereafter for the first 3 weeks. This has enabled us to determine early areas of cerebritis / abscess formation, or the development of hydrocephalus. If the postoperative intracranial pressure rises over 20 Hgmm, and those not respond to the hyperventilation and osmotherapy a CT scan is performed immediately.

The discovery of a surgical lesion – that is haematoma or pulped brain – necessitates a return to the operating room for lesion evacuation. If the cause of elevated ICP is brain swelling to Mannitol dosage is adjusted to maintain a serum osmolarity of 305 to 320 mosm. If this fails pentobarbital therapy is initiated.

**Complications**

Major complications are infection, cerebrospinal fluid leakage, epilepsy and vascular injury. If an infection occurs in the flap site it is debrided and reclosed.
• Abscess formation usually require surgical removal, cerebritis require antibiotic treatment.

• CSF leakage is usually treated by 90 degree elevation of the patients head, if this fails a lumbar subarachnoid catheter is inserted for CSF diversion and kept in place for 10 days. If this too fails surgery may be necessary to seal any leaks.

• Routinely patients are kept on anticonvulsants for a year following injury. In cases where posttraumatic epilepsy develops, this problem usually remains a lifelong one.

• Vascular problems (traumatic aneurisms, arteriovenous fistulas) require angiographic work-up prior to surgical correction, or correction by interventional radiology.

• Posttraumatic hydrocephalus may be treated by VP-shunt insertion or 3rd ventriculostomy.

The most accurate predictive factor for prognosis remains the neurological status upon admission. Patients who are alert can usually be expected to have the most favorable outcome. High velocity missiles and missiles that pass tranventricularly or through more than one lobe are associated with a much higher mortality.

Conclusions

Do not want to treat the patient in the field!

After rapid sorting of casualties stabilize, and transfer them by helicopter into trauma center without procrastination!

After preoperativ measures the aims of urgent surgery are: evacuation of intracranial hematomas, meticulous debridement of all layers of the wound, and watertight dural and skin closure.

The work of a surgeon in the field is difficult, often exhausting and calls for considerable surgical skill, experience and the finest judgement.

The aims of postoperative care are to contrroll the ICP vital and neurological signs, early detection and correction of postoperativ complications.

The complete rehabilitation and reconstructive neurosurgery are very important to full recovery of the head injured patient.

The major factors that influence outcome are those over which the physician may have little control!
Bibliography