Penetrating craniocerebral trauma

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There appears to be an increasing incidence and prevalence of cranial gunshot wounds in the world. The author reviews the history of neurosurgical treatment of penetrating brain injuries and defines the basic principles of ballistics and the mechanism of brain damage. The importance of the immediate sorting of casualties is stressed.

Introduction

Penetrating craniocerebral injuries are, by definition, associated with a tear in the dura. They are major causes of morbidity and mortality in the whole world. They have been characteristics casualties of war, caused predominantly by bullets, by shell fragments and by the explosive forces of grenades and booby traps. On the other hand, we can see an exponential growth in the number of gunshot wounds in civilian practice. In parallel with these trends is the developing competence of medicine to correct and compensate for very destructive lesions of trauma.

Centuries were to pass before surgeons have understood the cause and nature of inflammation, the mechanism of contamination of wounds, the consequences of removing or not removing the missile and the relation between velocity of impact and extent of damage. It is true that by the early twentieth century we had gained the basic understanding of inflammation, infection, terminal ballistics and cavitation and had general control of the problems through concepts of first aid hemostasis, debridement, antisepsis, antibiotics and reconstructive surgery. The employment of mobile neurosurgical teams up front, improvements of medical systems of medical record keeping and the increased sophistication of surgeons in scientific analysis and statistical generalisation have all combined in this century to produce a body of basic principles that help to guide the surgical management of penetrating craniocerebral wounds.
History

In the 1st World War Harvey Cushing was the pioneer in the delineation of those principles. He documented a progressive decline in the mortality rate from 55% to 29% with use of dural closure.

Small and Turner reported a mortality of 16% in the World War II.

In the Korean War the combination of faster evacuation by helicopter air ambulance and the forward deployment of definitive neurosurgical capability, more sophisticated antibiotic therapy and greater availability of whole blood, primary closure of dura at time of initial debridement were large steps forward in the military management of intracranial head wounds.

In the Vietnam War the overall mortality decreased to 9% because of rapid resuscitation, adequate debridement removal of all intracranial bone and metallic fragments, primary closure of the dura and scalp, careful postoperative radiography, prompt reoperation to remove retained bone fragments and prophylactic antibiotics and anticonvulsants.

In the Gulf War, in the Yugoslavian War and in Afghanistan the mortality of gunshot wounds reduced to 5-6% because of faster air evacuation, intracranial pressure and cerebral blood flow monitoring using telemedicine and more rapid and sophisticated diagnostic neurosurgical techniques and perioperative intensive care.

Ballistics

Ballistics is the science of the motion of projectile during its travel through the barrel of a firearm during its subsequent trajectory through the air and during its complicated motion within the body and the wounding capacity of various missiles. Principles of wound ballistics are crucial to the evaluation of gunshot wounds and their treatment. The motion of the bullet depends on several variable factors: size, shape, composition, velocity and stability of the bullet. The more irregular the shape of the missile the more liable it will be to tumble in the air with consequent loss of range and accuracy.

Bullets are basically unstable but spinning the bullet by means of rifling in the barrel gives it stability and this spin induces deviation from the line of the long axis of the bullet. A multitude of different bullet types exist: low and high velocity bullets with short or very long cartridge case. The magnum shell increases the energy of the bullet by 20 to 60% by increasing the gunpowder charge.
The most widely accepted theory states that the wounding capacity is related to the kinetic energy \((\text{mass} \times \text{velocity}^2)\). It can be easily seen that velocity is the more important factor. Any bullet travelling above the velocity of sound in air is regarded as high velocity and any bullet below the speed of sound is low velocity. Projectile travelling in the air over 5000 feet/sec is called ultra high velocity bullet.

**Mechanisms of brain damage**

The brain damage depends not only upon the energy of the missile but on the angle at which it strikes the head. A tangential blow will cause a gutter fracture and bone fragments are sent off as secondary missiles to be driven deeply into the brain. If the missile strikes more at right angles to the skull then the missile may traverse the brain in the line of its travel.

Tissue damage from bullets has been described as stemming from three mechanisms:

1. **Laceration and crushing** are produced by the direct force of the low velocity bullet moving the tissues in its path. No significant energy is transmitted to the tissues surrounding the wound track. Only those tissues that have come into immediate contact with the missile are damaged.

2. **Shock waves** are generated in tissue by high velocity bullets owing to compression of tissue ahead of the bullet. The region of compression moves away from the bullet in spherical form at a speed greater than the bullet itself approximately that of the velocity of sound in water (4800 feet/sec). The brain is very susceptible and shock waves are conducted along arteries and veins to cause damage at a distance. Missiles of high velocity produce a faster rise and greater degree of increased intracranial pressure and brain stem effects.

3. **Temporary cavitation** can be created by high velocity bullets as the penetrating missile releases its energy rapidly it absorbed by the local tissues which are accelerated violently forwards and outwards. This creates a cavity that has subatmospheric pressure thereby sucking secondary missiles as air bacteria clothes and debris in from entrance wound.

The cavity reaches the maximum size in a few milliseconds and then collapses in a pulsatile fashion leaving a narrow permanent cavity. This causes an immediate rise in the intracranial pressure which continues to rise and peaks within the first five minutes of injury. Laboratory studies have demonstrated most elegantly initial drops in cerebral blood flow cerebral perfusion pressure systemic arterial blood pressure and cardiac output. Autoregulation is also significantly impaired or abolished so that if the blood pressure is then iatrogenically increased the intracranial pressure rises concomitantly.
This rise in pressure in the case of a supratentorial wound may be transmitted downward along the neural axis causing injury to midbrain brainstem structures and spinal cord. The brain will be pulped small blood vessels and nerves will be disrupted and bone may be shattered without being hit directly. A direct relationship exist between the absorbed missile energy the peak cavity volume and the irreversible tissue damage.

**Sorting of casualties**

No task in the medical service requiring skilled judgement more than the sorting of casualties. The aims of triage are to sort out a mass of casualties in a logical fashion based on severity of injury the need for treatment the possibility of good quality survival on the surgical and medical care available for their treatment. It is those patients who requires urgent resuscitation and/or surgery that most care will be concentrated upon. Casualties are sorted into three priorities basically as follows: Case requiring resuscitation and urgent surgery (asphyxia, hemorrhage) who require early surgery (closed cerebral injury within increasing loss of consciousness) and patients requiring less urgent surgery (maxillofacial injuries without asphyxia).

**Conclusions**

With the increasing number of gunshot wounds, more specialists in gunshot wounds will arise. Advances in the management of gunshot missile wounds have come largely during wartime and tend to be forgotten during peacetime!

Ballistics is essential knowledge in the management of most gunshot wounds of the brain. Emergency care of the victim requires team approach which includes physicians, nurses and paramedical personnel.

**Bibliography**