MANAGEMENT OF GUNSHOT INJURIES OF THE EXTREMITIES – AN UPDATE

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Gunshot injuries are more common in N.W.F.P. as compared to other provinces of Pakistan. With the start of Afghan Jehad and influx of more than 3.5 million Afghan Refugees into Pakistan[1] NWFP has become a big market for firearms. More than a hundred factories are manufacturing arms here, including replicas of latest Soviet assault rifles.[2]

Increased incidence of gunshot injuries partly due to local customs and enmities and partly due to influx of automatic weapons and their free availability has put a great threat to health of the people in this province[3] and has resulted in an increase in orthopaedic and surgical casualties.

Wound Ballistics

The mechanism of injury is the key to understanding the pathophysiology of this type of wound and hence aids in predicting the extent of tissue injury and selecting proper treatment.[4]

The missiles having velocities more than 2,500 ft/sec are classified as high velocity missiles and below this range as low velocity missiles.[5] All the modern rifles can be classified as high velocity weapons.[6,7]

The effect of low velocity missiles travelling through tissues is a very localized laceration and crushing, producing a permanent cavity which is visible and obvious.[8] The size of the permanent cavity may be increased by the yaw or tumbling,[7] bullet fragmentation[9,10,11,12,13]; bullet deformation[8,14,15] bullet explosion and secondary missiles.[16,17,18] Low velocity missiles usually fail to produce any appreciable formation of a temporary cavity.[6]

The penetration power of a missile increases with increasing impact velocities.[19,20] Also the amount of tissue damage caused by fragments of the same shape and same mass rapidly increases with increasing velocity.[21]

When a high velocity bullet travels through the target it forces the target substance away from the front to sides, lacerating the surrounding tissues,[6] capillaries,[12] vessels and nerves and produces fractures.[22] This temporary cavity has a diameter many times larger than that of the missile itself because of the shock wave it generates and it is one of the major factors that cause tissue damage.[23] During the collapse of temporary cavity, the pressure inside it is sub-atmospheric, which sucks outside material and air into the wound and produces further damage and contamination.[16,24,25]

The shape of the missile or its deformation also affects the amount of damage produced along its path. Blunt missiles produce maximum disruption in the

initial part of its path. On the other hand the aerodynamic projectiles like rifle bullets cause minimal disruption at the surface provided it remains travelling point forward. If it deforms, yaws or fragments it causes its maximum disruption at the point along its path where this occurs but not at or near the surface of the target.[26]

Fully jacketed bullets are said to penetrate deeply into the tissues releasing less kinetic energy and thus cause less soft tissue damage. Semi-jacketed bullets, increasingly used in police department, on the other hand tend to deform and produce mushrooming effect on impact which increases deceleration and reduces tissue transit. Thus more kinetic energy is released in shorter time and the bullet remains in the wound of the criminal protecting innocent bystanders. Hence, design and composition of a bullet have also got a significant role in terminal or wound ballistics.[27]

More recently plastic bullets have been introduced to reduce mortality from clashes between soldiers and demonstrators but these can cause serious injuries in children.[28]

Shotgun wounds differ from those inflicted by other missiles because of a large spectrum of wound severity. This wide spectrum of wound severity is because the pellets tend to scatter as they travel. Although shotguns are low-velocity weapons, at close range the entire charge striking the target as a single missile acts as a high velocity missile due to its greater kinetic energy. At longer ranges the scattered pellets act as multiple individual missiles.[29]

When the charge of a standard shotgun hits a victim within the range of six meters, the tissue destruction is not much different from that caused by a high velocity missile.[30] There is massive soft tissue loss, bony and vascular disruption and a high infection rate.[31,32] When the muzzle-victim range is less than 2 meters, the entire charge including shell fragments, wadding and load of shot enter the wound as a single mass along with foreign material such as clothing.[33]

MANAGEMENT OF EXTREMITY GUNSHOT INJURIES

Management of Integument and Soft Tissue Injury:

In a patient who has received a gunshot injury of an extremity alone, without damaging bones or a major neurovascular bundle, the soft tissue injury may be the only problem deserving an undivided attention. In a patient with multiple gunshot wounds to head and neck or chest and abdomen, a comparable wound of the extremity might well be managed by mere dressing and the definitive treatment postponed until later.

A) Management of Wounds Caused by Low-Velocity Missiles:

Wounds caused by low-velocity missiles usually produce crushing and laceration with a smaller diameter of the permanent wound tract. Nerves and tendons are usually pushed out of the way due to their mobility, and vessels being elastic, give way and stretch due to penetrating force of the missile without being significantly injured. Hence simple conservative treatment in such injuries has very satisfactory results.[34,35]

Cleansing and irrigation remains the key to the successful management of these injuries. For effective reduction in bacterial counts the irrigation should be done under pressure. Povidine-iodine solution with out any detergent is probably the best[36] for cleansing purposes. If machines are available to deliver a jet of fluid under pressure the bacteria lodged in the depths of tissues are also washed away.[36,37] Adding antibiotics, which are not being used systemically, to

the irrigating solution such as Neomycin, Bacitracin and others may be advantageous if toxic concentrations are avoided.[38]

Early meticulous debridement is the first need of a bullet wound, as delay in the primary surgery increases the morbidity and mortality.[39,40] The average counts of bacteria in the devitalized area of the wound track increases with lapse of time, reaching a critical level within six hours after wounding, thus emphasizing the importance of wound debridement within six hours of injury.[41]

Debridement of skin should be as conservative as possible.[42] Only that part of the skin which is evidently devitalized around the entry and exit wounds should be excised. Some workers advocate thorough exploration of the all deep wounds irrespective of the type of weapon used.[43] If the initial debridement is inadequate, septic complications are the rule requiring repeated operations and prolonged morbidity.[30]

During the exploration it may be necessary to enlarge the wound or sometimes joining the entrance and exit wounds.[42] Tight fascia should be incised and debrided widely, as a small hole in a fascia can hide large volumes of non-viable muscle.[16,36] All dead tissues including devitalized muscle, fat and small pieces of bone lying free as well as all foreign material should be removed. A limb tourniquet should be avoided as it interferes with the determination of muscle viability.[44]

If the muscle around the bullet tract is non-contractile with no capillary bleeding and has changed its consistency and colour, it is irreversibly damaged and should be excised.[4,42,44,45] However the boundary between viable and non-viable tissue may not be clear cut immediately after the infliction of trauma. It becomes easier to define the borderline after a delay of six hours due to pronounced discolouration of the damaged tissue.[39] However the delay is not recommended for obvious reasons described above.

Bone debridement should be conservative.[44] Small isolated pieces of bone lying free should be removed but those with soft tissue attachment must be left.[42,43,44,46] Large pieces should be preserved if not grossly contaminated.[44,46] Osteomyelitis may result if all the dead muscle and free bone fragments around a comminuted fracture are not removed.[47]

Exception to the rule of removing all devitalized tissue are the structures such as large pieces of bone, tendons and nerves, which are important in the overall integrity of the limb. These structures should be treated initially with irrigation, systemic antibiotics and closed repeated obsrevations.[4]

Examination of the wound after 48 hours in an operating room is mandatory to ensure the complete debridement of all necrosed tissue which may have been missed in the previous operative procedure.[31,48] Rechecks and debridement should continue until all the tissue is viable and clean.[37]

Removal of Bullets:- These should be removed only if symptomatic, lying inside a joint cavity, easily accessible during operations for other reasons, or if there is possibility of damage to vital structures. Sometimes inability to remove a harmless bullet may produce psychologic trauma, and may delay patient's return to work.[49] Lead bullets usually remain inert in the body as these become surrounded by relatively avascular fibrous tissue.[35]

Dressing:- A dressing should protect the wound from dehydration and from further external mechanical trauma. It should be bulky enough to absorb the drainage from wound if such is present.[43] It is of great aesthetic importance as well, both for the patient and relatives.[36]

An open wound can be covered with a variety of biologic and synthetic dressings. When a skin graft is not taken even then it acts like a biologic dressing. Allografts,

xenografts and onion have been tried and shown to have a cleaning effect when applied and reapplied regularly.[16] Some commercial skin-like dressings such as porcine heterograft skin, or amnion have got similar beneficial effects.[4]

B) Management of Wounds caused by High Velocity Missiles:-

High velocity missiles produce much more disruption of the tissue and injury is not limited to the obvious bullet track.[25] The wide-spread damage to the surrounding structure may not be immediately appreciated as the entry and exit wounds are much smaller compared to extensive tissue damage within the body.[35] Treatment of high velocity wounds of the limbs are similar to the low-velocity missile wound management except that secondary closure is the rule[27] and the debridement needed is more extensive and far beyond the bullet tract.[50]

The wound management can be outlined as follows:

- Excision of skin margin.
- Removal of all devitalized fascia.
- Removal of all devitalized muscle.
- Removal of periosteum only when severely contaminated and retaining fragments of bone with soft tissue attachment.
- Preservation of tendons, nerves, blood vessels unless devitalized or avulsed.
- Removal of all foreign bodies.
- Systematic exploration of the wound, with jet lavage.
- Frequent wound examination and debridement of nonviable tissue is essential.[31,50]
- Antibiotics and tetanus prophylaxis is even more important, because an additional source of contamination is the air sucked into the temporary cavity through both the entry and exit wounds.

C) Management of Shotgun Wounds:-

Wounds caused by shotguns are different from those caused by single low or high-velocity missile, ranging from a few scattered superficial pellet wounds to the most morbid and lethal close range blast injuries.[29,33,35] Sherman and Parrish have classified shotgun wounds into three types on the basis of pellet distribution, the depth of penetration and the range of fire.[33]

Type I injuries represent the wounds which are inflicted at long range and penetrate only subcutaneous tissue and deep fascia. These are best treated by cleansing the wound and applying sterile dressings. Tetanus prophylaxis should be given while antibiotics are rarely indicated.[33]

Type II injury is the one inflicted at close range and cause wounds extending beneath the deep fascia and may produce significant injury with simple looking wounds. These wounds require special evaluation to exclude vascular injury, even if the distal pulses are present, by arteriography or exploration of the vessels. Primary repair can be considered with simple sutures.[33]

Type III wounds are inflicted at a range of less than 3 meters and produce extensive tissue destruction having a central defect surrounded by small holes of numerous pellets. The initial step is to decide whether to amputate the limb or to salvage it. The factors to be considered while deciding the fate of the injured extremity are the age of the patient, ability to treat shock, the presence of other life threatening injuries and the amount of remaining viable muscle. The ability to predict amputation following combined orghopaedic, vascular and soft tissue trauma to an extremity could eliminate prolonged attempts at salvage of a doomed limb.[51] The initial operative proce-

dures should be to restore circulation of the extremity but venous repair may be impossible.

The next step is the debridement of all injured tissue. This is the most important and also the most difficult procedure. In an attempt to conserve as much viable tissue as possible for subsequent coverage, the debridement may remain inadequate necessitating frequent wound examination and further debridements later on.[31] Soft tissue injuries should be treated by prompt and aggressive debridement, including a thorough search for the presence of shotgun wadding and early wound closure to minimize contractures and joint stiffness.[29,52,53] The debridement required is not as extensive as in the case of high velocity missile wounds due to the fact that the energy released by the individual pellets is less because of their low velocity.[35]

If haemostasis could not be secured after debridement, it means inadequate debridement due to retraction of the injured vessels into crushed tissue.[33] Early wound cover may be achieved by split thickness skin grafting or a local rotation flap.[29] Management of injury to vessels, nerves and bones should follow the same principles observed for other gunshot injuries and discussed under their respective headings.

CONTROL OF INFECTION

Bullet wounds are always contaminated[35] because the heat generated at the time of fire is insufficient to make these bullets sterile. Other secondary projectiles such as skin, clothing, gunpowder debris, surrounding inanimate structures and shell wadding may carry potentially pathogenic bacteria and may also delay wound healing.[17] The incidence of infection in gunshot injuries of the extremities associated with fractures has been reported to be 22%.[54] The open fracture wounds most susceptible to secondary infection are the close range shotgun wounds.[55]

The local factors which predispose the wound to proliferation of bacteria and infection are the presence of necrotic, devitalized or crushed tissue, dead space, haematoma, and heavy contamination with soil.[56,57] The best local prophylactic measures are the complete debridement of all non-viable tissue as early as possible after the wound is inflicted,[42] because a delay in surgical treatment leaves the damaged tissue as a medium for infection.[39] In addition to this, repeated washing of exposed tissue with Ringer's lactate is certainly very important and addition of antibiotics to this solution which are not being used systemically may offer some advantage.[44,58] A culture of wound should be taken in the emergency room for culture and antibiotic sensitivity.[44] The level of bacterial contamination is an important factor in wound sepsis, and the risk of infection is correlated with the number and type of organisms in the wound when the patient leaves the operating room after wound treatment and not when the patient entered the operating room.[54].

Although the avoidance of haematoma, by carefully placing the suction drains, and doubtful skin closures are important principles in the prevention of dangerous infections in traumatic wounds,[58] foreign bodies including sutures and metallic implants also increase the risk of infection in contaminated wounds.

If clinical signs of infection appear in a post-traumatic wound, early complete reopening and debridement is indicated without waiting for pus to emerge.[58]

Use of Antibiotics

Prophylactic antibiotics are more often misused due to false indications for prophylaxis.[38] As systemic antibiotics do not reach well into the wounds which are several hours old, local antibiotics are more effective. For local use water-soluble antibiotics are preferred over ointment-based

antibiotics due to their better penetration into the tissues.[36]

Some workers do recommend systemic antibiotics for short-term prophylaxis in open fracture treatment for at least 48 hrs as this can prevent some serious infections in the injured patient.[43,44,46,59,60,63] Their use, however, may also predispose the patient to some serious hospital-acquired infections with resistant organisms.[57]

Hyperbaric Oxygen

When facilities are available, the severely injured limb or part of an extremity is put in a chamber filled with oxygen under pressure. Its effect on anaerobic organisms is well documented.[36] Apart from the condition of local area, the systemic host resistance may also influence the risk of wound infection.[4] Systemic factors that potentiate wound infection are shock, malnutrition, diabetes mellitus, arteriosclerosis, malignancy, steroid medications, extremes of ages and obesity.[56]

Tetanus Prophylaxis

This includes adequate wound care and appropriate immunization. Passive and active (if indicated) immunization against tetanus should be instituted in the emergency room.[61,62] The preferred agent for active immunization is tetanus toxoid and for passive immunization, human tetanus immunoglobulins.[64] Tetanus is better prevented by following an immunization protocol based on several factors including time since injury, mechanism of injury, estimated bacterial contamination, presence of devitalized tissue, depth of wound and past immunization.

Prophylaxis against Gas Gangrene

Wound of the extremities involving skeletal muscles especially when contaminated with soil are prone to clostridial infection with the risk of gas gangrene and it may occur after several days if an inadequately debrided wound is closed primarily.[43,55] Gas in tissues does not always indicate clostridial infection, as high velocity missile injuries are associated with palpable and radiographic intrafascial gas in healthy tissue.[42]

The treatment of gas gangrene consists of:

- Prompt surgical decompression and debridement of wounds.
- Large i/v doses of penicillin.
- Fluid and electrolyte replacement.
- Administration of tetanus toxoid (T.T.) or tetanus immunoglobulin (TIG) as and when indicated.[65]
- Hyperbaric oxygen chamber treatment if available.[55]
- Administration of polyvalent anti gas-gangrene serum (AGGS) immediately in a dose of 3 ampoules repeated after 6 hours.[66]

MANAGEMENT OF FRACTURES

Gunshot fractures are all open fractures and frequently comminuted particularly when caused by high velocity missiles.[55] The management of Fractures starts with the management of hypovolaemia followed by extensive wound debridement which are the most important factors for decreasing morbidity.[59,60] As far as the treatment of fracture itself is concerned, the aim is to obtain bone healing without infection or malunion, and restore limb and patient function as early and as fully as possible.[44,46,67] This can be attained by proper alignment by overcoming deforming forces. Thus fractures can be treated by one of the following methods.

A) Symptomatic:- When a low-velocity missile hits the margin of a cortical bone it sometimes separates a small flat cortical piece from the otherwise intact bone in the form of a chip. If the site of impact is not so marginal, i.e. slightly deeper, the piece of cortex fractured apart is thicker than a

'chip' leaving a furrow behind, where it is called a divot fracture. Both these fractures are common in the diaphysis of long bones. In the metaphyseal part of long bones, where most of the bone is spongy or flat bones like scapula or ileum, the missile may perforate through the whole thickness of the bone leaving a hole, termed as a drill hole fracture.[68] Sometimes a missile impact produces longitudinal cortical fissures in a long bone.

These fractures which account for a small percentage of fractures caused by penetrating trauma, usually require symptomatic relief only. Divot fractures complicated by linear extension of fracture and drill hole type fracture may need a weight bearing cast or functional brace.[68]

B) Closed Reduction and Casting:- Fractures which are minimally displaced or can be reduced without difficulty may be managed in a plaster cast, if soft tissue injury associated with the fracture is not extensive. Minor soft tissue injuries can be managed through a window made in the cast over the wound. This method of total contact cast immobilization has been widely used throughout the military service in the management of open and closed tibial shaft fractures.

To this management, ambulation with weight bearing can be added which results in more favourable wound and fracture healing due to increased muscular activity and improved wound drainage. This ambulatory treatment also increases appetite and improves morale of the patient.[69]

Repeated follow up with radiographic evidence of maintenance of fracture alignment is essential. the disadvantages of the cast treatment include joint stiffness, muscle atrophy, general debility and prolonged recumbency in case of lower limb injuries.

C) Skeletal Traction:- Open fractures in which reduction is difficult to maintain in cast, or are associated with severe soft tissue injury and/or too comminuted to be fixed externally can be treated by skeletal traction. When applied to open comminuted femoral fractures, skeletal traction effectively reduces and maintains the reduction. Soft tissue injuries are easier to manage but hospital stay is prolonged. In fractures associated with vascular injuries, skeletal traction without trasfixation of fractured ends may cause stretching or twisting of the vascular anastomosis.[43,70]

Regular checking of neurovascular status is mandatory to prevent complications which may arise from the traction itself, and regular X-rays are required to check the position of the fracture, the efficacy of traction and progression of healing[71]

An alternative may be a skeletal traction until early union followed by cast immobilization, when there is no danger of redisplacement and also when the soft tissue injury is healed. If the fracture is minimally comminuted, internal fixation can be considered after an initial treatment with external traction, provided the wound closure either by delayed primary suture or skin graft has been obtained.

Early internal fixation with unreamed interlocked intramedullary nails can be considered if the wound condition is satisfactory like in Gustilo and Anderson Grade I and II fractures[72] caused by low velocity missiles.

Traction can also be applied through the skin but the grip is less firm than with direct skeletal traction and the skin is also susceptible to damage from large traction forces. It is utilized only when shorter periods of relatively light traction forces are needed as in children or in the treatment of upper limbs in adults.[71]

D) External Fixation:- It is the treatment of choice in Type II and Type III open fractures which are usual in high velocity gunshot injuries. Union rates are usually higher and infection rates usually lower with

this method.[27,73] External fixation is also a preferred method of fracture stabilization in fractures with segmental bone loss, vascular injury or comminuted fractures of the shafts of long bones.[70,74,75]

Advantages of external fixation in an open fracture management caused by gunshot wound to the limbs are:

- Easy application and less operative time.[76]
- Obviates dissection at the fracture site and implants, as in case of internal fixation.[77]
- There is free access to the wound and soft tissue care and nursing is made easy.[76,77,78]
- Allows adjustability of fracture alignment.[77]
- Low infection rates as compared to internal fixation.[76,79]
- Ability to stabilize injuries extending across two or more adjacent limb segments.[77]
- Minimal interference with adjacent joints.[77]
- Provides mobilization of limb and patient, including full weight bearing.[77]

External fixation can be used either as a temporary treatment, till the soft tissue heals, to be followed by internal fixation and cast application, or as the primary and definitive method of fracture management.[78]

JOINT INJURIES

Management of the joint injuries due to gunshots should follow the same principles of treatment applied to injuries of soft and osseous tissues but with a few exceptions. In case of joints, retained bullets should be removed due to the danger of proliferative synovitis and a progressive destructive arthritis[80,81] and lead intoxication.[82] This can be accomplished by arthroscopy in case of knee joint.[81]

Along with removal of intra-articular bullets, fragments of cartilage and bones should also be removed by washing out the joint with saline to prevent the destruction of joint.[43,80] It is necessary even if such fragments cannot be demonstrated radiographically and also if the joint is only traversed by a bullet and its final lodgement is exterior to the joint or within the bone.[55,83]

Primary closure of the wound can be performed if all the necrotic and foreign material has been removed and provided there will be no neurovascular compromise due to closure.[46] If the conditions are not ideal for primary closure then the wound should be left open to be closed secondarily later on. In such cases there is no need to tightly close the synovium following exploration and debridement of the joint wound. Instead a synovium may be closed loosely or left open to allow drainage of haematoma or pus formed following the injury. In the absence of any discharge, synovium would close spontaneously in 3 to 5 days after which skin can be closed safely.

Intra-articular instillation of antibiotics is not advised due to their effect of resulting in severe synovitis which may be clinically indistinguishable from early severe sepsis. Also the intravenous route is satisfactory to attain the effective intra-articular concentrations of these antibiotics.

WOUND CLOSURE

Primary closure of low-velocity missile wounds has been reported to be successful. Early definitive coverage after aggressive debridement of shotgun wounds has also been reported to have good results.[31] In severe open fractures of the tibia it reduced the risk of infection, non-union and subsequent amputation.[84]

If there remains any doubt about the freedom from necrotic tissue and foreign

material, primary closure of the wound should not be performed and a staged management be followed. It is more hazardous to close the wound prematurely than to leave it unsutured and ungrafted. Others recommend that the skin should never be sutured at the initial treatment to avoid infection, because of the possibility of dead tissues remaining even after most careful surgery and haematoma formation.[43]

When the wound is heavily contaminated or when approximation of wound edges is impossible without tension, the wound should be left open for either epithelialization or secondary closure by skin grafts[27] to prevent dangerous infections[58].

A high percentage of successful results during World War II attest the advantage of staged wound management, i.e. initial wound debridement followed by re-evaluation and elective wound closure after several days. This time interval between the operative procedures allows the wound to exhibit any sepsis, necrotic tissue or presence of foreign body, and gives an opportunity for more complete debridment.[39] This type of closure is also preferred for gunshot wounds.[27,43]

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