Terrorist Blast Injuries

D Dhar

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Abstract

Terrorist attacks are on rise all around the World. The explosive blast attack whether in enclosed or open space is the most favoured by terrorists. All blast injuries lead to multi system injuries and both civilian as well as military surgeons must be aware of the complexities of such injuries, in order to effectively manage such terrorist attacks. This paper tries to review the literature as regards the mechanisms, pathophysiology and management of blast injuries in general.

ABBREVIATIONS

ARDS (adult respiratory distress syndrome); BLI (Blast Lung Injury); BSA (Body surface area); CT (Computerized Tomography); DPL (Diagnostic Peritoneal Lawage); FAST (focused abdominal ultrasound); IED (Improvised Explosive Device)

INTRODUCTION

There has been increasing causalities from Terrorist blast injuries all around the world. Last decade itself has seen 10 fold increase in terrorist bombings([1]) . Bombings in enclosed spaces whether in the transport network (July 11 2006 Mumbai, July 7 2005 London) or night clubs as in Bali 2002) all indicate that surgeons whether from civilian or military cadre must be prepared and experienced to manage effectively and early such blast related injuries.

Previously such blast injuries occurring in war were managed by military surgeons but now since the scenario has shifted to civilian hospitals, the civil surgeon is a central component for mass causality situation management.

Very few civilian surgeons are familiar with the effect of blast injury. In order to provide the optimal care, respond swiftly and to recognize and manage life threatening injuries in a chaotic and confronting situation([2]), the surgeon must be familiar with effects of blast injury. In this paper we try to analyze the mechanism, pathophysiology of blast injuries with particular focus on surgical management of specific injuries and triage system applicable in such situations. In particular the author shares his experience with blast injury management from his home state of Jammu and Kashmir which is in state of terrorist violence for more than one decade.

Terrorist bombings target innocent civilian population and the random nature of such attacks, with extreme variability lead to extensive soft tissue damage with involvement of multiple body systems which adds to this complexity.

BIOPHYSICS OF BLAST INJURIES

Terrorists worldwide have been commonly using bombs, grenades, and recently improvised explosive devices (IED). IED's are commonly being used in urban warfare and one of the favourite explosive devices used by terrorists in state of Jammu & Kashmir, India.

The IED's are relatively cheap to manufacture with high mutilating effect and casuality rate([3]) . The blast explosion leads to expansive shock wave with initial component of high pressure wave arising from release of gases followed by negative pressure wave due to air being sucked back towards the site of explosion([4]) . Such blast waves cause pressure / fragmentation and incendiary effects([5],[6]). Injuries caused by explosive blast were classified by Zuekerman([7]) during world war according to the physical effects on the body caused by released energy.

Primary Injury : results from interaction of the blast shock wave with the body that is barotraumas. Gas filled organs such as lung, tympanic membrane and gut are most vulnerable([8]). This is due to dynamic pressure changes occurring at the air-liquid interfaces. Rupture of Tympanic membrane is the commonest injury which occurs at as low as 3 p.s.i above atmospheric pressure([9]) .

Secondary Injury : also referred to as fragmentation injury

results from the collision of energized fragments or blast projectiles with the body. Such projectile injuries can be metal fragments from explosives such as IED or glass pieces and are the commonest cause of injuries in urban blasts.

Tertiary Injuries : result from the displacement of whole body or body parts by the blast energy causing acceleration and deceleration injury and soft-tissue destruction.

Miscellaneous Injury : such as burns, asphyxia are not directly due to blast energy per se.

Most of the present day blast injuries are complex in nature. However the injury pattern will depend upon the nature of explosive used. Bombing in enclosed spaces such as bus/trains or restaurant lead to widespread injuries from projectiles – Fragmentaion injury, Primary blast injury and burns. This is evident from the fact that majority of patients more > 50% admitted in hospitals following blasts in Trains in Mumbai (India) on 11th July 2006, 7th July 2005 London train blast or Al Khobar Towers in Saudi Arabia in 1996 were having projectile injuries.

Burns are more common with incendiary devices such as napalm (used by U.S. Troops in Vietnam) which has powdered aluminum added to increase stickiness or burning time(9) . However burns are uncommon with conventional explosives as most of the oxygen is consumed during the explosion(4) . Present day military operation use thermobasic explosives which generates lot of heat(10) . Conventional bombs may be enhanced by addition of radioactive material creating so called " Dirty Bombs ".

TRIAGING

All surgeons must be familiar with Triage in order to identify those patients who have salvageable injuries and chance of survival with correctable surgical injuries. All patients with life threatening and limb threatening injuries must be promptly identified. De Palma et al have designed an algorithm to assist triage of multiple blast victims arriving in hospital(4). Tympanic membrane perforation has been proposed as initial marker signifying exposure to blast force as per this algorithm. However severe lung injury (BLI) may be concealed initially even with intact ear drum(9). So to be on the safer side it is imperative that all patients with isolated tympanic membrane injuries should be admitted for observation with ABG monitoring to rule out delayed BLI(4). Similarly patients with traumatic limb amputations or multiple long bone fractures should be given triage priority because of high rate of associated injuries(11). The degree of external trauma is a marker for risk of BLI. Presence of penetrating head or torso injury and burns >10% of BSA also are associated with an increased risk of BLI(12) .

Physiological indicator of more serious BLI are acidotic, hypothermic patients on arrival at hospital.

Mechanical Ventilation should be considered in patients who are tachypneic, tachycardia, with multiple penetrating wounds and extensive soft tissue damage.

Triage is a continuous process and it is imperative that senior surgeons should be actively involved so that patients are reassessed regularly to ensure they remain classified appropriately.

'Reverse Triage' is new term designed in a situation where hospitals receive large number of casualties. In such a situation victims with amputated body parts, who are unresponsive to painful stimulation should be considered nearly dead and relegated to expectant management(12). Experienced senior surgeons in such a situation are important in decision making(9).

'Walking Wounded' Most of the patients arriving in hospital come walking by themselves or come by vehicle within few hours of explosion(9) . Majority of these patients have minor injuries. It is imperative that all such patients should be monitored or followed up for the development of delayed injuries especially delayed lung and intestinal injury(12) .

MANAGEMENT

Resuscitation of the blast victims should start at the site of blast in order to control haemorrhage and stabilize fractures. Resuscitation should be taken on aggressive footing along with "Early management of Severe Trauma guideline". Surgeons should lead trauma teams and act as 'roving technicians' who should be able to carry out procedures such as I/V cannulation, Emergency tracheostomy, DPL (diagnostic peritoneal lavage) and quick preliminary examination in order to triage the patients. Regardless of the initial triage, all victims should be reassessed again at the receiving hospital preferably by the senior members of surgical team.

Access to sophisticated and extensive investigations is not possible in mass-casuality situations. So one has to rely on clinical examination on the basis of which many decisions will have to be made on spot. In suspected Intraabdominal injuries focused abdominal ultrasound (FAST) scanning can be helpful. CT scan is indispensable nowadays in accessing

head, thorax and abdominal blast injuries, Angiography/embolization is useful in the initial management of exsanguinating haemorrhage.

HEAD AND NECK INJURIES

The injuries of head and neck following bomb blast are varied and usually present as combination of concussion, brain contusion, petechial haemorrhages, subdural haematoma, cerebral edema, intra cranial vascular injuries, raised intracranial pressure and penetrating injuries of brain by metallic and bone fragments. Cerbral injury as a result of systemic arterial gas embolism (a consequence of lung barotrauma) is difficult to distinguish from the direct brain trauma.

Facio-maxillary, orbital, skull base, cervical injuries are often seen associated with Head blast injuries. The ear is the most vulnerable to blast injury. Effect vary from Tympanic membrane rupture to dislocation of ossicles with varying degrees of deafness, tinnitus vertigo to hearing loss([8]) . Tympanic membrane injury heals well and managed expectantly. Antibiotic eardrops are needed if the ear canal is contaminated with blast debris([4]) .

Eye injuries can range from simple conjunctival haemorrhages to serious injuries as hyphaemia, rupture of globe([4]) . Rarely Air emboli in retinal vessels is seen([9]) .

Complex Cranofacial injuries are managed by team of Neurosurgeons / Facio maxillary surgeon along with Otorhinolaryngological surgeon and opthalmologist.

The principles of management of blast brain injury include devitalised generous craniotomy, good ICP control, evaluation of intracranial haematomas, and brain, removal of all accessible bone and metal fragments and other foreign bodies. Use of anti convulsants and antibiotics is mandatory. Deeply embedded foreign bodies in brain may be left untouched. Partial lobectomy may be required to relieve brain stem compression and brain shift. The dura should be closed completely and dural defects in the base of skull repaired primarily. If brain swelling is anticipated the skull bone flap should not be replaced.

Chronic post concussion symptoms have been reported in US troops exposed to blast injury and these victims need long term rehabilitation([13]). Other Neurological, behavioural and psychiatric disorders have been reported after severe blast and fragmentation brain injury.

It is postulated that blast injury to thorax or extremity causes secondary oscillating high frequency shock waves to the brain and spinal cord leading to chromatolysis of neurons, increase in microglia, shrinkage of axoplasm, subarachnoid haemorrhage and multiple petechial haemorrhages.

Musculoskeletal Injuries are the commonest type of blast injuries seen in the survivors of blast explosions. Traumatic amputation of a lumb, as a marker of severe multisystem injury also has high mortality([2]) . Limb amputation can occur because of primary blast, or other causes as fragmentation or crush injury([12]) . Pelvic, spine fractures are associated with increased risk of critical organ injury.

All bone and soft tissue injuries following blast are contaminated with missile debris, skin flora, coliforms and environmental debris which may be deeply embedded because of dissection of the blast wave. Such wounds are prone to infection and secondary swelling.

All wounds should be thoroughly debrided along with extension of wounds, fasciotomy of all affected compartments and these wound should be left open, however it is desirable to cover structure such as tendons, vessels and nerves. All wounds should be reexamined within 48 hours to see for any non viable tissue so as to plan for second debridment. In addition peripheral thrombosis may occur up to 72 hours post injury, extending the volume of non-viable tissue.

All patients with open wounds or soft tissue injuries should receive tetanus prophylaxis and appropriate antibiotics cover. The use of bio degradable antibiotic beads is controversial but has been described in literature especially in compound fracture.

All fractures should be stabilized as early as possible. Compound fractures of long bones, forearms are best and quickly stabilized by external fixators. In foot and hand judicious use of percutaneous krischner wires is appropriate. External fixation is a preferred means of initial fracture stabilization before contemplating vascular repair.

Severely traumatized limbs with extensive soft tissue injury, prolonged >6 hours ischemia, complete disruption of important nerves justify considering early amputation([9]) Delayed amputation may be required because of complications such as infection and thrombosis. The amputation stump should be left open and covered with vacuum dressings.

THORACIC INJURY

Blast lung injury (BLI) should be considered in victim of blast explosion regardless of the distance the victim was from the blast center. All such patients need to be closely observed for any developing lung injury. Primary BLI may be immediately lethal or present as blunt trauma with pulmonary contusion often without rib fractures or chest wall injury([2]) . Delayed pulmonary damage may present as ARDS with hypoxia and diffuse pulmonary infiltrates

The exact mechanism of BLI is unclear / Pneumothorax. Disruption of the alveolar-capillary membrane may results in pulmonary contusion, preumothorase, haemothorax, pneumomediastinum, subcutaneous emphysema and pulmonary edema([2,3,4,5,6,7,8,9,10]) . The earliest sign of BLI is systemic arterial oxygen desaturation, in absence of other symptoms([4]) . Radiological features can range from a 'butterfly pattern' bihilar shadowing on the CXR to a 'whiteout' ([4]) . Significant radiological changes occur within first 2 hours following an explosion([2]) and precede clinical signs.

Management of BLI is supportive. Mechanical ventilation and effective chest drainage form the main stay of treatment. The role of corticosteroids is not established. New innovative devices such as Biolung which provide entrapulmonary gas exchange have been used on two patients in Iraq, but are not commercially available ([9]).

BLI has poor prognosis. Recently Pizov([16]) have proposed a BLI scoring system which may predict the risk of ongoing lung injury or the development of ARDS. (Table 1).

Figure 1

Table 1: Risk Factors For Severe BLI

- $P_aO_2 / F_iO_2 < 60$
- Diffuse Bilateral Pulmonary infiltrates on chest radiograph
- Broncho-Pleural fistula
- Head Injury
- Core temperature < 35° c
- Base deficit more negative than –4

Cardiac injuries from primary blast trauma include cardiac contusion, arrhythmias and coronary artery obstruction from air emboli ([14]) .

INTRA ABDOMINAL INJURIES

Gas filled bowel loops are particularly vulnerable to blast injury but explosive blast can also damage solid organs([14,15]) such as spleen and liver.

The bowel injury can vary in severity from minor submucosal haemorrhage to full thickness disruption and perforation([15]). Colon and ileocaceal junction are the most commonly affected sites. Delayed perforations is common and can occur up to 14 days following initial blast as a consequence of ischemia([15]) . Management of suspected intra abdominal injuries should be in accordance with the principles of damage control. FAST and contrast CT are invaluable in the assessment of intraabdominal haemorrhage whereas DPL can be difficult to interpret in patients with blast injuries because of high incidence of retroperitoneal and mesenteric haematoma. Hypotensive patients and those with obvious intra abdominal trauma should be taken to the operating theatre and made to undergo abbreviated laprotomy. Second look laprotomy should be considered with 12-24 hours post blast if uncontrolled leakage or bleeding is suspected.

All patients of blast intraabdominal injuries are at high risk of developing abdominal compartment syndrome. Gastro duodenal haemorrhage has been reported in victims of blast injuries. Gastro intestinal endoscopy can be useful in the diagnosis and follow up of intestinal injuries ([15]).

Perineum and groin injuries should be approached with a high index of suspicious for coexisting intra abdominal injury([12]). Complex pelvic fractures should be stabilized with external fixators. Embolization of pelvic vessels may be required to achieve hemostatis in exsanguinating haemorrhage from pelvic vessel disruption.

ASSOCIATED ISSUES

Blast victims are at high risk of developing coagulopathy and deep vein thrombosis; so haematologist should be involved in management policy. Prophylaxis against DVT is mandatory once the initial haemorrhagic event is controlled.

CONCLUSION

Blast injuries management needs multidisciplinary coordinated approach. Traditionally blast injuries in past were under domain of military surgeons but with phenomenon of global terrorism emerging all surgeons need

to be aware of the management of these injuries. Appropriate triaging of patients and proper insight of the injury patterns and understanding the pathophysiology of blast injuries will go long way in decreasing the morbidity and mortality in the event of blast injuries.

The state on their part should upgrade trauma centers with adequate trained staff and equipment to deal with such catastrophes.

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Author Information

Dinesh Dhar, M.S. (Ortho)
Specialist Orthopaedics