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Pediatric blast injuries: Distinguishing features and unique challenges

Charlie Joe Layoun, Eveline Hitti, Rachelle El Helou*

Department of Emergency Medicine, American University of Beirut, Beirut, Lebanon
**Corresponding author*

Abstract:

Blast injuries are a major cause of morbidity and mortality in modern conflicts and terrorist incidents, placing children in particular danger in both combat and civilian settings. Pediatric blast trauma differs notably from adult presentations due to unique anatomical, physiological, and developmental factors. This review highlights the etiology, demographic distribution, and injury patterns in pediatric blast victims, emphasizing distinctions from adults and the implications for clinical management. Children are frequently injured in terrorism-related explosions, explosive remnants of war, and accidental incidents such as fireworks, with a consistent male predominance. Head injuries are more common and severe in children, reflecting larger head-to-body ratios, thinner skulls, and a lack of protective equipment. Ocular trauma, tympanic membrane rupture, and primary blast lung injury occur at higher rates than in adults. Abdominal trauma, though less frequent, contributes disproportionately to mortality due to thinner abdominal walls and larger solid organs. Extremity injuries are the most common overall, particularly upper limb amputations from unexploded ordnance and lower limb amputations from landmines. Burn and inhalation injuries, although less prevalent, are associated with markedly higher mortality in children compared to adults. Management poses unique challenges: pediatric airway anatomy predisposes to obstruction; permissive hypotension strategies used in adults are inappropriate; and surgical needs, including laparotomy and orthopedic interventions, are more frequent. Beyond the physical trauma, psychosocial consequences are profound and require early, age-appropriate support. Pediatric blast injuries, therefore, demand customized guidelines that address their distinctive injury patterns and management requirements, highlighting the need for pediatric-specific protocols in emergency medicine.

Keywords:

Blast injury, emergency management, pediatric trauma

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ORCID:
CJL: 0009-0000-4221-1963
EH: 0000-0001-9619-6092
REH: 0009-0007-1731-9076

Address for correspondence:
Dr. Rachelle El Helou, Department of Emergency Medicine, American University of Beirut, Riad El Solh, Beirut, Lebanon.
E-mail: re112@aub.edu.lb

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Introduction

Pediatric blast injuries represent a complex and increasingly relevant form of trauma, occurring in varied settings ranging from accidental explosions to armed conflict and terrorism. Children experience distinct injury patterns compared with adults due to age-specific anatomical and physiological factors, making the direct application of adult-derived guidelines problematic.[1] This review summarizes current evidence on the epidemiology, mechanisms, and injury distribution of pediatric blast trauma and outlines key considerations for emergency management.

Epidemiology and burden of disease

Blast injuries have long been a feature of warfare and civilian life, yet their burden on children remains both substantial and underrecognized.[1] Children consistently account for a large proportion of conflict-related casualties, and, in recent conflicts, have made up 30%–50% of all civilians killed or injured by explosive violence.[2] In 2023, more than 1400 child casualties from explosion-related incidents were documented across 30 countries,

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though the true number is believed to be significantly higher.[3] Trends over the past decade show that children remain disproportionately affected, with global monitoring bodies identifying a stable or rising proportion of child victims compared with adults.[4] In parallel, UNICEF reports that over 470 million children – approximately 1 in 6 worldwide – live in areas affected by armed conflict, placing them at heightened risk of exposure to blast events and related trauma.[2] These figures highlight the magnitude of the problem and the need to understand pediatric-specific injury patterns and clinical challenges.

Mechanisms and types of blasts

Blast injuries occur when an explosive device detonates, triggering a rapid chemical reaction that transforms solid or liquid material into highly pressurized gas.[5] This sudden expansion generates a powerful blast wave that displaces the surrounding air or water, causing widespread damage.[5] The blast wave comprises of an initial high-pressure shock wave followed by a blast wind – an intense, fast-moving air mass.[1]

Blast injuries are generally classified into five main categories. Primary injuries result from the direct effect of the blast wave as it propagates through the body with injuries most evident in gas-containing organs and organs comprised of structures with differing tissue densities at risk of damage by shearing forces. Secondary injuries are penetrating injuries from shrapnel and flying debris in the blast wind. Tertiary injuries are caused by bodily propulsion from the blast, with the majority of injuries resulting from abrupt deceleration at the time of impact. Quaternary injuries encompass burns, inhalational, and crush injuries,[1,6] and quintenary injuries arise from reactivation of latent infections as a consequence of immunosuppression.[7]

Injury characteristics and distribution by setting

The cause and setting of a blast injury strongly influence injury patterns and victim outcomes. Unintentional injuries from household items are often isolated with lower mortality, while terrorism-related blasts tend to cause severe multisystem trauma.

Unintentional blasts from household or commercial explosives

Fireworks are a major source of accidental blast injury in children. In the United States alone, more than 15,000 cases were reported in 2020.[8] These incidents most often occur during the holidays and typically result in burns to the hands and fingers, but powerful or illegal commercial explosives may produce lacerations, fractures, partial amputations, or ocular injuries.[9-11] Head and neck trauma, lower-limb and auditory injuries are less commonly described.[9] Most victims are boys aged 8–15 years, often injured while lighting or holding fireworks rather than as bystanders.[10,11] Mortality from fireworks is low, yet hospitalization or surgery is required in up to 20%–60% of cases.[9,10]

Unintentional blasts in active or prior conflict zones

Explosive remnants of war and unexploded ordnance are a major source of pediatric blast injury in postconflict settings such as Afghanistan, Iraq, and Cambodia.[12-14] Injuries from these small, often brightly colored devices tend to involve multiple casualties with a younger male predominance, as they are often encountered during daily group tasks like farm work or play.[12] These injuries lead to a higher rate of upper-limb amputations in 24%–52% and an increased incidence of head, neck, and chest trauma.[13,15] In Türkiye, Can *et al*. described severe hand trauma and amputations in 43% of children injured by landmines.[16] Mortality is lower than with high-grade explosives, but functional loss remains substantial, often necessitating surgery and rehabilitation.[13]

Intentional injury from terrorism or active conflict zones

Terrorism-related blasts produce the most lethal forms of pediatric injury, resulting from either direct targeting of this vulnerable group or collateral exposure in densely populated areas. Children affected are most often between 8 and 12 years of age.[8,17,18] Mortality is markedly higher than in accidental blasts (15.4% vs. 5.2%)[8] with increased injuries to the thoracoabdominal region, head and face, and lower limbs.[12,17,19] Data from the Afghanistan war show that improvised explosive devices accounted for 68% of pediatric blast admissions, with an overall mortality of 18.5%.[17] A Turkish series of 25 children from the Syrian conflict reported multi-system injuries in 84% of cases and a 44% mortality when thoracic or abdominal trauma was involved.[18] Most notably, the ongoing war in Gaza has killed more than 20,000 children and injured over 42,000, producing the largest cohort of childhood amputees in recent history.[20]

Body regions most affected in children

Patterns of injury in pediatric blast trauma and their severity vary by body region and reflect children's unique anatomical and developmental vulnerabilities. The sections below outline the major regions affected and their clinical significance, while all incidence rates and comparative statistics are detailed in Table 1.

Craniofacial injury

Children are particularly susceptible to head, ear, and eye blast injuries because of their anatomical proportions, thinner cranial structures, and limited use of protective gear.[12] Head injuries in this population tend to be more common, more severe, and more strongly associated with mortality, especially in younger children whose biomechanics place the head closer to the point of

Table 1: Incidence of blast injuries by body region in children versus adults

Region	Children (%)	Adults (%)	Key comments
Head	Head injury: 6–54[12]	Head injury: 16–29[12]	Children have a higher incidence and greater severity of head trauma due to larger head-to-body ratio, thinner cranial bones, and shorter distance between their head and ground[8,12,17]
Ear	Middle-ear rupture: 17[56]	Middle-ear rupture: 3[56]	The ear is the most vulnerable organ to primary blast. Children show higher TM and middle-ear injury rates and require early otologic evaluation, especially in preverbal children[21-23,25]
Eye	Globe perforation: 28[12] Blindness: 21–28[12]	Globe perforation: 14[12] Blindness: 10[12]	Children have higher ocular trauma severity with a twofold increase in perforations and blindness compared with adults.[12,15,26] Fireworks are a major cause of eye injuries in children[57,58]
Thorax	Lung contusion: 51 of torso injuries[12,59] Primary BLI: 25 of admissions[60] Death: 8[12]	Lung contusion: 35 of torso injuries[12,59] Primary BLI: 6.7–8.1 of survivors[61,62]	The flexible chest wall in children transmits blast overpressure directly to the lungs with a higher rate of primary BLI without rib fractures or signs of external injury[1,27]
Abdomen/pelvis	Abdominal injury: 12[59] Death: 18[12] Laparotomy: 23[12,63]	Abdominal injury: 20[59]	Less frequent but more lethal in children. Thin abdominal wall and larger solid organs increase injury severity. Hollow viscus injuries may present late, and common operative findings include bowel and vascular trauma[8,12,27,64]
Upper extremities	Severe trauma from landmines: 43[16] Fractures: 47[33] Distal amputation: 44–94[12] Proximal amputation: 14–34[12]	Civilian and blast-related injuries: 31–33[65,66]	Children sustain more upper-extremity injuries due to hand-level interaction with ERWs/UXOs. Distal amputations more common in accidental blasts[12,14]
Lower extremities	Injuries 25–86[12,17] Transtibial amputations: 25[17]	Injuries: 11[65]	Landmines and IEDs produce the highest lower-limb injury burden in children. Injuries include degloving, open fractures, and heavy contamination. Damage near the distal femur or tibial growth plates increases the risk for long-term deformity. Incidence rises with age; adolescents resemble adult injury patterns, while children <3 years show lower involvement[12,17,34]
Burns	Incidence: 9–12[12] Mortality: 36–40[5,12] Inhalation injury mortality: 39[12]	Mortality: 5[5,12] Inhalation injury mortality: 4[12]	Children have higher burn mortality due to larger %TBSA involvement and smaller reactive airways; higher operative burden and ICU stays[12,39]

BLI: Blast lung injury, TM: Tympanic membrane, ERWs: Explosive remnants of war, UXOs: Unexploded ordnance, IED: Improvised explosive devices, TBSA: Total body surface area, ICU: Intensive care unit

impact.[12,17] The ear is often the first organ injured in a blast because the air–tissue interface at the tympanic membrane makes it highly vulnerable to overpressure, resulting in tympanic membrane and middle-ear damage even when external signs are minimal.[21-23] This is particularly concerning in preverbal children, where hearing loss may go unnoticed.[24,25] The eyes, despite comprising a very small surface area, bear a disproportionate share of pediatric blast trauma and are more likely to sustain penetrating injury, globe rupture, and vision-threatening damage compared to adults.[12,15,26] Together, these factors make the craniofacial region a major driver of morbidity in pediatric blast victims and warrant a low threshold for comprehensive neurologic, otologic, and ophthalmologic assessment.

Thoracoabdominal injury

The thoracoabdominal region represents a major site of morbidity in pediatric blast trauma due to the unique structure of the developing chest and abdomen. Children's highly compliant thoracic cage transmits blast overpressure more directly to the lungs. As a result, primary blast lung injury (BLI) – such as pulmonary contusions and occult parenchymal damage – is more common and more clinically significant than in adults, often occurring even in the absence of rib fractures.[1,27] Abdominal injury, though less frequent, tends to be more lethal in children because their thinner abdominal wall, lower fat padding, and proportionally larger solid organs amplify the force transmitted to underlying structures.[8,27] Hollow viscus injuries may also present in a delayed fashion, increasing the risk of missed or evolving pathology.[12] When abdominal blast trauma occurs, operative intervention is common, with bowel and vascular injuries representing the most frequent surgical findings.[12,28] Negative laparotomies are uncommon, which supports maintaining a low threshold for surgical exploration when severe intra-abdominal injury is suspected in the context of blast injuries.[29]

Extremity injury

Extremity trauma is a hallmark of pediatric blast injury, accounting for up to 69% of cases in conflict zones.[12] One of the most harrowing examples is the ongoing war in Gaza, where, by June 2025, over 4000 children have lost one or both limbs,[30] with around 10 new amputations occurring every day.[31,32] Compared to adults, children are significantly more likely to sustain upper limb injuries following blasts, and children who suffer lower extremity injury are more severely affected than adults.[12,33] Limb injuries sustained during childhood frequently lead to lasting functional impairment, especially when associated with early amputation and prolonged recovery. In conflict settings, inadequate access to pediatric rehabilitation and prosthetic care amplifies long-term disability and psychosocial impact, making extremity trauma a major source of morbidity in pediatric blast survivors.[12,17,34]

Acute compartment syndrome is a serious, limb-threatening complication in pediatric blast trauma. While it can occur in both upper and lower extremities, it is especially difficult to diagnose in children due to its atypical presentation. Classic adult signs may be absent; instead, children may exhibit subtle findings like increasing anxiety, restlessness, or escalating analgesic needs.[1,35] Small shrapnel wounds can conceal serious vascular injury, so early compartment pressure monitoring is essential when perfusion is unclear.[1] When fasciotomy is performed promptly, children generally have favorable outcomes due to their superior healing capacity.[36]

Burns and inhalation injury

Pediatric burn injuries in conflict zones are predominantly caused by civilian incidents, such as scalds, open fires, and flash burns from household fuels rather than from blasts.[12] Blast-related burns in children are rarely isolated and are often accompanied by complex polytrauma that worsens outcomes. Compared to adults, children suffer significantly higher mortality from blast-related burns, particularly when inhalational injury is present.[5,12] Children experience proportionally larger percent of total body surface area burned (%TBSA), predisposing them to complications such as hypotension and myocardial dysfunction.[12] %TBSA exceeding 30% is a principal cause of death in this population.[37] Inhalational injuries are also more common and deadlier in children compared to adults, due to the smaller, more reactive pediatric airway.[12] Pediatric burn victims aged 6 months to 3 years are up to 14 times more likely than adults to require surgical intervention, such as escharotomies and fasciotomies.[38] These high operative demands, combined with longer intensive care unit stays and limited rehabilitation access in low- and middle-income countries, amplify the burden of pediatric burn care compared to adults.[12,39]

Management of Pediatric Blast Injuries

Despite injury being a leading cause of death and disability in children, systematic pediatric-specific protocols are lacking, with most trauma centers following adult-derived guidelines with pediatric considerations. In the absence of such protocols, providers caring for pediatric trauma victims in general and blast victims in particular should familiarize themselves with issues that are unique to the management of children.[40]

Airway

One of the most time-sensitive priorities when managing a pediatric blast victim is securing a patent airway. Children have relatively large occiputs that cause neck flexion when lying flat, which can obstruct the airway. Placing a blanket under the shoulders may help align the neck and maintain an open airway in children under the age of 8 years.[37] In children with blast injuries who require either a head-tilt-chin-lift or a jaw thrust to open the airway, a jaw thrust is preferred to maintain spinal neutrality.[37] Rigid cervical collars are often avoided in smaller-sized children due to their improper fit in the younger age group and, therefore, their potential to worsen airway obstruction. Manual in-line stabilization is preferred.[41] Moreover, the pediatric larynx is higher than the adult's, with a floppier epiglottis, a narrower trachea, and easily compressible soft tissues. These differences make children, in general and especially those with trauma or inhalational injury, more prone to rapid obstruction from swelling or improper handling.[27,37]

Breathing

Compared to adults, children desaturate faster due to a higher mass-specific oxygen consumption and smaller functional residual capacity. Their compliant chest walls predispose children to atelectasis and fatigue[42] and lead to pulmonary contusions and pneumothoraces without overlying rib fractures.[43,44] When tension pneumothorax is suspected, needle choice for decompression differs from adult guidelines, with ultrasound and computed tomography data revealing thinner chest wall thickness in children under 13 years, necessitating the use of shorter needles.[45,46] In BLI, practice typically follows lung-protective ventilation strategies and limits unnecessary crystalloid administration.[47,48]

Circulation

Children have a higher total body water content, a greater surface area-to-mass ratio, and a higher metabolic rate, making them more susceptible to hypovolemia and electrolyte imbalances.[49] Permissive hypotension, now considered routine practice in adult major trauma management, is inappropriate in the pediatric setting.[37] Resuscitation generally requires weight-based isotonic fluid boluses (typically 20 mL/kg), with an emphasis on early administration of blood products as soon as they are available.[49] In children with a high %TBSA, maintenance fluids must be calculated using pediatric, age-adjusted methods and added alongside resuscitation volumes. All fluids are typically warmed to prevent hypothermia.

Intraosseous access is often preferred in children during emergencies, as their thinner cortical bone and vascular marrow allow for quicker and more reliable access when IV insertion is difficult or delayed.[37,49]

Disability

Neurological assessment in pediatric blast victims focuses on rapidly identifying altered mental status and preventing secondary brain injury. Level of consciousness should be assessed using the alert, voice, pain, unresponsive (AVPU) scale. Children who respond only to pain or are unresponsive generally correspond to a Glasgow Coma Scale score of 8 or less. Pupil size, symmetry, and reactivity must be documented. Clinicians should assess limb tone and movement, noting abnormal posturing such as decorticate or decerebrate patterns. Bedside glucose testing is essential, as hypoglycemia can mimic or worsen neurologic depression. Values <3 mmol/L should be treated with 2 mL/kg of 10% dextrose followed by a glucose infusion to prevent recurrence. Decreased responsiveness may compromise airway protection, warranting early airway intervention in children Graded *P* or U on AVPU. Signs of raised intracranial pressure, such as worsening consciousness, unequal pupils, bradycardia, or hypertension, should prompt immediate neuroprotective steps, including head elevation, maintaining oxygenation and blood pressure, and considering hyperosmolar therapy while arranging urgent imaging and neurosurgical review. Frequent reassessment is crucial, as blast-related brain injuries may initially lack external signs yet evolve rapidly over time.[37,50-53]

Exposure, burns, and psychosocial considerations

Similar to adults, pediatric victims of blasts must be exposed from head to toe, front and back, to complete a thorough assessment of the extent and nature of their wounds and burns. %TBSA should be calculated using age-based charts such as the Lund Browder chart or using the 1% rule, which states that the surface area of the child's palm represents 1% of their TBSA. Because children have a higher surface-area-to-volume ratio than adults, they are more susceptible to hypothermia in trauma settings; therefore, once the initial exposure assessment is completed, they should be promptly covered and actively kept warm with their temperature monitored.[54,55]

Beyond the physical trauma, blast injuries in children carry significant emotional consequences that must be addressed during the blast aftermath. Fear, pain, grief, and confusion are common responses, and reactions vary based on age and developmental stage. Young children may regress or cling to caregivers, school-aged children may experience somatic complaints and memory issues, while adolescents often face distress over body image, independence, and peer relationships. Avoiding separation from parents or guardians is pivotal, as children draw security and emotional stability from their presence. If separation is inevitable, reuniting separated children with their caregivers should be completed as soon as possible. Frontline staff must use age-appropriate language, provide reassurance without false promises, and involve caregivers actively in care and decision-making. It is also important to create a child-friendly environment to reduce fear, using examples such as age-appropriate toys, cheerful colors in recovery areas, and medical play to help younger children understand procedures. Children's dignity and rights must be always be respected, while trying to involve them, when appropriate, in decisions about their care. This would help them regain a sense of control and support their emotional recovery. Comfort for caregivers is equally vital, as their distress can also affect the child's recovery.[37,40]

Conclusion

Blast injuries remain a devastating result of modern conflict, and children are disproportionately affected. Their distinct physiological and anatomical features make them more vulnerable than adults to both immediate trauma and long-term complications. While adult guidelines may serve as temporary references in time-sensitive situations, pediatric patients require tailored protocols that recognize their unique injury patterns. Beyond the physical injuries, the emotional and cognitive impact of blasts on children is profound, demanding comprehensive rehabilitation strategies that integrate medical, psychological, and social support. Ultimately, advancing pediatric-specific guidelines and preparedness is essential to ensure that injured children receive the specialized care and protection they deserve.

Author contributions statement

CJL, EH: Conceptualization, methodology, investigation, resources, data curation, and writing – original draft. REH: Conceptualization, methodology, investigation, resources, data curation, writing – original draft, review and editing, and supervision. All authors approved the last version of the manuscript.

Conflicts of interest

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