



# Management and Treatment Principles for Pediatric Abdominal and Thoracic Trauma After Disaster

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## Abstract

Thoracoabdominal organ injuries are one of the most common causes of earthquake-related mortality in children. The majority of severe injuries are when caught under the rubbles. In severe cases who can reach health care in the early period, milder injuries, morbidity, and mortality can be prevented with effective and rapid interventions. In the management, physical examination and traditional diagnostic/therapeutic invasive methods become important as laboratory and imaging tools may be out of use in the early post-disaster period. On the other hand, it should always be kept in mind that Crush syndrome, which develops secondary to earthquakes, has more mortal outcomes. Therefore, interventions should be fast and effective. In addition to preventive approaches, learning medical intervention and adapting to unfavorable conditions in disaster situations is very important, especially for medical personnel of countries in seismic zone.

**Keywords:** Abdominal trauma, chest trauma, children, earthquake, guideline, trauma

## Introduction

Resuscitation of children after earthquakes and crush injuries is mostly parallel to those of adults. However, important anatomical and physiological differences of children, which could affect viability, should additionally be kept in mind. Small body surfaces and non-ossified elastic skeletons are advantageous for children as means of protection from crushes and fractures.<sup>1</sup> Conversely disadvantages of children that can play a role in multiple life-threatening injuries could be mentioned as weekly protected abdominal and thoracic organs due to immature musculoskeletal system, lack of fully developed physiological compensatory mechanisms, and high body surface-to-body weight ratio.<sup>2</sup> Children are also more prone to dehydration and hypothermia.

Injury mechanisms in earthquakes are mostly blunt traumas, majorly, blunt strikes, crushes, and falling.<sup>3</sup> Extremity traumas mostly accompany systemic injuries.<sup>3</sup> Renal functions could easily deteriorate secondary to dehydration. While general trauma features familiar to pediatric surgeons are also valid for earthquakes, lack of availability to biochemical and radiological investigations, delayed access to healthcare, and nephrotoxicity secondary to myolysis are features that are unique to natural disasters, which may necessitate non-ordinary approaches and reapplying traditional methods.

Children may suffer from irreversible damage and serious morbidity after earthquake injuries. Not overlooking minor details may prevent life-long sequelae, which is why every child deserves a fast, aggressive but equally gentle resuscitation, no matter how severe the injury is. Severe thoracoabdominal injuries commonly result in on-site mortality.<sup>4</sup> This chapter mostly focuses on management

of thoracoabdominal injuries at emergently organized healthcare facilities, rather than the field (the rubble).

## General Approaches (ABCDE)

### Airway

The most important step of resuscitation and initial intervention is to provide a secure airway. Oxygen supplementation should be given to conscious children to maintain oxygen saturation above 95%. In the setting of hypovolemic shock, unconsciousness, major extremity losses, and severe fascial and airway injuries require endotracheal intubation.

The steps of endotracheal intubation are summarized in Figure 1.<sup>5</sup> If an orotracheal intubation route is obscured, tracheostomy should be performed. If this is not possible, needle cricothyrotomy should be attempted temporarily. Formulas for appropriate endotracheal tube size and fixation distances are summarized in Table 1.<sup>5</sup> Uncuffed tubes should be preferred in children under 8 years old unless in the setting of recurrent patient transfer and/or high-pressure ventilation requirement.<sup>6</sup> Using a guide wire would be helpful while intubating small children.

### Breathing

Respiration parameters differ significantly among different pediatric age groups. Most commonly, respiratory failure occurs due to central nervous system and thoracic injuries. Abdominal injuries can also affect respiratory functions secondary to pain and pressure effect. Traumatic hemothorax and pneumothorax require emergent interventions. Mediastinal shift could easily occur due to the mobile nature of mediastinum in small children. This may cause impaired venous return and respiration of the contralateral hemithorax with consequent hypoxia and cardiac arrest, even after single-sided injuries.

Tube thoracostomy is the surgical treatment for pneumothorax and hemothorax. Diagnosis is usually made via chest x-ray or computed tomography (CT). If these are not available and there is cardiovascular instability, physical examination and thoracentesis

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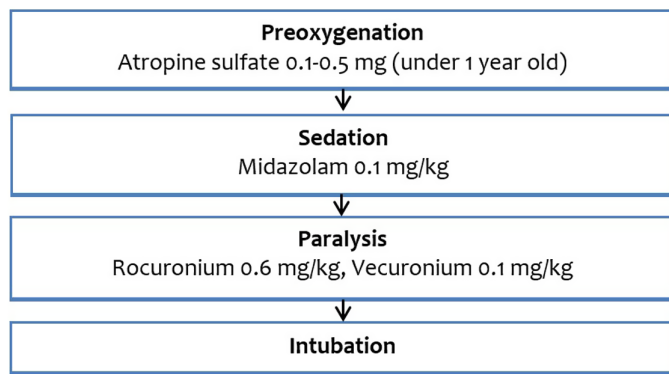
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**Figure 1.** Endotracheal intubation.

can provide the diagnosis. Thoracentesis should be done along the line of presumed thoracostomy. Tube thoracostomy should be performed quickly in both definitive diagnosis and when in doubt. The head side of the bed should be elevated to 30°-45° and a roller should be placed under the ipsilateral hemithorax. The incision site is determined following asepsis. A local anesthetic should be injected if the patient is alert and conscious (bupivacaine 2 mg/kg, lidocaine 4 mg/kg). The tube should be inserted into the thoracic cavity at the level of the 4th-5th intercostal space (nipple level), in between the anterior and mid-axillary lines, gliding over the lower rib to prevent damage to neurovascular structures. After the appropriate incision is made, a long hemostatic clamp is pushed toward the thoracic wall, stopping when the pleural cavity is entered. Afterward the clamp is slightly retrieved and opened to expulse the opening, and the tube is advanced over it.

### Circulation

Circulatory problems are difficult to diagnose during the early periods of a traumatic injury. Multiple findings should be evaluated simultaneously. Hemodynamic parameters vary significantly among age groups (Table 2). An important difference from adults is that hypotension occurs as a late-onset finding and represents shock state. Early-onset findings of impaired circulation are<sup>5</sup>

- tachycardia;
- impaired capillary return and skin circulation, cold extremities;
- weakened peripheral pulses and low pulse pressure (<20 mmHg);
- impaired consciousness, sleep tendency; and
- decreased urinary output (1-2 cc/kg/h in infants, 1 cc/kg/h for children, and 0.5-1 cc/kg/h for adolescents).

**Table 1.** Diameters and Distances of Endotracheal Tubes

	Diameter	Distance
Formula	4+ (Age/4)	12+ (Age/2)
0-28 days	3-3.5	9-12
1-24 months	4-4.5	12-13

Initial steps for managing circulatory insufficiency are estimation of body weight and blood volume according to patient's age group, ensuring large diameter parenteral lines, fluid resuscitation, and preserving body temperature.

Body weight in relation to patients' age can be estimated by using "10+ (age × 2)" formula. Intravenous (IV) volume can be calculated as approximately 80 cc/kg under 1 year of age and 70 cc/kg over 3 years of age. For providing parenteral lines, conventional multi-trauma steps should be followed (Figure 2).

If muscular crush is not present, routine usage of crystalloids and blood products can be applied in early resuscitation (Figure 3). However, this standard approach should be modified if Crush syndrome is suspected or if a child is rescued late from the field. For children with suspected crush syndrome, intravenous hydration should be started with isotonic saline bolus (20 cc/kg) repeated twice and continued with alkalinized solutions in high volumes. Children rescued after prolonged periods of time show affected kidney functions, severe dehydration, and hypernatremia. These cases should receive controlled intravenous replacements starting from the onset of treatment. Except in the presence of cardiac arrest, first replacements should be cautious high-flow hydrations rather than bolus treatments. Hypoglycemia should be checked. Urine output should be monitored. Correction of hypernatremic dehydration should be expanded to the first 48 hours, taking attention not to lower sodium levels more than 0.5 cc/h.<sup>7</sup> Since the main factor contributing to long-term survival under the rubble is considered to have a relatively minor injury, and Crush syndrome is less expected in these cases, even in the presence of high blood creatinine kinase levels.<sup>8</sup>

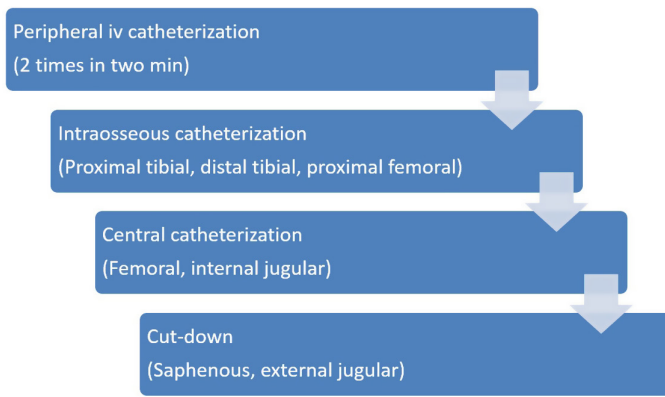
Patients responsive to resuscitations should be monitored and followed up at wards or intensive care units. In the presence of active and ongoing hemorrhage, blood product replacements should include an erythrocyte suspension: fresh frozen plasma: thrombocyte suspension ratio of 1 : 1 : 1.<sup>9</sup>

Optimal body temperature is maintained as a standard approach in patients with unaffected central nervous systems. Parenteral fluids should be heated before infusions, if possible. Heaters and blankets should be used to prevent heat loss and head coverage must be done for infants.

**Table 2.** Vital Signs of Children

Ages	Weight (kg)	Pulse/min	Tension (mm Hg)	Breath/min	Urine (mL/kg/h)
0-12 months	0-10	<160	>60	<60	2
1-2 years	10-14	<150	>70	<40	1.5
3-5 years	14-18	<140	>75	<35	1
6-12 years	18-36	<120	>80	<30	1
>12 years	36-70	<100	>90	<30	0.5

Source: American College of Surgeons (2018).<sup>5</sup>



**Figure 2.** Parenteral access algorithm for children. Source: Adapted drawing: American College of Surgeons (2018).<sup>5</sup>

External systemic examination and neurologic evaluation should be carried out and recorded as routinely performed, quickly and without causing hypothermia.

A nasogastric tube should routinely be placed in patients on mechanical ventilation or with abdominal injuries. A Foley catheter must be implemented for all patients with dehydration, crush history, or hemorrhage.

### Chest Trauma

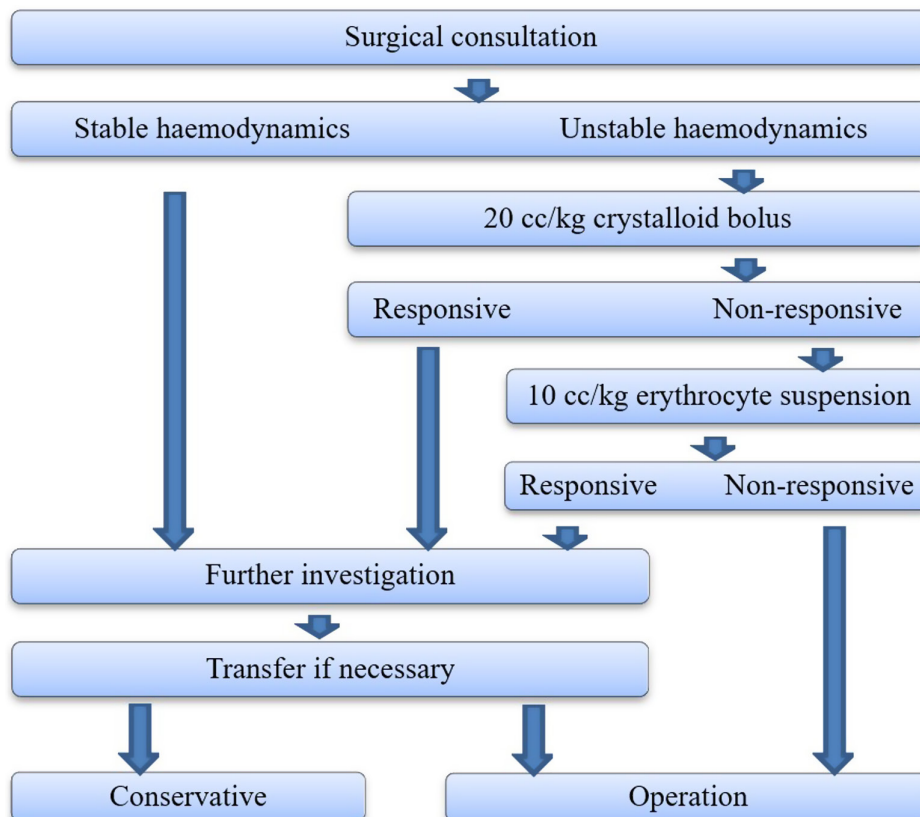
Thoracic injuries are routinely encountered after earthquake injuries.<sup>10</sup> Hemothorax and pneumothorax are routinely managed. However, access to routine tools may not be possible during natural disasters. It is under these circumstances that physical

examination and thoracentesis come into prominence. The general approach to conscious or unconscious patients is summarized in Figure 4. Even though it is rarely encountered in blunt injuries (compared to penetrating traumas), pericardial tamponade should be differentiated from hemo/pneumothorax.

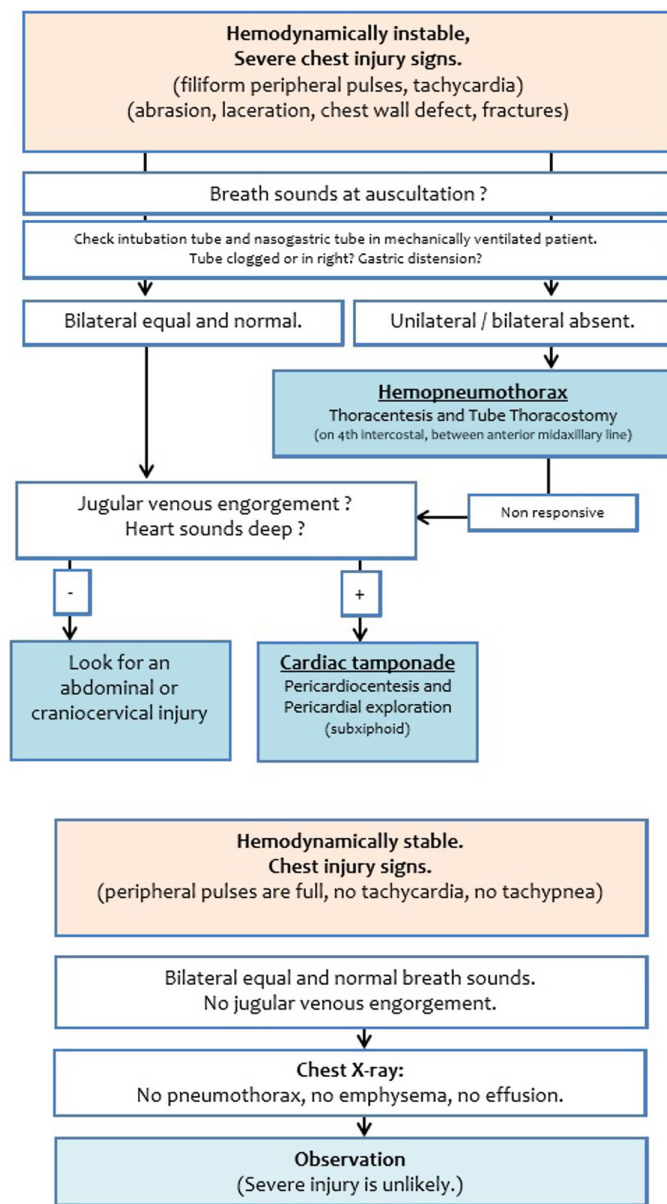
First-line radiological investigation is direct radiography. The efficacy of CT is not clear for thoracic traumas. After evaluating clinical findings and direct radiography, if thought to provide additional information to guide the treatment, CT can be used.

For pneumothorax and injuries involving the airways, direct radiography is thought to be sufficient for first-line imaging. A pneumothorax that is not visible on the chest x-ray would also be clinically insignificant. In the case of a tension pneumothorax, airway injuries or wide parenchymal lacerations should be suspected. Treatment of a tension pneumothorax is tube thoracostomy done at the level of 4th-5th intervertebral space. However, if performing tube thoracostomy is not immediately possible, a wide-bore vascular cannula (the largest that can be found) should be inserted from the second intercostal space at the midclavicular line or from the preferred tube thoracostomy location to provide temporary decompression.

Another commonly encountered clinical presentation is pneumomediastinum, which can emerge with blunt injuries after earthquakes without any additional underlying injuries. While the underlying cause is not well known, it is thought to occur secondary to a sudden increase in airway pressures while the vocal cords are closed. These cases can be managed conservatively if there is no accompanying pleural effusion, tension pneumothorax, dysphagia, or respiratory distress. An oral contrast esophagogram study should be performed for cases with pleural effusion or worsening pneumomediastinum.



**Figure 3.** Intravenous resuscitation algorithm according to hemodynamics. Source: Adapted drawing: American College of Surgeons (2018).<sup>5</sup>



**Figure 4.** Algorithms in cases of chest trauma.

Hemothorax is managed with tube thoracostomy, as pneumothorax. Hemothorax cases that do not cause atelectasis, respiratory or circulatory insufficiency, or are not visible on direct radiography can be managed conservatively. Tube thoracostomy is indicated for cases that become radiologically visible or are symptomatic. Emergency thoracotomy is indicated if tube thoracostomy is insufficient for drainage, drained blood is over 15 cc/kg or 2 cc/kg/h.<sup>2</sup>

Pulmonary contusion is the most common form of thoracic damage. Hemorrhage and edema occur at the pulmonary parenchyma secondary to trauma. Treatment relies on preventing atelectasis and providing respiratory support. Intravenous steroids (methyl prednisolone 2 × 1 mg/kg) and antibiotherapy (ampicillin-sulbactam 2-3 × 50 mg/kg) are used in cases with bilateral involvement.<sup>11</sup>

### Abdominal Trauma

For children with suspicious abdominal injuries, decisions should be made in accordance with hemodynamic findings and state of consciousness (Figure 5).<sup>12,13</sup> If the patient is unconscious or hemodynamically unstable, fluid resuscitation should immediately

be started prior to secondary investigations. If hemodynamic findings are not responsive to resuscitation with intravenous bolus fluids and blood products, emergency surgical exploration is indicated. For patients with stable and/or responsive hemodynamics, secondary investigations are done. For unconscious patients, CT is pursued, after evaluation of physical findings and urine output in response to fluid resuscitation without waiting for laboratory results.

Indications for CT should carefully be selected in earthquake injuries. Severe hypernatremic dehydration and nephrotoxicity secondary to myolysis are very frequent in patients rescued under the rubble. Intravenous injection of contrast agents can cause deterioration of the already worsened renal functions, resulting in a life-long need for renal replacement therapy. This is why even when it is indicated, contrast-enhanced CT should not be performed before assuring appropriate renal status. Other diagnostic studies can be pursued when in need or appropriate cases can be followed with serial physical examinations. Computed tomography without intravenous contrast has no value in traumatic injuries and should not be performed.

Diagnostic peritoneal lavage (DPL) is a procedure that can be of use in cases of severe abdominal trauma where CT cannot be accessed or is not appropriate. Diagnostic peritoneal lavage can assist in surgical decision-making in the presence of hemodynamic instability or problems with transportation.<sup>5</sup> After the abdominal skin is incised 1-2 cm above or below the umbilicus, 16-18 Gauge cannula is inserted into the abdominal cavity through the linea alba. After the needle is withdrawn, the abdominal cavity is filled with 10 cc/kg of warm saline solution. The patient is rotated laterally to both sides in order to circulate the fluid inside the abdomen. The infused fluid is then retrieved through the cannula and is biochemically evaluated. "Positive DPL findings" are erythrocyte level above 100 000/mm<sup>3</sup>, leukocyte level above 500/mm<sup>3</sup>, presence of bacteria with gram staining, and elevated amylase levels. Indication and performance of DPL are the responsibility of the surgeon.

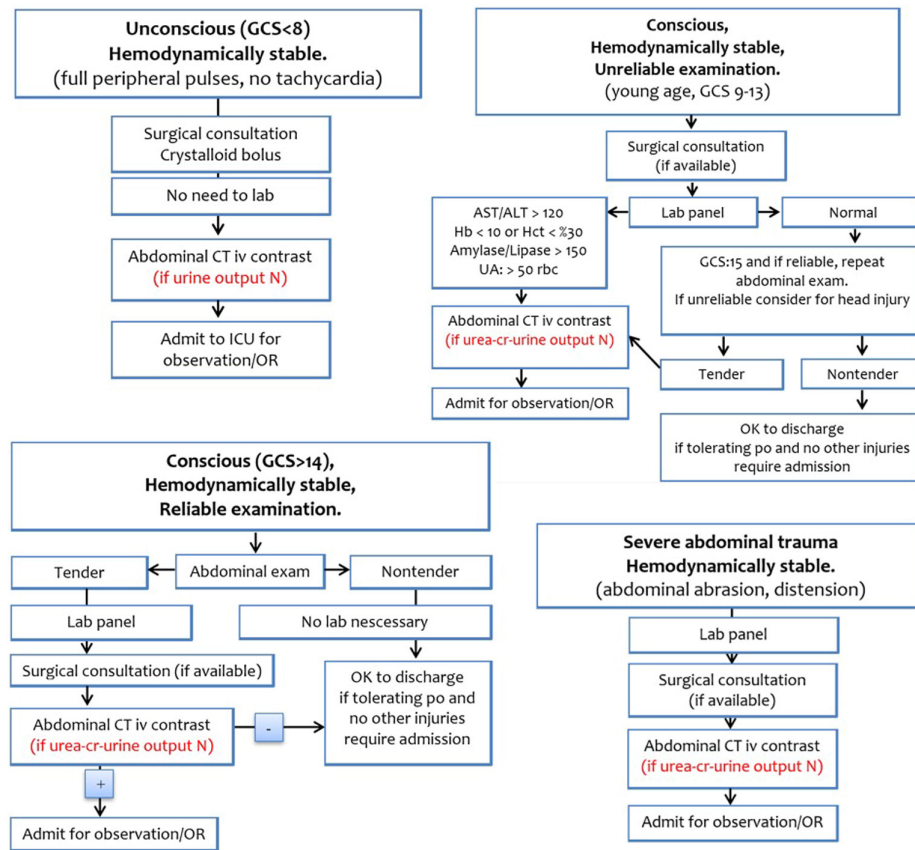
The conservative management based on hemodynamic stability for injuries regarding liver and spleen is excepted today as the first-line option in the management of almost all solid organ injuries. Conservative management consists of absolute bed rest and immobility. Inpatient follow-up should set place at centers consisting of transfusion and intensive care emergency surgical units, under the supervision of a pediatric surgeon. If these circumstances cannot be met, patient transfer to appropriate centers should be organized.

For pancreatic injuries, mild cases with early onset presentations may be missed due to normal physical examination and laboratory findings. Elevated amylase levels and CT findings are diagnostic. However, it should be kept in mind that central nervous system injuries and prolonged fasting can also result in elevated amylase levels. Management protocols are based on the damage localization and presence of ductal injury. Endoscopic retrograde cholangiopancreatography is the first-line method for pancreatic head and neck injuries with partial ductal involvement. Sphincterotomy with stenting may reduce the need for operation for incomplete lacerations.<sup>14</sup> Operative management is required for complete pancreatic ductal lacerations.<sup>15</sup> Spleen preserving distal pancreatectomy should be performed for injuries of the pancreatic body and tail.

Injuries of the small bowel are hard to detect with laboratory and radiological findings, while nearly all present clinically with peritoneal irritation findings.

Renal injuries can arise as frequently as injuries related to liver and spleen. For patients with clinical and radiological indications for an abdominal CT, an additional late-phase scanning after 5





**Figure 5.** Algorithms in cases of abdominal trauma. ALT, alanine transferase; AST, aspartate aminotransferase; cr, creatinine; CT, computed tomography; GCS, Glasgow coma score; Hb, hemoglobin; Hct, Hematocrit; N, normal; UA, complete urinalysis. Source: Adapted drawing: Fallon et al (2016).<sup>12</sup>

minutes should be done in the presence of findings such as macroscopic hematuria, microscopic hematuria with hemodynamic changes (red blood cell  $>50/\text{mm}^3$ ), flank abrasion or ecchymosis, and lower rib fractures. Conservative management is the method of choice for hemodynamically stable patients. Surgery is indicated in the presence of hemorrhagic shock, ongoing hemorrhage after massive transfusion, or angioembolization. Bladder drainage and bed rest is required when there is dysuria secondary to massive hematuria or contrast extravasation from the renal pelvis. JJ stenting or percutaneous nephrostomy should be performed in the presence of severe ongoing pain, infections with high fever, and expanding urinoma or ileus.

Bladder and urethral injuries should be suspected in the presence of pelvic fracture with massive hematuria, voiding difficulty, urethrorrhagia, perineal-scrotal hematoma, and suprapubic distension with decreased urine output. In these cases, radiological examination should be performed if possible, and the gold standard diagnostic modality is retrograde cystourethrography. However, if radiological access and patient transfer are not possible and the patient develops "glob vesicale," it is important to provide bladder drainage. For transurethral drainage, it is beneficial to prefer thinner feeding tubes over ballooned Foley catheters. Catheterization should be attempted once or maximally twice with excessive use of lubricants. If these attempts fail, a percutaneous catheter should be inserted into the distended bladder under local anesthesia, 1-2 cm above the pubis.

Extraperitoneal bladder injuries can be observed under suprapubic drainage. Surgical repair should be performed for intra-peritoneal injuries, bladder neck lacerations, extraperitoneal cases

unresponsive to conservative management, and hemodynamically stable cases undergoing laparotomy for other injuries. For hemodynamically stable urethral injuries, catheterization of the proximal urethra and bladder is attempted via early cystourethroscopy. If this attempt fails, suprapubic drainage is performed with the case being reserved for delayed primary repair.

### Summary

Operational and accessible equipment and supplies play a significant role in the acute phase of disaster management. Approach to pediatric thoracoabdominal injury cases that are rescued from under the rubble within the first hours or days after the earthquake is generally similar to usual multi-trauma cases. At this point, laboratory and radiological investigations that may be out of use should be replaced by serial physical examinations and interventional diagnostic/therapeutic applications. In conditions where radiological and biochemical examinations are available, specific findings of "Crush syndrome" should be looked out for. Contrast-enhanced CT indications should be selective. In the presence of Crush Syndrome, parenteral access should be promptly provided to maintain high intravascular volume and follow the set algorithms. Children that are rescued several days after the earthquake are usually not severely injured and medical conditions are generally more favorable for these cases. However, the treatment of severe hypernatremic dehydration and prerenal renal failure has an important role in the management of these cases.

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## References

- Sever MS, Erek E, Vanholder R, et al. The Marmara earthquake: epidemiological analysis of the victims with nephrological problems. *Kidney Int.* 2001;60(3):1114-1123. [\[CrossRef\]](#)
- Topuzlu Tekant G, Hakalmaz AE, Travma P, Travma EC. *Tip Kitabevi*. 2nd edn. Istanbul: EMA; 2022:545-587.
- Qiu J, Liu GD, Wang SX, et al. Analysis of injuries and treatment of 3,401 inpatients in 2008 Wenchuan earthquake--based on Chinese Trauma Databank. *Chin J Traumatol.* 2010;13(5):297-303.
- Gunst M, Ghaemmaghami V, Gruszecki A, Urban J, Frankel H, Shafi S. Changing epidemiology of trauma deaths leads to a bimodal distribution. *Proc (Bayl Univ Med Cent).* 2010;23(4):349-354. [\[CrossRef\]](#)
- American College of Surgeons. *Advanced Trauma Life Support*. 10th edn. Chicago: American College of Surgeons, Committee on Trauma; 2018.
- Sanchez JJ, Paidas CN. Childhood trauma. Now and in the new millennium. *Surg Clin North Am.* 1999;79(6):1503-1535. [\[CrossRef\]](#)
- Powers KS. Dehydration: Isonatremic, hyponatremic, and hypernatremic recognition and management. *Pediatr Rev.* 2015;36(7):274-283; quiz 284-285. [\[CrossRef\]](#)
- Kiani QH, Qazi M, Khan A, Iqbal M. The relationship between timing of admission to a hospital and severity of injuries following 2005 Pakistan earthquake. *Chin J Traumatol.* 2016;19(4):221-224. [\[CrossRef\]](#)
- Snyder CW, Neff LP, Chandler NM, Kerby JD, Josephson CD, Russell RT. Association of blood product ratios with early mortality in pediatric trauma resuscitation: A time-dependent analysis from the National trauma databank. *J Trauma Acute Care Surg.* 2023. [\[CrossRef\]](#)
- Bartels SA, VanRooyen MJ. Medical complications associated with earthquakes. *Lancet.* 2012;379(9817):748-757. [\[CrossRef\]](#)
- Tovar JA, Vazquez JJ. Management of chest trauma in children. *Pediatr Respir Rev.* 2013;14(2):86-91. [\[CrossRef\]](#)
- Fallon SC, Delemos D, Akinkuotu A, Christopher D, Naik-Mathuria BJ. The use of an institutional pediatric abdominal trauma protocol improves resource use. *J Trauma Acute Care Surg.* 2016;80(1):57-63. [\[CrossRef\]](#)
- Notrica DM, Eubanks 3rd JW, Tuggle DW, et al. Nonoperative management of blunt liver and spleen injury in children: evaluation of the ATOMAC guideline using GRADE. *J Trauma Acute Care Surg.* 2015;79(4):683-693. [\[CrossRef\]](#)
- Garvey EM, Haakinson DJ, McOmber M, Notrica DM. Role of ERCP in pediatric blunt abdominal trauma: a case series at a level one pediatric trauma center. *J Pediatr Surg.* 2015;50(2):335-338. [\[CrossRef\]](#)
- Emre Ş, Özcan R, Eliçevik M, Kuruoğlu S, Şenyüz OF. *Surgical Treatment of Blunt Pancreatic Injuries in Children*. 30. National Congress of Pediatric Surgery, Ankara, Türkiye; 2012. Report No.: 106.