Pediatric chest trauma: a unique challenge

Fabrizio Minervini[1], Marco Scarci[2], Gregor J. Kocher[3], Peter B. Kestenholz[1], Pietro Bertoglio[4]

[1]Department of Thoracic Surgery, Kantonsspital Luzern, Lucerne, Switzerland; [2]Department of Thoracic Surgery, Ospedale San Gerardo, Monza, Italy; [3]Division of General Thoracic Surgery, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland; [4]Division of Thoracic Surgery, IRCCS Sacro Cuore-Don Calabria Hospital and Cancer Care Centre Negrar-Verona, Negrar, Italy

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Correspondence to: Fabrizio Minervini, MD, PhD. Department of Thoracic Surgery, Kantonsspital Luzern, Spitalstrasse, 6000 Lucerne, Switzerland. Email: fabrizio minervini@hotmail.com.

Abstract: Blunt and penetrating trauma in children are uncommon but nevertheless remain a major source of morbidity and mortality. The peculiarity of some anatomic and physiologic factors makes the management and the treatment of pediatric thoracic trauma very difficult. A thorough evaluation of the patient along with a proper management are key factors in order to obtain excellent short- and long-term outcomes. Our review focuses on clinical presentation, diagnostic pathways and treatment options in pediatric chest trauma patients.

Keywords: Pediatric trauma; chest trauma in children; thoracic trauma

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Introduction

Trauma is the leading cause of mortality in the pediatric population older than 1 year with a reported number of more than 9,000 children who die every year in the United States due to trauma related injuries (1).

The most common causes of death in this age group are traffic accidents, followed by falling from heights, and bicycle accidents (2).

Thoracic trauma occurs in about 5% to 12% of the children admitted to the hospital after a trauma. Despite this low percentage, they are associated disproportionately with high morbidity and mortality, much more than other types of injuries (3). The rarity of these injuries increases the complexity of the management in the emergency department (ED).

Physicians in the ED should apply the advanced trauma life support (ATLS) guidelines used in the setting of adult trauma patients, while keeping in mind that anatomy, physiology, metabolism, injury pattern, management and consequent therapeutic options have peculiar characteristic in children.

In addition, the knowledge about a child's development stage is mandatory in order to identify sensorium abnormalities related to trauma, such as hypoperfusion or hypoxemia.

Clinical presentation

The clinical presentation of children after thoracic trauma can range from chest wall or intrapleural injuries (rib fractures, flail chest, pneumothorax, hemothorax) to lung (pulmonary contusion or laceration), heart, tracheobronchial, esophageal or diaphragmatic injury. However, a blunt or penetrating chest trauma represents a unique challenge due to the peculiarity of the anatomy and physiology in children.

The resistance to external blunt forces is reduced in children because the chest wall is more compliant and the thickness of the subcutaneous and muscular layers is reduced compared to the adult counterpart. All this causes an increased level of energy transmission to the thoracic

organs (the ribs are more elastic, the costal cartilages are not ossified and therefore tend to bend instead of fracture) after a blunt trauma, which subsequently results in an increased frequency of internal organ injuries.

In addition, children develop hypoxemia more rapidly than adults due to diminished functional residual capacity and a higher metabolic rate, which is associated with a higher oxygen need.

Before the initial assessment of the patient, taking a comprehensive medical history is essential since often the first thoracic trauma signs are murky and therefore a high index of suspicion is crucial.

The assessment of the child, according to the ATLS, starts with the primary survey using the "ABCDE" systematic approach that allows to identify and, accordingly, treat life-threatening injuries.

During this assessment the presence of the family can be extremely important in helping the physician to assess the child's mental status and, of course, providing support to the patient.

ATLS guidelines suggest a chest X-ray (CXR) as first imaging modality to evaluate the extent of the thoracic trauma even if nowadays the clinical utility is still debated (4-6).

The most common injury in children with blunt thoracic trauma is pulmonary contusion with a reported incidence over 50% (7). As discussed above, the high elasticity of the pediatric bone results in a tendency for the ribs to bend and not to break, transferring in this way the blunt forces to the lung and the other thoracic organs. Nevertheless, rib fractures are observed in 1–2% of pediatric chest trauma patients with an incidence ranging up to 60% in cases of major pediatric polytrauma.

The presentation of pulmonary contusions can vary from uncomplicated findings seen on a CXR to serious respiratory insufficiency. Lung contusion can be identified clinically due to an abnormal auscultation over the injured area, respiratory distress, local tenderness, and rarely hemoptysis (8). After the contusion, the involved alveoli are filled with blood, resulting later in consolidation with consequent ventilation/perfusion mismatch, hypoventilation, and hypoxia. Other observed severe complications are pneumonia (20%), acute respiratory distress syndrome (ARDS, 5% to 20%) and death (15% to 20%) (9).

Sometimes, alveolar disruption causes air extravasation into the parenchyma leading to the formation of several cystic spaces that may evolve into a pneumatocele.

The second most common reported injury is pneumothorax which is observed as isolated injury in 30% of the cases. A small pneumothorax is often asymptomatic but a large pneumothorax on the other hand can cause clinical symptoms that overlap with those produced by lung parenchymal damage: tachypnea, distress, and decreased saturation. Clinically the involved hemithorax appears to be distended, hyperresonant to percussion, with diminished breath sounds on auscultation. If a tension pneumothorax is present, the mediastinum is displaced to the contralateral side with impairment of the venous return. It should keep in mind that a tension pneumothorax is more common in children than in adults because of the higher mobility of the mediastinal structures (10).

Hemothorax is a common injury as well. It is often caused by laceration of the lung, intercostal or intrathoracic vessels but it could potentially also be a sign of great vessel injury. It occurs in 13% to 29% of children with blunt chest trauma and is associated with a 57% mortality (11). Hemothorax in children may lead to significant blood loss and should be managed immediately in order to avoid hypovolemic shock, lung volume loss, empyema and possible lung entrapment.

Mediastinal injury may include injuries to the great vessels, tracheo-bronchial injury, heart injury, oesophageal and diaphragmatic rupture. These injuries are rarely observed after thoracic trauma, but some of them are potentially lethal (up to 32% in the first hour) (12).

Imaging

In case of pediatric patients with a chest trauma, radiologic evaluation is fundamental to define the following diagnostic or therapeutic steps. On the other hand, a particular caution should be taken as children are roughly four times more sensitive to radiation than adults due to their cell division rate and to their longer life expectancy (13). In order to reduce to a minimum, the quantity of ionizing radiation given to a pediatric patient, the "as low as reasonably achievable" (ALARA) and the "image gently" (14) principles have been defined. Despite these concerns, no threshold for an increased risk of developing cancer have been detected so far (13), and this topic is still under debate. Consequently, in the management of pediatric patients, exams requiring ionizing radiation should be performed with caution and ultrasounds (US) and magnetic resonance imaging (MRI) should be used when possible.

To date, no clear guidelines on the management of

chest trauma in pediatric patients are available and they mostly rely on adult trauma management and on ED staff experience. According to patients' clinical conditions, imaging tests should be always associated to functional test such as electrocardiography to evaluate any possible abnormalities (15).

The first-line imaging test in patients with thoracic trauma is CXR which is preferred to computed tomography (CT) scan because of its lower quantity of radiation (roughly 0.02 and 5.4 millisieverts respectively) and lower costs. In the emergency bay, supine antero-posterior CXR is usually performed, but its sensitivity is reported to be lower compared to a CXR taken in an upright position (13); nevertheless, it allows to perform a first screening of the trauma patients in order to make further decisions. In a large retrospective, single institutional study performed on 1,035 pediatric patients involved in thoracic traumas, Golden and her colleagues (16) propose a new algorithm for the use of CT scan compared to sole CXR: they found out that in all patients with normal CXR, chest CT scan did not change the management of the patient. They therefore propose to perform CT scan only in those patients with evident abnormalities of the CXR, with a consequent reduction of radiation risk and money expenditure. The same conclusions were drawn by other retrospective studies (17-21). On the other hand, due to the lack of proper guidelines on the management of pediatric trauma, decision of imaging tests is left to the ED physician. In a retrospective study evaluating the proportion of CT scans for pediatric blunt trauma among 130 trauma centers in Canada, Sathya and coworkers (22) found a significant higher proportion of CT scans performed in adult or mixed trauma centers when compared with dedicated pediatric trauma centers.

Due to the peculiar anatomy of children, ribs and sternal fractures as well as mediastinal injuries (such as cardiac, tracheobronchial or esophageal injuries) are much rarer than in adults after blunt trauma; on the other hand, pulmonary contusions, pneumothorax, hemothorax, pneumomediastinum or injuries of the thoracic spine are more frequent.

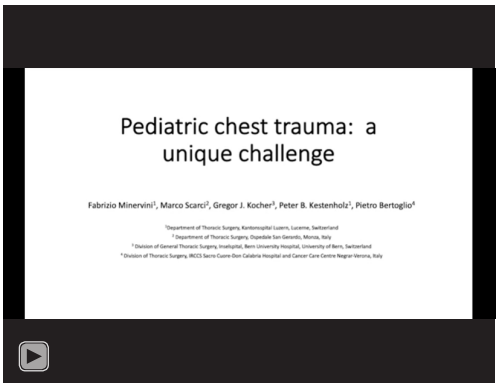
CXR can be considered the examination of choice in case of pulmonary contusions, pneumothorax or hemothorax.

In the event of pulmonary contusions, which are often present after a blunt trauma in children, CT scan owns a higher sensitivity, while their appearance on CXR is plagued by a possible delay of some hours (15,23). Nevertheless, findings of CXR are more predictive of the subsequent clinical course (23,24).

In patients with pneumothorax, supine anteroposterior CXR showed a lower sensitivity (36–48%) compared to the erect position, but pneumothorax can be suggested by indirect radiological signs (13,24). Although CT scan is the most sensitive technique to reveal any extent of air in the pleural cavity, the majority of pneumothoraces missed at CXR are not usually clinically relevant and they often do not require any additional treatment, unless the patient needs positive pressure ventilation (13,24,25). Recently, the use of US in the emergency scenario is gaining more and more consensus thanks to its versatility, but it requires expert and trained staff. Vasquez and his colleagues retrospectively compared the rate of diagnosis of pneumothorax of CRX or CT scan compared to chest US in an emergency setting: they found a lower sensitivity of US for pneumothorax (45%), while specificity and accuracy were 98.6% and 96% respectively. The authors acknowledged that US were performed with the focused assessment with sonography for trauma (FAST) technique which is taken in a single point, anteriorly. Nevertheless, none of the patients who were false negative at the US examination either had pulmonary contusions or required further intervention for pneumothorax after radiological work up (26).

In case of patients with hemothorax, the presence of fluid in the pleural space can be correctly diagnosed by supine or upright CXR; in supine position the fluid manifests like a veil or thickening of the pleural line, while in upright position the fluid collects at the bottom part of the chest obliterating the costophrenic sulcus. Concurrently, chest US seem to be more specific than and as sensitive as supine CXR in detecting hemothorax (27).

CT scan should be performed in case of more complicated scenarios such as pneumomediastinum or thoracic spine injuries. In patients with pneumomediastinum, CXR can reveal the presence of air in the mediastinum, but CT scan is necessary to rule out tracheal or esophageal ruptures (which are anyway rare in children) and guide further invasive diagnostic procedures such as tracheo-bronchoscopy or esophagram (28). Although supine CXR might evidence some thoracic spine injury, lateral radiographs or chest CT are much more sensitive (18,24); more in details, vertebral body compression fractures are more easily diagnosed with lateral CT scout or sagittal CT reconstruction 3D, while burst fractures can be revealed by frontal CXR or sagittal CT reconstruction (29). MRI is indicated in case of cord injury (30).



Video 1 Pediatric chest trauma (47).

Treatment

Pediatric thoracic trauma is often treated following the guidelines of adult thoracic trauma management (31-33).

Treatment of pulmonary contusions is merely related to pain control and oxygenation of the patient; frequent evaluation of symptoms and gas exchange is therefore necessary. Pain relief should be guided according to the compliance and cooperation of the patient, associating intravenous or oral painkillers to additional measures such as epidural anesthesia, rib blocks or patient-controlled pumps (15). In severe trauma patients, mechanical ventilation might be required, but pulmonary contusions often do not have a significant impact on outcomes (34).

Pneumothorax and hemothorax are managed according to their extent. CXR-negative and CT-positive hemothorax or pneumothorax do not usually require invasive procedures and they can be followed up to rule out a possible increase or whether they become clinically relevant (34,35). In case of large hemothorax or pneumothorax, a chest drain is required to evacuate air and/or blood. In adult patients as well as in children guidelines indicate the "safe triangle" as the best place to insert a chest drain (36). There is only little evidence on the best type and size of chest drain in pediatric patients to date and most of the reported series are based on adult cohorts; it must be considered that smaller intercostal spaces in children make them even more sensible to chest drain diameter, which is directly related to pain perception. ATLS guidelines (33) suggest an increasing size of chest drain based on age and weigh of the patient. While Teague and colleagues (37) recently suggested the "rule of 4" to choose the correct chest drain diameter (4 multiplied by the optimal size of patients' endotracheal tube), but their findings were only based on their own experience and they were not validated by clinical studies. In case of hemothorax, larger bore tubes (28–30 Fr) are suggested by ATLS (33) and British Thoracic Society Guidelines (32); nonetheless, an American prospective study (38) evaluated outcomes of the use of 14-Fr pig tails compared to large-bore drains in case of traumatic hemothorax, reporting no differences in terms of drain output and failure rates. Conversely, in case of sole pneumothorax, a small-bore drain is generally accepted: a randomized controlled trial (39) comparing 14-Fr pig tail and 28-Fr silicon chest tubes in the management of uncomplicated traumatic pneumothorax found similar rates of duration, complications and failures between the two groups, with a significant lower pain in patients who were treated with a pig tail. These findings are anyway inconsistent with some other observational studies (40,41). In case of penetrating traumas with open pneumothorax, occlusive dressing and subsequent chest drain is required (42).

In the event of persistent pneumothorax and air leak with functioning chest drain, an unforeseen airway injury should be carefully checked. In most cases, conservative treatment with mechanical ventilation and early extubation is curative; in case of failure of conservative management, surgical repair is needed (34).

Patients with pneumomediastinum, once esophageal or tracheobronchial injuries are ruled out, can be managed conservatively with a strict radiological follow up (13,25).

Surgery for pediatric trauma patients should be offered in patients with ongoing injuries which cannot be treated conservatively (for instance, the evidence of active bleeding) or in case of failure of conservative treatments; moreover, in case of retained hemothorax pleural toilette should be performed to avoid fibrosis or development of a trapped lung.

Recently, minimally invasive surgery (MIS) has gaining an increasing consensus in thoracic surgery allowing a reduced postoperative pain and a faster postoperative recovery (43). Although no prospective studies are available for the use of MIS in pediatric trauma patients, evidences from adults seem to support its use in hemodynamically stable patients (34,44). Limited experiences reported in literature seems to validate the feasibility of MIS also in children (34,45,46) (*Video 1*).

Conclusions

Thoracic trauma in children can lead to severe injuries which are associated with high morbidity and mortality. A

suspicion for the presence of life-threatening conditions is crucial in order to make the right diagnosis and apply the right treatment.

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References

1. Centers for Disease Control and Prevention (CDC). National Centers for Injury Prevention and Control. National action plan for child injury prevention. Atlanta: CDC, NCIPC, 2012.
2. Peterson RJ, Tepas JJ 3rd, Edwards FH, et al. Pediatric and adult thoracic trauma: age-related impact on presentation and outcome. Ann Thorac Surg 1994;58:14-8.
3. Black TL, Snyder CL, Miller JP, et al. Significance of chest trauma in children. South Med J 1996;89:494-6.
4. Ong D, Cheung M, Cuenca P, et al. Clinical utility of routine chest X-rays during the initial stabilization of trauma patients. South Med J 2019;112:55-9.
5. Gutierrez A, Inaba K, Siboni S, et al. The utility of chest X-ray as a screening tool for blunt thoracic aortic injury. Injury 2016;47:32-6.
6. Wisbach GG, Sise MJ, Sack DI, et al. What is the role of chest X-ray in the initial assessment of stable trauma patients? J Trauma 2007;62:74-8; discussion 78-9.
7. Moore MA, Wallace EC, Westra SJ. Chest trauma in children: current imaging guidelines and techniques. Radiol Clin North Am 2011;49:949-68.
8. Bonadio WA, Hellmich T. Post-traumatic pulmonary contusion in children. Ann Emerg Med 1989;18:1050-2.
9. Vane DW, Keller M S, Sartorelli K H, et al. Pediatric trauma: current concepts and treatments. J Intensiv Care Med 2002;17:230-49.
10. Nakayama DK, Ramenofsky ML, Rowe MI. Chest injuries in childhood. Ann Surg 1989;210:770-5.
11. Sarihan H, Abes M, Akyazici R, et al. Blunt thoracic trauma in children. J Cardiovasc Surg (Torino) 1996;37:525-8.
12. Bliss D, Silen M. Pediatric thoracic trauma. Crit Care Med 2002;30:S409-15.
13. Piccolo CL, Ianniello S, Trinci M, et al. Diagnostic imaging in pediatric thoracic trauma. Radiol Med 2017;122:850-65.
14. Strauss KJ, Goske MJ, Kaste SC, et al. Image gently: ten steps you can take to optimize image quality and lower CT dose for pediatric patients. AJR Am J Roentgenol 2010;194:868-73.
15. Ahmed OZ, Burd RS. Management issues in critically ill pediatric patients with trauma. Pediatr Clin North Am 2017;64:973-90.
16. Golden J, Isani M, Bowling J, et al. Limiting chest computed tomography in the evaluation of pediatric thoracic trauma. J Trauma Acute Care Surg 2016;81:271-7.
17. Holscher CM, Faulk LW, Moore EE, et al. Chest computed tomography imaging for blunt pediatric trauma: not worth the radiation risk. J Surg Res 2013;184:352-7.
18. Patel RP, Hernanz-Schulman M, Hilmes MA, et al. Pediatric chest CT after trauma: impact on surgical and clinical management. Pediatr Radiol 2010;40:1246-53.

19. Markel TA, Kumar R, Koontz NA, et al. The utility of computed tomography as a screening tool for the evaluation of pediatric blunt chest trauma. J Trauma 2009;67:23-8.
20. Hershkovitz Y, Zoarets I, Stepansky A, et al. Computed tomography is not justified in every pediatric blunt trauma patient with a suspicious mechanism of injury. Am J Emerg Med 2014;32:697-9.
21. Renton J, Kincaid S, Ehrlich PF. Should helical CT scanning of the thoracic cavity replace the conventional chest x-ray as a primary assessment tool in pediatric trauma? An efficacy and cost analysis. J Pediatr Surg 2003;38:793-7.
22. Sathya C, Alali AS, Wales PW, et al. Computed tomography rates and estimated radiation-associated cancer risk among injured children treated at different trauma center types. Injury 2019;50:142-8.
23. Kwon A, Sorrells Jr DL, Kurkchubasche AG, et al. Isolated computed tomography diagnosis of pulmonary contusion does not correlate with increased morbidity. J Pediatr Surg 2006;41:78-82.
24. Hammer MR, Dillman JR, Chong ST, et al. Imaging of pediatric thoracic trauma. Semin Roentgenol 2012;47:135-46.
25. Moore MA, Wallace EC, Westra SJ. Chest trauma in children: current imaging guidelines and techniques. Radiol Clin North Am 2011;49:949-68.
26. Vasquez DG, Berg GM, Srour SG, et al. Lung ultrasound for detecting pneumothorax in injured children: preliminary experience at a community-based level II pediatric trauma center. Pediatr Radiol 2019. [Epub ahead of print].
27. McEwan K, Thompson P. Ultrasound to detect haemothorax after chest injury. Emerg Med J 2007;24:581-2.
28. Moore MA, Wallace EC, Westra SJ. The imaging of paediatric thoracic trauma. Pediatr Radiol 2009;39:485-96.
29. Vander Have KL, Caird MS, Gross S, et al. Burst fractures of the thoracic and lumbar spine in children and adolescents. J Pediatr Orthop 2009;29:713-9.
30. Vialle LR, Vialle E. Pediatric spine injuries. Injury 2005;36 Suppl 2:B104-12.
31. Bertoglio P, Guerrera F, Viti A, et al. Chest drain and thoracotomy for chest trauma. J Thorac Dis 2019;11:S186-91.
32. Laws D, Neville E, Duffy J, et al. BTS guidelines for the insertion of a chest drain. Thorax 2003;58 Suppl 2:ii53-9.
33. ACoSCo T. Advanced trauma life support for doctors (ATLS) student course manual. 9th ed. Chicago: American College of Surgeons, 2012.
34. Pearson EG, Fitzgerald CA, Santore MT. Pediatric thoracic trauma: current trends. Semin Pediatr Surg 2017;26:36-42.
35. Choi PM, Farmakis S, Desmarais TJ, et al. Management and outcomes of traumatic hemothorax in children. J Emerg Trauma Shock 2015;8:83-7.
36. Bowness JS, Nicholls K, Kilgour PM, et al. Finding the fifth intercostal space for chest drain insertion: guidelines and ultrasound. Emerg Med J 2015;32:951-4.
37. Teague WJ, Amarakone KV, Quinn N. Rule of 4's: Safe and effective pleural decompression and chest drain insertion in severely injured children. Emerg Med Australas 2019;31:683-7.
38. Bauman ZM, Kulvatunyou N, Joseph B, et al. A prospective study of 7-year experience using percutaneous 14-French pigtail catheters for traumatic hemothorax/hemopneumothorax at a level-1 trauma center: size still does not matter. World J Surg 2018;42:107-13.
39. Kulvatunyou N, Erickson L, Vijayasekaran A, et al. Randomized clinical trial of pigtail catheter versus chest tube in injured patients with uncomplicated traumatic pneumothorax. Br J Surg 2014;101:17-22.
40. Martin K, Emil S, Zavalkoff S, et al. Transitioning from stiff chest tubes to soft pleural catheters: prospective assessment of a practice change. Eur J Pediatr Surg 2013;23:389-93.
41. Roberts JS, Bratton SL, Brogan TV. Efficacy and complications of percutaneous pigtail catheters for thoracostomy in pediatric patients. Chest 1998;114:1116-21.
42. Reynolds SL. Pediatric thoracic trauma: recognition and management. Emerg Med Clin North Am 2018;36:473-83.
43. Bendixen M, Jørgensen OD, Kronborg C, et al. Postoperative pain and quality of life after lobectomy via video-assisted thoracoscopic surgery or anterolateral thoracotomy for early stage lung cancer: a randomised controlled trial. Lancet Oncol 2016;17:836-44.
44. Wu N, Wu L, Qiu C, et al. A comparison of video-assisted thoracoscopic surgery with open thoracotomy for the management of chest trauma: a systematic review and meta-analysis. World J Surg 2015;39:940-52.
45. Stringel G, Xu ML, Lopez J. Minimally invasive surgery in pediatric trauma: one institution's 20-year experience. JSLS 2016. doi: 10.4293/JSLS.2015.00111.

46. Alemayehu H, Clifton M, Santore M, et al. Minimally invasive surgery for pediatric trauma-a multicenter review. J Laparoendosc Adv Surg Tech A 2015;25:243-7.

47. Minervini F, Scarci M, Kocher GJ, et al. Pediatric chest trauma. Asvide 2019;6:319. Available online: http://www.asvide.com/watch/33004

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