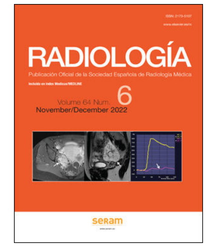
Radiología 65 (2023) 258–268

seram
Sociedad Española de Radiología Médica

RADIOLOGÍA

www.elsevier.es/rx



RADIOLOGY THROUGH IMAGES

Severe non-cardiovascular thoracic trauma: diagnostic clues on computed tomography

A. Villanueva Campos[a,*], A. Oikonomou[b], L. Jiménez-Juan[c], L. Gorospe Sarasúa[a], A. Villanueva Marcos[d]

[a] *Departamento de Radiología, Hospital Universitario Ramón y Cajal, Madrid, Spain*
[b] *Departamento de Radiología, Sunnybrook Health Sciences Centre, Universidad de Toronto, Toronto, Canada*
[c] *Departamento de Radiología, St. Micheal's Hospital, Universidad de Toronto, Toronto, Canada*
[d] *Departamento de Radiología, East Surrey Hospital, Surrey and Sussex Healthcare NHS Trust, Redhill, United Kingdom*

Received 26 September 2022; accepted 16 November 2022
Available online 13 May 2023

KEYWORDS
Thoracic trauma;
Multiple trauma;
Computed tomography

Abstract
Objective: About 60% of multiple trauma patients have thoracic trauma, and thoracic trauma results in the death of 10% of these patients. Computed tomography (CT) is the most sensitive and specific imaging modality for the diagnosis of acute disease, and it helps in the management and prognostic evaluation of patients with high-impact trauma. This paper aims to show the practical points that are key for diagnosing severe non-cardiovascular thoracic trauma by CT.
Conclusion: Knowing the key features of severe acute thoracic trauma on CT is crucial to avoid diagnostic errors. Radiologists play a fundamental role in the accurate early diagnosis of severe non-cardiovascular thoracic trauma, because the patient's management and outcome will depend largely on the imaging findings.

PALABRAS CLAVE
Traumatismo torácico;
Politraumatismo;
Tomografía computarizada

Traumatismo torácico grave no cardiovascular: claves diagnósticas en tomografía computarizada.

Resumen
Objetivo: El traumatismo torácico ocurre en aproximadamente el 60% de los pacientes politraumatizados y es causa de muerte en un 10 %. La tomografía computarizada (TC) es la prueba de imagen más sensible y específica en el diagnóstico de patología aguda y ayuda en el manejo y valoración del pronóstico en los pacientes con traumatismo de alto impacto. El objetivo de este artículo es mostrar puntos clave y prácticos para el diagnóstico con TC de patología no cardiovascular en traumatismo torácico grave.

* Corresponding author.
E-mail address: Avillanuevacampos10@gmail.com (A. Villanueva Campos).

Conclusión: El conocimiento de los aspectos clave en TC de patología aguda en traumatismo torácico grave es crucial para evitar errores diagnósticos. El radiólogo tiene un papel fundamental en el diagnóstico correcto y precoz de dicha patología, ya que de ello dependerá en gran parte el manejo y evolución de los pacientes.

Introduction

About 60% of polytrauma patients present thoracic trauma injuries, accounting for approximately 10% of trauma-related deaths.[1]

Trauma injuries are classified into two categories: penetrating or blunt, depending on whether the skin is pierced. Blunt trauma accounts for 70% of trauma cases and is the most frequent kind in Spain. The main cause is a high-impact trauma event, such as a road traffic accident or fall. Penetrating trauma injuries include stab and gunshot wounds.[2]

Computed tomography (CT) is the most sensitive and specific imaging modality for high-impact trauma, not only for diagnosing acute trauma injuries, but also for evaluating prognoses and contributing to optimal patient management.[3]

The aim of this paper is to present practical findings that are key for diagnosing severe non-cardiovascular thoracic trauma by CT, covering the different anatomical areas affected. It is beyond the scope of this paper to provide a detailed description of the different mechanisms of injury, a thorough explanation of each of the phenomena, or details regarding the CT techniques used.[1]

Chest wall

Evaluation of the chest wall (skin, subcutaneous cellular tissue and bone) of polytrauma patients yields a great deal of information about the event and provides indications of the kind of injuries that might be found in the chest or abdomen.

In blunt trauma, it is important to pay attention to the subcutaneous fat, as any stranding indicates the site of the contusion, the trauma mechanism and possible associated internal injuries.

A classic example is the seat belt sign, characterised by contusions on the chest, abdominal, and pelvic walls, corresponding to the diagonal and horizontal positioning of the straps. Approximately 30% of patients who present with skin abrasions are also found to have suffered bone fractures and visceral injuries, thereby correlating to the so-called seatbelt syndrome.[4] The most common injuries involved in this syndrome are rib, sternal and Chance fractures, pulmonary contusions, mesenteric and intestinal haematomas, and on occasion, myocardial, aortic or diaphragmatic fractures (Fig. 1). Chance fractures typically occur when the passenger is only wearing the lap belt, which results in a hyperflexion of the vertebral body and distraction of the posterior elements.[4]

In cases of penetrating trauma, on the other hand, the diagnostic approach changes in that it is always necessary to look for the entry and exit orifices, as well as the trajectory. Ditkofsky et al.[5] describe the importance of the following three key concepts:

1) There may be multiple entry orifices and multiple trajectories in the same patient.
2) The trajectories are not always linear, so sometimes the entry and exit orifices are not at the same level, thus visceral lesions may not be located along the same plane.
3) There is not always an exit orifice, and in such cases, it is necessary to look for the foreign body (bullet or blade) that remains inside the patient.

In penetrating trauma, it is also important to carefully examine all structures along the injury trajectory and search carefully for both what is present and what is not. The eyes of the radiologist can more easily diagnose what is present and abnormal than those structures that are 'absent' (Fig. 2).

Another concept that warrants special attention because of the urgency of management required is flail chest. Its definition has varied over the years,[6,7] and it is now used to describe the presence of two or more fractures in three or more contiguous ribs (Fig. 3).[8] It is important to note that flail chest can lead to paradoxical breathing, which is why more than 50% of these patients require immediate intubation. Surgical treatment is reserved for cases in which conservative management has failed.[8]

Finally, it is worth remembering that the most common chest wall injuries are rib fractures. Fractures occurring in the first three ribs indicate high-energy trauma and this increases the risk of vascular (subclavian vessels) and brachial plexus injury; middle rib fractures are usually associated with pulmonary and cardiovascular injuries; and fractures of the final ribs mean that the likelihood of abdominal injury (liver or spleen) is greater.[8]

Lungs

There is a broad spectrum of lung injuries in severe thoracic trauma and they usually occur simultaneously in the same patient. The most frequent injuries are lung contusions and lacerations. It is important to note that non-traumatic pathology, such as infections or tumours, may coexist and should be recognised and reported.

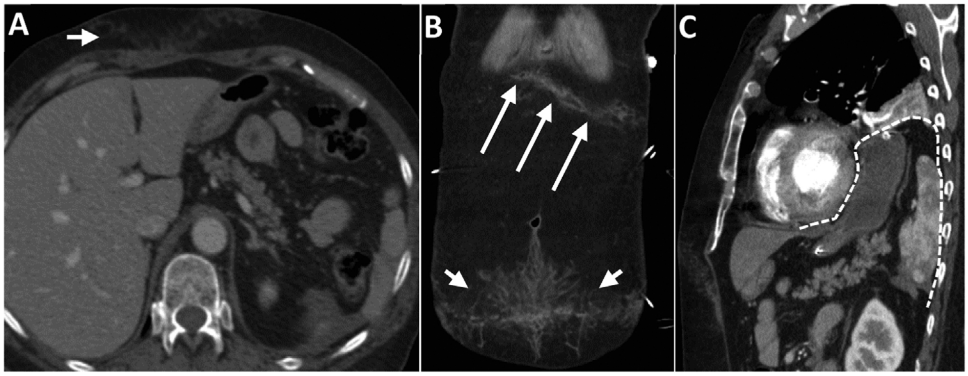


Figure 1 65-year-old woman, front passenger in a road traffic accident, with **seatbelt syndrome**. A) Axial CT image (mediastinal window) showing fat stranding in the subcutaneous tissues of the chest wall (arrows). B) Coronal reconstruction of CT in which the angle of the subcutaneous fat stranding is better appreciated (oblique in the lower thoracic wall [long arrows] and horizontal in the abdominal wall [short arrows]). (C) Sagittal reconstruction of CT scan showing a rupture of the left hemidiaphragm with herniation of the stomach, pancreas and spleen (dashed line).

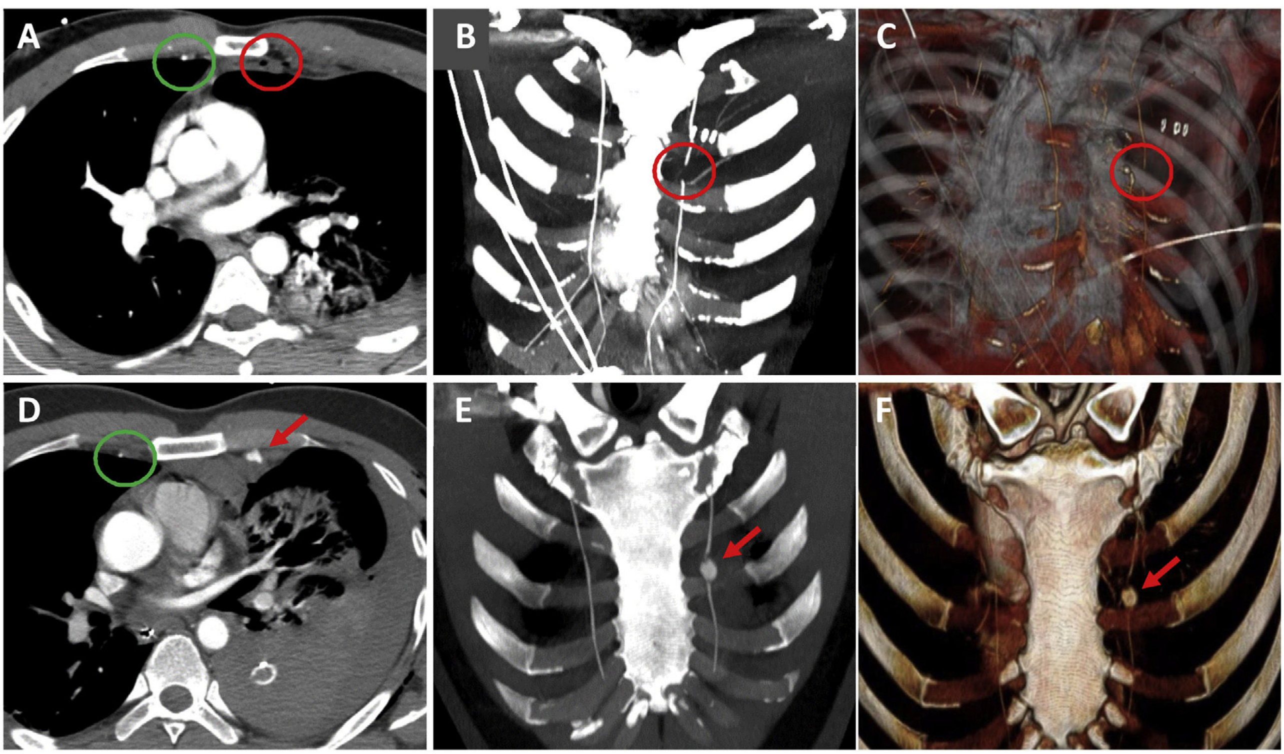


Figure 2 Two male patients following self-harm (self-inflicted stabbing), aged 24 (top row) and 39 (bottom row). Chest CT images reveal findings in the internal thoracic artery (ITA). A-C) Axial image (mediastinal window) (A), coronal maximum intensity projection (MIP) (mediastinal window) reconstruction (B) and 3D reconstruction (C) in which there is an **absence of opacification in segments of the left ITA** (red circle), compatible with a **dissection**. D-F) Axial image (mediastinal window) (D), coronal MIP reconstruction (mediastinal window) (E) and 3D reconstruction (F) showing **irregular outpouchings in the left ITA**, compatible with a **pseudoaneurysm** (red arrow). The green circle represents the right internal thoracic vessels, which show no alterations. The aim of these two cases is to demonstrate the difficulty in identifying structures that, due to their small size, are only visible in the axial plane in a single slice or are not visible at all (as in the first case), as well as to highlight the usefulness of MIP and 3D reconstructions.

Pulmonary contusions

Lung contusions are caused by an accumulation of blood in the pulmonary alveoli and interstitium, but, unlike lacerations, there is no shearing of the pulmonary parenchyma.[1] They are more common in blunt trauma than in penetrating trauma.[1]

Lung contusions will manifest differently on CT depending on the amount of blood and the time elapsed since the traumatic event (Fig. 4).[6,9] They can be observed as

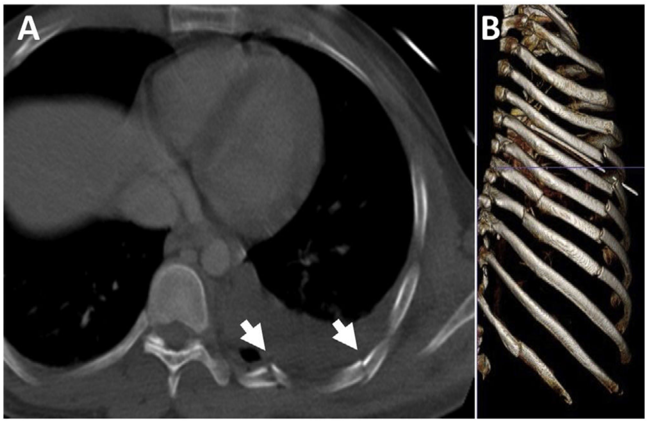


Figure 3 50-year-old male involved in a motorcycle accident, with **flail chest**. Axial chest CT image (bone window) (A) and 3D reconstruction (B) show two fractures in more than three contiguous ribs (arrows). Flail chest is a marker of severity and may be associated with paradoxical breathing.

focal, patchy or diffuse opacities, which are typically non-segmental and sometimes cross the fissures as they do not follow a bronchial route, unlike infections and aspirations (Fig. 5).[1,9]

As with hepatosplenic contusions, pulmonary contusions may exhibit contrast extravasation, thus indicating active bleeding. However, this is rare and occurs mostly in severe cases.[10]

It should be stressed that contusions usually resolve within two to four days, and should disappear completely within a maximum of 14 days.[11] It is important to note that if they persist for longer, or if any new consolidation appears after the first 24 h of the trauma, complications, such as pneumonia, lung abscesses or acute respiratory distress syndrome (ARDS), should be suspected.[9] Lung contusions are independent predictors for the development of ARDS, respiratory dysfunction and death.[1,12,13]

Pulmonary lacerations

By definition, a laceration involves the rupture of the lung parenchyma. Due to the elastic nature of the lung—and unlike lacerations typically found in solid organs (such as the liver or spleen)—lung lacerations are not linear in morphology, but are usually round or oval shaped.[13] There may be a solitary lesion or several (Swiss cheese sign)[14–16] (Fig. 6).

Pulmonary lacerations are classified as pneumatoceles, haematoceles or haematopneumatoceles, depending on the content of the cavity. The term pneumatocele, also known as a pulmonary pseudocyst, is commonly associated with pulmonary infection but the same term is used in the context of trauma.[17,18] Haematoceles are also referred to as pulmonary haematomas[1,13,19] (Fig. 7).

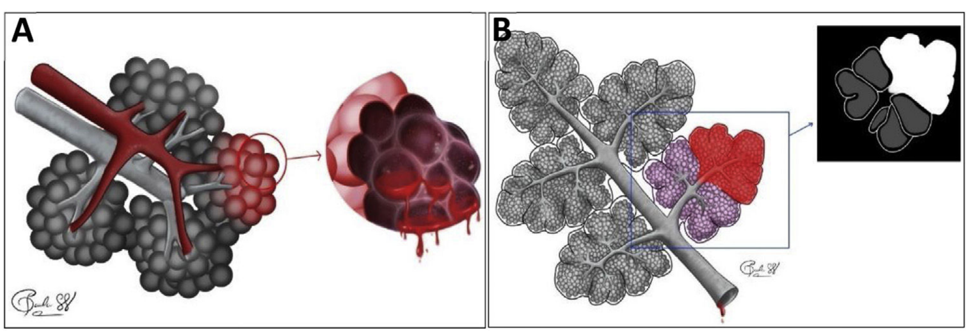


Figure 4 **Diagram** illustrating different **patterns of pulmonary contusion**, which vary according to the **amount of blood** present and the **time elapsed** since the trauma. Initially (A), blood occupies the alveoli producing a centrilobular nodular pattern. Subsequently, the secondary pulmonary lobule fills and, depending on the volume of blood may manifest ground glass opacities and/or consolidations (B). When the blood passes into the respiratory tract, the patient may present haemoptysis.

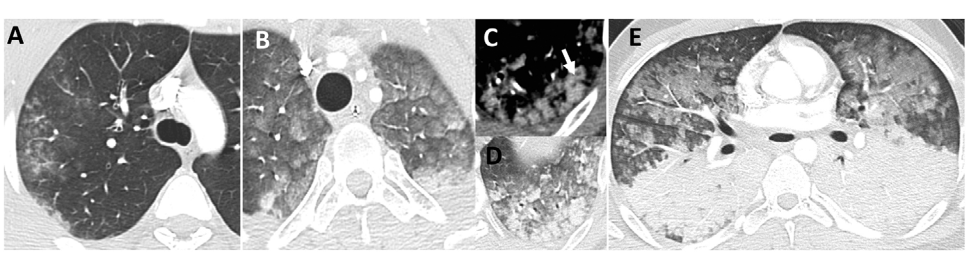


Figure 5 Chest CT images of three different blunt trauma patients with different lung contusion patterns. A) Axial image (lung window) showing **centrilobular nodules ('tree-in-bud' sign)**. B-D) Axial image (B, lung window) showing **ground-glass opacities** and axial images (C, mediastinal window and D, lung window) showing some **high-density** opacities in the mediastinal window (arrow), with unaffected interlobular septa. E) Axial image (lung window) showing **ground-glass opacities and consolidations**. When the bronchi are not filled with blood, air bronchograms can be seen within the pulmonary contusions.

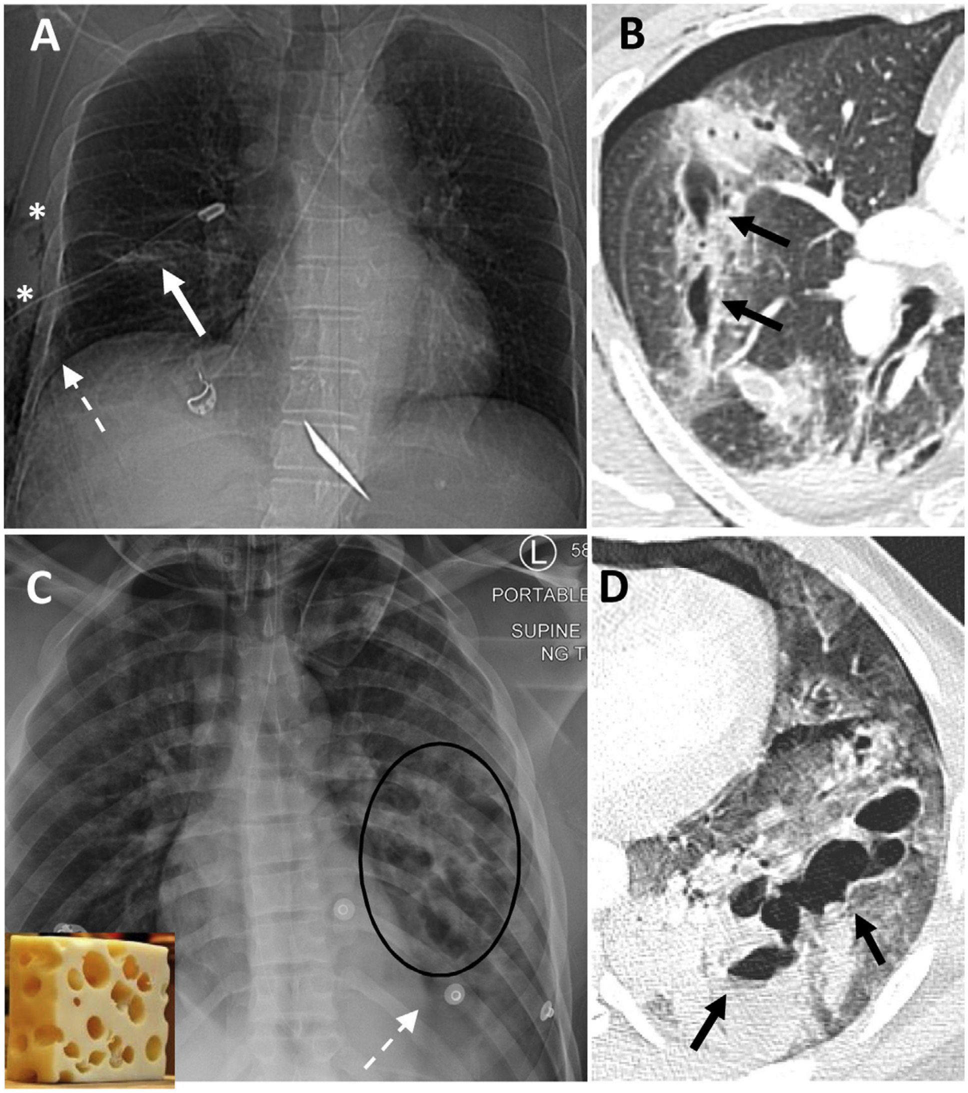


Figure 6 Images of two patients with penetrating thoracic trauma caused by stabbing (top row) and blunt trauma (bottom row). A) Chest CT topogram showing linear opacity in the right lung (arrow), subcutaneous emphysema (asterisks) and pneumothorax (dashed arrow). B) Axial chest CT image (lung window) showing a **single lung laceration with linear morphology** (arrows). C) Portable radiograph showing poorly defined opacity in the left lung (ellipse) and pneumothorax (dashed arrow). D) Axial chest CT image (lung window) showing **multiple lung lacerations with round/oval morphology** (arrows) resembling **'Swiss cheese'**. These patients often have pulmonary contusions surrounding the lacerations and small ipsilateral pneumothoraces.

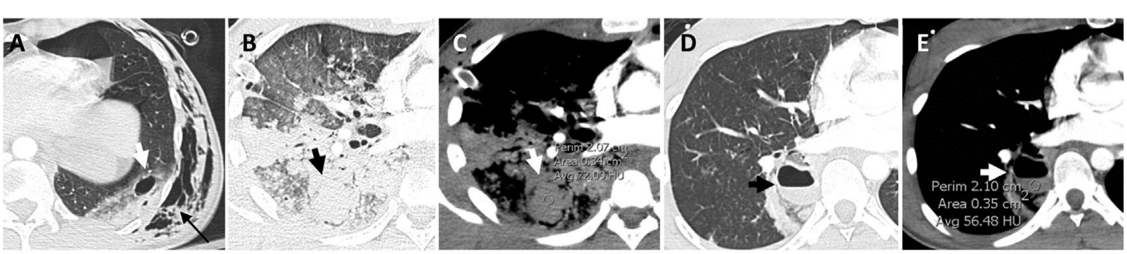


Figure 7 (A) 32-year-old male involved in a motorcycle accident. Axial chest CT image (lung window) showing a thin-walled **pneumatocele** (thick arrow) and subcutaneous emphysema (thin arrow). B and C) 39-year-old male involved in a motorcycle accident. Axial CT images of the chest (lung window [B] and mediastinal window [C]) showing a high-attenuation nodular lesion (72 HU) compatible with a **haematocele** (arrow). D and E) 27-year-old woman who fell from the sixth floor. Axial chest CT images (lung window [D] and mediastinal window [E]) showing a cavitated nodular lesion with air-blood level (arrow) compatible with a **pneumohaematocele**.

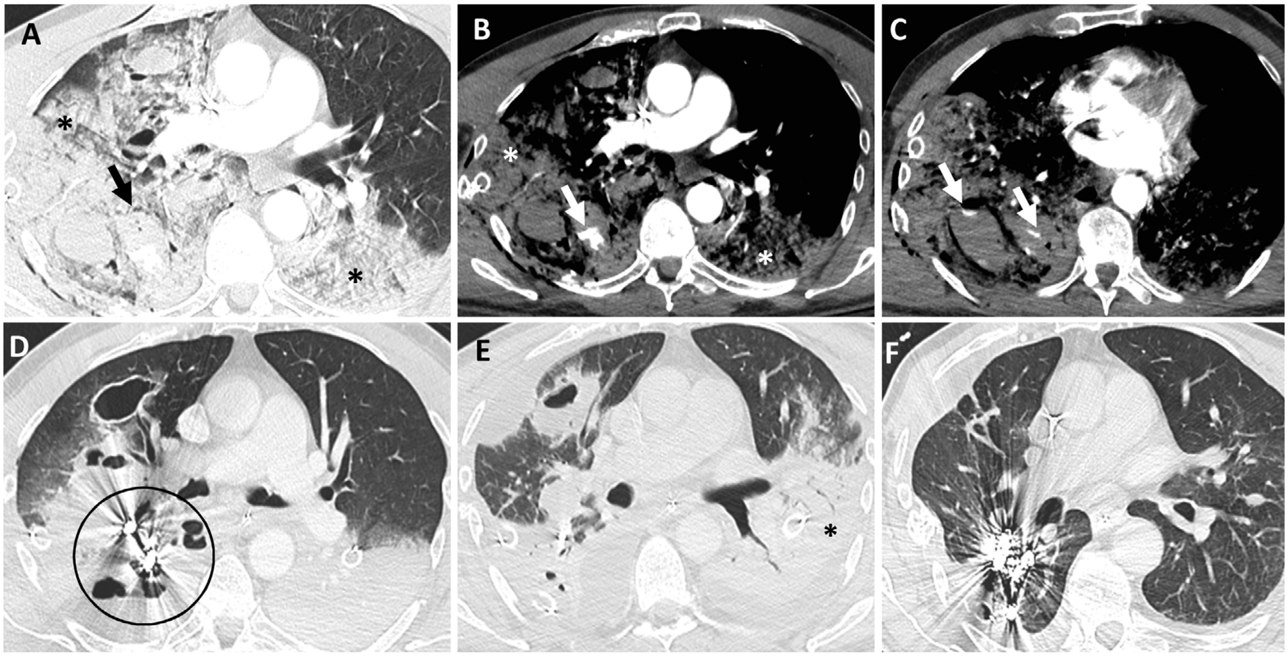


Figure 8 58-year-old pedestrian hit by a car. A-C) The images in the top row (axial chest CT images in lung window [A] and mediastinal window [B and C]) show several right pulmonary haematoceles in which foci of **active bleeding** (arrows) and extensive bilateral pulmonary contusions (asterisks) are observed. This complication is rare and was treated with embolisation of several pulmonary arteries. D-F) Bottom row images (axial chest CT images in lung window) obtained at four days (D), three weeks (E) and two months (F) after the trauma show the embolisation material (circle in D) and the progressive decrease in size of the haematoceles. Note the appearance of pneumonic consolidation in the left lung (asterisk in E), a relatively frequent complication in this type of patient.

Treatment of lung lacerations is usually conservative, with resolution taking longer than it does for contusions. It may take weeks or months to resolve, and in some cases, residual fibrotic atelectasis may be observed. As with contusions, lacerations that are persistent or increase in number may indicate complications, such as lung abscesses, bronchopleural fistulas or active bleeding.[9] This last complication is rare and requires urgent interventional treatment[20] (Fig. 8).

Pulmonary hernias

Radiologists must also be aware of the possibility of pulmonary hernias, which can be difficult to detect when small (Fig. 9). Their importance lies in the fact that they can develop complications, such as pulmonary strangulation, recurrent infections and tension pneumothorax.[21,22]

Pleural space

Pneumothorax

Pneumothorax is the term used to refer to the presence of air within the pleural cavity. This occurs in approximately 30–40% of thoracic trauma cases.[9,15] As air tends to rise and the patient is in the supine position when the CT scan is performed, the pneumothorax tends to be localised anteriorly and medially within the pleural cavity.[14]

Given its clinical urgency and immediate need for treatment, it is important to diagnose tension pneumothorax, which is defined as the progressive accumulation of a large amount of air in the pleural cavity, due to a one-way valve mechanism.[15] Tension pneumothorax should be diagnosed by anteroposterior chest radiograph, with the patient in the supine position. This radiograph is routinely performed on severely polytraumatised patients prior to CT scanning, and signs of tension pneumothorax include a contralateral mediastinal deviation, inversion of the ipsilateral diaphragm and increased intercostal space. It requires immediate drainage, which can lead to pulmonary oedema if performed too quickly.[14]

It is also important to diagnose small pneumothorax, paying attention to less common locations, such as the paravertebral region (posterior), as these patients are often subjected to positive mechanical ventilation or require anaesthesia/endotracheal intubation (EI), which makes a small pneumothorax more likely to rapidly increase in size.[9,14]

A particular difficulty in patients who are smokers/ex-smokers is in differentiating small bullae or paraseptal emphysema from small focal pneumothorax. In such cases, these doubts should be raised in the report.

Haemothorax

The presence of blood in the pleural cavity is called haemothorax. In such cases, high attenuation pleural fluid (>25 HU) is seen on CT, sometimes accompanied by the

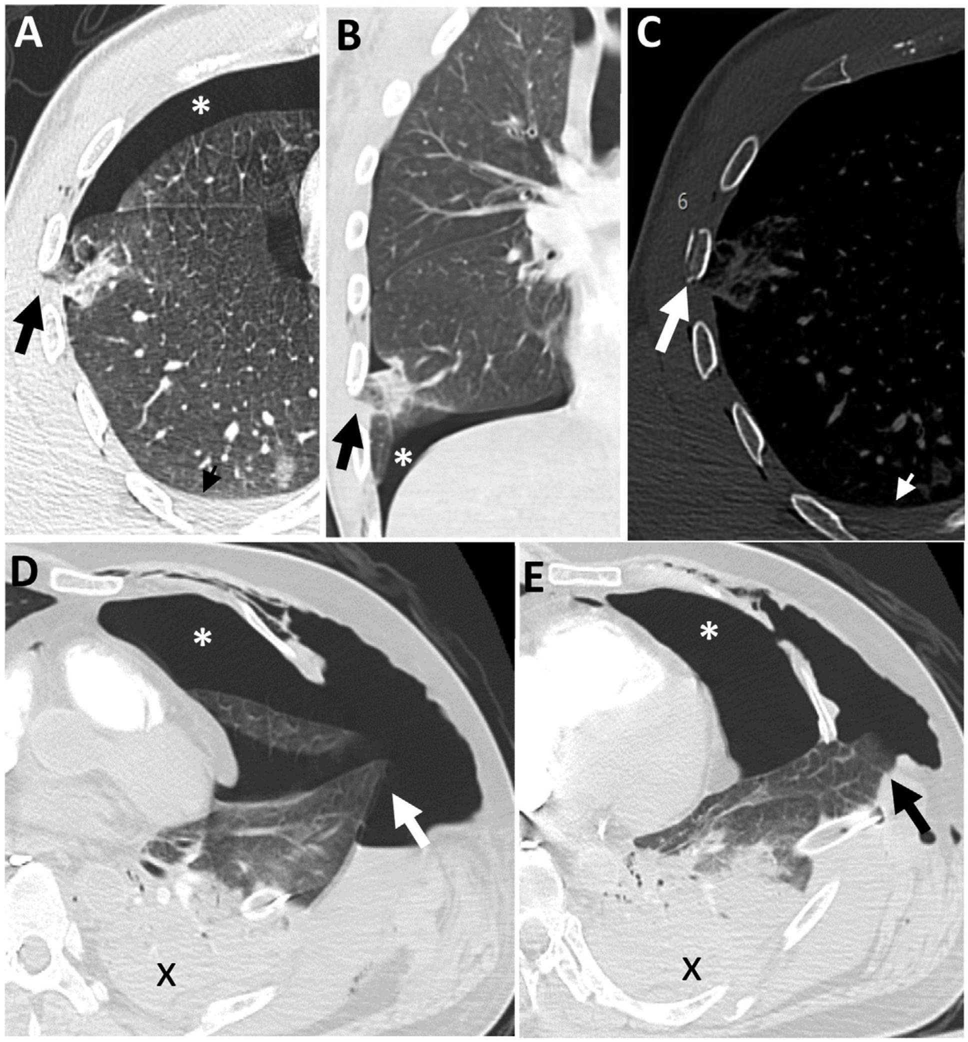


Figure 9 30-year-old male involved in a motorcycle accident (A-C). Chest CT images (axial [A] and coronal [B] in lung window, axial [C] in bone window) showing a small **pulmonary hernia** (black arrows), rib fracture (white arrow), pneumothorax (asterisks) and minimal pleural effusion (arrowheads). Coronal reconstructions, rib fractures or a history of a chest drainage tube are very useful diagnostic clues for its detection. 40-year-old male who fell from the ninth floor (D and E). Axial chest CT images (lung window) showing a large left pulmonary hernia (arrows), pneumothorax (asterisks) and lower lobe contusion/atelectasis (x).

haematocrit effect or clots. The haematocrit effect has a characteristic fluid-fluid level, presenting as highly dense in the lower part due to sedimented erythrocytes with low attenuation values in the upper portion due to the liquid supernatant.

Once the diagnosis is made, it is important to always check for active bleeding. That is, if there is a focus of high attenuation in the arterial phase that increases in later phases. The most frequent sources of arterial bleeding are the intercostal, subclavian or internal thoracic arteries (Fig. 10). This constitutes a medical emergency requiring embolisation.

In contrast, when haemothorax is caused by venous bleeding, a hyperdense focus is not usually identified and it is typically self-limiting due to the tamponade effect of the adjacent lung parenchyma.[15]

It is important to differentiate a haemothorax from an extrapleural haematoma, in which blood collects outside the pleural cavity. The key is to look for whether there is a line of fat between the blood collection and the chest wall (Fig. 11). Extrapleural haematomas do not resolve with a chest tube and may require surgical evacuation.[1] If haemothorax and extensive extrapleural haematomas coexist, it can be difficult to differentiate one from the other (Fig. 12).

Tracheobronchial tree and oesophagus

Traumatic airway injuries are rare (0.4–1.5%) and difficult to diagnose. Of the reported patients, 50% died within the first hour following the trauma.[16] The most common location in penetrating trauma is the anterior wall of the cervical trachea while in blunt trauma, it is the posterior wall of the distal trachea near the carina, because the membranous wall is weaker than the cartilaginous wall.[23]

Discontinuity of the tracheobronchial wall with direct air leakage is the most specific finding, although rare. There are several indirect signs including the presence of

Figure 10 91-year-old woman who was hit by a car. Axial chest CT image (mediastinal window, arterial phase) showing a large heterogeneous right pleural effusion with high attenuation (asterisk) compatible with a **haemothorax**, and **active bleeding** from an intercostal artery (white arrow). The black arrow points to the extrapleural line of fat.

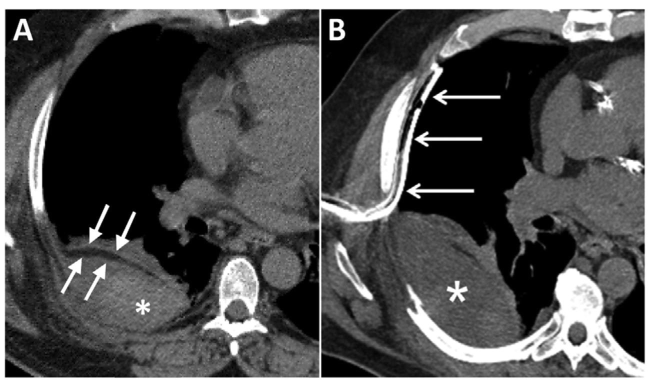


Figure 11 Alcoholic patient who fell downstairs. Axial images of non-contrast CT, mediastinal window (A-B). (A) Extrapleural linear fat (arrows) is seen between the haematoma (asterisk) and the lung. These findings were initially interpreted as a haemothorax, and so a drainage tube was placed (arrows in B) but was not effective. In fact, the tube was unable to penetrate the **extrapleural haematoma** (asterisk). The patient also had rib fractures.

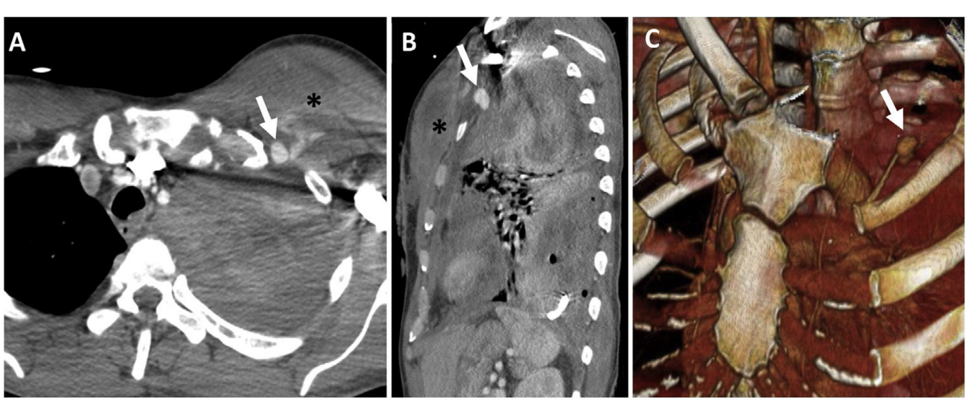


Figure 12 32-year-old male after self-harm (self-inflicted stabbing). A-C) Chest CT images (axial [A] and sagittal [B], mediastinal window; 3D reconstruction [C]) showing a ruptured **pseudoaneurysm of the left internal thoracic artery** (arrow) as a complication of a displaced rib fracture. The rupture of this pseudoaneurysm caused an extensive **haemothorax** and left **extrapleural haematomas** with a loss of extrapleural fat, causing difficulties in differentiation. Haematomas are also seen in the thoracic wall (asterisks).

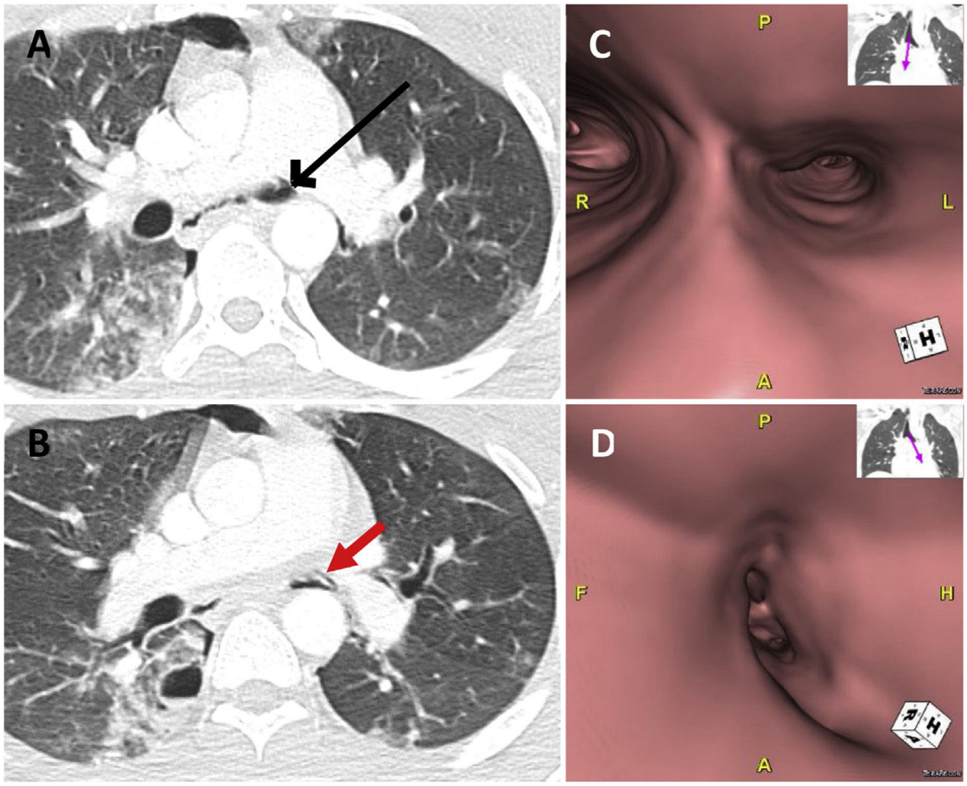


Figure 13 **Rupture of the left main bronchus** in a 19-year-old patient involved in a motorcycle accident. A and B) Axial chest CT images (lung window) showing an irregularity and small loss of continuity in the wall of the left main bronchus (thick arrow in A), partially collapsed, as well as a small pneumomediastinum (thin arrow in B). C and D) 3D reconstructions (virtual bronchoscopy) showing the collapsed bronchial lumen (conventional fibrobronchoscopy confirmed the suspicion of bronchial rupture). The patient underwent a left pneumonectomy after an unsuccessful attempt to repair the bronchial rupture.

persistent pneumomediastinum or pneumothorax despite drainage intubation, ectopic EI location, overdistended EI balloon > 2.8 cm and the 'fallen lung' sign.[24] This sign indicates a significant transection of a main bronchus, with a collapsed lung not attributable to pneumothorax or effusion. In this instance, the lung falls posteriorly away from the pulmonary hilum instead of ipsilateral displacement towards the hilum.[25] Fig. 13 illustrates an example of a main bronchus rupture, without the fallen lung sign due to its small size.

Once an airway rupture has been diagnosed, an oesophageal rupture must also be considered, as both injuries frequently coexist. While oesophageal rupture is also associated with pneumomediastinum, this is usually localised to the periesophageal region, and the volume of air is less than in tracheal injury due to lower intraluminal pressure.[1] In addition, it is common to find adjacent bands of fluid, a finding not common in airway ruptures.[26]

Intrathoracic ectopic air

It is often difficult to distinguish between pneumomediastinum, pneumopericardium and pneumothorax. To differentiate between them, it is important to pay attention to the content of the air and where it is located and limited to[9,15,27] (Fig. 14).

It is of critical importance to know how to distinguish between these entities, as it has a major impact on patient management.

- In cases of pneumomediastinum, it is necessary to find a cause. There are four main possibilities that should be checked: airway injury, oesophageal rupture, leakage of air into the thorax (from the neck or abdomen) or the Macklin effect. The Macklin effect is a relatively obscure cause of pneumomediastinum resulting from alveolar rupture with air dissecting along the peribronchovascular interstitial sheaths into the mediastinum. It has also been described in non-trauma settings (such as chronic obstructive pulmonary disease).[28] It should be noted that there may be more than one cause for the pneumomediastinum and, if so, this should be stated in the radiology report.
- The importance of early diagnosis of pneumopericardium lies in the risk of cardiac tamponade and death. Therefore, in cases of tension pneumopericardium—and even in some patients with mild pneumopericardium and mechanical ventilation—it is necessary to use a drainage tube.[29]

Conclusion

The radiologist must be able to identify the main radiological findings in CT scans for severe acute non-cardiovascular trauma injuries in order to make a correct and early diag-

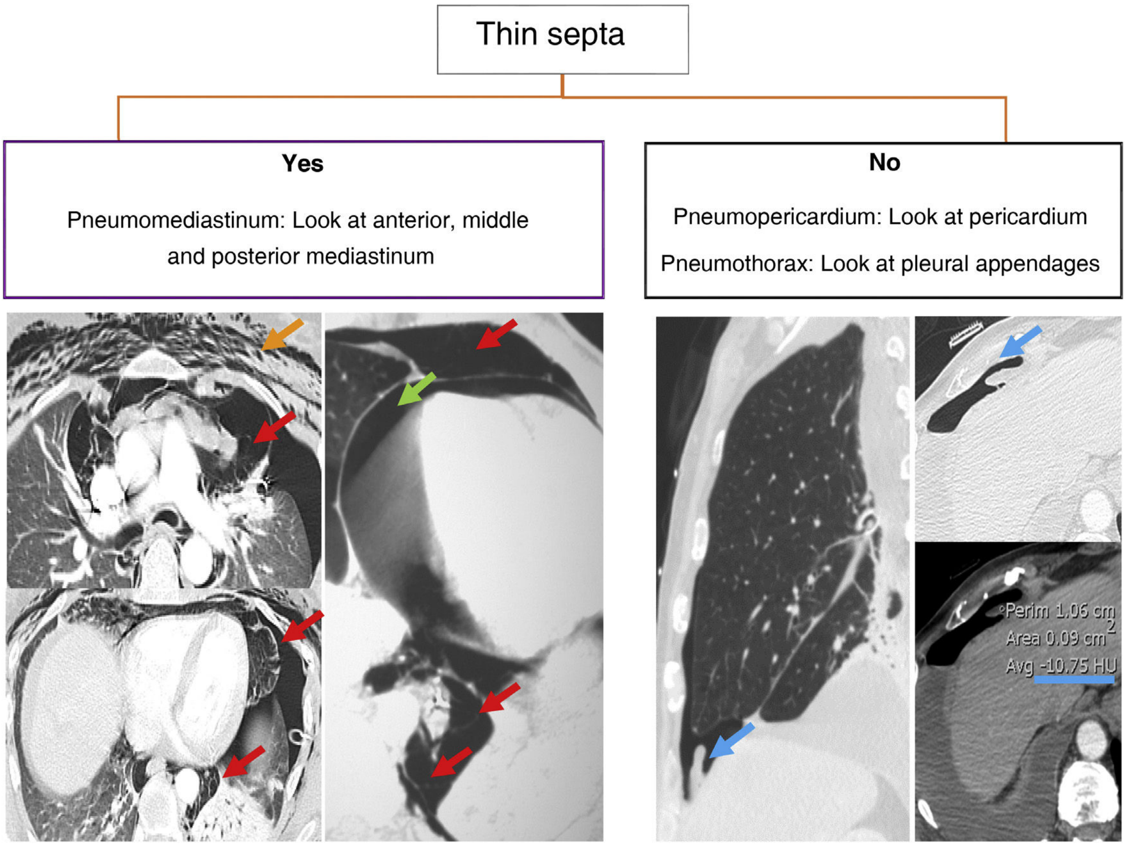


Figure 14 **Algorithm** for differentiating **ectopic air in the thorax**. It is very important to note whether the air collection and surrounding anatomical structures (chest wall, pericardial line) contain thin septa. The different colours of the arrows correspond to the different locations of the ectopic air: pneumomediastinum (red), subcutaneous emphysema (orange), pneumopericardium (green), pneumothorax (blue).

nosis because it has a significant effect on the subsequent management and evolution of the patient.

Funding

This research has not received funding support from public sector agencies, the business sector or any non-profit organisations.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.rxeng.2023.05.002.

References

1. Lewis BT, Herr KD, Hamlin SA, Henry T, Little BP, Naeger DM, et al. Imaging manifestations of chest trauma. RadioGraphics. 2021;41:1321–34.
2. Dogrul BN, Kiliccalan I, Asci ES, Peker SC. Blunt trauma related chest wall and pulmonary injuries: an overview. Chin J Traumatol. 2020;23:125–38.
3. Galvez C, Arenas-Jimenez J, Del Campo J, Maroto S, Sirera M, Lirio F. Diagnostic imaging pathways in the setting of acute chest wall trauma. J Vis Surg. 2020;6:21.
4. Hayes CW, Conway WF, Walsh JW, Coppage L, Gervin AS. Seat belt injuries: radiologic findings and clinical correlation. Radiographics. 1991;11:23–36.
5. Ditkofsky NG, Maresky H, Mathur S. Imaging ballistic injuries. CAR J. 2020;71:335–43.
6. Thoongsuwan N, Kanne JP, Stern EJ. Spectrum of blunt chest injuries. J Thorac Imaging. 2005;20:89–97.
7. Guttentag AR, Salwen JK. Keep your eyes on the ribs: the spectrum of normal variants and diseases that involve the ribs. Radiographics. 1999;19:1125–42.
8. Talbot BS, Gange CP Jr, Chaturvedi A, Klionsky N, Hobbs SK, Chaturvedi A. Traumatic rib injury: patterns, imaging pitfalls, complications, and treatment [published correction appears in Radiographics. 2017;37:1004]. Radiographics. 2017;37:628–51.
9. Oikonomou A, Prassopoulos P. CT imaging of blunt chest trauma. Insights Imaging. 2011;2:281–95.
10. Tominaga N, Hayakawa M, Yokobori S. Blush in lung contusions is not rare and has a high risk of mortality in patients with blunt chest trauma. Front Med (Lausanne). 2022;9:858511.
11. Wanek S, Mayberry JC. Blunt thoracic trauma: flail chest, pulmonary contusion, and blast injury. Crit Care Clin. 2004;20:71–81.

12. Miller PR, Croce MA, Bee TK, Qaisi WG, Smith CP, Collins GL, et al. ARDS after pulmonary contusion: accurate measurement of contusion volume identifies high-risk patients. J Trauma. 2001;51:223–30.
13. Požgain Z, Kristek D, Lovrić I, Kondža G, Jelavić M, Kocur J, et al. Pulmonary contusions after blunt chest trauma: clinical significance and evaluation of patient management. Eur J Trauma Emerg Surg. 2018;44:773–7.
14. Kaewlai R, Avery LL, Asrani AV, Novelline RA. Multidetector CT of blunt thoracic trauma. Radiographics. 2008;28: 1555–70.
15. Miller LA. Chest wall, lung, and pleural space trauma. Radiol Clin North Am. 2006;44:213–24.
16. Mirvis SE. Imaging of acute thoracic injury: the advent of MDCT screening. Semin Ultrasound CT MR. 2005;26:305–31.
17. Choudhary S, Pasrija D, Mendez MD. Pulmonary contusion. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2022. PMID: 32644340.
18. Phillips B, Shaw J, Turco L, McDonald D, Carey J, Balters M, et al. Traumatic pulmonary pseudocyst: an underreported entity. Injury. 2017;48:214–20.
19. Altoos R, Carr R, Chung J, Stern E, Nevrekar D. Selective common and uncommon imaging manifestations of blunt nonaortic chest trauma: when time is of the essence. Curr Probl Diagn Radiol. 2015;44:155–66.
20. Freixinet Gilart J, Ramírez Gil ME, Gallardo Valera G, Moreno Casado P. Chest trauma. Arch Bronconeumol. 2011;47:9–14.
21. Chaturvedi A, Rajiah P, Croake A, Saboo S, Chaturvedi A. Imaging of thoracic hernias: types and complications. Insights Imaging. 2018;9:989–1005.
22. Clark AJ, Hughes N, Chisti F. Traumatic extrathoracic lung herniation. Br J Radiol. 2009;82:e82–4.
23. Moser JB, Stefanidis K, Vlahos I. Imaging evaluation of tracheobronchial injuries. Radiographics. 2020;40:515–28.
24. Scaglione M, Romano S, Pinto A, Sparano A, Scialpi M, Rotondo A. Acute tracheobronchial injuries: impact of imaging on diagnosis and management implications. Eur J Radiol. 2006;59:336–43.
25. Tack D, Defrance P, Delcour C, Gevenois PA. The CT fallen-lung sign. Eur Radiol. 2000;10:719–21.
26. Ho AS, Ahmed A, Huang JS, Menias CO, Bhalla S. Multidetector computed tomography of spontaneous versus secondary pneumomediastinum in 89 patients: can multidetector computed tomography be used to reliably distinguish between the 2 entities? J Thorac Imaging. 2012;27:85–92.
27. Villanueva Campos AM, Etxano Cantera J, Patel N, Villanueva Marcos AJ. Apéndices pleurales: descripción, incidencia y relación con el índice de masa corporal. Radiologia. 2021, http://dx.doi.org/10.1016/j.rx.2021.03.008.
28. Wintermark M, Schnyder P. The Macklin effect: a frequent etiology for pneumomediastinum in severe blunt chest trauma. Chest. 2001;120:543–7.
29. Anand R, Brooks SE, Puckett Y, Richmond RE, Ronaghan CA. Pneumopericardium resulting from blunt thoracic trauma. Cureus. 2020;12:e11625.