Acute Tracheobronchial Injuries

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Abstract

Tracheobronchial injuries are an unusual clinical entity accounting for 0.2–8 % of all cases of blunt chest trauma. Actually, most patients die before arriving at the emergency department, from either associated injuries to vital structures, hemorrhage, tension pneumothorax, or respiratory insufficiency from an airway injury. Signs and symptoms may be very subtle or nonspecific and therefore clinical diagnosis is easily overlooked. In this chapter, the authors will review the radiological and CT signs of acute tracheobronchial injuries. Furthermore, mechanism of injury, terminology, and clinical issues will be discussed. Finally, management notes and treatment will be illustrated.

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1 Introduction

Acute tracheobronchial injury is a rare injury usually related to blunt trauma that involves a partial or complete laceration or puncture of the tracheal or bronchial wall. Death occurs in approximately 30 % of patients with tracheobronchial tears, with 50 % of fatalities occurring within the first hour (Scaglione et al. 2006).

Delayed or missed diagnosis can result in death or severe complications including airway stenosis, atelectasis, pneumonia, bronchiectasis, mediastinitis, sepsis, and decreased pulmonary capacity (Baugartner et al. 1990).

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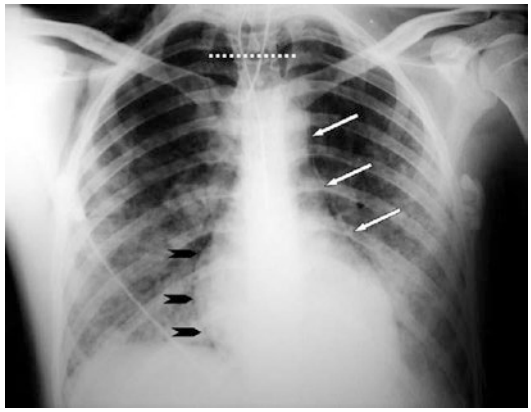

Fig. 1 Penetrating tracheal injury secondary to intubation. Supine chest radiograph shows overdistention of the endotracheal cuff (*dashed line*). Furthermore, left pneumomediastinum (*arrows*), right heart contour outline (*arrowheads*), and bilateral pulmonary contusions are also evident (Reproduced with permission from Elsevier)

Fig. 2 Cervical tracheal injury secondary to blunt trauma. Parasagittal reformatted 16-row MDCT image depicts displacement of the endotracheal cervical tube (*arrowheads*) through a wall defect consistent with a cervical tracheal injury. This finding was confirmed by bronchoscopy (Reproduced with permission from Elsevier)

Tracheal trauma can result from external or internal injuries. External or penetrating injuries can have devastating effects (Fig. 1), including perforation or transection of the tracheobronchial tree and the esophagus. Penetrating injuries to the thoracic trachea are often associated with heart and great vessel trauma. More than 50 % of gunshot wounds and 10 % of stab wounds involving the tracheobronchial tree distal to the cervical trachea are rapidly fatal (Scaglione et al. 2006).

Internal or non-penetrating injuries may occur secondary to inhalation of noxious fumes or gases, tracheal compression on the rigid vertebral column, or due to aspiration of liquids or foreign bodies. When the tracheobronchial tree is occluded by foreign bodies or there is a sudden chest compression with closed glottis, as in crush or steering wheel injuries, an explosive rupture may occur (Stark 1995).

During recent years, an increase in traffic accident has caused an increase in blunt tracheobronchial injuries, and the most common non-penetrating injury mechanism is the motor vehicle accident. The exact mechanism of intrathoracic, tracheobronchial disruption from non-penetrating trauma is unknown, but these injuries include longitudinal lacerations of the distal trachea or near the carina (usually within 2.5 cm), with complete or partial disruption of the main bronchus (more common, right bronchus) and other lobar bronchi.

2 Mechanism of Injury

The causes of airway injuries are divided into blunt trauma, penetrating trauma, or iatrogenic rupture and into neck (larynx and cervical trachea) or thoracic lesions (chest trachea and bronchi).

Blunt trauma at the neck can cause a hyperextension mechanism that results in tracheal tears and paramedian vertical fractures of the larynx and trachea or lead to complete laryngeal–tracheal separation (Dougenis 2002; Milner 2008); another mechanism is direct blow to the neck injuring the thyroid or cricoid cartilages but also the tracheal rings due to compression against the vertebral column. In a vehicle accident, both mechanisms happen: neck hyperextension from sudden deceleration and direct impact of the neck to the steering wheel or the dashboard: this is the "padded dashboard syndrome" (Nelson 2007) (Fig. 2). Other mechanisms are consequent to improper use of seat belts as a direct blow to the neck in front-on collision or by the sudden increase of intratracheal pressure while the glottis is reflexively closed (Rathlev et al. 2007).

The usual mechanisms of tracheobronchial disruption are (1) excessive pressure in the bronchial tree when the glottis is closed, causing airway blowout at the point of the greatest diameter, i.e, the carina (Laplace's law); in this case, the rupture occurs when the intraluminal pressure exceeds the elasticity of the membranous trachea and bronchi; (2) decrease in the anterior–posterior chest diameter with increase in the lateral diameter; when the lungs are pulled out laterally, the main bronchi and carina become disrupted; and (3) severe and sudden deceleration giving rise to sheer forces that disrupt the airway at the points of relative fixation such as the cricoid cartilage and the carina, similar to the mechanism of traumatic injuries of the thoracic aorta (Huth et al. 1997). In most of cases, probably a combination of these three mechanisms causes the airway lesion (Kiser et al. 2001).

Tracheobronchial injuries are rare in the pediatric population, because the pediatric patient's chest wall is more elastic than the adult's chest wall (Balci et al. 2004). This elasticity decreases when the age increases due to the progressive ossification of the rib cage and the development of increased intercostal muscle tone (Grant et al. 1998). Spontaneous tracheal rupture in a pediatric patient can be secondary to paroxysmal coughing or pernicious vomiting. Non-penetrating tracheobronchial injuries less commonly are secondary to fractures of the regional skeleton of the upper thorax, particularly of the first three ribs.

According to data published by Burack et al., even though only 1 of 188 patients who did not die rapidly on the scene or after the admission to the emergency department had sustained a tracheal injury, it is important for the radiologist to identify this kind of lesion, since missed diagnosis may have fatal consequences (Burack et al. 2007).

Acute injuries of the tracheobronchial tree may be iatrogenic in origin: tracheal intubation, tracheotomy, bronchoscopy or other per-oral intervention (tracheal or esophageal stent placement), and surgery (Paraschiv 2014). The most common cause of iatrogenic tracheobronchial rupture is tracheal intubation, especially when it is performed in stressful, emergency conditions. The site of injury is, preferentially, the posterior membranous wall (Massard et al. 1996; Marty-Ane et al. 1995).

Post-intubation tracheobronchial rupture is an emergency condition, secondary to tube tips placed excessively, cuff over inflation that produces excessive stretching of the membranous wall or by endotracheal tube-repositioning maneuvers without deflating the cuff (Figs. 1 and 3).

Bulging of tracheal wall until tracheal rupture can be a complication of hyperinflated cuff that can lead to ischemic necrosis and subsequent tracheomalacia or strictures, particularly if its diameter exceeds 1.5 times the tracheal diameter (Chen et al. 2001b).

Factors favoring post-intubation tracheal rupture are the lack of experience of the anesthetist; use of double-lumen endotracheal tubes, or a too-thick endotracheal tube; presence of chronic pulmonary disease; and congenital tracheal anomalies.

The conditions most commonly associated with injuries of the trachea in intubation procedure are female gender, age over 50 years old, double-lumen tube, and excessive pressure in the endotracheal cuff (Paraschiv 2014).

A rare complication of blunt chest trauma is the tracheoesophageal fistula that may occur to focal necrosis of the esophageal wall and lead to perforation into the trachea (Stark 1995).

3 Terminology and Clinical Issues

The natural history of blunt tracheobronchial injuries may vary from one patient to another. Many patients immediately die at the trauma scene for acute respiratory insufficiency or within 2 h for associated injuries. A small proportion of patients may present in a delayed fashion, usually within 4 weeks of injury, with hemoptysis, pneumonitis, or both, complicating an obstructed airway (Scaglione et al. 2006). Only rarely do patients present with a healed airway injury years later, typically with dyspnea or the diagnosis of asthma.

Tracheal or main stem bronchi injuries are often not recognized initially, due to its rare incidence, lack or subtle clinical manifestations,

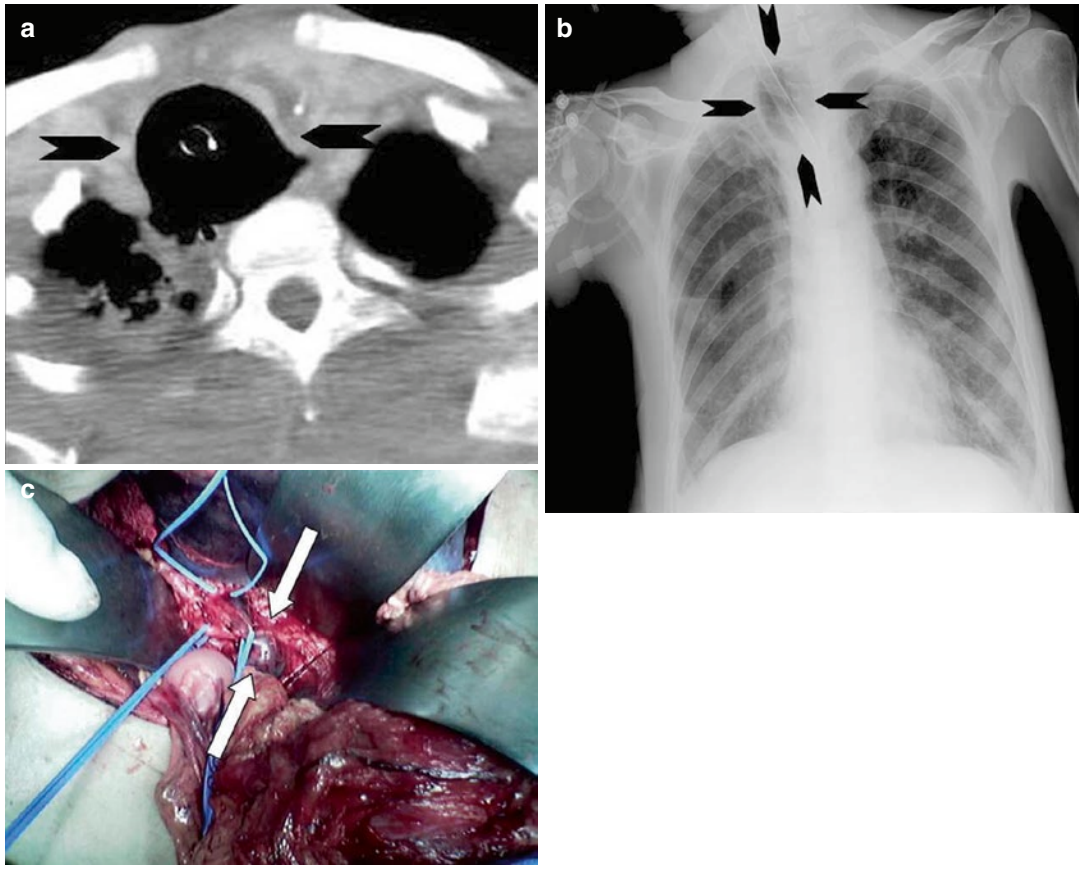

Fig. 3 Penetrating tracheal injury after intubation. (**a**) At the level of the thoracic inlet, chest CT scan shows overdistention of the endotracheal cuff (*arrowheads*). (**b**) Corresponding chest radiograph clearly depicts the same CT finding (*arrowheads*). (**c**) Surgical specimen shows endotracheal cuff herniation through the injured tracheal wall (*arrows*) (Reproduced with permission from Elsevier)

and the much more overt clinical signs of other more common associated injuries (Wiot 1983).

After an acute airway injury, the common symptoms are dyspnea and respiratory distress, hoarseness, or dysphonia. The most common signs of airway injuries are subcutaneous emphysema, pneumomediastinum, pneumothorax, and hemoptysis. These symptoms and signs are nonspecific for this kind of injury. Cervical–thoracic subcutaneous emphysema is the most common finding (65–87 %) (Paraschiv 2014). Pneumothorax, due to the splitting of the mediastinal pleura, occurs in 17–70 %, and the most specific characteristic is the inability to re-expand the lung after chest tube positioning.

A rare clinical manifestation is Hamman's sign, a crackling sound, synchronous with heartbeats, may be heard over the precordium produced by the heart beating against air-filled tissues (Wong and Knight 2006).

4 Imaging

4.1 Radiological Signs

Radiological studies improve the diagnosis of tracheobronchial injuries, especially when the clinical findings are subtle and in the first hours after the injury.

Standard or supine chest and cervical X-rays may reveal early suggestive signs as deep cervical or mediastinal emphysema (92–100 %), pneumomediastinum (85 %), or pneumothorax (40 %).

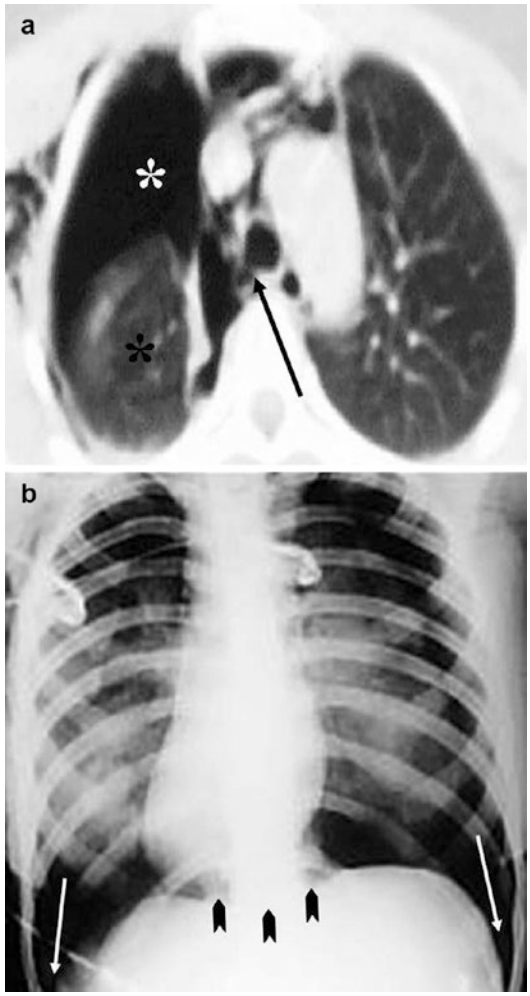

Fig. 4 Blunt bronchial injury (**a**) CT scan shows right-sided subcutaneous emphysema, pneumothorax (*white asterisks*), and pneumomediastinum. The right lung, which is partially collapsed, is detached from the main bronchus (*arrow*) and drops posteriorly (*black asterisk*) in the right hemithorax—the "fallen lung" sign. (**b**) Supine chest X-ray shows the "deep costophrenic sulcus" sign (*arrows*) and the "continuous diaphragm sign" (*arrowheads*) (Reproduced with permission from Elsevier)

These are the most common findings in radiographs. When the pneumomediastinum or pneumothorax is conspicuous, in supine position, the signs of "continuous diaphragm" or "deep costophrenic sulcus" can be appreciated (Fig. 4) due to the redistribution of the air preferentially accumulated over the diaphragmatic structure and anterior to the lungs, respectively (Scaglione et al. 2002).

Other signs suggestive for tracheobronchial injuries include tracheal deformity and overdistended endotracheal balloon cuff (Figs. 1 and 3). On lateral radiographs of the cervical spine, a high position of the hyoid bone associated to deep cervical emphysema can be an important indication of tracheal transection (Polansky et al. 1984).

Defect in tracheal contour, deviation of the endotracheal tube tip, and tube's cuff overdistention or protrusion beyond the edge of the tracheal wall (Chen et al. 2001b) are more specific signs of tracheobronchial rupture.

In some cases, the overdistention of balloon precedes the pneumomediastinum of several hours and may be the first and "small" signs of tracheobronchial injury. A cuff diameter greater than 2.8 cm is an indirect sign of tracheal tear (normal diameter of trachea is 2.7–2.8 cm), excluding other causes: balloon is located in the esophagus, patient is chronically intubated, or preintubation of tracheal enlargement (Rollins and Tocino 1987).

A tracheobronchial lesion may be also seen as a "bayonet sign" when a sharp angulation of the normal tracheal column or of the bronchial lumen occurs (Scaglione et al. 2002).

The "fallen lung" sign may be appreciated when the air leak through the injured tracheobronchial wall leads to lung collapse below the hilus, indicating complete rupture or transection of the main bronchi. This sign was first described by Oh et al. in 1969 and Kumpke in 1970.

A bronchocele/pneumatocele may also be detected after blunt trauma as a consequence of compression–decompression trauma of the chest causing rupture of the small airways and is seen as round radiolucent areas on a chest X-ray (Scaglione et al. 2002; Barbick et al. 2005) (Table 1).

4.2 CT Signs

Chest X-ray may miss some signs of tracheobronchial injuries as about 40 % of pneumothorax or a small amount of extrapulmonary soft tissue air, whereas the CT scan represents the

Table 1 X-ray findings

Specific
Defects in tracheobronchial contours
Deviation of the endotracheal tube tip
Tube's cuff protruding beyond the edge of the tracheal wall
"Bayonet" sign
"Fallen lung" sign
Bronchocele/pneumatocele
Suggestive
Tracheal deformity
Overdistended endotracheal balloon cuff (>2.8 cm)
Subcutaneous cervical or mediastinal emphysema
High position of the hyoid bone associated to deep cervical emphysema
Pneumothorax with "deep costophrenic sulcus" and "continuous diaphragm" signs
Pneumomediastinum
Ingravescent pulmonary atelectasis

gold standard with a sensibility of more than 85 % for diagnosis of injuries and rupture of the tracheobronchial wall. CT allows the direct visualization of the site of tracheobronchial injury, showing focal defects (Fig. 5) or the absence of the wall with "bayonet" or "fallen lung" signs contour deformity or abnormal communication with other mediastinal structures (Lupetin 1997; Baumgartner et al. 1997), overdistention or herniation of the endotracheal cuff (Figs. 6 and 7) with the appearance of "mickey-mouse head" when it occurs through the anterolateral walls of the trachea, displacement of the endotracheal tube, and bronchocele (Figs. 8, 9, 10, and 11) (Chen et al. 2001b, Scaglione et al. 2002).

These findings are not specific for tracheobronchial injuries but are helpful to identify the site of the tracheobronchial tear that needs to be confirmed at bronchoscopy or surgery.

Associated findings, highly suggestive for tracheobronchial injury, are pneumothorax or pneumomediastinum, soft tissue emphysema, and "air leak," particularly if detected at the level of the carina is consistent with main bronchus injury (Scaglione et al. 2006; Savas and Alper 2008) (Table 2).

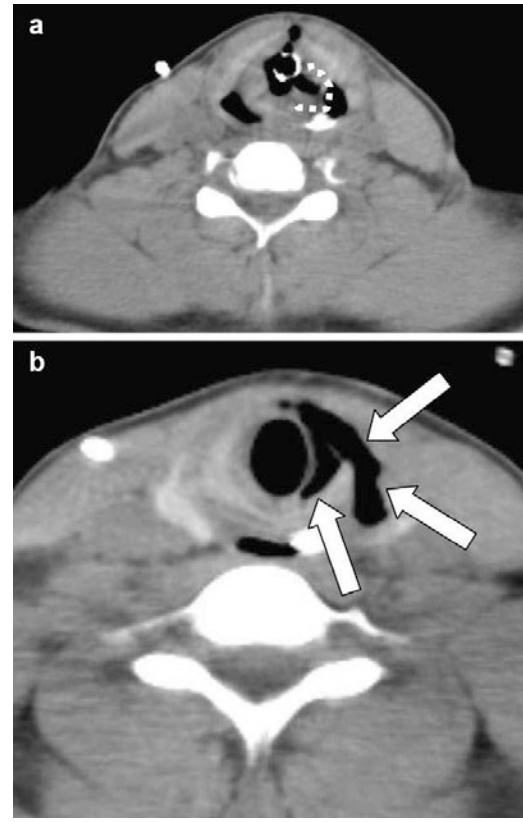

Fig. 5 Cervical tracheal injury secondary to blunt trauma. (**a**) 16-Section MDCT axial source image of the neck (wide window) shows lateral cervical tracheal wall discontinuity (*dashed line*). (**b**) More caudally, "air leak" is clearly evident (*arrows*) (Reproduced with permission from Elsevier)

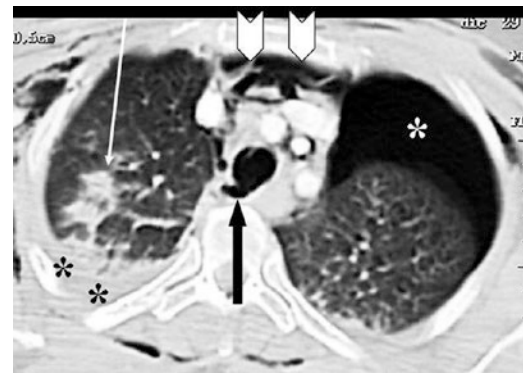

Fig. 6 Blunt tracheal injury after motor vehicle crash. CT demonstrates posterior herniation of the endotracheal cuff (*black arrow*). Furthermore, CT shows diffuse subcutaneous emphysema, right pulmonary contusion (*white arrow*), small pleural effusion (*black asterisks*), pneumomediastinum (*arrowheads*), and left pneumothorax (*white asterisk*) (Reproduced with permission from Elsevier)

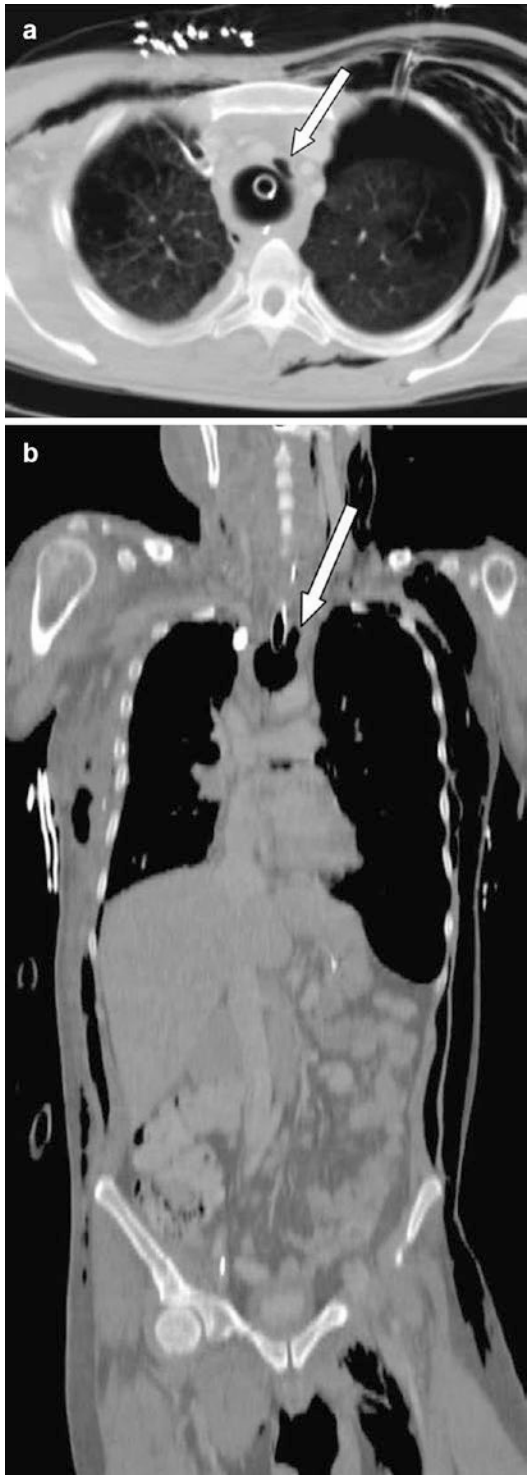

Fig. 8 Blunt bronchial injury after motor vehicle accident. (**a**) At the level of the thoracic carina, in the posterior mediastinum, axial CT scan shows "air leak" (*thick arrow*) in direct connection to the right main bronchus consistent of bronchial injury. This finding was confirmed by bronchoscopy. Associated findings as subcutaneous emphysema, right rib fracture (*small arrow*), pleural effusion (*black asterisks*), small pulmonary contusion (*white arrowhead*), bilateral pneumothorax (*white asterisks*), and pneumomediastinum (*black arrowheads*) are also visible. (**b**) A contiguous, more caudal CT scan also depicts direct "air leak" (*arrow*) and the associated findings (except for the rib fracture) (Reproduced with permission from Elsevier)

Fig. 7 Tracheal injury after blunt trauma (motor vehicle crash). (**a**) 16-Section MDCT axial source image of the neck (lung window) shows overdistention of the endotracheal tube cuff herniated through a tracheal wall defect (*arrow*). Note also massive subcutaneous emphysema and left pneumothorax. (**b**) Coronal reformatted 16-row MDCT scan shows herniation of the endotracheal cuff (*arrow*) and provides a comprehensive evaluation of the spread of the subcutaneous emphysema and the left pneumothorax (Reproduced with permission from Elsevier)

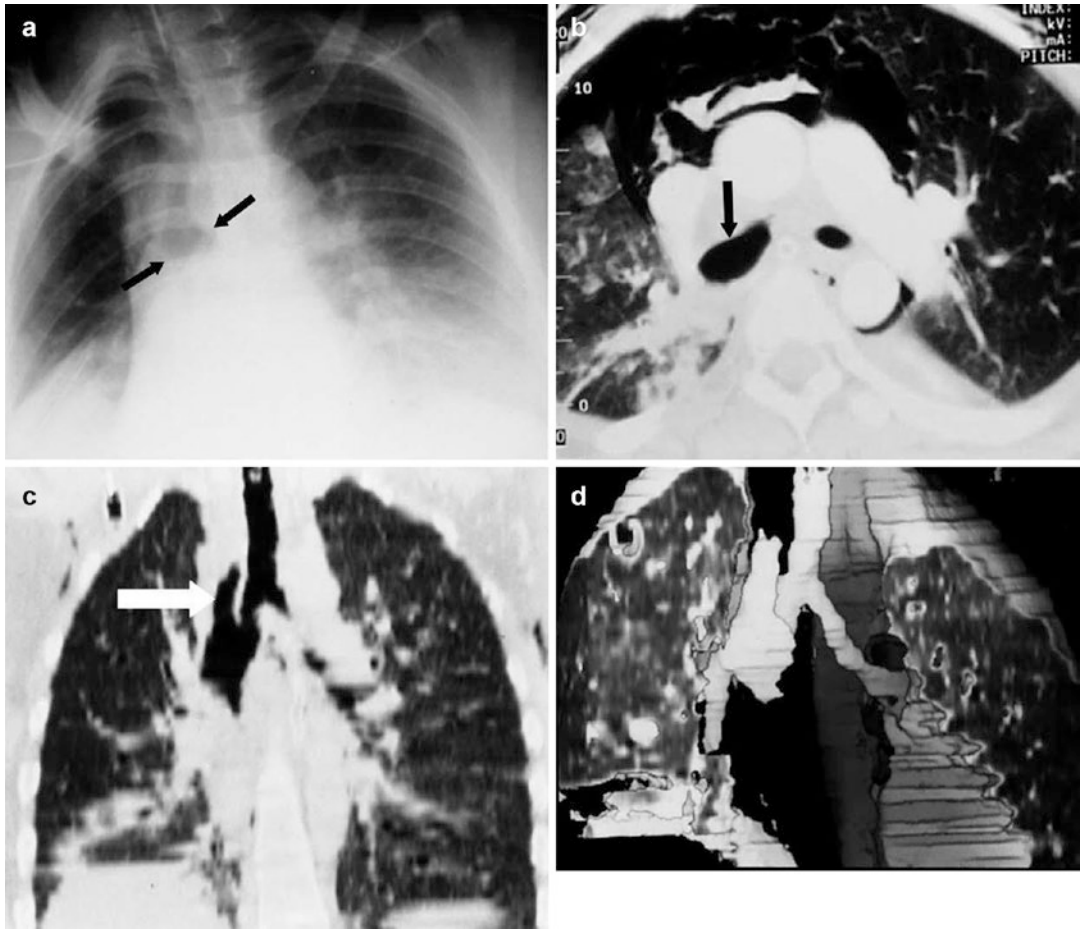

Fig. 9 Blunt bronchial injury after motor vehicle crush. (**a**) Supine chest radiograph shows enlargement of the right main bronchus (*arrows*). (**b**) Axial CT scan confirms the enlargement of the right main bronchus (*arrow*). (**c**) Frontal MIP CT reformation image shows longitudinal extension of injury and also depicts a bronchial pseudodiverticulum (*arrow*). (**d**) SSD reformation image gives optimal representation of the injury surface (Reproduced with permission from Elsevier)

5 Delayed Presentation Injuries

From 5 to 80 % of the tracheobronchial injuries can be missed during the first 72 h after the trauma. With time, the bronchus will be filled with fibro-granulation tissue and organizing hematoma resulting either an airway stenosis or a complete obstruction. Tracheal or bronchial stenosis increases the susceptibility to recurrent lung infections leading to bronchiectasis and parenchymal destruction. In the complete airway obstruction, the lung is filled with mucus but protected by infections. Once a delayed tracheobronchial injury is diagnosed, they should be referred to surgery, with different modalities (Chen et al. 2001a; Demir et al 2006).

6 Management and Treatment

After a possible tracheobronchial injury, immediate intubation should be avoided, as attempt to blindly overpass an upper airway injury may

Fig. 10 Bronchial injury after blunt trauma after motor vehicle accident. Coronal reformatted 16-row MDCT scan shows left main bronchus discontinuity (*arrows*) (Reproduced with permission from Elsevier)

worsen the laceration and/or create false passage of the tube (Baumgartner et al. 1997). Therefore, spontaneous breathing of the patient should be preferred until safe airway has been achieved. As bronchoscopy represents the procedure of choice to find the site of the rupture and to make sure that the tube's cuff is inflated beyond the site of the injury, endobronchial intubation over a flexible bronchoscope is the preferred method for diagnosis and management of a tracheobronchial injury (Riley et al. 2004; Karmy-Jones and Wood 2007, Cassada et al. 2000). The rationale for surgery is closing of the airway defect to improve ventilation, preventing mediastinal spillage and infection, and avoiding spontaneous healing complications. Small tears and lacerations should be closed with direct sutures, while complete or partial transections require debridement of the infected and devitalized tissues, trimming of the edges of the injured airway, and end-to-end anastomosis.

Many studies have described the possibility for nonoperative management in patients with post-intubation tracheal lacerations (Conti et al. 2006; Schneider et al. 2007; Jougon et al. 2000; Lamp 2004). The indications for such management are small lacerations (<2 cm), a tube's cuff inflated distally to the site of the injury, adequate ventilation, reduction or solving of pneumothorax once a chest tube is placed, not increasing subcutaneous emphysema, and absence of infection.

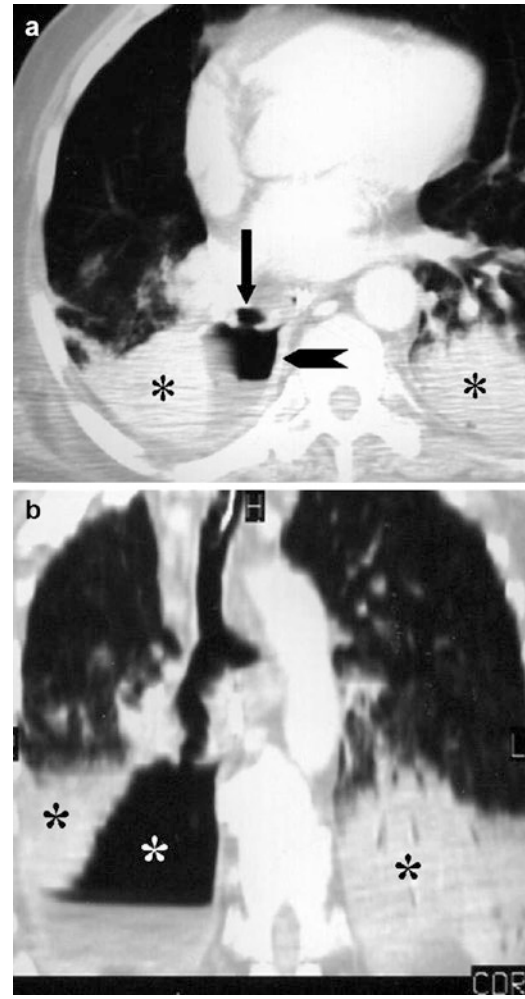

Fig. 11 Penetrating trauma after bronchoscopy. (**a**) CT scan shows right middle bronchus defect (*arrow*) in direct communication with an air-leveled area indicating hydropneumothorax (*arrowhead*). In addition, bilateral pulmonary atelectasis (*asterisks*) is also visible. (**b**) Frontal MPR reformation shows the right middle bronchial discontinuity and the longitudinal extension of the hydropneumothorax (*white asterisk*). Pulmonary atelectasis (*blackasterisk*) (Reproduced with permission from Elsevier)

Table 2 CT findings

Specific
Deformity or discontinuity of the tracheobronchial wall
"Bayonet" sign
"Fallen lung" sign
Abnormal communication of tracheal lumen with other mediastinal structures
Herniation of the endotracheal cuff
Displacement of the endotracheal tube
Bronchocele/pneumatocele
Associated
Air leakage around the presumed site of injury
Soft tissue emphysema
Pneumothorax/Pneumomediastinum
Airway stenosis or complete obstruction (late findings)

Even if the prognosis of conservative management is favorable, the patients should be under strict follow-up, and surgery is necessary if airway loss, inadequate ventilation, or signs of infection and sepsis arise.

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