ABSTRACT
Background: Motor vehicle collisions (MVC) are a major burden on healthcare systems. Saudi Arabia is one of the countries with a high mortality rate of MVC. Blunt tracheobronchial injuries are rare; however, it is a catastrophic event that requires a high center of care. Lack of experience and advanced faculty prompt early stabilization and transfer of the victim for advanced care. Due to the uncertainty of management of these injuries, we would like to share our experience in dealing with such injuries. Objective: To address the difficulties in initial management and transfer of patient with blunt traumatic tracheobronchial injuries. Methods: This is a single-center retrospective case-series study including patients admitted as cases of trauma including all age groups with blunt acute tracheobronchial injuries confirmed by imaging or bronchoscope. Results: In our study, four patients with tracheobronchial injuries were identified, and a retrospective analysis was performed. Two of the males and one of the females are adults, while the other two are pediatrics. Two of them have a right main bronchial injury and the other two have a left main bronchial injury. Posterolateral thoracotomy and bronchial anastomosis were performed on all four patients and were followed up. Conclusion: In Saudi Arabia, blunt trauma is a prevalent type of injury, although tracheobronchial injuries are uncommon. In the event of trauma, a high index of suspicion of tracheobronchial injuries in a high mechanism injury warrants prompt treatment. Due to a lack of experienced and specialized hands in this field, management may be delayed, and eventually lead to unfavorable outcomes, hence we thought of a guide to facilitate the decision-making. Keywords: Blunt tracheobronchial injury, trauma, clinical pathway, guide.

1. BACKGROUND
Motor vehicle collisions (MVC) are a major burden on healthcare systems. In Saudi Arabia, they resulted in more than 80,000 deaths over two decades (1). The vast majority of those injuries are blunt mechanisms affecting multiple systems. Traumatic tracheobronchial blunt injuries are rare and require early referral to advanced centers (2). Many of these patients do not reach the emergency department alive if it was severe and associated with other vital organs injury. Moreover, the presence of non-specific signs and symptoms may delay the diagnosis leading to unfavorable outcomes. An early diagnosis and urgent management are primordial to reducing both morbidity and mortality. The diagnosis is made by bronchoscopy, which remains the gold standard and should be performed in all instances of suspected airway injury for an earlier diagnosis and a better survival rate. We would like to share our experience with blunt tracheobronchial injury in a level two trauma center in terms of associated injuries and outcomes.

2. OBJECTIVE
The aim of this case study was to address the difficulties in initial management and transfer of patient with blunt traumatic tracheobronchial injuries.

3. MATERIAL AND METHODS
This is a single-center retrospective case-series study including patients admitted as cases of blunt trauma between November 2014 to October 2015 who were admitted or transferred to King Fahad Hospital of the University (an academic center). Data was obtained from QuadraMed medical system; version 6.3.1, review of medical records and imaging.

Inclusion criteria were all age groups, blunt trauma with a manifestation of acute tracheobronchial injuries confirmed by imaging or bronchoscope. Exclusion criteria: penetrating traumas, and trauma without airway injury.
4. RESULTS

A retrospective analysis was used for the records. All patients were operated for tracheobronchial injuries by thoracic surgeons. Descriptive data such as MCV timing, transferred from another hospital status, mechanism of injury, modality of diagnosis, time Interval between trauma and surgery, surgical approach, mortality, and postoperative surveillance were obtained. The manuscript has been reported in line with PROCESS 2020 guidelines (3).

4.1. First case

A 27-year-old, male, referred to our hospital as a case of a fall down on his face and chest to the ground from a height of 6 feet while working. Upon arrival to the emergency department (ER) of the referring hospital, he had an unprotected airway with Glasscow coma scale (GCS) 5/15, and on a cervical collar. The patient had a left flail chest, and minimal air entry bilaterally with oxygen saturating (SpO2) of 91%. The circulation was intact with blood pressure (BP) 157/78 mmHg and heart rate (HR) 63 beat/min with obvious mild bleeding from the nose. Resuscitation was done by inserting bilateral chest tubes. The patient was intubated and stabilized. Pan computed tomography (CT) scan was done which showed mild brain edema, bilateral maxillary fracture, right mandibular fracture, C-2 vertebral body fissure fracture, fractured ribs from 1 to 8, flail segments on left 6th to 8th rib, and surgical emphysema on both sides of neck and chest with pneumomediastinum, minimal bilateral pneumothorax with chest tubes in place. The patient was transferred to the surgical intensive care unit (SICU) at our hospital for further care. A repeated CT scan showed the same previous findings in addition to avulsed left main bronchus with bilateral hemopneumothorax. The case was discussed by our multidisciplinary team, and since the patient has a C-2 vertebral body fracture, he was not fit for a rigid bronchoscope. A CT angiography was done and showed normal carotid arteries. The patient continued to have more air leaks on the right side while the left side had low oscillation with high ventilatory requirements and major air loss.

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Age (years)</th>
<th>Sex</th>
<th>MVC timing</th>
<th>Transferred from Another Hospital</th>
<th>Mechanism of injury</th>
<th>Modality of diagnosis</th>
<th>Time Interval between Trauma and Surgery (hours)</th>
<th>Surgical Approach</th>
<th>Intervention</th>
<th>Mortality (days)</th>
<th>Postoperative Surveillance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27 [M]</td>
<td>Yes</td>
<td>May 2016</td>
<td>Yes</td>
<td>Fall from height</td>
<td>CT scan</td>
<td>LMB avulsion (72)</td>
<td>LPT</td>
<td>Left chest tube insertion</td>
<td>26</td>
<td>Patient bronchial tree with intact anastomosis</td>
</tr>
<tr>
<td>2</td>
<td>9 [M]</td>
<td>Yes</td>
<td>June 2015</td>
<td>No</td>
<td>MVC</td>
<td>Intraoperative finding</td>
<td>RMB avulsion and Right lung laceration</td>
<td>RET</td>
<td>Right chest tube</td>
<td>6</td>
<td>Not done N/A</td>
</tr>
<tr>
<td>3</td>
<td>46 [F]</td>
<td>No</td>
<td>Nov. 2014</td>
<td>No</td>
<td>MVC</td>
<td>CT scan and fiberoptic bronchoscope</td>
<td>RMB avulsion (24)</td>
<td>RPT</td>
<td>Right chest tube</td>
<td>N/A</td>
<td>Good anastomosis with no stenosis or stricture</td>
</tr>
<tr>
<td>4</td>
<td>14 [M]</td>
<td>Yes</td>
<td>Oct. 2015</td>
<td>Yes</td>
<td>MVC</td>
<td>CT scan and fiberoptic bronchoscope</td>
<td>LMB avulsion and Left lung laceration</td>
<td>LPT</td>
<td>Left chest tube</td>
<td>28</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 1. Summary of the cases. Abbreviations: MVC: motor vehicle crash; CT: computed tomography; LMB: left main bronchial; RMB: right main bronchial; LPT: left posterolateral thoracotomy; RPT: right posterolateral thoracotomy; RET: right exploratory thoracotomy; N/A: not applicable.
The patient was taken to the operation room (OR) for exploration and possible repair. A left posterolateral exploratory thoracotomy was done. The left main bronchus was avulsed from the carina with a gap defect in between. The anastomosis seemed to be difficult, therefore the arch of the aorta was mobilized anteriorly. A direct anastomosis was done using multiple interrupted 3/0 PDS sutures starting from the posterior to the anterior wall. A fiberoptic bronchoscope was done and confirmed patent anastomosis with no defect. The patient was then shifted back to SICU. On day three postoperatively, a repeat flexible bronchoscope showed an intact anastomotic line with a moderate amount of pus which was washed out. While he was in SICU, the patient developed pneumosepsis and was treated with IV antibiotics. Ten days later, he developed a left pneumothorax and another chest tube was inserted. Trials of weaning failed due to poor compliance of the lungs and perfuse thick secretions.

A tracheostomy was done, and the patient was transferred to the ward. The chest tubes were removed when a chest x-ray (CXR) showed good bilateral lung expansion, no collection, and no pneumothorax. On postoperative day 26th, the patient coded twice and succumbed to his illness.

4.2. Second case

A 9-year-old, male, referred to us as a victim of a motor vehicle collision (MVC). The patient was having a patent airway and on a cervical collar. He was noticed to have a decreased air entry on the right side with SpO2 of 91%, and a chest tube was inserted right away. The patient was unstable the HR was 132 beats/min and BP of 80/40 mmHg without evidence of external bleeding. The focused assessment with sonography for trauma (FAST) scan was inconclusive. The patient was confused with a GCS of 12/15, pupils were equal and reactive bilaterally. A CXR showed a looped tube with a partially inflated right lung with moderate hemothorax. Since the air entry was still minimal on the right side with his right lung being partially collapsed, a 2nd chest tube was inserted. The patient received 1 unit of cross-matched packed red blood cells (pRBCs). He was intubated and shifted to the OR for a right exploratory thoracotomy. Upon arrival to OR, the patient was asystole, chest compression was started, and one minute later the patient was retrieved. He underwent a right posterolateral thoracotomy, there was uncontrolled bleeding at the right upper and middle lobes, and partial pneumonectomy was done. The right main bronchus was avulsed which was repaired by interrupted 3/0. After that the patient underwent exploratory laparoscopy, there was no solid organ injury, contused
left triangular hepatic ligament, and edematous small bowel with around 450 ml of free hemoserous fluid. Postoperatively, the patient was shifted intubated to the pediatric intensive care unit (PICU). On day three, the patient had worsened subcutaneous emphysema over the right side chest and neck with suspicion of a right bronchial air leak. He was taken back to OR for re-exploration, and the right bronchial stump was found disrupted. A completion pneumonectomy was done, and a second-time repair of the right bronchial stump was performed. The patient had a very bad postoperative course of sepsis and acute respiratory distress syndrome (ARDS) and he succumbed to his injuries 6 days after the second operation.

4.3. Third case

A 46-year-old female, not known to have any medical chronic illness was brought to another hospital as a victim of MVC with a suspicion of right main bronchus tear associated with pneumomediastinum, chest subcutaneous emphysema, and small splenic tear showed on initial CT scan of chest and abdomen. She was transferred to our center for further care. Upon receiving the patient, she had patent airway, bilateral equal air entry with crepitition, on a 5 liters oxygen delivered through a face mask with SpO2 of 100%. Bilateral chest tubes were inserted and connected to suction with persistent air leak on the right chest side with no distended neck veins. The HR and BP were within normal ranges. She was oriented with GCS 15/15, with intact sensation and motor in all limbs. There was a contusion on the upper side of the right chest and surgical emphysema in the neck, chest, abdomen, pelvis, and back. A CXR showed clear lungs and surgical emphysema, bilateral chest tubes in place, and surgical emphysema in the neck chest, and abdomen. All labs were within the normal range. A repeated pan-CT scan of the chest and abdomen showed a right main bronchus avulsion and splenic injury. Fiberoptic bronchoscopy confirmed a tear at the right main bronchus. The patient underwent a right posterolateral thoracotomy. Upon exploration, there was extensive cervical emphysema extending into the mediastinum and a complete avulsion of the right main bronchus from the carina, in addition to pericardial tears that were not bleeding. The anastomosis was done with interrupted 4/0 PDS sutures starting from posterior or anterior. The anastomotic line was reinforced by a 2/0 vicryl. The hilum was explored and there was a complete oblique transection of the left main bronchus. An end-to-end anastomosis with 3/0 PDS was done. The anastomosis was examined by flexible bronchoscopy which revealed intact anastomosis. A second surveillance flexible bronchoscopy revealed thick secretions but no stricture or defects were noticed. Unfortunately, the patient developed a very stormy postoperative course of persistent sepsis. He passed away on postoperative day 28th due to sepsis, ASRD, multiple pneumatocele, and renal failure.

5. DISCUSSION

Tracheobronchial injury is rare integrity of injury that occurs between the cricoid cartilage and the division of lobar bronchi and their segmental bronchi. Previously, tracheobronchial injuries were recognized to be lethal, while improvement in emergency medical services and regional trauma centers has resulted in a high diagnostic rate of alive patients with airway injuries presenting to the emergency department. Tracheobronchial injuries could be caused either by blunt, penetrating, or iatrogenic traumas (2). It is a life-threatening event that can be easily missed initially in patients with polytrauma. Its incidence is about 0.4% in adults while it accounts for 0.05% of the pediatric age group (4, 5). However, this incidence is not accurately true as most of the patients die before reaching the hospital (6). Even though they present to the hospital alive, the total death rate remains about 30% (7). Tracheobronchial injuries are infrequent in children before the age of 8; because young children tend to have shorter necks and larger heads, which serves as a protective mechanism against injuries to the larynx and cervical trachea (4). Three theories are ex-
plaining the pathophysiology of blunt tracheobronchial injuries. The sudden anteroposterior compression and subsequent transverse diameter widening will be apart from the lungs away from the carina. Another theory states that a rapid increase in airway pressure against the closed glottis will result usually in a rapture of the membranous portion of the tracheobronchial tree (8).

The third hypothesis is possibly related to the fast deceleration, such as that observed in automobile accidents, which generates shearing pressures between the more firmly attached carina and the more loosely attached lung tissue (9).

Tracheobronchial injuries often occur within 2.5 cm of the carina in 40-80% of cases (10). According to Symbas et al, the right major bronchus is afflicted more frequently than the left (26%-17.5%, respectively) (11). This has been ascribed to the fact that the aorta provides some protection to the left major bronchus (12). Furthermore, because the distal trachea and right major bronchus overlie the vertebral bodies, the latter becomes the anvil at the time of impact, increasing the risk of rupture (13). These injuries are often associated with an esophageal injury.

The signs and symptoms are subtle and non-specific for tracheobronchial injuries such as dyspnea, tachypnea, and respiratory distress which are found in 59-100% of the patients (14). The most specific sign of tracheal disruption is subcutaneous emphysema, while the air leak is a pathognomonic sign of near-total or total avulsion of the cervical trachea which occurs in around 60% of the patients (15). Moreover, in the presence of near-total or total avulsion of bronchus, the ipsilateral lung collapses towards the periphery rather than centrally due to the loss of central anchoring. This situation creates is a hallmark finding “absent hilum” known as the “falling lung sign of Kumpe” which is pathognomonic of tracheobronchial injuries (16-19). The occurrence of pneumothorax, as well as mediastinal or subcutaneous emphysema, strongly implies an intrathoracic injury. These often emerge minutes after the trauma, but they can be delayed, with reports in the literature ranging up to 4 days between the injury and diagnosis (20). Tension pneumothorax is also common, occurring in up to 24% of cases (21). Pneumothorax that continues after closed chest drainage or a collapsed lung that fails to inflate should raise concerns of a severe intrathoracic injury. Respiratory distress is not always present, but it is clearly the decisive factor in its treatment, as it can range from mild discomfort to severe respiratory distress requiring immediate resuscitation. Hemoptysis caused by tracheobronchial vascular rupture is uncommon, yet it can be fatal (4). Some of the symptoms are associated with the location of the injury. So, we found that patients who presented with a neck injury had severe respiratory distress symptoms and arrived at death sometimes. But patients with cervical trachea injury presented with stridor, severe respiratory distress, hoarseness, hemoptysis, and cervical subcutaneous emphysema. And the one with mediastinum injury presented with pneumomediastinum and pneumopericardium. It should be noted that an isolated tracheal rupture is usually not associated with pneumothorax. A bronchial rupture is usually accompanied by pneumomediastinum and an ipsilateral pneumothorax (14). In general, the following signs should alert the physician to tracheobronchial rupture: persistent large air leak, mediastinal emphysema, subcutaneous emphysema, hemoptysis, pneumothorax, tension pneumothorax, massive atelectasis, and failure to expand the lung with thoracostomy tube drainage (5).

Around 50% of tracheobronchial injuries are missed during the first 24-48 hours, assuming the patient survives the initial trauma which may be related to the development of airway obstruction (22). If the early diagnosis of airway damage is delayed or missed, granulation tissue and strictures of the trachea or bronchus develop during the first 1 to 4 weeks, resulting in pneumonia, bronchiectasis, atelectasis, and abscess formation. Even when the airway can be restored, this condition often results in nonfunctional lung tissue distant from the stenosis. When the airway is entirely clogged, however, the distal lung is frequently covered with mucus, which protects it from infection. These individuals do not have parenchymal damage, but rather have functioning lung tissue beyond the blockage (2).

On plain CXR which is the initial investigation of choice, subcutaneous emphysema can be seen. The CT scan may reveal mediastinal air, tracheobronchial air column separation, the exact site of the separation, or tracheal deviation. The CT scan is not recommended in patients who are hemodynamically unstable or have a compromised respiratory system. A negative CT scan does not rule out the necessity for bronchoscopy or other diagnostic tests (23). However, it is not adequate for the diagnosis (10). The most conclusive approach to diagnosing tracheobronchial injuries is a direct examination of the tracheobronchial tree. The investigation of choice for establishing the diagnosis and determining the exact site, nature, and extent of the damage is flexible fiberoptic bronchoscopy and should not be substituted by a CT scan or other imaging techniques (12, 24-27). Other literate, on the other hand, argue that bronchoscopy may not always be necessary for early therapy, particularly in cases with well-tolerated lesions and where the diagnosis of tracheal disruption is apparent based on symptoms, clinical examination, and radiographic imaging (28). However, tracheobronchial injuries can be readily missed in inexperienced hands, hence such examinations should be conducted by competent bronchoscopists (26). Further, bronchoscopy typically worsens ventilatory conditions because increased airway pressure during anesthetic induction may promote air leakage (28, 29). A clean cut with an abrupt termination of the mucosa, heaped-up mucosa, or a coiled portion of cartilage is all common tracheobronchial injury findings. tracheobronchial injuries may cause blood in the tracheobronchial tree (30). Neither the less, if there is a lot of bleeding, determining whether the blood is originating from the damaged mucosa or the lung parenchyma can be difficult (31). During bronchoscopy, obstruction of the airway with blood and inability to de-
tect the more distal lobar bronchi owing to a collapsed mainstem bronchus should also warn. When the lesion is covered by the endotracheal tube, tracheobronchial injuries might be overlooked (32). Rigid bronchoscopy should be conducted to provide a conclusive diagnosis if flexible bronchoscopy reveals negative or confusing results but the clinical situations imply tracheobronchial injuries (26, 33). After the cervical spine has been cleared of damage, rigid bronchoscopy should be done (10).

The goal of treating these patients and the challenge is to have a secure and patent airway (34). So, the management of tracheobronchial injuries can be operative or non-operative. Patients with stable hemodynamics, small lacerations <4 cm, not involving all layers, with no other major associated injuries, and adequate control of air leakage by chest drainage are managed conservatively (34, 35). Moreover, endotracheal intubation beyond the site of damage, preferably with spontaneous breathing, permits the trachea to heal on its own. Positive pressure ventilation should be avoided since it increases the likelihood of the injury worsening. The idea of avoiding intubation should be considered if the patient’s condition is otherwise stable and the damage is confined. In small lacerations, conservative therapy has shown positive outcomes with few long-term sequelae (12, 36, 37). Prophylactic antibiotics should be administered to the conservatively managed patient, who should be constantly monitored for airway impairment and pulmonary sepsis. Coughing can create a significant rise in intratracheal pressure (160-180 cm H2O), which might further exacerbate the damage, and antitussives may be helpful (38). But because of the complexity of the airway lesions and the need to obtain prompt, stable control in patients with major associated injuries, surgical treatment is the mainstay of treatment for these lesions (10). In the acute setting, surgical repair is a standard (9). The surgical approach depends on the site of injury, if the patient sustains a lesion at the trachea, right main bronchus, or proximal left main bronchus, a right posterolateral thoracotomy is performed for optimal exposure of the lesion (40). But if the injury is in the distal left main bronchus (>2cm from the carina), then left posterolateral thoracotomy is used. Simple tracheobronchial injuries can be treated with debridement of injured tissue without impairing blood supply and end-to-end anastomosis of the injured airway (41). We believe that before attempting a repair, it is best to do suctioning, irrigation and culturing of the distal bronchial tree. Gentle insufflation before anastomosis will demonstrate the expandability of the atelectatic obstructed lung. Even long-term-collapsed lungs may regain significant function. On rare occasions, intrapericardial hiliar mobilization may be a useful adjunct for tension-free anastomosis. From our perspective, Tracheobronchial injury repair should be visualized via flexible bronchoscopy at the end of the procedure. Prompt or early extubation is preferred. If postoperative ventilation is required, an effort is made to avoid placing the cuff of the endotracheal tube against the suture line. The gas pressure of ventilation is less inimical to healing than is the irritating contact of an inflated cuff. The lowest effective pressures should be employed for ventilation and cuff inflation.

Traumatic tracheobronchial injuries are a substantial impact on the health system with significant morbidity and mortality. High suspicion of vigilance should be prompt in the case of blunt tracheobronchial injuries as it is a life-threatening condition and may be missed in the case of massive injuries without any obvious signs and symptoms. Most centers in our region are lacking specialized cardiothoracic surgeons and a delay in management may lead to unfavorable outcomes, hence we thought of a roadmap to guide these centers to the right decision in the case of blunt tracheobronchial injuries, Figure 1. Essentially, further studies should be commenced in this field to further explore the best treatment modalities, timing, and prognosis.

5. CONCLUSION

Blunt trauma is a common variant of injuries in Saudi Arabia and tracheobronchial injuries are rarely encountered in practice. A high index of suspicion of tracheobronchial injuries in high mechanism injury in case of trauma should be prompt which can be detected initially by radiological studies and confirmed by bronchoscope. Good to know the limitations and resources to improve the quality of care of such cases, and lack of experienced and specialized hands in this field may delay the management and eventually lead to unfavorable outcomes, hence we thought of a guide to facilitate the decision-making. We believe in a multidisciplinary approach to those types of traumas to make a clear strategy and plan of care.


