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• Original Article •

The Surgical Outcome for Patients with Tracheobronchial Injury in Blunt Group and Penetrating Group

Chang Wan Kim, M.D., Jung Joo Hwang, M.D., Hyun Min Cho, M.D., Jeong Su Cho, M.D.[1], Ho Seok I, M.D.[1], Yeong Dae Kim, M.D.[1], Do Hyung Kim, M.D.[2]

Department of Trauma Surgery, Pusan National University Hospital Trauma Center, Pusan,
[1]Department of Thoracic and Cardiovascular Surgery, Pusan National University Hospital, Pusan,
[2]Department of Thoracic and Cardiovascular Surgery, Pusan National University Yangsan Hospital, Yangsan, Korea

Purpose: Tracheobronchial injuries caused by trauma are rare, but can be life threatening. The objective of this study was to evaluate the surgical outcome for patients with tracheobronchial injuries and to determine the difference, if any, between the outcomes for patients with penetrating trauma and those for patients with blunt trauma.

Methods: From January 2010 to June 2015, 40 patients underwent tracheobronchial repair surgery due to trauma. We excluded 14 patients with iatrogenic injuries, and divided the remaining 26 into two groups.

Results: In the blunt trauma group, injury mechanisms were motor vehicle accident (9 cases), free falls (3 cases), flat falls (1 case) and mechanical injury (1 case). In the penetrating trauma group, injury mechanisms were stab wounds (10 cases), a gunshot wound (1 case) and a stab wound caused by metal pieces (1 case). The mean RTS (Revised Trauma Score) was 6.89±1.59 (range: 2.40-7.84) and the mean ISS (Injury Severity Score) was 24.36±7.16 (range: 11-34) in the blunt group; the mean RTS was 7.56±0.41 (range: 7.11-7.84), and the mean ISS was 13±5.26 (range: 9-25) in the penetrating trauma group. In the blunt trauma group, 9 primary repairs, 1 resection with end-end anastomosis, 2 lobectomies, 1 sleeve bronchial resection and 1 pneumonectomy were performed. In the penetrating trauma group, 10 primary repairs and 2 resections with end-end anastomosis were performed. Complications associated with surgery were found in one patient in the blunt trauma group, and one patient in the penetrating trauma group. No mortalities occurred in either groups.

Conclusion: Surgical management of a traumatic tracheobronchial injury is a safe procedure for both patients with a penetrating trauma and those with a blunt trauma. [J Trauma Inj 2016; 29: 1-7]

Key Words: Injury, Trachea, Bronchus, Surgery, Blunt injury, Penetrating injury

I. Introduction

Traumatic tracheobronchial injury can mostly develop due to blunt and or penetrating events occurring in the chest and thorax area. These injuries often lead to fatal complications however; the research has been constrained due to the insufficient number of reported cases. Many clinicians lack adequate clinical knowledge, especially when distinguishing between two different types of injury mechanisms that can ultimately affect the course of the treatment and patient prognosis. This specific

* Address for Correspondence : **Do Hyung Kim, M.D.**
Department of Thoracic and Cardiovascular Surgery, Pusan National University Yangsan Hospital,
20 Geumo-ro, Mulgeum-eup, Yangsan-si, Gyeongsangnam-do 50612, Korea
Tel : 82-55-360-2127, Fax : 82-55-360-2157, E-mail : yumccs@nate.com

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study is designed to investigate the surgical outcome of tracheobronchial injuries as well as the difference between the subtypes, blunt injury and the penetrating injury group.

II. Materials and Methods

Excluding 14 patients with iatrogenic injuries due to endotracheal intubation, total 26 among 40 patients who went through surgery for tracheobronchial injury repair between Jan 2000 to June 2015 were selected as the subject of the study. Every patient was classified into either the blunt or the penetrating group and the severity of the trauma was measured by using the Revised Trauma Score (RTS) and the Injury Severity Score (ISS). Also, preferred surgical method, post-operative progression, and time spent during patient transportation (from ER to OR) were specifically examined in a retrospective manner. The collected data were registered by using Microsoft Excel 2013 spreadsheet (Microsoft Co., Redmond, WA, USA) and statistical analysis was completed using SPSS ver. 18.0 (SPSS Inc., Chicago, IL, USA), in which statistical significance was defined only when the p value was less than 0.05.

III. Results

The mean age of the entire population was 41.9±18.4 (5-75) years old, with 21 male patients. 14 patients were classified as blunt group, with a mean age of 42.4±21.4 (5-25) years old, including 11 male patients. 12 patients were grouped into the penetrating group, with a mean age of 41.3±14.9 (16-69) years old, including 10 male patients. The major cause of the injury in a blunt group was motor vehicle accident (MVA); total number of 9 cases, followed by 3 cases of free falls, 1 case of flat falls, and 1 case of mechanical injury. The most common cause of the injury in the penetrating group was stab wound; total number of 10 cases, followed by 1 case of gunshot wound and 1 case of a stab wound caused by metal pieces. Tracheobronchial injuries were varied in terms of the location and direction of the trauma. Among blunt group, entire population was composed of 6 cases of cervical trachea injuries (43%), 3 cases of thoracic tracheal injuries (21%), 2 cases of right bronchus injuries (15%), and 3 cases of left bronchus injuries (21%). On the other hand, all 12 cases of the penetrating group were presented with the injuries specifically limited to cervical trachea area. Considering the mechanism of injury in the blunt trauma patients, 4 out of 6 cases of cervical injuries were caused by extension/flexion injuries due to MVA, and only 2 cases were caused by direct collision. In total 8 cases of tracheobronchial injuries, 5 cases were the consequences of direct collision to steering wheel. And only 1 case was a direct result from an accident in compressor machine usage. 2 cases were caused by falls, with unrevealed mechanism.

In terms of the location of injuries, the sites of 6 cases of neck blunt trauma were found to be cricoid cartilage and 2nd tracheal cartilage junction. Furthermore, 8 cases were known to be thoracic blunt type, 2 cases were found at the right bronchus, 3 cases were found at the left bronchus, and 3 cases

Table 1. Associated injuries in blunt group and penetrating group.

	blunt group		penetrating group	
other organ injury				
with one site injury	chest	1	chest	1
	abdomen	1	abdomen	1
	low extremity	1		
with two site injury	chest+abdomen	1		
	abdomen+lower extremity	2		
	lower extremity+upper extremity	1		
with three site injury	chest+head+spine	2		
	abdomen+head+lower extremity	1		
	head+lower extremity+upper extremity	1		

at the thoracic trachea area. Conversely, penetrating trauma group included 10 cases of stab wounds (among 12 cases), and all wounds were limited to the cervical region. According to foreign case reports, the majority of penetrating wounds were the result of gunshot, however, most of the national reports were heavily weighted in stab wounds, reflecting Korean government's strict regulation against possession of firearm. The mean RTS was 6.89±1.59 (2.40-7.84) in blunt group, and 7.56±0.41 (7.11-7.84) in penetrating group, thus showing no statistically significant difference (p: 0.171) between two parties. However, the mean value of ISS in the blunt group was 24.36±7.16 (11-34) and that of the penetrating group was 13±5.26 (9-25), indicating blunt group presented statistically more significant meaning (p<0.001). Reasonable explanation for greater ISS score in the blunt wound patients was that many cases of injuries accompanied with other organ injuries (Table 1).

Among the entire subjects, para-tracheal injuries were found only in the penetrating group. There were 5 cases accompanied with esophageal injuries, 5 cases of thyroid gland injuries, 1 case with recurrent laryngeal nerve injury, and 1 case of internal carotid injury. There were 4 cases of single site Para-tracheal injury without the damage of trachea, and 4 cases had multiple site injuries. This is solely due to the fact that para-tracheal injuries strongly depend on the location and direction of the penetrating wounds. The mean time of patient transportation taken from the emergency room to the operation room was 45.64±55.10 (4-168) hours in the blunt group, and 6.50±3.50 (3-14) hours in the penetrating group, indicating the blunt group statistically spend more time than the other group. (p: 0.006) There were 8 cases (57.1%) in the blunt group, received delayed operation for more than 12 hours. In 5 cases, delayed diagnoses were made due to abnormal findings during hospitalization and in 3 cases, tracheobronchial injuries were diagnosed as soon as patient arrives at emergency room however, surgery was delayed due to time spent with installing mechanical ventilation and supportive treatment in order to stabilize patients' vital states. (Table 2).

For surgery in the blunt group, 9 cases of primary sutures (64.9%), 1 case of resection and end-to-end anastomosis (7.6%), 2 cases of lobectomy (14.3%), 1 case of main bronchial sleeve lobectomy (7.6%), and 1 case of pneumonectomy (7.6%) were performed,

Table 2. Transportation time taken from the emergency room to the operation room.

	Blunt group	Penetrating group	p-value
Time from Emergency room to operation room (hour)	45.64±55.10 (4-168)	6.50±3.50 (3-14)	0.006
Delayed Operatio n (12>hour)	8/14 (57.1%)	0/12 (0%)	0.005

Table 3. Location of tracheobronchial injury, operation approach and operation name.

Location of Tracheobronchial injury		Approach		Op name	
Cervical level	18	Cervical incision	18	Primary repair of trachea	15
				Trachea resection & end-end anastomosis	3
Thoracic level	3	Mid sternotomy	1	Primary repair of trachea	1
	2	Right thoracotomy	4	Primary repair of trachea	2
				Right middle lobectomy	1
				Right lower lobectomy	1
	3	Left thoracotomy	3	Primary repair of trachea	1
				Left bronchial sleeve resection	1
				Left pneumonectomy	1

while in the penetrating group, 10 cases of primary suture (83.3%) and 2 cases of resection and end-to-end anastomosis (16.7%) were performed. Highly invasive procedures such as lobectomy, main bronchial sleeve lobectomy, and pneumonectomy were performed in a blunt group when the operation was not performed in ideal time but delayed. Resection of the right middle lobe and the right lower lobe was performed respectively due to the severe adhesion and infection in the area of peribronchial injury, in patients who developed complete pneumothorax during hospital care and got diagnosed during exploratory thoracotomy. In the similar context, bronchial sleeve resection and pneumonectomy were performed as lobar pneumonia developed during hospital care and bronchial occlusions were diagnosed in bronchoscopy (Table 3).

There were procedures performed simultaneously in order to treat patients. Primary repair was done in all 5 cases of esophageal injuries, and left thyroid lobectomy and total thyroidectomy were performed, in 2 cases among the 5 cases of thyroid injuries. Primary repair of internal carotid vein was done in 1 case of internal carotid vein injury. Surgical complication was relatively rare; there was 1 case (7.1%) in the blunt group and 1 case (8.3%) in the penetrating group. The complications were mostly vocal cord edema and mediastinitis, and there were no significance difference in the incidence of complications between the two groups (p: 0.208). Also there were no deaths in both groups.

IV. Discussion

Tracheal injuries by trauma can be classified into 3 subtypes, including iatrogenic, blunt and penetrating groups according to the mechanism underneath the injury. Especially, non-healthcare related injuries can be further divided into blunt injury group and penetrating injury group. Tracheal injuries caused by blunt trauma develop as a result of direct collision, excessive extension/flexion injury, or crushing injury. The rupture of the cervical and the cricotracheal junctions are often caused by extension/flexion injuries, while tracheobronchial injuries mostly develop as the result of direct collision or severe crush.(1) The location of blunt injury varies; the most common site of the blunt upper trachea injury is the junction between the cricoid cartilage and the 2nd tracheal ring and the frequent location of the tracheobronchial injuries in the thoracic cavity is arranged in the order of frequency: the right main bronchus (47%), left main bronchus (32%), intrathoracic trachea (19%), and bilateral bronchi (2%).(2,3) Tracheal injuries due to penetrating trauma can be classified into gunshot wound and other miscellaneous wounds. As mentioned earlier, despite the fact that most common cause of the injury is known as gunshot, the most common ones in Korea is stabbing, due to nation's policy against firearm possession. The location of the injury is usually around the cervical area, which is most readily stabbed. Injuries of the thoracic trachea, where sharp deadly weapons can hardly be reached, are found less commonly. In this study, 10 out of 12 penetrating injuries were due to stabbing, and the all cases of penetrating wounds were found in the cervical trachea. About 10%~50% of tracheal injuries are accompanied with the injuries of the cervical spine, esophagus, and surrounding blood vessels. Since the blunt trauma often accompanies with cervical spine fracture, performing procedures such as endotracheal intubation, tracheostomy, and neck flexion are not recommended until the stability of cervical spine is confirmed. In a stab wound, there is a high possibility of esophagus or blood vessel injury around the trachea. If diagnosis has been delayed or misguided in esophageal injuries, the leakage of contents such as saliva, refluxed gastric acid, bile acid, and pepsin through the injured lesion of the esophagus, which lead to severe inflammation and even worse mediastinitis, is known to be fatal. Arterial injury can cause fatal consequence as well, and therefore it must be repaired immediately.(4) In this study, there were no case where a blunt trauma patient presenting injuries of the cervical spine, esophagus, and the blood vessels around the trachea. However, injury of the surrounding tracheal areas is always possible and thus requires close attention. In penetrating trauma, 8 out of 12 cases showed surrounding organ injuries, in which esophagus and thyroid gland were known to be the most

frequently affected area. Except tracheal injury, there were 4 cases accompanied with 2 organ-injuries, and 4 cases with 1 organ-injury. The degree and type of injuries of the surrounding organs were associated with the direction and depth of the penetrating trauma. In a patient with cervical penetrating trauma with suspicious tracheal injury, the degree of injury should be thoroughly evaluated, especially examining the depth and direction of the damage. There is high probability of esophageal rupture in penetrating trauma patients, and such diagnosis is difficult since esophagus is located at the posterior of trachea. It is essential to observe the presence of esophageal injury when patients with penetrating trauma present unusual features in cervical esophagus area. Tracheal injuries can be attended by injuries of other organs. The most significant prognostic factor is head trauma. Symptoms of airway obstruction caused by coma can be easily misunderstood as tracheal obstruction from tracheal injury, and airway management can be challenging due to maxillofacial hemorrhage.(5)

During our research, endotracheal intubation was performed in 5 cases as patients presented mental deterioration soon after they enter the emergency room. Since endotracheal intubation is usually a treatment of choice for patients with loss of consciousness, it is difficult to promptly diagnose tracheal injury under such circumstance. The possibility of tracheal rupture should always be considered when there are suspicious clinical signs such as pneumomediastinum, severe subcutaneous emphysema, bilateral pneumothorax and massive air leakage. Injuries that occur from MVA, including all sorts of damages at thoracic wall, lungs, liver, large blood vessels, and limbs, can be accompanied with tracheal injury. Since the post-op complications, after repairing tracheal injury is often followed by loss of patient, it is very important to make right diagnosis as well as to start efficient treatment.(4-6)

Regardless of the mechanisms of injury, supraglottic or infraglottic submucosal edema can rapidly progresses in the presence of tracheal injury. Consequently, tracheal obstruction occurs as well. In addition, the reduced diameter of trachea due to damaged submucosal layers induces epiglottic emphysema, which ultimately leads to tracheal obstruction at the top of the vocal cord. Also, comorbid submucosal hematoma due to trauma causes tracheal obstruction and a series of events such as submucosal edema, emphysema, and hematoma develop within few hours of trauma. Coughing or talking can aggravate edema as well as hematoma.(7-9) Therefore, airway management is the most significant factor for a patient's survival in treating tracheal injury. When a patient with tracheal injury due to blunt trauma entered emergency room, both the diagnostic and treatment approach can be difficult due to the fact that tracheal injury often followed by multiple organ injuries.(6)

In penetrating trauma cases, delayed diagnosis is rare because most injuries are found near around trachea, thus understanding clinical signs of tracheal rupture are clear and simple. However, as hemorrhage caused by paratracheal injury is aspirated into the injured lesion of trachea, causing dyspnea, rapid airway management and maintaining hemostasis are the most significant factors in terms of promoting patient's survival rate. When a patient with multiple traumas is admitted to emergency room, and any radiologic findings of pneumothorax, hemothorax, rib fracture, spinal cord injury cervical subcutaneous emphysema and mediastinal emphysema, are observed, attending must suspect tracheal injury. Also, in such a circumstance, bronchoscopy can be brought into attention. Since endotracheal intubation is often performed prior to bronchoscopy under emergency situation, one should be aware that diagnosis can be delayed due to intubation. Mucosal injury, cartilage exposure, hemorrhage, and impaired function of vocal cords can be identified through bronchoscopy, which is the most accurate and effective and only diagnostic method. Also, it works as a guide in the process of endotracheal intubation.(10) Furthermore, cervical and thoracic CT is useful tool in order to diagnose mediastinal emphysema, mediastinal hematoma, and injuries of surrounding tissues, which cannot be detected in cervical/thoracic x-ray film. At the same time, those tools are very helpful in diagnosing any adjacent organ injuries. Especially, development of multi-detector row CT allows us to obtain multi-dimen-

sional images of organs and vessels that are extremely helpful in diagnosing any types of anatomical malformations.(11) The important clinical signs in patients with tracheal injuries due to blunt trauma include mediastinal emphysema, continuous pneumothorax and air leakage, and post-traumatic pneumothorax. In case of intrathoracic tracheobronchial injury, mediastinal emphysema occurs due to air leakage through ruptured area during respiration. In severe cases, unilateral or bilateral pneumothorax as well as mediastinal emphysema progresses upwards, causing emphysema of soft tissue surrounding larynx as well as upper airway, similar to what happens in cervical injuries. Tracheal injury needs to be suspected when there is mediastinal emphysema and pneumothorax with continuous air leakage after chest tube insertion. Because there is no surrounding tissue protecting right main bronchus, progression is rapid in the tracheal injury. However, because thoracic trachea as well as left main bronchus is surrounded by sternum, aorta, aortic arch, esophagus, vertebrae and surrounding soft tissues, the air may be constrained if the injured area is small enough.

Patient may experience dyspnea or lung collapse, as the result of stenosis, caused by formation of granulomatous tissue as well as fibrotic elements. Once those complications are progressed, more complex surgical treatment such as tracheal resection and end-to-end anastomosis has to be selected as the treatment of choice. In order to prevent further complication and promoting mortality rate, early prompt diagnosis is essential. The mortality of patients with tracheal injuries was up to 15~30%, and the cause of death included irreversible shock, aspiration of massive blood, injuries of cervical or thoracic vessels, and multiple organ injuries. Sometimes airway management is failed under emergency situation and the patient expires.(13) Cicala et al. reported that the mortality of upper airway injury patients was 24% (11 of 46), and the causes included hemorrhage 45%, tracheal problem 36%, brain injury 9%, and sepsis 9%.(14) The prognosis of patients who have received surgical treatment is determined by the degree of trauma, time of surgery, and surgeon's capacity. Although vocalization and tracheal function is mostly recovered to pre-injury status in case of mild injuries, many cases of severe injuries require surgical treatment due to voice change and tracheal instability.(2) When surgery is performed within 24~48 hours of trauma, probability of facing complications such as stenosis of trachea, obstruction, voice change, production of granulomatous tissue, and wound contraction can be reduced.(15) The most significant and long-term factors of prognosis is the function of vocal cords. The most common post-op complication is the ulceration of granulomatous tissue. The possibility of such event can be reduced by using antibiotics as well as stent for a proper period of time. There are various measures, such as steroid injection into tissue, radiation therapy, and long-term sprinting to prevent formation of granulomatous tissue; however, there is no definitive method other than endoscopic removal of tissue.(16,17) Factors affecting the survival rate of tracheobronchial injury include the location of trauma, time spent to diagnose, the cause of injury, and treatment measures. According to Kiser et al., in comparison of mortality by the causes of injury, crushing injury was 27%, which was higher than 13%, the mortality of MVA or falls. When mortality was reviewed according to the location of trauma, it was 26% for trachea, 16% for right bronchus, 8% for left bronchus, and 60% for bilateral bronchi, indicating the mortality was high in the injuries of bilateral bronchus and organs. For time spent to diagnosis, the mortality was 25%~40% within 7 days, and 3% after 7 days, indicating the cases requiring emergency treatment showed greater mortality. The mortality of surgical treatment was 3~13%, indicating higher survival rate than the mortality of conservative treatment, 25%~73%. In surgical treatment, the mortality rate of patients who treated with simple repair was 3%, and significantly lower than that of patients who treated with resection of bronchus or lung parenchyme which was 13%.(3)

Crucially, blunt trauma patients often presented with multiple organ injuries and diagnosis can often be delayed for such a reason. Once diagnosis has been delayed, the entire course of treatment can be easily altered from a simple procedure such as early

simple suture to highly dangerous procedure as sleeve resection, end-to-end anastomosis and/or lobectomy etc. Therefore, early and prompt diagnosis is important in treating patients with blunt trauma.

V. Conclusion

The mechanism of different types of tracheobronchial injuries can be varied due to a location of injury, accompanied injuries of the adjacent organs, frequency of other organ injuries, and clinical progression. Fastidious classification among the different types of traumatic events is strongly recommended. Also, in order to aim at the low incidence of complications and improved mortality, the aggressive surgery can be considered the most significant treatment option.

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