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The blunt thoracic trauma model on rat lungs: an experimental study

Orhan Yücel (*), Onur Genç (*), Ayhan Özcan (**), Hasan Çaylak (*), Alper Gözübüyük (*), Sedat Gürkök (*), Kuthan Kavaklı (*), Mehmet Dakak (*)

SUMMARY

Blunt chest trauma is an important clinical problem leading to injury of heart, lungs and other intrathoracic organs. However, some aspects of the pathophysiology of this kind of injury are poorly understood. In this experimental study, we aimed to establish a new model of unilateral blunt chest trauma in rats and to characterize its effects on cardiopulmonary physiology, hemodynamics and intrathoracic organs. The rats were separated into five groups and each group contained ten rats. In the control group, no blast trauma was delivered. The second, third and fourth groups were groups of mild intensity, moderate intensity and severe intensity trauma groups, respectively. The last group, fifth group, was the survivor group, and a light blast trauma was applied to this group like Group II. Basic cardiopulmonary parameters (heart rate, breath rate and SpO_2) were monitorized and recorded during the first 120 minutes. Gross and histological examinations of the lungs were performed and statistical analysis was performed. The cardiovasculary response to the injury was bradycardia in the light injury group and tachycardia in the moderate injury group. The pulmonary response was decreased SpO_2 and the lung contusion was the most common pathology in all trauma groups. This study established a useful model for the study of blunt trauma in small animals. Lung contusion more obviously occurred than other pathologies and some forms of ventilation and perfusion mismatch took role in all trauma cases. The associated injuries were related with high mortality rates.

Key words: *Blunt chest trauma, lung contusion, trauma model*

ÖZET

Rat akciğerlerinde künt torasik travma modeli: deneysel bir çalışma

Künt toraks travması kalp, akciğerler ve diğer intratorasik organlarda hasara neden olan önemli bir klinik problemdir. Ancak, bu tür travmalarda fizyopatolojinin bazı yönleri tam olarak aydınlatılamamıştır. Bu deneysel çalışmada ratlarda yeni bir tek taraflı künt toraks travması modeli geliştirmeyi ve travmanın kardiyopulmoner fizyoloji, hemodinami ve intratorasik organlara olan etkilerini araştırmayı amaçladık. Her biri on rattan oluşan beş grup oluşturuldu. Kontrol grubunda künt travma oluşturulmadı. İkinci, üçüncü ve dördüncü gruplar sırasıyla hafif, orta ve ağır şiddette travma gruplarıydı. Son grup olan sağ kalım grubuna ikinci grupla aynı olarak hafif şiddette bir travma uygulandı. Temel kardiyopulmoner parametreler (kalp atım hızı, solunum sayısı, SpO_2) ilk 120 dakika içerisinde monitörize edilerek kaydedildi. Akciğerlerin gros ve histolojik incelemeleri yapılmış ve istatistiksel analiz uygulanmıştır. Hafif travma grubunda travmaya kardiyovasküler yanıt bradikardi olarak ortaya çıkarken, orta şiddette travma grubunda taşikardi izlenmiştir. Bütün travma gruplarında travmaya pulmoner yanıt olarak düşmüş bir SpO_2 değeri saptanmıştır ve akciğer kontüzyonu bütün travma gruplarında en yaygın patoloji olarak belirlenmiştir. Bu çalışma, küçük deney hayvanlarında künt travma çalışması için kullanışlı bir model ortaya koymuştur. Akciğer kontüzyonu diğer patolojilerden daha belirgin bir şekilde ortaya çıkarken, bütün travma olgularında ventilasyon ve perfüzyon bozukluğunun bir şekli olaya katılmaktadır. Eşlik eden yaralanmaların yüksek mortalite oranı ile yakın ilgisi bulunmaktadır.

Anahtar kelimeler: *Künt toraks travması, akciğer kontüzyonu, travma modeli*

* Department of Thoracic Surgery, Gulhane Military Medical Faculty
**Department of Pathology, Gulhane Military Medical Faculty

Reprint request: Dr. Orhan Yücel, Department of Thoracic Surgery, Gulhane Military Medical Faculty, Etlik-06018, Ankara, Turkey
E-mail: orhanycl@gmail.com

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Introduction

Thoracic trauma accounts for a quarter of deaths due to multiple injuries according to the U.S. Government Statistical Institute records (1,2). The vast majority of chest traumas occur due to blunt injuries (1,2). The incidence of isolated blunt thoracic injury among the multiple injuries was 16% (3). Endothelial cell injury occurs directly proportional to the intensity of trauma after the blunt chest trauma (BCT). We aimed to investigate the effects of BCT on lung by using a new BCT model in rats.

Material and Methods

This study was performed on the Animal Research Laboratory of the Gulhane Military Medical Academy. Ethics committee's permission of the Gulhane Military Medical Academy was obtained before the study. Fifty adult rats Norvecus weighing between 120 and 160 grams were used. All rats were fed with rat feed including 25% protein (4).

We developed a new and easy way of doing trauma model for occurring BCT (Figure 1) (5). Our new model essentially was made up from three components. First component is 90 cm long pipe and pipe stabilization part, second support table and third metal weights including of 40, 70, 100 grams.

The rats were separated into five groups and all groups contained ten rats. Group I was control group. The control group was subjected to the same experimental protocol, but no blust trauma was delivered. The second group was mild intensity BCT, third was moderate intensity BCT and the fourth was severe intensity trauma groups. The last one was the fifth group; we called this group survivor group. A light blast trauma, like Group II, was applied to the survival group. Test subject groups and intensity of trauma applied onto subjects are shown in Table I. The rats were anesthetized with intraperitoneal xylazine 10 mg/kg and ketamine 90 mg/kg. Three different

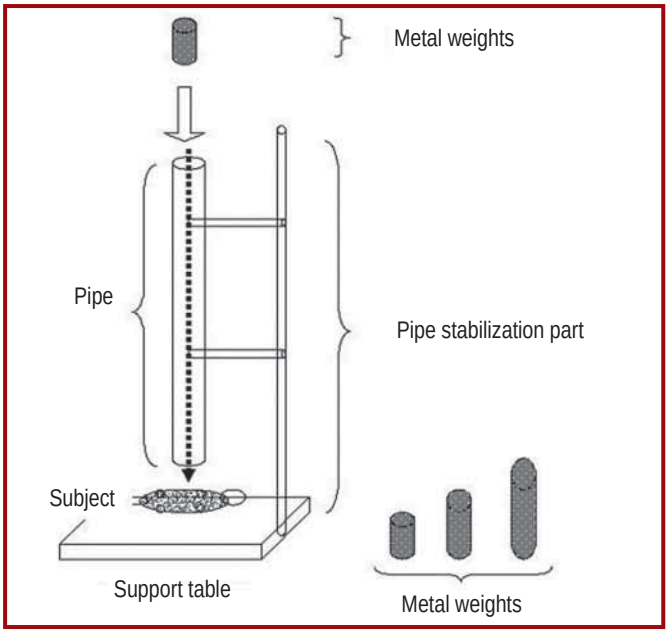

Figure 1. Our blunt trauma model

Table I. Intensity of trauma according to the test subject groups

Group	Applied weight (g)	Intensity of trauma (joule)
Group I (Control)	40	0.04
Group II (Light)	40	0.04
Group III (Moderate)	70	0.07
Group IV (Severe)	100	0.10
Group V (Survivor)	40	0.04

intensity traumas were applied onto rats. Rats were placed in lateral decubitis position over the trauma model's support part. All rats were heated by using tungsten electric bulb (100W/220V) and oxygen supply was obtained. Metal weights were dropped from 1 m height onto rats through the plastic pipe for gaining mild, moderate and severe trauma. Analgesia was obtained by using buterfenol (0.5 mg/kg, sc).

Cardiac rates, breath rates, and SpO_2 values of rats were recorded in 1st, 5th, 10th, 30th, 60th, 90th, and 120th minutes. All the rats were sacrificed except for the Group V by giving lethal dose of xylazine and ketamine after 120th minutes. The survivor group was followed for 10 days and was sacrificed. The lungs of sacrificed rats were examined microscopically and macroscopically. Statistical analysis was done with Kruskal-Wallis, Mann-Whitney U, and Chi-Square tests.

Results

BCT caused initially a significant decrease in the heart rate. Then, the cardiovascular response to injury was bradycardia in the light injury group and tachycardia in the moderate injury group. Heart rate of selected time points for comparison among different trauma intensities is presented in Figure 2. Respiratory rate was calculated at 120 min after injury. Respiratory rate was recorded after trauma. This study showed that a bradypne occurred during the first minute after trauma in all trauma groups. Then, the respiratory rate response was an increasing mode in the moderate injury group. Respiratory rate never reached the levels measured before chest trauma (Figure 2). SpO_2 values were relatively increased one hour after anesthesia in Group I. The same increase was not seen in the trauma groups (Groups II and III). While the trauma intensity resulted in significant heart rate differences, there were no changes related with time. There were significant increases on heart rate, on 10th, 20th, 30th, 40th, and 50th minutes after trauma in Group III, and then it turned to normal rate ($p<0.05$). The pulmonary response was the decreasing SpO_2 for all trauma groups (Figure 2).

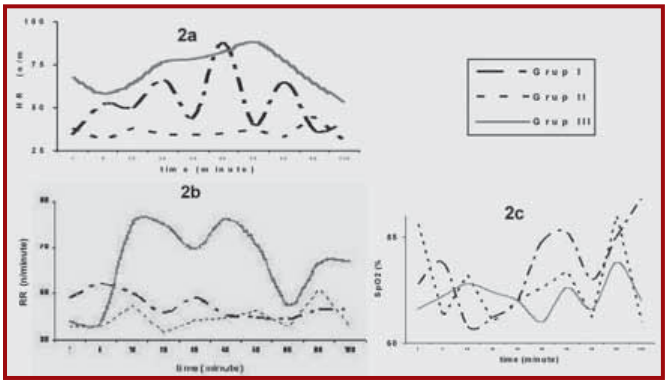

Figure 2. Heart rate (2a), respiratory rate (2b) and SpO_2 (2c) of selected time points for comparison among different trauma intensities are presented

A few minutes after the trauma, 2 in Group II, and 9 in Group IV, a total of 11 rats, were dead due to trauma. Autopsy examination showed pulmonary contusion (90%), pulmonary laceration (63%), pulmonary hematoma (45%) and pulmonary hemorrhage (20%). The most frequent pulmonary lesion was pulmonary contusion (90%) ($p<0.05$) (Figure 3).

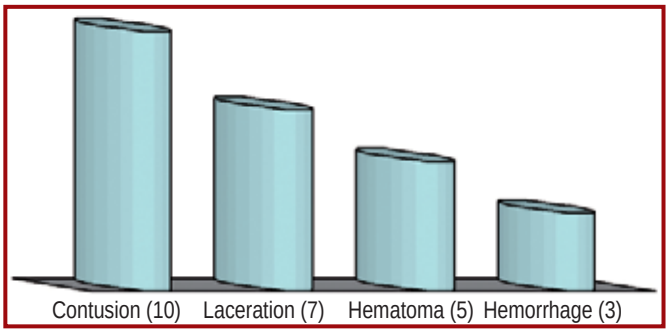

Figure 3. Distribution of the incidence of lung pathology

The lung contusion was the most common pathology in all trauma groups ($p<0.05$). In this study, other important macroscopic findings were non-pulmonary lesions including pericardial hematoma in two rats (one in Group II and one in Group III), one left ventricle laceration, one left ventricle contusion and two cardiac lacerations in Group IV.

Intraparenchymal hemorrhage, including intraalveolar, intrabronchial and subpleural hemorrhage was the microscopic findings in all trauma groups. Intraparenchymal hemorrhage was divided into four groups due to histopathological findings (Figure 4).

The distribution of pulmonary collapse according to the lobe is shown in Table II.

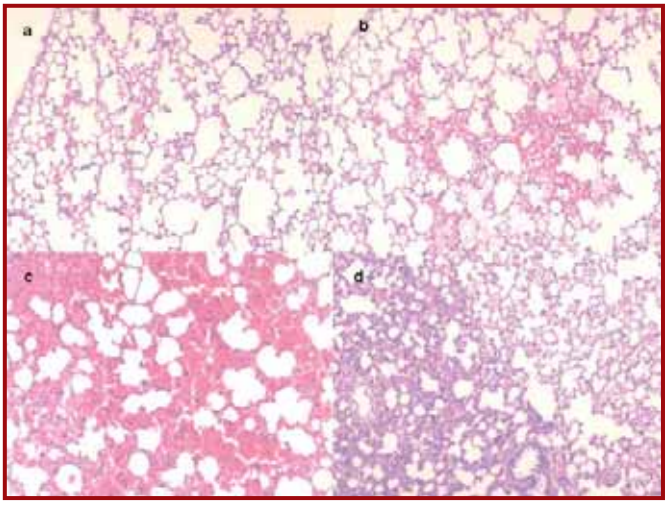

Figure 4. Microscopic findings of the lung: (**a**) Mild hemorrhage, (**b**) Moderate hemorrhage, (**c**) Severe hemorrhage, (**d**) Pulmonary collapse

Table II. Distribution of the incidence of lung collapse according to the lobe

Location	Group	Collapse (+), n (%)	All (n)
Right upper lobe	Group I	0 (0)	10
	Group II	1 (10)	10
	Group III	1 (10)	10
	Group IV	1 (10)	10
Right middle lobe	Group I	0 (0)	10
	Group II	3 (30)	10
	Group III	2 (20)	10
	Group IV	2 (20)	10
Right inferior lobe	Group I	0 (0)	10
	Group II	4 (40)	10
	Group III	2 (20)	10
	Group IV	0 (0)	10
Left upper lobe	Group I	0 (0)	10
	Group II	1 (10)	10
	Group III	2 (20)	10
	Group IV	2 (20)	10
Left inferior lobe	Group I	0 (0)	10
	Group II	5 (50)	10
	Group III	5 (50)	10
	Group IV	1 (10)	10

A survival study was carried out to test the long term effects of BCT. No death occurred during the 10-day observation period.

Discussion

BCT is one of the most important leading causes of morbidity and mortality around the world (2,3). Main causes of BCT contain motor-vehicle crash, strike, earthquake and falling from height (6). The mortality rate of BCT is around 25% (1). The understanding of physiopathology and the relationship between time and physiopathology will decrease morbidity and mortality and clarify diagnosis and treatment process.

In this study we easily constituted a BCT model useful on small animals (5). We used rats because it is easy to obtain, reproduce and maintain for long follow-up. We aimed to investigate the effects of BCT on the cardiopulmonary parameters and microscopic and macroscopic level of lung by using this trauma model.

The BCT is always associated with cardiac changes. Forces applied to the chest wall may cause cardiac rhythm disorders and also may result in a sudden death. We performed right sided trauma on the rats in order to decrease the incidence of heart injury. In mild intensity trauma group, bradycardia was seen from beginning to the 120th minute of trauma. We thought that vagal response was the cause of bradycardia. Bradycardia, hypotension and apnea after trauma were also reported in two studies (7,8). In Group III, heart rate was significantly higher. We realized that tachycardia occurred due to intrathoracic hemorrhage. Compared with other studies, the cause of low incidence of cardiac injury depends on the localizations of applied trauma. We preferred right sided trauma instead of left sided or anterior trauma to avoid cardiac injury. A significant decrease was seen in SpO_2 after trauma due to deteriorated ventilation and perfusion (V/Q) value. Deterioration in V/Q occurred at the beginning of trauma and got worsen during the next period. It is very important in clinical practice for the patients with chronic obstructive pulmonary disease and children whose defense mechanism has not developed yet.

Pulmonary contusion was seen in 70% in Group II, 100% in Group III, and 80% in Group IV. It was proved that pulmonary contusion is the major pathology in BCT patients. Mirua et al. have found pulmonary contusion of 49% in their study with BCT in their series containing 161 patients (9). We found pulmonary contusion in light traumatized rats; pulmonary laceration, pulmonary hematoma, and hemorrhage increased with the intensity of trauma. We made au-

topsies on 11 rats which died within 5 minutes after trauma to evaluate the mortality associated with lung injury. We found that pulmonary contusion (90%) was the most common complication, but pulmonary laceration was the most mortal complication (63%). Peclet et al. reported a rate of pulmonary laceration of 43% in their series containing 2086 patients (10). Hemothorax increasing with the intensity of trauma may also be seen in all groups. From this point, we can conclude that all patients who were exposed to trauma should be examined for hemothorax (1,11).

We have studied the effects of different trauma intensities in lung lobes. This is the unique side of our study. In the study of Knoferl et al., trauma was applied to the left hemitorax and intraparenchymal hemorrhage was reported in both hemitoraces (about 53%) (12).

We had also important dates about the long-term outcomes of contusion and collapse by using the survival group, which the same intensity of trauma was applied with Group II. The rate of contusion was the same with Group II, and it showed that contusion did not recover in early period. The rate of collapse was 50% and it was higher in Group V than in Group II. The increasing collapse in Group V was due to the parenchymal injury and obstruction of bronchial air way caused by secretion and hemorrhage. This finding is very important in clinical practice for the mucolitic treatment and pulmonary rehabilitation in patients with BCT.

As a result this study has established a useful model for the study of blunt trauma in small animals (5). Lung contusion is always more obvious than other pathologies and some forms of ventilation and perfusion mismatch accompanied blunt trauma in each case. The associated injuries are strictly related with high mortality rates.

References

1. Battistella F, Benfield JR. Blunt and penetrating injuries of the chest wall, pleura and lungs. In: Shields TW (ed). General Thoracic Surgery. 4th ed. Vol 1. Baltimore: Lippincott Williams-Wilkins 2004: 767-784.
2. Boyd AD. Chest wall trauma. In: Hood RM, Boyd AD, Culliford AT (eds). Thoracic Trauma. 5th ed. Vol 1. Philadelphia: WB Saunders, 1989: 101-133.
3. Soysal Ö. Künt göğüs travmaları. In: Yüksel M, Kalaycı G (eds). Göğüs Cerrahisi. 1nci baskı. İstanbul: Sim Matbaacılık, 2001: 447-464.
4. Zutphen LEM, Baumans V, Beynen AC. Laboratuar hayvanlarının biyolojisi, yetiştirmesi ve barındırması. Laboratuvar Hayvanları Biliminin Temel İlkeleri (Çeviri ed: Tayfun İde). 2003: 205-233.
5. Yucel O. Künt toraks travması ve akciğere etkileri (deneysel çalışma, uzmanlık tezi). Ankara: GATA, 2004: 1-63.
6. Roux P, Fisher RM. Chest injuries in children: an analysis of 100 cases of blunt chest trauma from motor vehicle accidents. J Pediatr Surg 1992; 27: 551-555.
7. Guy R, Watkins PE. Cardiopulmonary, histological, and inflammatory alterations after lung contusion in a novel mouse model of blunt chest trauma. Shock 19(6): 519-525, 2003. Shock 2004; 21: 190-191.
8. Irwin RJ, Lerner MR, Bealer JF, Brackett DJ, Tuggle DW. Cardiopulmonary physiology of primary blast injury. J Trauma 1997; 43: 650-655.
9. Miura H, Taira O, Hiraguri S, et al. Blunt thoracic injury. Jpn J Thorac Cardiovasc Surg 1998; 46: 556-560.
10. Peclet MH, Newman KD, Eichelberger MR, et al. Thoracic trauma in children: an indicator of increased mortality. J Pediatr Surg 1990; 25: 961-965.
11. Bundy DW, Tilton DM. Delayed hemothorax after blunt trauma without rib fractures. Mil Med 2003; 168: 501-502.
12. Knoferl MW, Liener UC, Seitz DH, et al. Cardiopulmonary histological and inflammatory alterations after lung contusion in a novel mouse model of blunt chest trauma. Shock 2003; 19: 519-525.