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Original Article *Özgün Araştırma*

EVALUATION OF THORACIC INJURIES WITH THORACIC CT IN PATIENTS WITH RETURN OF SPONTANEOUS CIRCULATION AFTER CARDIOPULMONARY RESUSCITATION

Kardiyopulmoner Resüsitasyon Sonrası Dolaşımın Sağlandığı Hastalarda Gelişen Toraks Yaralanmaların Toraks BT ile Değerlendirilmesi

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ABSTRACT

Objective: In this study, we aimed to identify post-CPR (cardiopulmonary resuscitation) injuries.

Material and Methods: This study was conducted retrospectively in 47 patients who had non-traumatic arrest and return of spontaneous circulation after CPR. Age, gender, CPR duration, findings of thoracic CT after CPR and mortality data of patients were evaluated.

Results: The median age of the patients in our study was 73 years (IQR: 18) and 59.6% of the patients were female. The age and duration of CPR were significantly higher in patients with identified CPR-related injuries ($p<0.05$). There was no correlation between CPR-related injury and gender and death ($p>0.05$). Rib fractures were found in 48.9%, lung contusion in 23.4%, hemothorax in 17%, pneumothorax in 10.6%, pneumomediastinum in 4.3% and clavicle fracture in 2.1% of all patients.

Conclusion: Injuries due to chest trauma often develop in cases that respond to CPR. Therefore, clinicians who follow-up the patient should keep in mind that injuries may occur after CPR and determine treatment protocols aimed for these complications in terms of post cardiac arrest.

***Keywords**: Cardiopulmonary resuscitation, computed tomography, thoracic injuries*

ÖZ

Amaç: Bu çalışmada kardiopulmoner resusitasyon (CPR) sonrası gelişen yaralanmaları tespit etmeyi amaçladık.

Gereç ve Yöntemler: Çalışma, nontravmatik sebeplere bağlı arrest olan ve CPR sonucu spontan dolaşımın sağlandığı 47 hastada retrospektif olarak yapıldı. Hastaların yaş, cinsiyet, CPR süresi, CPR sonrası toraks tomografisindeki bulgular ve mortalite durumları değerlendirildi.

Bulgular: Çalışmamızdaki hastaların yaş ortancası 73 (IQR: 18) yıl olup, hastaların %59.6'sı kadındı. CPR'a bağlı yaralanma saptanan hastaların yaş ve CPR süresi anlamlı olarak yüksekti ($p<0.05$). CPR'a bağlı yaralanma ile cinsiyet ve eksitus olma arasında ilişki saptanmadı ($p>0.05$). Hastaların %48.9'unda kosta fraktürü, %23.4'ünde akciğer kontüzyonu, %17'sinde hemotoraks, %10.6'sında pnömotoraks, %4.3'ünde pnömomediastinum ve %2.1'inde klavikula fraktürü saptandı.

Sonuç: CPR'a yanıt veren olgularda toraks travmasına bağlı yaralanmalar sıklıkla gelişmektedir. Bu nedenle hastayı takip eden klinisyenlerin CPR sonrası yaralanmalar oluşabileceğini akılda tutmaları ve kardiyak arrest sonrası bakımda bu komplikasyonlara yönelik tedavi protokollerini belirlemeleri gerekmektedir.

***Anahtar Kelimeler**: Kardiopulmoner resusistasyon, bilgisayarlı tomografi, toraks yaralanmaları*

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INTRODUCTION

Cardiopulmonary resuscitation (CPR), is a process of artificial support for the reactivation of the stopped heart and /or respiratory system and for the purpose of artificially sustaining circulation / respiration during this period (1). The current CPR guideline recommends chest compressions with sufficient number and depth (2). Due to pressure on thorax being the main component of CPR, it is inevitable to injure thorax and structures in the thorax. These traumas can result in a variety of pathologies, ranging from simple rib fractures to severe contusions that can be life-threatening. The effect of the existing traumas on the lung leads to an increased risk of mortality in the following periods (1,3). In an autopsy study, skeletal trauma was reported in 90%of cases who underwent CPR (4). CPR related injuries (CPR-RI) have been reported with a ratio up to %100 in active CPR (5,6).

In this study, we aimed to contribute to the literature by analyzing thoracic injuries due to CPR.

MATERIALS AND METHODS

After the approval of the local ethics committee of Ahi Evran University (Date: 29.01.2019, decision number: 2019-02/28), our study was conducted retrospectively in 47 patients who had arrest due to non-traumatic causes and return of spontaneous circulation after CPR.

In patients who had cardiac arrest due to non-traumatic causes and return of spontaneous circulation after CPR, CT images were acquired to identify both CPR-related injuries and pathologies that cause cardiac arrest between the dates of 01.01.2016 and 31.12.2018 in the Emergency Service of Ahi Evran University.

Patient information was obtained from patient charts and hospital automation system. Age, gender, duration of CPR, thorax CT findings and mortality data of patients were evaluated.

A 16-channel multidetector CT (GE Revolution CT, Wuxi, China) was used for acquisition of images. The imaging device has 140 kV tube voltage of, 200 mA tube current, 1.375 Pitch detector, 0.98 s rotation time, 5 mm cross section thickness, 5 mm cross section range and 512×512 matrix. Acquired CT images were viewed at a window width of 350 HU and a window level of 40 HU.

The study included patients over 18 years of age who had non-traumatic cardiac arrest, return of spontaneous circulation after CPR, has thoracic CT in hospital automation system, no history of CPR and no chest / cardiac surgery for any reason in their medical history.

Patients who were under 18 years of age, who had traumatic arrest, who didn't respond to CPR, who had BT imaging with artifact or no BT imaging in hospital automation system or who previously underwent CPR or chest/cardiac surgery were excluded from the study.

Statistical Analysis

SPSS 22.0 software was used for data analysis. Distribution of variables was evaluated by Kolmogorov Smirnov test. Median and interquartile range (IQR) were used for expressing quantitative data and frequency and ratio values were used for expressing qualitative data. Mann-Whitney U test was used for data analysis. Chi-square test was used for the analysis of qualitative independent data. $p<0.05$ was considered significant.

RESULTS

The median age of the patients in our study was 73 years (IQR: 18); 59.6%of the patients were female and 40.4%were male. The median duration of CPR was 30 minutes (IQR: 20 min) and 78.7%of the patients died in the intensive care unit. The age and duration of CPR were significantly higher in patients with CPR-related injuries ($p<0.05$). Although the frequency of CPR-related injuries was high in women, there was no significant relationship between gender and injury ($p>0.05$). There was no statistically significant relation between the mortality and injury ($p>0.05$) (Table 1).

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Table 1: Relation of CPR-RI with age, gender, CPR duration and mortality

		Whole Study Group	Injury		p
		(n:47)	Present (n:32)	Non-Present (n:15)	
Age, Median (IQR)		73 (18)	76 (16)	63 (20)	0.027
Gender	Male, n (%)	19 (%40.4)	10 (%31.2)	9 (%60)	0.061
	Female, n (%)	28 (%59.6)	22 (%68.8)	6 (%40)	
CPR duration, Median (IQR)		30 (20)	30 (25)	20 (20)	0.016
Mortality	Alive, (n) %)	3 (%6.4)	1 (3.1)	2 (13.3)	0.235
	Emergency, n (%)	10 (%21.3)	7 (%21.9)	3 (%20)	
	Intensive Care Unit, n (%)	34 (%72.3)	24 (%75)	10 (%67.7)	

Rib fractures were found in 48.9%, lung contusion in 23.4%, hemothorax in 17%, pneumothorax in 10.6%, pneumomediastinum in 4.3%and clavicle fracture in 2.1%of all patients. Pericardial effusion, scapula fracture, intraabdominal organ injury or vertebral fracture were identified in none of the patients. Rib fractures were mostly bilateral (60.9%) and fractures on left hemithorax (26.1%) were the second most common. Rib fractures were most commonly in the anterior (65.2%) and lateral (60.9%) regions of the chest. Pulmonary contusions were mostly seen in bilateral (45.5%) and left hemithorax (45.5%); while the incidence of contusion was higher in the lower part of the lung (42.9%). Hemothorax and pneumothorax were frequently seen in the left hemithorax (Table 2).

In our study mortality rate was 93.6%; factors age, gender, CPR duration and factors resulting from CPR-RI had impact on mortality at different levels, however none of the factors had an effect on mortality alone ($p>0.05$) (Table 3).

DISCUSSION

In order to ensure adequate perfusion in cardiopulmonary resuscitation, it is suggested that compression depth should be at least 5 cm, compression frequency should be at least 100 pressure / min and pressure location should be the lower half of sternum (2,3). In this pressure depth and frequency, CPR related injuries (CPR-RI) are frequently seen (6). However, it is stated that the reported incidence of complications due to CPR is higher than reported in the literature (7). In the previous studies, it has been stated that the frequency of CPR-RI is between 32-45% and this rate may increase up to 100%in patients who have undergone active compression and decompression (5,6). We found that the rate of CPR-RI in our study was 68.1%and this rate is consistent with the literature since active compression and decompression were applied to all patients.

Studies have reported that elderly individuals and female gender are more prone to CPR-related rib fracture, which is attributed to the high incidence of osteoporosis in older women (8-10). Seung et al. and Cho et al. reported that the frequency of CPR-RI was higher in the elderly (11,12). In their study, Kim et al. reported that the frequency of chest trauma due to CPR was high in female patients (13). In our study, statistically significant relation was found between CPR-related injury and age in accordance with the literature, and CPR-RI was more frequent in elderly patients. In female patients, although CPR-RI was more frequent, this difference was found to be statistically insignificant. This may be related to the fact that bone and soft tissues are more susceptible to trauma due to advanced age.

Table 2: Characteristics of thorax injuries identified with CT

		n (%)	n (%)
Rib fracture			23 (%48.9)
	Right	3 (%13)	
	Left	6 (%26.1)	
	Bilateral	14 (%60.9)	
	Anterior	15 (%65.2)	
	Lateral	14 (%60.9)	
	Posterior	3 (%13)	
Contusion			11 (%23.4)
	Upper	1 (%9.1)	
	Lower	6(%42.9)	
	Upper+Lower	4 (%36.4)	
	Right	1 (%9.1)	
	Left	5 (%45.5)	
	Bilateral	5 (%45.5)	
Hemothorax			8 (%17)
	Right	2 (%25)	
	Left	4 (%50)	
	Bilateral	2 (%50)	
Pneumothorax			5 (%10.6)
	Right	1 (%20)	
	Left	3 (%60)	
	Bilateral	1 (%20)	
Sternum fracture			3 (%6.4)
Pneumomediastinum			2 (%4.3)
Clavicle fracture			1 (%2.1)

Table 3: Factors that cause mortality

						95%C.I. For Odds Ratio	
	B	**S.E.**	**Wald**	**p**	**Odds Ratio**	**Lower**	**Upper**
Age	0.005	0.035	0.021	0.885	1.005	0.939	1.076
Gender	-0.209	1.252	0.028	0.867	0.811	0.070	9.438
CPR Duration	0.080	0.078	1.048	0.306	1.083	0.930	1.261
Rib fracture	20.587	11848.658	0.000	0.999	872349137.747	0.000	.
Contusion	20.695	7876.977	0.000	0.998	972148530.580	0.000	.
Hemothorax	-1.155	2.709	0.182	0.670	0.315	0.002	63.684
Pneumomediastinum	16.941	34337.638	0.000	1.000	22763741.998	0.000	.
Pneumothorax	-17.177	17895.434	0.000	0.999	0.000	0.000	.
Clavicle fracture	19.045	42690.262	0.000	1.000	186648323.640	0.000	.
Presence of injury	-39.713	14386.867	0.000	0.998	0.000	0.000	.
Constant	-19.801	54054.755	0.000	1.000	0.000		

Seung et al. and Cho et al. reported that the frequency of CPR-RI increases as the duration of CPR increases (11,12). Kashiwagi et al. reported that the incidence of rib fracture was increased in patients with prolonged CPR duration (10). However, in some studies it was reported that CPR duration did not change the frequency of CPR-RI (9,14,15). In our study, it was found that CPR with a longer duration was performed in patients with higher frequency of CPR-RI. As CPR duration prolongs, injury frequency might increase due to high numbers of compression, in other words trauma, to chest area.

Studies have reported that the most common complication of CPR is rib fracture (1,10,16). Chai et al. reported that the incidence of rib fracture due to CPR was 53% (1). Choi et al. reported that rib fracture secondary to CPR-RI was identified in 58.5% of the cases. The fractures were usually bilateral and most commonly on the anterior and lateral surfaces (16). In the study of Kashiwagi et al., it is reported that rib fracture was reported in 70% of the cases with CPR-RI and stated that the most common localization was anterolateral (10). In their study, Beom et al. compared the complications related to chest compressions performed according to cardiopulmonary resuscitation between guidelines before and after 2010 and reported that the incidence of rib fracture was higher in both groups and the incidence of rib fracture was higher in the post-2010 CPR group (17). In our study, in accordance with the literature, it was found that the most common injury in CPR-RI was rib fracture (48.9%) and these fractures were mostly bilateral and on anterior and lateral surfaces of the chest. Although the current guidelines suggest compression to the lower half of the sternum, we believe that the rescuers involuntarily shift to the left and right to increase the pressure to the heart during CPR. This might lead to the increased rates of rib fractures.

In their study, Cha et al. reported that the incidence of lung contusion was 41% (1). Choi et al. found this rate to be 54.9% and reported that the most commonly affected area was on the posterior surfaces of the upper and lower zones of the lung (16). In our study, the incidence rate of contusion of the lungs was 23.4%. The frequency of contusion was higher in the lower zones of the lungs and left lung. As a result of the compression-related energy applied to the chest wall during CPR, it may cause lung parenchymal damage. We also think that the rapid change of negative pressure within the chest wall due to repetitive compression and decompression leads to acceleration-deceleration type of injury.

Studies have reported that the incidence of sternal fractures varies between 4-21% in CPR-RI and these fractures are usually accompanied by rib fractures (1,3,5,6,14,16). Middle region of the sternum was reported to be the most common area of sternal fracture in these patients (16). In our study, the frequency of sternum fracture was 6.4%in CPR-RI and all fractures were in the middle region of the sternum in accordance with the literature. The incidence of sternum fracture might be related to co-morbidity, especially osteoporosis and characteristics of the geography (race, eating habits etc.). Fracture localization might be associated with compression localization recommended in the CPR guideline.

In the study of Cha et al., hemothorax and pneumothorax rates in cases with CPR-RI were reported as 11% and 10%, respectively. Choi et al. reported hemothorax and pneumothorax rates in CPR-RI cases as 37.8% and 6.1%, respectively (16). Kashiwagi et al. reported hemothorax and pneumothorax rates in CPR-RI cases as 0.46% and 7.6%, respectively (10). In the study of Beom et al., it was reported that life-threatening complication rates were increased in CPRs performed after 2010 (17). In our study, hemothorax was identified in 17% of patients with CPR-RI, while this rate was 10.5% for pneumothorax. The frequency of hemothorax and pneumothorax development was higher in the left

hemithorax as in other injuries. We think that hemothorax and pneumothorax may develop due to rib fractures damaging the surrounding tissues and lungs and to the concussion of the lungs which are constantly under pressure during CPR. The fact that rib fractures are more frequent on the left hemithorax and that the chest compression is directed towards the left side may have caused the lesions to be more frequent on the left side of the chest.

Miller et al. reported the prevalence of mediastinal hemorrhage as 10.2% and the frequency of cardiac injury as 7.5% in patients with CPR-RI (5). In the study of Kashiwagi et al., the frequency of hemopericardium was identified as 0.9% in patients with CPR-RI (10). The most common cardiac injuries associated with CPR are pericardial injury, hemopericardium, myocardial contusion and conduction system injuries (5). No cardiac injury was identified in our study. This may be due to the fact that cardiac injuries other than hemopericardium cannot be identified on CT.

Among the less common injuries among CPR complications; clavicle fracture, costochondral junction separation, vertebral fracture and subcostal bleeding have been described (5,6). Although intra-abdominal injury due to CPR has been reported in the literature, its frequency has not been beyond case reports (18,19). No intra-abdominal organ injury was identified in our study. Also, pneumomediastinum and clavicle fracture were found in 4.3% and 2.1% of cases, respectively.

Complications resulting from CPR-RI have been reported to increase mortality (1). Choi et al. reported that 41.3% of patients died after CPR (16). In our study, it was found that 93.6% of the cases died and even though CPR-RI contributed to mortality, none of the factors had an effect on mortality alone.

The most important limitation of our study was its retrospective nature, while small sample size and single-centered study design were among the other significant limitations. In addition, the use of 16-slice CT may be another limitation of the study.

In conclusion, injuries due to chest trauma often develop in cases responding to CPR. Therefore, clinicians who follow the patient should keep in mind that complications may occur after CPR and determine treatment protocols aimed for these complications in terms of post cardiac arrest.

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