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ORIGINAL ARTICLE

Complications of cardiopulmonary resuscitation in non-traumatic cases and factors affecting complications

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Abstract In this study, bodily injuries related to chest compression were examined in non-traumatic death cases that underwent autopsy. This study aimed to evaluate factors that can affect these injuries.

Data were collected retrospectively, and injuries related to chest compression during cardiopulmonary resuscitation were determined over a 10-year period. Age, gender and cause of death were determined, and when cardiopulmonary resuscitation was performed, cardiopulmonary resuscitation duration, intubation and the injury that occurred due to chest compression were also determined.

The study included data from 203 cases. The most frequent injuries were a single fracture in the left ribs (19.7%). Only the duration of cardiopulmonary resuscitation was determined to be associated with injuries. Ventricle rupture in 1 case and liver laceration in 2 cases were the most significant injuries.

It has been shown that during cardiopulmonary resuscitation, severe injuries can occur due to thoracic compression. Only a positive correlation with the duration of cardiopulmonary resuscitation was found in our study.

1. Introduction

The importance of the quality and number of chest compressions applied during cardiopulmonary resuscitation (CPR) is emphasized in current CPR guides. For effective CPR, 30 unit compressions should be implemented to depress the rib cage

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4–5 cm and should be repeated every 15–18 s.[1] Depending on these compressions, several injuries ranging from simple ecchymosis in tissues and organs of the chest to life-threatening myocardial rupture/laceration may occur.[2,3] In bone structures and soft tissue, costal fractures are the most frequently seen injuries.[3] These injuries that may occur during CPR have been determined with various radiological imaging techniques (radiography, computed tomography (CT), magnetic resonance imaging (MRI)) and autopsy studies.[4,5] Some studies have found that as age and CPR duration increase, the frequency and number of injuries may also increase.[6] The presence of other factors that may affect the occurrence of these injuries remains unclear. In addition, it is important to determine whether these injuries are life-threatening and what factors cause an increase in the risk of life-threatening injuries. In this study, injuries that occurred related to CPR were determined from the autopsy results of non-traumatic cases where CPR had been performed. The presence of a probable relationship was examined between the injuries and factors such as age, gender, CPR duration, CPR performed before arriving at the hospital and advanced airway usage. We also aimed to review whether these injuries have a life-threatening effect and to determine what the effect of the above mentioned factors is on life-threatening injuries.

2. Material and methods

This study was a cross-sectional survey, and data were collected retrospectively. Data from cases that underwent autopsy in the Institution of Forensic Medicine over a 10-year period, between January 1, 2003 and December 31, 2012, were evaluated. Cases were excluded from the study if the cause of death was associated with force or trauma. The study initially included 245 non-traumatic death cases that had undergone CPR. Forty-two cases with insufficient data were excluded from the study, leaving a total of 203 cases from hospital files and emergency team records for evaluation. Age, gender and cause of death were determined, and when CPR was performed, CPR duration and the injury that occurred due to chest compression were also determined. Life-threatening injuries were determined and evaluated using the guideline "Evaluation of injury crimes with regards to forensic medicine defined in Turkish Criminal Law" which is based on the Abbreviated Injury Scale (AIS).[7] AIS is a guide that is used to analyze the threat to life of individual injuries. According to this guide, an injury that creates a life risk is assessed to determine whether the injury has the potential to endanger the patient's life rather than being a concrete life risk. Data were analyzed using the SPSS 15.0 software program. Values are expressed as number, percentage and mean ± standard deviation. *T*-test was used in the comparison of continuous variables, and the Chi-square test was used for the comparison of discrete variables. Logistic regression analysis was performed to determine the factors affecting complications. A value of $p < 0.05$ was considered statistically significant.

3. Results

Data of 203 non-traumatic death cases that underwent autopsy were analyzed. The cases included 143 males (70.4%) and 60 females (29.6%), with an average age of 47.1 ± 17.1 years (range of 17–78 years). The most common cause of death was found to be causes associated with cardiovascular disease (Table 1). No injury associated with the application of CPR was determined in 116 cases. A single fracture in the left ribs was determined in 40 cases, multiple fractures in the left ribs in 37 cases and left rib fractures with sternum fractures in 10 cases (Table 2).

When demographic data were analyzed, no statistically significant difference was found between male and female individuals in terms of injury ($p = 0.183$). There was also no statistically significant difference between the groups with injury and without injury in terms of mean age ($p = 0.798$). A total of 133 cases were intubated with advanced airway (endotracheal tube), and 70 cases were not intubated. There was injury in 40.6% ($n = 54$) of intubated cases and 47.1% ($n = 33$) of non-intubated cases. When the data from the two groups were compared, there was no statistically significant relationship associated with compression between the intubation process and thorax injuries ($p = 0.371$). CPR was performed in 90 cases before arriving at the hospital and in 113 cases in the hospital. Injury was detected in 47.8% ($n = 43$) of the group that received CPR before arriving at the hospital and in 38.9% ($n = 44$) of the group that received CPR in the hospital. No statistically significant difference was found between the two groups ($p = 0.206$). Compression was performed for 0–30 min in 46 cases, 31–60 min in 90 cases and ⩾61 min in 67 cases. Injury occurred in 23.9% ($n = 11$) of the 0–30 min CPR group, 23.9% ($n = 11$) of the 31–60 min CPR group and 55.2% ($n = 37$) of the ⩾61 min CPR group. A statistically significant relationship was determined between CPR duration and injury ($p = 0.004$). As a result of logistic regression analysis on the factors of age, gender, place of CPR implementation, forward airway method and CPR duration, only CPR duration was determined to have an effect on the occurrence of injury. In cases with 31–60 min of CPR, the odds ratio (OR) was calculated as 2.953 (95% CI: 1.283–6.796), and in cases with ⩾61 min of CPR, the OR was 6.117 (95% CI: 2.270–16.486) compared to cases with ⩽30 min of CPR (Table 3). According to the reports evaluated by forensic medicine specialists, 19.2% ($n = 39$) of cases had a life-threatening injury. Left ventricle rupture in 1 case was the most significant of these injuries. This case was a 67-year-old female who died due to cerebral hemorrhage, and she had a history of hypertension, myocardial infarction and osteoporosis. CPR was applied for 60 min by the doctors in the intensive care unit (ICU). The patient had a laceration with 0.7 × 1 cm breadth and 0.8 cm depth in the apex of the left ventricle. In the myocardia sections, old microscopic infarct areas were partly observed by the laceration region. Segmental multiple fractures between 3 and 6 ribs, including the fourth rib,

Table 1 Causes of death.

Causes of death	*n*	%
1. Cardiovascular disease	80	39.4
2. Pathological brain hemorrhage	53	26.1
3. Medical drug poisoning	24	11.8
4. Pesticide poisoning	13	6.4
5. Cancer	12	5.9
6. Other	21	10.3

Table 2 Thorax injuries due to CPR.

Thorax injuries	*n*	%
1. Left costal fracture (single)	40	19.7
2. Left pneumothorax	39	19.2
3. Left costal fracture (Multiple)	37	18.2
4. Left hemothorax	33	16.3
5. Left lung contusion	22	10.8
6. Right hemothorax	15	7.4
7. Right pneumothorax	11	5.4
8. Fracture of the sternum	10	4.9
9. Right lung contusion	5	2.5
10. Left ventricular rupture/laceration	1	0.5

which fit the laceration region, were observed. 100 cc free blood was observed in pericardial sac, in addition to this 300 cc free blood was in the left hemi thorax, pericardial sac was observed ruptured from the same projection of laceration. The patient had intracerebral pathological bleeding, which was determined as the death of cause.

Other life-threatening injuries included 29 cases (74.4%) of left costal multiple fractures and 10 cases of sternum compression fractures. In addition, there was a liver laceration in 2 cases (1%). Regarding details of these cases, the first liver laceration case was a 68-year-old male whose cause of death was determined to be cardiovascular disease (e.g. myocardial infarction). CPR was started at home with the 112 Emergency Medical Services (EMS) team and was continued in the ambulance and at the emergency department, for a total of 40 min. There was a 3×3 cm irregular laceration on the front side of the hepatic right lobe. A segmental fracture in the sternum was observed. 600 cc free blood was drained from the abdomen, and no other bleeding point was observed. The second patient with a liver laceration was a 52-year-old male whose cause of death was determined to be lung cancer. Doctors applied CPR for 60 min in the ICU. There was a 2×1 cm irregular laceration on the front side of the hepatic right lobe. A segmental compression fracture was observed in the sternum. 500 cc free blood was drained from the abdomen, and there was no other bleeding point observed.

A single rib fracture was observed in the left thorax in 40 cases (19.7%), the 3rd rib in 1 one case, the 4th rib in 23 cases, the 5th rib in 14 cases and the 6th rib in only 2 cases. There were multiple fractures in 37 cases (18.23%). Mostly 4th and 5th ribs were broken in the left in 25 cases. The 3rd–6th ribs were fractured together in 7 of the cases, and the 4th–6th ribs and sternum were fractured in 5 of the cases. Nine of the cases had isolated sternum fractures (4.4%). One case had a compression fracture in the sternum and a right 5th rib fracture. Thus, it was found that the 4th and 5th left ribs were the most commonly fractured ribs.

When the factors affecting life-threatening injuries were assessed, the age OR was calculated as 1.067 (95% CI: 1.035–1.101) and the male OR as 2.964 (95% CI: 1.193–7.364) compared to females. The OR of cases with 31–60 min of CPR was calculated as 0.960 (95% GA: 0.304–3.036), and the OR of cases with $\geqslant$61 min of CPR was 7.998 (95% CI: 2.191–29.197) compared with cases of $<$30 min (Table 4).

When these results were evaluated, the factors of age, gender and CPR duration were determined to have an effect on the increased risk of life-threatening injury. However, intubation and place of CPR (before hospital/in hospital) were found to not be related to life-threatening injuries.

Table 3 Evaluation by logistic regression analysis of factors affecting the development of complications.

Variable		Odds ratio	95% Confidence interval
CPR Duration	$\leqslant$30 min	1	
	31–60 min	2.953	1.283–6.796
	$\geqslant$61 min	6.117	2.270–16.486

4. Discussion

Various injuries related to CPR are reported in the literature. Frequent abrasion, ecchymose, and subcutaneous hematomas of the neck and head, mucosal membrane lacerations, teeth fractures, airway aspiration, larynx and pharynx soft tissue and bone injuries, laceration of carotid intima, recurrens nerve, sinus piriformis, vocal cord, and arytenoid cartilage injuries, rare hyoid cartilage, thyroid cartilage fractures, and ulcer of tracheal mucosa are observed in association with airway management. Autopsy findings after cardiac massage are facial and conjunctival petechial, retinal hemorrhage, subarachnoid hemorrhage, rib and sternum fractures (very frequent), atelectasia, lung laceration, hemothorax, pneumothorax, pleura and cardiac injuries (frequent), cervical spine injuries, pericardial tamponade due to aorta and cardiac rupture, liver, spleen, pancreas, stomach, and intestine lacerations (rare), hemoperitoneum, etc. Additionally skin burns due to defibrillation and cardiac or renal injuries due to rhabdomyolysis can be observed[8–11] Boz reported that based on autopsy studies, ecchymosis (28.8%) is the most common injury in patients undergoing CPR. Furthermore, bleeding in the costal area (17.6%) and rib and sternum fractures were also reported as frequent injuries, and no injury was observed in patients without CPR.[2] In another study, thoracic injuries were observed in 42.7% of patients who had undergone CPR and of these, 31.6% were rib fractures, 21.1% were sternal fractures, and 20.4% were mediastinal hemorrhage.[12] In this study, the most common injury was a single fracture of the left rib following chest compressions. In addition, only two cases of liver injury were determined, and no other abdominal

Table 4 The evaluation by logistic regression analysis of factors affecting life-threatening injuries.

Variable		Odds ratio	95% Confidence Interval
Age		1.067	1.035–1.101
Gender	Female	1	
	Male	2.964	1.193–7.364
CRP Duration	$\leqslant$30 min	1	
	31–60 min	0.960	0.304–3.036
	$\geqslant$61 min	7.998	2.191–29.197

injuries were associated with chest compressions. A positive relationship has been shown between age and injuries caused by chest compressions. Chest injuries, including rib fractures in particular, may be more frequent in elderly patients receiving CPR.[13] Hellevuo examined the relationship between bodily injuries and compression depth and frequency during CPR and reported a relationship between the depth of CPR and iatrogenic injuries in male patients, but not female patients.[14] Boz noted that the relationship between gender and injuries was not statistically significant.[2] Kim assessed CT scans of non-traumatic death cases that returned to normal sinus rhythm and found that female gender is a risk factor for rib fractures.[4] In our study, while no relationship was determined between age and gender with chest injury, both age and gender appear to be influential factors in the occurrence of life-threatening injuries.

The application of pre-hospital CPR is mostly performed by non-physician healthcare providers. This raises the question of whether there is any difference between the injuries related to chest compressions applied by non-physician personnel out of the hospital and in-hospital applications. In a study that radiologically evaluated injuries in cases that returned to a normal cardiac rhythm after successful CPR, it was detected that non-physician personnel increased the risk of injury.[4] In this study, there was no statistically significant difference in terms of injury between pre-hospital (non-physician staff) and hospital CPR applications. However, our study was an assessment of non-traumatic death cases, and the data of patients who recovered after CPR were excluded from the study.

The duration of chest compression application is known to be a significant factor in terms of injury.[6] In this study, the CPR period was found to be positively correlated with the occurrence of injury. As application time increases, so does the risk of injury. The duration of chest compression was evaluated in three groups, and the risk of injury was found to be highest in the group where CPR had been applied for 60 min or more.

CPR can cause life-threatening injuries. It is reported that pericardial tamponade due to aorta and cardiac rupture, internal bleeding due to liver and spleen lacerations, and gastrointestinal bleedings as a result of CPR can be mortal.[9] Left ventricular rupture/laceration has been reported as the most serious of these injuries.[15,16] It is also known that large artery, liver and spleen injuries may occur in addition to cardiac injury.[3,17] Takada reported that CPR compressions in patients with acute myocardial infarction did not cause left ventricular rupture.[18] In our study, according to the guideline "Evaluation of injury crimes with regards to forensic medicine defined in Turkish Criminal Law", 39 patients were determined to have a life-threatening injury. The most significant of these injuries was rupture/laceration of the left ventricle in 1 patient. Forensic medicine specialists revealed that there were fatal injuries like lung contusion, hemothorax, pneumothorax, liver laceration, and ventricular rupture in the majority of patients with multiple rib fractures and in all patients with a sternal fragmented fracture. Liver injuries in 2 cases were considered rare and fatal injuries. We found that age, gender and duration of CPR were among the risk factors that could result in the occurrence of life-threatening injuries.

It is a big issue to determine the injuries associated with CPR and the other reasons in forensic medicine. For example, the determination of injuries of the head and neck associated with CPR (abrasion, ecchymose, subcutaneous hematoma, bleeding and lacerations, bone and cartilage fractures) from violence injuries (e.g. garotte) will uncover the cause of death. When we consider injuries like retinal and conjunctival hemorrhages, facial petechial, rib fractures, subarachnoid hemorrhage after cardiac massage can be observed in child abuse cases, interpretation of these findings becomes vital.[9]

Claiming of resuscitation related injuries as violence injuries may result filing suits.[9] Also health care providers can face filing suits with the claiming of misapplying the CPR procedures.[10]

As a result, considering the CPR associated injuries that can be also observed in trauma and assaults, interpreting of findings in autopsy and defining the cause of death are important in terms of preventing the further claims.

It is difficult to consider whether these injuries actually contributed to death or were incidental. However, we believe that some of these injuries may have contributed to death, and it would be more useful to consider these injuries as CPR complications. CPR complications can be reduced and can be acceptable under a reasonable rate, but it is not possible to completely avoid CPR complications.

5. Conclusion

It has been shown that due to thoracic compression, severe injuries can occur during CPR. In non-traumatic cases assessed from autopsy reports, thoracic injuries were the most common injury type, in particular a single left rib fracture (19.7%). Age, gender, the place where CPR was performed and the duration of the CPR could be related to the occurrence of the injuries. However, there was only a positive correlation with the duration of CPR. From the autopsy findings of the non-traumatic patients, 19.2% of the injuries occurred during CPR, were shown to have increased the risk of mortality and may be related to age, gender and duration of CPR.

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Conflict of interest

None declared.

Ethical approval

Necessary ethical approval was obtained from the institute ethics committee.

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