

Forensic Aspects of Probable Life-Threatening Complications of Closed Chest Cardiopulmonary Resuscitation in Non-Traumatic Patients

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Abstract Cardiopulmonary resuscitation (CPR) is a life-saving procedure that can also cause many life-threatening injuries to patients. The complications that can arise from the application of CPR are confronted by the existing legal system as a medical error and since forensic pathologists often encounter various types of CPR-related injuries during autopsies, they must be able to distinguish between CPR-related injuries and those caused by other factors. The aim of the present study was to analyze the findings of autopsy reports of patients who received CPR to determine the frequency of its related life-threatening injuries and to determine the possible factors that affect and increase the risk of these injuries. The study included 58 non-traumatic death cases that had undergone CPR and CPR-related injuries were determined based on X ray/CT interpretation reports. The results concluded that the advanced life support was provided in the vast majority of cases (70.7%). The mean duration of CPR provided was (22.0 ± 12.35 & 21.5 ± 13.56 min.) in males and females respectively and defibrillation procedure took place in 79.3% of cases. The most common complications detected were the thoracic cage complications where the costal injuries were the most frequent complications in 48.4% of cases, mid-clavicular rib fracture was the most frequent one and 66.7% of sternal fractures were detected at the level of the third rib. Males were more susceptible to rib and sternal fractures than females. The factors of age, gender and CPR duration were found to have an effect on the increased risk of life-threatening injuries. The risk of injury increases especially when the compression depth exceeded 6 cm. and CPR duration exceeds 30 min. The present study concluded that CPR complications may decrease the patient's chance of survival and can cause death by itself. The present study recommend detailed post-mortem studies on CPR related life-threatening injuries on a trial of their prevention.

Keywords | Cardiopulmonary resuscitation, non-traumatic cases and life-threatening complications.

Introduction

Sudden death from cardiac arrest is a major medical issue and one of the biggest people's fears. The chain of Basic Life Support is the only way to improve the survival which includes early access and on time implementation of cardiopulmonary resuscitation (CPR) (Deliligka et al., 2016).

CPR is an emergency procedure involving external chest compression and artificial ventilation that aims to restore oxygenated blood flow to the brain and heart in individuals with cardiac arrest (Olds et al., 2015) while it can also cause many life-threatening injuries to patients (Hashimoto et al., 2007).

CPR contains a significant violation risk with forensic relevance, for the patient and the physician (Buschmann and Tsokos, 2009) and CPR-related injuries are confronted by the existing legal system as a medical

error, as in the performance of any medical procedure with adverse outcome (Deliligka et al., 2016).

CPR complications can cause death by itself, or it can be misinterpreted to be a blunt trauma as a cause of death, and also it can be evaluated as medical malpractice (Özer et al., 2010). Since forensic pathologists often encounter various types of CPR-related injuries during autopsies, they must be able to distinguish between them and those caused by other factors (Hashimoto et al., 2007).

Although there have been many studies focused on the incidence of or factors related to complications of CPR (Rilana Baumeister et al., 2015) a little attention has been paid to this potential problem (Hokea and Chamberlaina, 2004) and CPR related life-threatening injuries created a need for detailed post-mortem studies for their prevention (Kaldirim et al., 2016).

Awareness of those complications is vital in autopsy investigations as in fatal traumatic cases they may be interpreted as additional trauma signs and in fatal non-traumatic cases autopsy may be misinterpreted by those complications findings and suggesting traumatic cause of death. Thus, information about possible CPR complications are crucial for forensic medical specialists to distinguish them from actual trauma symptoms and important for physicians who perform resuscitation to be aware of those complications in terms of comprehension and a reduction in medical errors (Beydilli et al., 2015).

The aim of the present study was to analyze the findings of autopsy reports of individuals who received CPR to determine the frequency of CPR related life-threatening injuries and to determine the possible factors that affect and increase the risk of those injuries.

Subjects and methods

Subjects

Autopsy reports from complicated cases received CPR between 2014 and 2017 in the mortuary in Council of Forensic Medicine in Riyadh of Saudi Arabia were analyzed retrospectively after an ethical approval obtained from the scientific committee. The study included 58 non-traumatic death cases that had undergone CPR measures according to American Heart Association guideline and subjected for evaluation from hospital files and emergency team. Autopsies were performed when the cause of death was uncertain. The socio-demographic characteristics, the definitive cause of cardiac arrest, suggested cause of death and data about CPR provided (basic life support/advanced life support, duration of CPR, defibrillation and specification of persons performing chest compressions) were extracted from the medical records. The inclusion criteria involved the fatal cases after cardiac arrest suspected to CPR without any history or evidence of trauma prior to CPR. Cases below 18 years or with thoracic and abdominal trauma during attempted resuscitation were excluded from the study.

Methods

Life-threatening injuries were evaluated using the guideline based on the Abbreviated Injury Scale (AIS). The cases were investigated through post-mortem chest X-ray imaging and/or chest/upper abdomen computed tomography (CT) and the complications were determined based on X-ray/CT interpretation reports which were conducted by hospital's radiologist. The presence of a probable relationship between the injuries and factors such as age, gender, CPR duration and depth of chest compression was examined. Data from each autopsy was recorded according to a standardized study protocol for external and internal injuries.

Statistical analysis

The SPSS software was used. Mean and percentages for variables were calculated and χ^2 test used for comparisons of categorical variables and t-test for means of data with normal distribution while P values < 0.05 were considered to indicate statistical significance. Odds ratio and 95% Confidence interval were calculated for

evaluation by logistic regression analysis of factors affecting the CPR related life-threatening injuries.

Results

Among the autopsy cases who underwent CPR and whose autopsy detected resuscitation complications, all CPR procedure were took place inside the hospital by trained physicians and there were 58 cases, 38 of them (65.5%) were males and 20 (34.5%) were females, their mean age was 48.2 ± 15.4 (mean \pm SD) and mean body mass index (BMI) was 26.7 ± 5.14 . **Table (1)** shows that among the autopsy cases, the most frequent cause of death was found to be related to cardiovascular disease (55.2% of cases) followed by pathological brain hemorrhage in 19% of cases.

Table (2) shows the specifications regarding CPR provided to the study group, in which basic life support alone was performed in 17 (29.3%) cases and advanced life support was provided in the vast majority of cases (70.7%). The mean duration of CPR provided to individuals was 22.0 ± 12.35 min. in males while it was 21.5 ± 13.56 min. in females and defibrillation takes place in 46 (79.3%) of cases. A positive association was detected between mean chest compression depth and the CPR-related injuries, as when the compression depth increases the risk of injury increases especially when the chest compression depth exceeded 6 cm. The differences between males and females were not statistically significant regarding CPR type, depth of chest compression and duration of CPR or receiving defibrillation procedure.

Table (3) shows that the most common complications detected were the thoracic cage complications which showed highly significant difference between males and females followed by lung complications while the least common complications were the upper airway complications.

Table (4) shows that males were more susceptible to complications related to chest compression. Costal injuries were the most frequent complication and the most common injury was a single rib fracture in the anterior part of the thoracic cage. Lung contusion, pneumothorax, haemothorax, ventricular rupture and liver laceration showed statistically non-significant difference between males and females while thoracic cage fractures showed highly significant difference between males and females. **Figure (1)** shows pneumothorax after external CPR.

Table (5) shows that among the costal fractures after CPR, the mid-clavicular rib fractures were the most frequent fractures with a highly significant difference between males and females followed by the parasternal rib fractures, while (80.6%) of the rib fractures were at the left side of the thorax as illustrated in **Figure (2)** which showed fracture of the third rib after external CPR.

Table (6) shows that males were more susceptible to sternal fracture and 66.7% of sternal fractures were detected at the level of the third rib as illustrated in **Figure (3)** with a highly significant difference between males and females.

Table (7) shows that the factors of age, gender and CPR duration were found to have an effect on the increased risk of life-threatening injuries and they are

positively correlated with the occurrence of them especially the CPR period as when application time increases the risk of injury increases.

Table (1): Distribution of cause of death in the present study population.

Cause of death	No.	%
Cardiovascular disease	32	55.2
Pathological brain hemorrhage	11	19
Cancer	7	12
Others	8	13.8

Table (2): CPR specifications in the present study population.

Parameter	Male	Female	percentage	P
Type of provided CPR:				
Basic life support (BLS)	10	7	29.3	0.105
Advanced life support (ALS)	28	13	70.7	0.699
CPR duration (minutes) (mean ± SD)	22.0 ± 12.35	21.5 ± 13.56	-	0.799
Mean chest compression depth:	-	-	-	-
< 5 cm.	9	7	27.6	0.25
5-6 cm.	29	13	72.4	0.34
> 6 cm.				
Defibrillation				
Yes	31	15	79.3	0.106
No	7	5	20.7	0.106

Table (3): CPR complications related to chest compression.

Complication	No. (58)	Gender		P
		Male (38)	Female (20)	
Upper airway	2	2	-	-
Thoracic cage	43	28	15	0.005 *
Lung	7	4	3	0.963
Heart	3	2	1	0.876
Abdomen	3	2	1	0.876

*Statistically significant

Table (4): Distribution of injuries due to cardiopulmonary resuscitation.

Injuries	Gender		Percentage	P
	Male	Female		
Esophageal bleeding	2	-	3.4	-
Costal fracture	16	12	48.4	0.005*
Sternal fracture	4	1	8.6	0.005*
Both costal and sternal fracture	3	1	6.8	0.05*
Pneumothorax	3	-	5.2	-
Haemothorax	2	1	5.2	0.977
Lung contusion	4	3	12	0.766
Ventricular rupture	2	1	5.2	0.977
Liver laceration	2	1	5.2	0.977

*Statistically significant

Table (5): Distribution of costal fractures according to their location in the studied population.

Fracture location	Location		Gender		Percentage	P
	Rt	Lf	Male	Female		
Parasternal	2	8	6	4	31.2%	0.05*
Midclavicular	4	14	11	7	56.3%	0.05*
Axillar	1	3	2	2	12.5%	-

*Statistically significant

Table (6): Distribution of sternal fractures according to its location in studied population.

Fracture location	Gender		Percentage	P
	Male	Female		
Level of 2nd rib	-	-	-	-
Level of 2nd–3rd intercostal space	-	-	-	-
Level of 3rd rib	5	1	66.7	0.01
Level of 3rd–4th intercostal space	-	-	-	-
Level of 4th rib	2	1	33.3	0.987

Table (7): The evaluation by logistic regression analysis of factors affecting life-threatening injuries.

Variable	Odds ratio	95% Confidence interval
Age	1.077	1.01-1.21
Gender	Female 1	-
	Male 2.664	1.13- 6.23
CPR Duration	≤ 30 min. 1	-
	31-60 min. 0.95	0.34-3.23

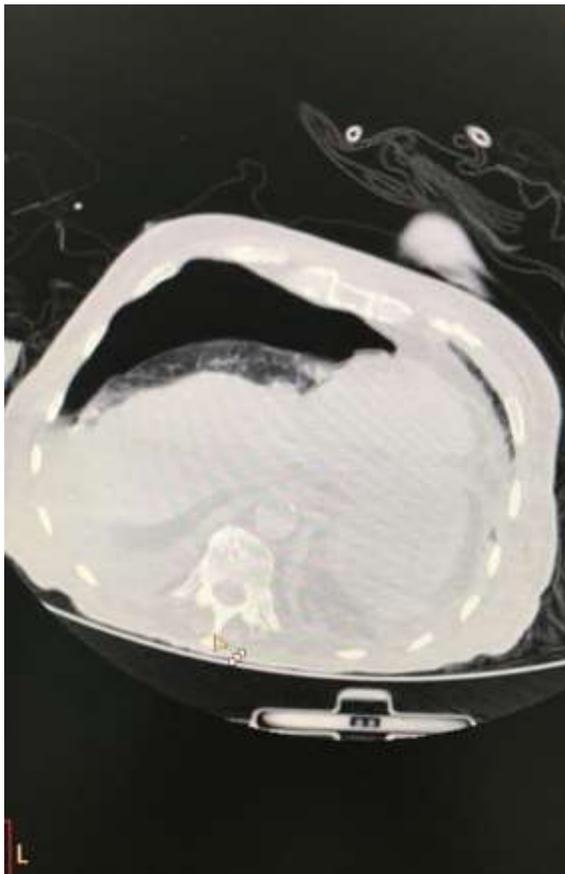


Figure 1: Chest CT scan (case of pneumothorax after external CPR).

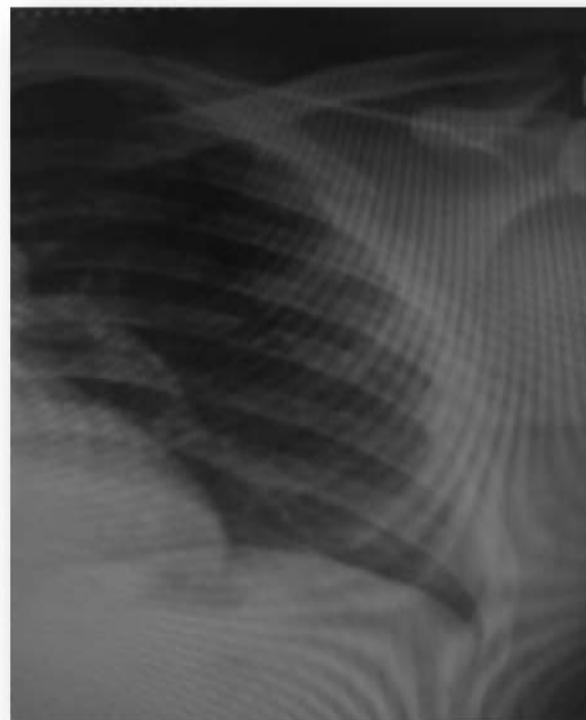


Figure 2: Chest X-ray (case of third rib fracture after external CPR)

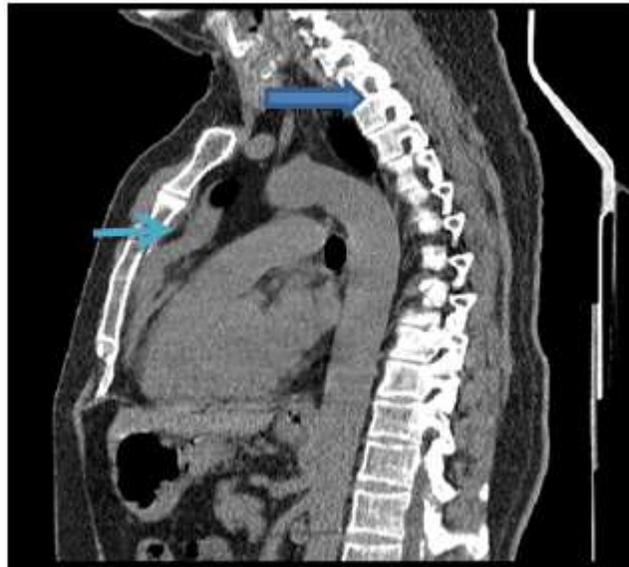


Figure 3: Chest CT scan (case of sternal fracture after external CPR)

Discussion

There were many changes in CPR international guidelines within the last decades, but effective chest compression remains the cornerstone of successful CPR (Travers et al., 2010).

If closed-chest compressions are not performed properly during basic life support measures, they can be traumatic where published values for the incidences of resuscitative injuries range from 21% to more than 65% (Sommers 1991).

In general, autopsy is the most sensitive method for detecting complications of resuscitation (Kim et al., 2013).

The present results revealed that the most common complications detected after CPR procedure were the thoracic complications in 86.2% of cases, among the thoracic complications the costal injuries were the most frequent complications (48.4%) and sternal fracture (8.6%). The present results are in accordance with the results revealed that prevalence of rib and/or sternum fractures after resuscitation varies between 16% and 75% (Machii et al., 2000).

In patients with unsuccessful CPR after cardiac arrest, rib fractures were more frequent after mechanical CPR (Smekal et al., 2014).

CPR-associated injuries were found in 93.7% of cases and the majority of injuries were skeletal chest fractures (rib fractures in 73.7%, sternal fractures in 66.3%)

(Rudinskáa 2016). The present study concluded that among the costal fractures the midclavicular rib fractures were the most frequent fractures (with highly significant difference between males and females) in 58% of fracture cases followed by the parasternal fractures in 32.2% and 80.6% of the rib fractures were at the left side of the thorax which are in accordance with Özer et al. (2010) results, they revealed that sixty-nine percent of the rib fractures were at the left side of the

thorax, seventy-one percent of the fractures were found at the midclavicular line, 14% at the parasternal and 12% were found at the axillary line.

Ryan et al. (2003) results concluded that rib fractures due to resuscitation are mostly located between 3rd and 8th ribs and are more common at the left side and at the region between the parasternal and axillary line. The present results were in difference with the previous results which concluded that rib fractures were found in 29% and sternal fracture in 14% (Black et al., 2004).

The present results concluded that 66.7% of sternal fractures were detected at the levels of the third rib which in accordance with Lederer et al. (2004) results which concluded that sternal fractures predominantly occurred in its lower third. Sternal fractures were found in 29 (4.8%) of CPR-receiving cases (Özer et al., 2010). The present results revealed that males were more susceptible to rib and sternal fractures and these results are in contrast with Kim et al. (2011) results which concluded that females were more susceptible to rib and sternal fractures. More females sustained rib fractures than males (37% versus 26%). There was no significant gender difference for sternal fracture (females 17%, males 12%) (Black et al., 2004).

The present results proved a positive relationship between age and gender and injuries caused by chest compressions, rib fractures in particular may be more frequent in elderly patients receiving CPR.

Black et al. (2004) reported that the incidence of rib fractures increased with age. These results are in accordance with Hellevuo et al. (2013) results which reported a relationship between the depth of CPR and the injuries in male patients, but not female patients.

Boz et al. (2008) reported that the relationship between gender and injuries was not statistically significant. Kim et al. (2013) found that female gender is a risk factor for rib fractures. The present results are in

contrast with Kaldırım et al. (2016) results which noted that there was no relationship between age and gender with chest injury. In the present study, the CPR period was found to be positively correlated with the occurrence of injuries.

The results are in accordance with Guzel et al. (2013) results which reported that the duration of chest compression application is known to be a significant factor in terms of life threatening injuries.

Kaldırım et al. (2016) reported that the risk of injury was found to be highest in the group where CPR had been applied for 60 min or more. The current study concluded that when the compression depth increases the risk of injury increases especially when the compression depth exceeded 6 cm. This in accordance with a study concluded that CPR-related injuries were associated with deeper mean compression depths of < 5, 5–6 and > 6 cm., the percentages of injuries were 28%, 27% and 49% respectively (Hellevuo et al., 2013).

Conclusion and recommendations

According to the present study outcomes, serious complications of CPR in patients after unsuccessful CPR may contribute to death or may be potentially lethal. Thoracic cage fractures especially rib fractures were more likely to present a common complication of CPR, and are mostly not avoidable. The number of fatal injuries due to chest compressions during cardiopulmonary resuscitation increased as the compression depth exceeded 6 cm. and there is a positive correlation with the long duration of CPR. The risk of mortality may be related to age, gender and duration of CPR. In the future, prospective multicenter studies with a larger number of individuals are needed in order to focus on CPR- related complications.

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الملخص العربي

الجوانب الطبية الشرعية للمضاعفات المحتملة المهددة للحياة الناجمة عن الإنعاش القلبي الرئوي المغلق في

المرضى الغير مصابين

سحر محمد مصطفى

يعد الإنعاش القلبي الرئوي إجراءً لإنقاذ الحياة والذي يمكنه أن يسبب أيضاً العديد من الإصابات التي تهدد حياة المرضى. بما أن المضاعفات التي يمكن أن تنجم عنه يعدها النظام القانوني القائم كخطأ طبياً، وحيث أن ممارسي الطب الشرعي غالباً ما يواجهون أنواعاً مختلفة من الإصابات قد تكون ذات صلة بالإنعاش القلبي الرئوي أثناء القيام بتقرير الصفة التشريحية للجثث، لذا يجب أن يكونوا قادرين على التمييز بين الإصابات الناجمة عن الإنعاش القلبي الرئوي وتلك التي تنتج عن عوامل أخرى. وكان الهدف من هذه الدراسة هو تحليل نتائج تقارير الصفة التشريحية للمرضى الذين تلقوا الإنعاش القلبي الرئوي لتحديد معدل إنتشار هذه الإصابات و التي قد تهدد الحياة وكذلك تحديد العوامل المحتملة التي قد تؤثر على زيادة معدلات هذه الإصابات. وشملت الدراسة ٥٨ حالة وفاة غير متعرضه للإصابات و التي خضعت للإنعاش القلبي الرئوي وقد تم تحديد الإصابات الناتجة عنها على أساس نتائج تقارير كلاً من الأشعة السينية و المقطعية. وقد خلصت النتائج إلى أن تقنية دعم الحياة المتقدمة قد قدمت إلى الغالبية العظمى من الحالات بنسبة (٧٠,٧٪) و كان متوسط مدة الإنعاش القلبي الرئوي (٢٢,٠ ± ١٢,٣٥ و ٢١,٥ ± ١٣,٥٦ دقيقة) في الذكور والإناث على التوالي، و قد تمت محاولة السيطرة على الرجفان القلبي في ٧٩,٣٪ من الحالات. وكانت المضاعفات الأكثر شيوعاً التي تم رصدها هي مضاعفات القفص الصدري، و كانت إصابات الضلوع هي أكثر المضاعفات شيوعاً في ٤٨,٤٪ من حالات المضاعفات الصدرية، بينما كانت كسور الضلوع من ناحية وسط الترقوة هي الأكثر شيوعاً، وقد تم رصد ٦٦,٧٪ من الكسور في عظمة القص عند مستوى الضلع الثالث وقد كان الذكور أكثر عرضة لكسور الضلوع وعظمة القص أكثر من النساء. ووجد أن عوامل العمر والجنس ومدة الإنعاش القلبي الرئوي لها تأثير على زيادة خطر الإصابة الناجمة عن الإنعاش القلبي الرئوي والتي قد تهدد الحياة. وقد لوحظ إزداد خطر هذه الإصابة خاصة عندما يتجاوز عمق الضغط على الصدر ٦ سم. و كذلك عندما تتجاوز مدة الإنعاش القلبي الرئوي ٣٠ دقيقة. وقد خلصت هذه الدراسة إلى أن مضاعفات الإنعاش القلبي الرئوي قد تقلل من فرص المريض في الحياة، ويمكن كذلك أن تسبب الوفاة. و توصي الدراسة بالقيام بدراسات مفصلة للصفة التشريحية تخص الإصابات الناجمة عن الإنعاش القلبي الرئوي المهددة للحياة في محاولة لمنعها.