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Original Research

Heart injuries related to cardiopulmonary resuscitation: a risk often overlooked

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Abstract

Background: Current studies focus primarily on skeletal injuries following cardiopulmonary resuscitation (CPR). Few studies report on intrathoracic injuries (ITI) and none, to our knowledge, focus exclusively on cardiovascular injuries related to cardiac massage. This study was based on autopsy findings and assessed the incidence of non-skeletal CPR related injuries related to chest compression. **Methods**: This was a retrospective forensic autopsy cohort study conducted in a single institution after resuscitation. Pathologists recorded autopsy data using standardized protocol contained information from external and internal examination of the body. **Results**: Thirty-eight autopsy reports (21 males and 17 females), post- CPR-failure were studied. Heart lesions were reported in 19 patients (group A). The average age was 65.7 years (69.05 group A and 66.5 group B). Median weight was 75.2 Kg and was significantly higher in group B ($p = 0.01$). Pericardial lesions were identified in 6 patients in group A and 2 in group B ($p = 0.2$ ns). No significant difference was observed among the two groups (Table 4) with the exception of the average number of rib fractures which was higher in group A ($p = 0.04$). Autopsy findings revealed heart injuries in 50% of patients with a high prevalence (52.6%) of left ventricle injuries. **Conclusion**: Cardiac lesions represent frequent and serious complications of unsuccessful CPR. Correct performance of chest compressions according to guidelines is the best way to avoid these complications.

Keywords: Resuscitation; Cardiovascular injuries; Autopsy study; Intrathoracic injuries

1. Introduction

The current standard for cardiopulmonary resuscitation (CPR) was first described in the early 1960s [1]. CPR is a series of maneuvers aimed to restore the flow of oxygenated blood to the brain and heart when the patient is in cardiac arrest [2,3]. Despite the many changes in international guidelines for CPR, chest compression remains the cornerstone of successful resuscitation. However, chest compression can lead to extensive traumatic injuries due to the force and violence necessary [4,5]. The spectrum of reported injuries ranges from 21% to 97% [3–6] with an array of clinical patterns which range from skeletal chest fractures to severe life-threatening injuries such as cardiac tamponade, cardiac rupture or liver laceration [7].

In the current literature there are many studies that focus primarily on skeletal lesions, few on intrathoracic injuries (ITI) and to our knowledge none that focus exclusively on cardiovascular damages related to cardiac massage [8–13].

The study based on post- mortem autopsy assessed the incidence of non-skeletal CPR related injuries with particular attention to cardiovascular injuries directly related to chest compression.

2. Material and methods

2.1 Patients

Patients were recruited retrospectively from 196 who underwent CPR between 2012 and 2021.

Thirty-eight non-trauma and non-surviving patients, 21 males and 17 females, who died in the shock-room during the CPR and undergo autopsy were enrolled in the study.

All patients were intubated, independently of the diagnosis, and treated in the shock-room at Lehrkrankenhaus Feldkirch General, Visceral and Thoracic Department by an experienced emergency team (one consultant in anesthesiology, one fellow in anesthesiology, one consultant in general surgery, two specialized nurses). The shock-room is equipped with a high-resolution CT scan. CPR was always performed by medical personnel in keeping with international guidelines.

Demographic and clinical data were obtained based on the CPT codes. All data was then reviewed to identify survived or deceased patients who underwent CPR. Autopsies of non-survivor patients were performed in the department of forensic medicine. All patients were over 18 years old. Exclusion criteria included patients resuscitated during transport for longer than 20 minutes and/or incomplete or unavailable medical data. The recruited patients were assigned to 2 groups: patients with autopsy cardiac le-

sions (group A) and patients without autopsy cardiac lesions (group B). Cardiac lesions were classified as followed: life-compatible injuries (contusion of the myocardium); non-life compatible injuries: laceration or rupture of the myocardium (transmural lesion of the endocardium and myocardium).

2.2 Data collection

Demographic data (age, gender, cause of death) and clinical parameters about CPR provided (basic/advanced life support, duration of CPR, specification of persons performing chest compressions, defibrillation, drugs administration) were collected. Autopsies were performed according to the recommendation 3 on the harmonisation of Medico-Legal Autopsy Rules, adopted by the European Council in 1999. Autopsy related data was recorded using standardized study protocol which contained data from external examination (presence and localization of cutaneous lesions, subcutaneous emphysema etc.) and internal examination of the body.

2.3 Statistical analysis

For statistical analysis The Mann-Whitney U test and the Fisher exact tests were used. A p-value < 0.05 was considered significant. Statistical analysis was carried out using the IBM SPSS Statistic 19.0 software (Armonk, USA) package.

3. Results

Autopsy reports showed cardiac lesions in 19 patients (group A). Nineteen patients without cardiac injury were controls (group B). The average age was 65.7 years (69.05 in group A and 66.5 in group B), median weight was 75.2 Kg and was significantly higher in group B ($p = 0.01$). The two groups were similar in terms of general demographics, admission and autopsy diagnosis as summarized in Table 1.

A total of 84.2% of the patients (17 from group A and 15 of group B) had at least one comorbidity. The most common were hypertension and coronary artery disease. Ischemic disease, confirmed by autopsy and histopathology, was the most frequent cause of death (50% of cases), followed by pulmonary embolism (18.4%).

Table 2 shows CPR and first treatment data. Three patients in group A had cardiac lesions not compatible with life (2 with atrial lacerations and 1 with ventricle rupture). Pericardial lesions were present in 6 patients in group A and 2 in group B respectively ($p = 0.2$ ns). Hemotransfusion was similar in both groups as was CPR starting time, need of catecholamines, troponin T values and serum levels of potassium.

Autopsy findings showed skeletal lesions in 78.9% of patients (17 from group A and 13 from group B) ($p = 0.6$) (Table 3). The incidence of visceral injuries was 60.5% (89% in group A and 42% in group B; $p = 0.18$ ns). The injuries included rib fractures, sternal and vertebral lesions, liver and lung injuries, pericardial lesions, heart contusions and spleen lacerations. The average number of rib fractures was higher in group A ($p = 0.04$) but no other significant differences were seen between the two groups. The multivariate analysis showed that a higher median weight and male sex have a protective effect on visceral injuries.

Table 4 outlines the pattern of cardiac CPR related injuries with heart injuries in 50% of patients with a high prevalence (52.6%) of left ventricle injuries.

4. Discussion

This is an autopsy-based study focused on the incidence and severity of non-skeletal injuries following CPR. Patients recruited for this study were assigned to two groups: those with and without cardiac lesions (19 patients in each group). Most patients (84.2%) had at least one comorbidity including hypertension, coronary artery diseases, diabetes, arteriosclerosis, cirrhosis, lung disease or osteoporosis.

We report that lacerations of visceral organs are common in autopsies after CPR. The pericardium, heart and liver are the most frequently involved organs. Contusions of the lungs and heart are the most common non skeletal injuries. Left ventricular injuries were seen in 52.6% and cardiac contusion in 84.2% of autopsies following CPR. The presence of visceral injuries was not associated with age, height or diagnosis at admission. Female gender was not an independent prognostic factor for visceral injuries as reported in previous studies. Conversely, a higher median weight seemed to have a protective effect on the onset of visceral injuries (Table 1). A possible explanation of this difference could be the lack of the thickness of tissues resulting in decreased protection to visceral organs during CPR.

Hemotransfusion, CPR starting time, need of catecholamines, troponin T values and serum levels of potassium were not independent prognostic factors for CPR related-cardiac lesions. The total incidence of CPR associated thoracic injuries in this study population was (78.9%). Other authors showed similar results in term of the injurie rates after CPR [3,5,7,8,10].

The average number of rib fractures was significantly higher in patients with cardiac lesions at autopsy. The mechanisms of skeletal injuries are well known and described in the medical literature. The high rate of visceral lesions (60.5% of patients of which 89% had cardiac lesions) may be a result of our study population composed of only non survivors after CPR. Therefore, it seems logical to attribute this data to a more aggressive resuscitation technique and to a prolonged cardiac massage performed to save a patient's life.

Moreover, our study is based on autopsy not imaging findings that may be more accurate in lesion detection.

The highest percentages of heart injuries (50% of patients with a high prevalence and 52.6% of left ventricle

Table 1. Clinical data and admission/autopsy diagnosis.

Clinical data	Patients with autoptic cardiac lesion (n: 19)	Patients without autoptic cardiac lesion (n: 19)	Total patients (n: 38)	Mann-Whitney U test
Male/Female	6/13	15/14	21/17	$p < 0.05$
Age median (range)	96.5 (23–91)	66.5 (52–90)	65.7 (23–91)	
Weight median (range)	69.15 (55–101)	81.2 (65–106)	75.2 (55–106)	$p < 0.05$
Height median (range)	166.8 (152–190)	173.9 (165–194)	170.4 (152–194)	
N. of patients with at least one of the disease	17 (89.4%)	15 (78.9%)	32 (84.2%)	
Hypertension	6 (31.5%)	11 (57.8%)	17 (44.7%)	
Coronary artery disease	8 (42.1%)	9 (47.3%)	17 (44.7%)	
Diabetes	3 (15.7%)	0	3 (7.8%)	
Arteriosclerosis	5 (26.3%)	6 (31.5%)	11 (28.9%)	
Nephropathy	3 (15.7%)	3 (15.7%)	6 (15.7%)	
Cirrosis	0	2 (10.5%)	2 (5.2%)	
Lungs disease	2 (10.5%)	1 (5.2%)	3 (7.8%)	
Osteoporosis	8 (42.1%)	1 (5.2%)	9 (23.6%)	
Diagnosis at the admission	Myocardial ischemia: 9 Pulmunary embolism: 5 Aortic aneurysm: 3 Stroke: 2	Myocardial ischemia: 10 Pulmunary embolism: 4 Aortic aneurysm: 3 Stroke: 2	Myocardial ischemia: 19 Pulmunary embolism: 9 Aortic aneurysm: 6 Stroke: 4	
Autopsy diagnosis	Myocardial ischemia: 8 Pulmunary embolism: 4 Aortic aneurysm: 3 Stroke: 2 Others: 2	Myocardial ischemia: 6 Pulmunary embolism: 3 Aortic aneurysm: 3 Stroke: 4 Others: 3	Myocardial ischemia: 14 Pulmunary embolism: 7 Aortic aneurysm: 6 Stroke: 6 Others: 5	

Table 2. Cardiopulmonary resuscitation data (CPR data).

CPR data	Patients with autoptic cardiac lesion (n: 19)	Patients without autoptic cardiac lesion (n: 19)	Total patients (n: 38)
N. Patients requiring emotrasfusion	9 (47.3%)	10 (52.6%)	19 (50%)
CPR started before the admission	8 (42.1%)	3 (15.7%)	11 (28.9%)
CPR started after the admission	11 (57.8%)	16 (84.2%)	28 (73.6%)
CPR min duration median (range)	29.05 (15–45)	28.6 (12–55)	28.8 (12–55)
N. Patients requiring catecholamines	8 (42.1%)	8 (42.1%)	16 (42.1%)
Trop T pm/mL median (range)	22.7 (0–81)	16.1 (0–35)	19.9 (0–81)
K mmol/L median (range)	4.4 (3–6.7)	4,4 (3–6.1)	4.4 (3–6.7)

CPR, cardio-pulmonary resuscitation.

damage) reported in our study compared to those previously [6,9,10,14] described could be similarly explained.

In our series pericardial and cardiac injuries were detected by autopsy (21.05% and 50% respectively) with high prevalence of left ventricle lesions (26.3%). Miller *et al.* [6], in a recent analysis of CPR-associated injuries, reported rates of pericardial injury of 8.9% and of cardiac damage rate up to 4.4% respectively.

The spectrum of cardiac injuries (Table 4) detected in our series are consistent with those previously described [15–26]. Both contusions of the epi-, myo-, or endocardium, lacerations or chamber ruptures involving the right atrium, right ventricle and left ventricle were detected by autopsy. It is important to highlight that there are cases in which cardiac damage is not associated with thoracic wall injuries and/or myocardium weakened by ischemia. Abdominal organs are shown, in previous studies, to be less affected by CPR related trauma. Percentage of liver and spleen lesions CPR related injuries varies through different series, from 0.6 % by Meron *et al.* [27] to 2.1% by Krischer *et al.* [28]. In our series a liver contusion was detected in one patient (Table 4).

Table 3. Internal organs injury and autopsy finding.

Internal injuries	Patients with autoptic cardiac lesion (n: 19)	Patients without autoptic cardiac lesion (n: 19)	Total patients (n: 38)	Mann-Whitney U test
N. Patient with at least one skeletal lesion	17 (89.4%)	13 (68.4%)	30 (78.9%)	-
Median number rib fractures	6.2 (2–10)	4.4 (1–10)	5.4 (1–10)	$p < 0.05$
Sternum lesion	11 (57.8%)	7 (36.8%)	18 (47.3%)	-
Vertebral lesion	2 (10.5%)	1 (5.2%)	3 (7.8%)	-
Pericardial lesion	Contusion: 2 Leceration: 4 Total: 6 (31.5%)	Contusion: 1 Leceration: 1 Total: 2 (10.5%)	Contusion: 3 Leceration: 5 Total: 8 (21%)	-
Liver	Contusion: 1 (5.2%)		Contusion: 1 (2.6%)	-
Lung	Contusion: 7 Leceration: 2 Total: 9 (47.3%)	Contusion: 5 Leceration: 0 Total: 5 (26.3%)	Contusion: 12 Leceration: 2 Total: 14 (36.8%)	-
Aorta	Laceration: 1 (5.2%)	0	0	-
Spleen	0	Laceration: 1 (5.2%)	Laceration: 1 (2.6%)	-
Hemothorax	Median mL: 1672 (800–3000) N. Patients: 9 (47.3%)	Median mL: 2285 (1000–4000) N. Patients: 7 (36.8%)	Median mL: 1940 (800–4000) N. Patients: 12 (31.5%)	-
Hemopericardium	Median mL: 200 (150–500) N. Patients: 3 (15.7%)	Median mL: 200 N. Patients: 1 (5.2%)	Median mL: 200 (150–500) N. Patients: 4 (10.5%)	-
Hemoperitoneum	Median mL: 0 N. Patients: 0	Median mL: 1000 N. Patients: 1 (5.2%)	Median mL: 1000 N. Patients: 1 (2.6%)	-

Table 4. Cardiac injuries.

Cardiac injuries	Total n. patients: 19
Contusion	16 (84.2%)
Laceration (not life compatible)	2 (10.5%)
Rupture (not life compatible)	1 (5.2%)
Right atrium	5 (26.3%)
Right ventricle	3 (15.7%)
Left atrium	3 (15.7%)
Left ventricle	10 (52.6%)
Bilateral	2 (10.5%)

5. Conclusions

CPR related non-skeletal and cardiac injuries may be underestimated and clinically misunderstood. In survivors after CPR this could lead to a rapid deterioration or impact on the patient's quality of life. Further comparative studies based on post- mortem autopsy are required to strengthen the body of evidence in order to assess the real incidence of non-skeletal CPR related injuries with particular attention to cardiovascular lesions directly related to chest compression. Cardiovascular injuries related to CPR represents a risk that may be often overlooked.

Author contributions

PG—data collection, data analysis, writing, review, last versions control. AR—data collection, data analysis, writing, review, last versions control. VO—writing, review, last versions control. VH—data collection, last versions control. IK—review, last versions control.

Ethics approval and consent to participate

Not applicable.

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Conflict of interest

The authors declare no conflict of interest.

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