Injuries after cardiopulmonary resuscitation in the pre-hospital and hospital care in two regions of the Czech Republic: retrospective observational cohort study

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Study protocol

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Abstract

Background

Chest compressions applied manually or with mechanical devices can encounter various types of injuries. The aim of this study is to analyse the correlation between the way the chest compressions were applied and the types of injury in deceased patients who underwent CPR for sudden cardiac arrest of non-traumatic aetiology. Study is reported as per STROBE guidelines.

Methods

This is a retrospective observational cohort study from two geographical regions of the Czech Republic. Adult patients (>18 years old) with sudden cardiac arrest of non-trauma aetiology resuscitated by the emergency medical services were included.

The cohorts were divided based on the way the chest compressions were provided – manual compressions, compressions provided by mechanical device, and compressions provided manually with the use of cardio pump. The variables used were injuries found during the autopsy.

Results

The research set of 113 cases of non-traumatic adult sudden cardiac arrests consisted of 75 men and 38 women. Average time of resuscitation was reported as 32.9 minutes. Manual chest compressions were performed in 46 (40.35%) cases, manual chest compressions using cardio pump in 27 (23.68%) cases, and mechanical chest compressions in 40 (35.08%) cases.

Conclusions

The use of cardio pump or mechanical chest compressions relates to more left side serial rib fractures and skin injuries, than manual chest compressions in the group of deceased adults who underwent resuscitation of non-trauma origin.

Background

Chest compressions applied manually or with mechanical devices can encounter various types of injuries [1]. These injuries can be a serious complication for the patient during and/or after the resuscitation and can be also life-threatening [2]. Most injuries occur in the chest area, with less frequent injuries to the abdomen, head, and upper half of the torso [3].

Higher frequency of injuries is reported in patients who did not survive (87%) compared to the group of patients who survived sudden cardiac arrest (13%) [1]. Negligible difference between the sex of the patient and whether the chest compressions were provided by lay people or by professionals were recorded [4]. Fatal injuries caused by the resuscitation (CPR) related to chest compressions (CC) are less
common but very serious. These injuries most often include heart injuries (cardiac tamponade, rupture of the right ventricle), lacerations of the lungs, injuries of the intra-abdominal organs (laceration of the liver lobe, injury to the pancreas, ruptures of the diaphragm) [2,5–8].

Lower frequency of research dealing with intrathoracic injuries and drawing attention to the occurrence of heart lesions, which are a significant complication related to chest compressions was reported by previous research [2].

Limited data was reported about the different ways of performed CC compared to the autopsy findings, especially when cardio pump is used. The aim of this study is to analyse the correlation between the way the chest compressions were applied and the types of injury in deceased patients who underwent CPR for sudden cardiac arrest of non-traumatic aetiology. Study is reported as per STROBE guidelines.

Methods

Study design and setting

This was a retrospective observational cohort study. The study took place in two geographical regions of the Czech Republic – South Moravian and Olomouc Regions, covering area with almost 2 million of inhabitants and dealing with approx. 1200 resuscitations per year, that is similar proportion to other Regions of the Czech Republic [9]. The study flowchart is visualised on figure 1.

The Ethical Committee of Emergency Medical Services of the Karlovy Vary Region reviewed the protocol and approved the study (Decision No. ZZSKVK/EK/052022). Given the epidemiological and retrospective nature of the study with deceased patients, and use of deidentified data, the need for informed consent was not relevant (also based on the Czech national legislation – Act. Nr. 372/2011 Coll.).

Participants

Adult patients (>18 years old) with sudden cardiac arrest of non-trauma aetiology resuscitated by the emergency medical services were included when deceased in the pre-hospital care and transported to Department of forensic medicine University Hospital St. Anna, or University Hospital Olomouc.

Variables

The cohorts were divided based on the way the chest compressions were provided – manual compressions, compressions provided by mechanical device (LUCAS®2, Wall Mount Physio-Control, US) device, and compressions provided manually with the use of cardio pump (ResQ PUMP, ZOLL Medical Corporation, USA).

The variables used were injuries found during the autopsy, as a dependent variable, and were categorized by its location and extent of the injury as follows: fracture of ribs on the right hemithorax (serial/isolated),
fracture of ribs on the left hemithorax (serial/isolated), fracture of sternum, skin injuries (hematomas and skin lacerations).

Data sources

Primary data were extracted from the electronic healthcare records (European Medical Distribution, Czech Republic, and STAPRO NIS MEDEA, Czech Republic) of the emergency medical services in both regions and then the electronic healthcare records in both University hospitals were screened to find the autopsy records (paper records) of resuscitated patients.

Sources were screened firstly in the University Hospital Olomouc from the year 2017, when the electronic healthcare records were started. Due to technical issues with database search second University Hospital was included into the study design to obtain sufficient data. The electronic database of University Hospital St. Anna is robust and made it possible to reach 100 cases sooner – that is the reason for 5 years period in one hospital compared to 5 months in another.

Statistical analyses

For statistical analyses the Chi square test for two-dimensional (CxR) contingency tables was used with differences considered as statistically significant at p < 0.05. SPSS Statistics (version 29, IBM, USA) was used for all the statistical analyses. The size of the research set is a limitation of the analyses in relation with the $\chi^2$ statistic method used.

Results

The research set of 113 cases of non-traumatic adult sudden cardiac arrests consisted of 75 men and 38 women. Average age of male was 69 (range from 35 to 96), female 72 (range from 27 to 95). Leading cause of death was sudden heart failure, acute myocardial infarction, pulmonary embolism, and hypoxia. In the skin injuries analysis only 86 patients were included due to the missing data describing injuries to the skin.

Average time of resuscitation was reported as 32.9 minutes. Manual chest compressions were performed at 46 (40.35%) cases (Brno 49.2%, Olomouc 26.6%). Manual chest compressions using cardio pump were used at 27 (23.68%) cases (Brno 23.68%, Olomouc 0%). The mechanical chest compressions were used at 40 (35.08%) cases (Brno 11.59%, Olomouc 71.11%). The length of chest compressions provided is summarised in table 1.

The occurrence of severe injuries (bilateral haemothorax, haemorrhage around liver and pancreas, lungs contusion, laceration of myocardium, rupture of stomach lining) was noticed in individual cases without statistical significance.

The results of injuries (dependent variables) compared to cohorts of CC methods are shown on table 1. As some kind of rib fracture was found in almost all cases the results of rib fractures are shown
comparing the severity of fractures – none or isolated versus serial fractures.

**Discussion**

The study found that the use of cardio pump or mechanical chest compressions relates to more left side serial rib fractures and skin injuries, than manual chest compressions in the group of deceased adults who underwent resuscitation of non-trauma origin.

Injuries on the left side might be associated with or are a risk factor to other injuries to the internal organs (e.g., heart and lung). Ribs, sternal fractures [10], and severe soft tissue injuries [11] were previously reported as the most common injuries that were caused by manual chest compressions. Cardio Pump is a device used for manual chest compressions working on a system of active compression and decompression. The positive effect of CP compared to manual CC is controversial and the use of the device is not mentioned in the European Resuscitation Guidelines 2021 [12]. Serious iatrogenic damage to the patient, that can also be potentiated by the patient’s age, have been reported [13,14]. The devices for mechanical chest compressions are used more often than CP and other studies also reported higher frequency of chest injuries after using the LUCAS®2 device in pre-hospital emergency care (e.g. 72.7%) [15]. Other works confirm this higher frequency of injuries after using the LUCAS®2 device. Among the most common injuries are rib fractures [10], life-threatening visceral injuries [16] and thus the recommendation for use during CPR is limited [11,12].

Injuries of visceral organs around the heart, lungs and neck are also described [17]. From the results of 93 cases out of 1,878 autopsies performed, contusions were the most common with a frequency of 57% of the identified pathologies, followed by lacerations in 17.2% of cases. The occurrence of haemothorax in 34.4% and hemopericardium in 8.6% was also noted [17]. Injuries to the intra-abdominal organs most often include lacerations of the liver lobe on the left side, which is closely related to the xiphoid process of the sternum. The frequency is described as 0.6–3% of cases [18]. Heart injuries, especially the occurrence of cardiac tamponade due to myocardial rupture, are not numerous in the databases [5,6].

Results of this study supports the findings of previous authors but adding a comparison of manual chest compressions with cardio pump. Despite it is not mentioned in the European Resuscitation Council Guidelines 2021, it is used as an alternative to manual compressions. These results showed on limited number of patients, that the injuries related to the use of cardio pump are like the use of mechanical chest compressions and thus the use might be limited as mentioned in the ERC Guidelines 2021 [12].

Before drawing any conclusions, the limitations of our study should be noticed. Most importantly, this was a retrospective study with all its limitations and that study subjects were only deceased patients. It is possible that in the survivors’ group different injuries might be spotted and this might introduce a selection bias. Another limitation is small sample size that did not show other relations, despite the statistics showed that some correlations might be present (based on z score).
Conclusions

The use of cardio pump or mechanical chest compressions relates to more left side serial rib fractures and skin injuries, than manual chest compressions in the group of deceased adults who underwent resuscitation of non-trauma origin.

Abbreviations

CPR – cardiopulmonary resuscitation
CC – chest compressions
CP – cardio pump
ERC – European Resuscitation Council

Declarations

Ethics approval and consent to participate

All patients included in this analysis were deceased and consent to participate is not relevant (based on the Act. Nr. 272/2011 Coll. of the Czech Republic).

Consent for publication

Not applicable.

Availability of data and materials

All data generated and analysed during this study are included in this published article.

The baseline data used and analysed during the current study are available from the corresponding author on a reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions
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References


Table

Table 1
<table>
<thead>
<tr>
<th></th>
<th>Manual</th>
<th>Manual with CP</th>
<th>Mechanical</th>
<th>In total</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of CPR (average; range)</td>
<td>29.5 (10; 50)</td>
<td>30.7 (20; 60)</td>
<td>37.8 (20; 90)</td>
<td>32.9 (10; 90)</td>
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<tr>
<td>Right hemithorax severe fractures</td>
<td>YES</td>
<td>35 (31%)</td>
<td>20 (17.7%)</td>
<td>35 (31%)</td>
<td>90 (79.6%)</td>
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<tr>
<td></td>
<td>NO</td>
<td>11 (9.7%)</td>
<td>7 (6.2%)</td>
<td>5 (4.4%)</td>
<td>23 (20.4%)</td>
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<tr>
<td>Left hemithorax severe fractures</td>
<td>YES</td>
<td>35 (31%)</td>
<td>26 (23%)</td>
<td>38 (33.6%)</td>
<td>99 (87.6%)</td>
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<td>11 (9.7%)</td>
<td>1 (0.9%)</td>
<td>2 (1.8%)</td>
<td>14 (12.4%)</td>
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<tr>
<td>Sternal fracture</td>
<td>YES</td>
<td>30 (26.5%)</td>
<td>20 (17.7%)</td>
<td>27 (23.9%)</td>
<td>77 (68.1%)</td>
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<tr>
<td></td>
<td>NO</td>
<td>16 (14.2%)</td>
<td>7 (6.2%)</td>
<td>13 (11.5%)</td>
<td>36 (31.9%)</td>
</tr>
<tr>
<td>In total</td>
<td>46 (40.7%)</td>
<td>27 (23.9%)</td>
<td>40 (35.4%)</td>
<td>113 (100%)</td>
<td></td>
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<tr>
<td>Skin injuries¹</td>
<td>YES</td>
<td>11 (12.8%)</td>
<td>15 (17.4%)</td>
<td>18 (20.9%)</td>
<td>44 (51.2%)</td>
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<td></td>
<td>NO</td>
<td>19 (22.1%)</td>
<td>4 (4.7%)</td>
<td>19 (22.1%)</td>
<td>42 (48.8%)</td>
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<tr>
<td>In total</td>
<td>30 (34.9%)</td>
<td>19 (22.1%)</td>
<td>37 (43.0%)</td>
<td>86 (100%)</td>
<td></td>
</tr>
</tbody>
</table>

Notes: CP – Cardio Pump; for length of CPR the data are presented as average time in minutes and range from minimum to maximum; Other data presented as absolute number and % out of total (113); ¹ Only 86 patients included due to missing data on skin injuries; * indicates statistically significant results on p<0.05

**Figures**
Figure 1

Legend not included with this version.