Resuscitation 88 (2015) 86–91

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Computed tomography findings of complications resulting from cardiopulmonary resuscitation☆

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ARTICLE INFO

Article history:
Received 8 August 2014
Received in revised form
11 December 2014
Accepted 15 December 2014

Keywords:
Postmortem computed tomography
Cardiopulmonary resuscitation
Chest compression
Cardiac arrest
Chest injuries
Rib fractures

ABSTRACT

Introduction: This retrospective study was conducted to evaluate injuries related to cardiopulmonary resuscitation (CPR) and their associated factors using postmortem computed tomography (PMCT) and whole body CT after successful resuscitation.

Methods: The inclusion criteria were adult, non-traumatic, out-of-hospital cardiac arrest patients who were transported to our emergency room between April 1, 2008 and March 31, 2013. Following CPR, PMCT was performed in patients who died without return of spontaneous circulation (ROSC). Similarly, CT scans were performed in patients who were successfully resuscitated within 72 h after ROSC. The injuries associated with CPR were analysed retrospectively on CT images.

Results: During the study period, 309 patients who suffered out-of hospital cardiac arrest were transported to our emergency room and received CPR; 223 were enrolled in the study.

The CT images showed that 156 patients (70.0%) had rib fractures, and 18 patients (8.1%) had sternal fractures. Rib fractures were associated with older age (78.0 years vs. 66.0 years, $p < 0.01$), longer duration of CPR (41 min vs. 33 min, $p < 0.01$), and lower rate of ROSC (26.3% vs. 55.3%, $p < 0.01$). All sternal fractures occurred with rib fractures and were associated with a greater number of rib fractures, higher age, and a lower rate of ROSC than rib fractures only cases. Bilateral pneumothorax was observed in two patients with rib fractures.

Conclusions: PMCT is useful for evaluating complications related to chest compression. Further investigations with PMCT are needed to reduce complications and improve the quality of CPR.

1. Introduction

Chest compression has been the most important component of cardiopulmonary resuscitation (CPR) since the 1960s [1,2]. However, there are complications related to chest compression, such as rib and sternal fractures. While rare, fatal lacerations and haemorrhage of intra-abdominal or intra-thoracic organs can occur [3]. Although there have been many studies of the incidence of or factors related to complications of CPR, most of them are relatively old and based on autopsy or X-ray findings. In addition, the guidelines for CPR have been changing to involve quicker and deeper chest compression [4,5]. Except in some large urban areas, autopsies are rarely performed in Japan for patients unsuccessfully resuscitated by CPR on arrival at hospital. Postmortem computed tomography (PMCT) as a form of autopsy imaging has disseminated widely in Japanese tertiary care centres to investigate and identify the cause of death. To date, there have been no studies investigating the overall incidence of complications resulting from CPR regardless of resuscitation outcome using both PMCT and postresuscitation CT.

2. Methods

After receiving the approval of the Ethics Committee of Asahikawa Medical University, Hokkaido, Japan (Approval no: 1751), a retrospective study was conducted. The inclusion criteria were adult, non-traumatic, out-of hospital cardiac arrest patients who were transported to our emergency department between

☆ A Spanish translated version of the summary of this article appears as Appendix in the final online version at doi:10.1016/j.resuscitation.2014.12.022.

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http://dx.doi.org/10.1016/j.resuscitation.2014.12.022
0300-9572/

April 1, 2008 and March 31, 2013. Mechanical chest compression devices were not used in pre-hospital care and in the emergency department. The exclusion criteria were patients who had a traumatic cause of cardiac arrest and those who were under the age of 18 years. All staff of the emergency department had certification in American Heart Association (AHA) Basic Life Support (BLS) or as an Advanced Cardiovascular Life Support (ACLS) health care provider, and CPR was performed according to the 2005 or 2010 AHA guidelines [4]. Following CPR, PMCT was performed to investigate the injuries associated with CPR in patients who died without final return of spontaneous circulation (ROSC). Similarly, whole body CT scans were performed in patients who were successfully resuscitated within 72 h after ROSC. All CT images were acquired with a Toshiba Aquilion 64-channel CT machine (Toshiba Medical Systems, Otawara, Japan). Scan variables were as follows: rotation time 0.5 s; slice thickness 5.0 mm (chest and abdomen), 3.0 mm (neck), 4.0 mm (head); 120 kVp; 300 mAs; and 0.5-mm collimation. Only axial images were created based on our hospital's routine protocol for PMCT (unsuccessfully resuscitated cases) or post-resuscitation CT (successfully resuscitated cases). Sites and distributions of rib and sternal fractures were collected. Locations of rib fractures were classified into four types based on a recent PMCT study [6]: parasternal, anterolateral, posterolateral, and paravertebral area. The anterolateral area is composed of the midclavicular and ventral axillary lines, and the posterolateral area is composed of the midscapular and dorsal axillary lines. Because these lines are hard to distinguish on CT images, this classification approach was adopted. Locations of sternal fractures were documented as the nearest rib level. Background factors identified from medical records were compared between the rib fracture group and the non-rib fracture group, because rib fractures are considered the most common complications of chest compression during CPR [3]. In addition, the anteroposterior diameter of patients with no rib fractures was measured. Using CT images, the anteroposterior diameter was measured from the anterior surface of the skin to the posterior surface of the skin at the middle point of the lower half of the sternum (at the 4th rib level). To examine the effect of the updated guideline, the incidences of chest injuries and patient characteristics before and after October 2010, when CPR guidelines [4,5] were published, were compared. In our institute, all CT images were analysed by board-certified radiologists with clinical experience of more than six years to investigate and complete reports about the cause of cardiac arrest when taking CT. This time, all CT images were re-evaluated by one author experienced in emergency and critical care medicine and familiar with PMCT diagnosis. Variables that may have affected patients' outcomes, including age, sex, and the duration of CPR, were collected from medical records.

Data are presented as numbers with median (IQR). Comparisons were performed by Fisher's exact test and the Mann–Whitney *U*-test. Differences were regarded as significant at $p < 0.05$. All statistical analyses were performed using GraphPad Prism® version 6.0 for Windows (GraphPad Software, San Diego, CA, USA).

3. Results

During the study period, 309 patients with out-of-hospital cardiac arrest were transported to our emergency department and received CPR; 85 patients were excluded because they did not undergo CT (or underwent only head CT) ($n = 72$), were under the age of 18 years ($n = 6$), or had traumatic cardiac arrest ($n = 8$). Most of the patients who did not undergo PMCT were transported to our emergency department in 2008. At that time, PMCT was in the early period of introduction in our hospital. Therefore, not every emergency room doctor-in-charge would have been aware of the existence of PMCT, which could contribute to determining the cause of death. Finally, 223 patients were enrolled in the study.

Table 1
Complications associated with CPR in 223 patients.

Complication	No. of patients	(%)
Rib fractures	156	69.96
Multiple	148	66.37
Bilateral	117	52.47
One side	39	17.49
Right side	19	8.52
Left side	20	8.97
Sternal fractures	18	8.07
Pneumothorax	17	7.62
Bilateral	2	0.90
One side	15	6.73
Right side	10	4.48
Left side	5	2.24
Haemothorax	1	0.45
Haemopericardium	2	0.90

CPR, cardiopulmonary resuscitation.

Complications associated with CPR are shown in Table 1. The CT images showed that 156 patients (70.0%) had rib fractures, and 18 patients (8.1%) had sternal fractures. Most rib fractures were multiple ($n = 148/156$, 94.9%) and bilateral ($n = 117/156$, 75.0%). There was no difference in the number rib fractures per side in one patient: right 4 (2–5) (IQR), left 4 (3–5), ($p = 0.371$). Almost all rib fractures were distributed from the 2nd to the 7th rib (99.0%, 852/863) (Fig. 1) and affected the anterolateral region of the thoracic cage (95.0%, 883/931, including multiple fracture sites per rib) (Table 2). Sternal fractures were distributed from the 3rd to the 5th rib level, and all of them had same-level rib fractures. Overall, 17 patients (7.6%) had pneumothorax, 15 of which were unilateral (right 10/left 5), and 2 of which were bilateral (Fig. 2). There were two cases of suspected haemopericardium. All pneumothorax and haemopericardium cases had rib fractures. In addition, sternal fractures were observed in one case of suspected haemopericardium and five cases of pneumothorax.

Comparisons of the characteristics between the rib fracture group and the non-rib fracture group are shown in Table 3. The median (IQR) age of all patients was 75 (63.5, 84.0) years, and 129 patients were male. A total of 78 patients (35.0%) achieved ROSC. The median (IQR) total duration of CPR was 39 (27–49) min, 20 (14–25) min in the pre-hospital phase, and 18 (9–26) min in the emergency department. Rib fractures were associated with higher age [78.0 (67.0, 86.3) years vs. 66.0 (60.5, 78.5) years, $p < 0.01$], longer duration of CPR [41 (29, 51) min vs. 33 (23, 43) min, $p < 0.01$], and lower rate of ROSC (26.3% vs. 55.3%, $p < 0.01$). There was no significant difference in patients' sex ($p = 0.752$). All sternal fractures occurred in combination with rib fractures. The details of the rib fractures only group and the sternal fractures group were compared (Table 4). Sternal fractures were associated with older age

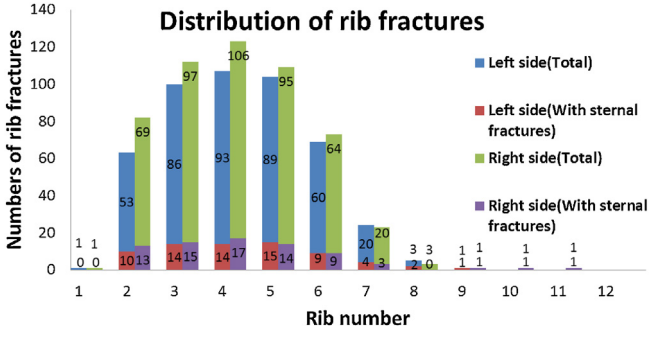

Fig. 1. Distribution of rib fractures.