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# Risk factors of occurrence of rib fracture or pneumothorax after chest compression for patients with cardiac arrest

**Tomohisa Nomura[1], Youichi Yanagawa[2], Hiroki Nagasawa[2], Ikuto Takeuchi[2], Kei Jitsuiki[2], Akihiko Kondo[2], Hiromichi Ohsaka[2], Kouhei Ishikawa[2], Kazuhiko Omori[2], Manabu Sugita[1]**
[1]Department of Emergency and Critical Care Medicine, Juntendo Nerima Hospital
[2]Department of Acute Critical Care Medicine, Juntendo Shizuoka Hospital

**Original Research Article**

***Corresponding author**
*Youchi Yanagawa*

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**Abstract:** We retrospectively investigated the risk factors of occurrence of rib fracture or pneumothorax after chest compression for patients with cardiopulmonary arrest (CPA) using computed tomography (CT). From March 2016 to February 2017, a medical chart review was retrospectively performed for all patients with out-of-hospital endogenous CPA. The subjects were divided into four groups: a rib fracture (RF) + group, which included patients who had rib fractures identified by CT; an RF – group; a pneumothorax (PX) + group, which included patients who had PX identified by CT; and a PX – group. During the investigation period, 100 patients were enrolled as subjects in the present study. Rib fracture was observed in 73 subjects. Pneumothorax was observed in 8 subjects. The rate of female gender, the average age and the rate of witness collapse were significantly higher in the RF + group than in the RF – group. The duration from the commencement of CPR by the EMTs to the CT examination in the RF + group was significantly longer than in the RF – group. The average age, rate of witness collapse and existence of rib fracture were significantly higher in the PX+ group than in the PX – group. The present study demonstrated that, among patients with out-of-hospital CPA, female gender, advanced age, witness collapse and a longer duration from the commencement of CPR by the EMT to the CT examination were risk factors for rib fractures.
**Keywords:** cardiopulmonary arrest; chest compression; rib fracture; pneumothorax.

## INTRODUCTION

Chest compressions for patients with cardiopulmonary arrest (CPA) are recommended at a rate of 100-120/min with adequate compression depth (5-6 cm) because blood flow is created primarily by increasing the intrathoracic pressure and directly compressing the heart, which in turn results in critical blood flow and oxygen delivery to the heart and brain [1,2].

The 2015 Guideline recommends pushing harder than the 2010 Guideline (at least 5 cm) [2]. In super-aging societies, fragility of the thoracic cage due to aging may increase the rate of complications, such as rib fractures, induced by hard chest compressions. However, few reports have addressed complications induced by chest compressions [3-6]. We previously reported on the difficulty of extubation after initial successful resuscitation of patients with CPA because of frail chest, resulting in the requirement of prolonged support with mechanical ventilation despite patients regaining consciousness [7].

Accordingly, we retrospectively investigated the risk factors of occurrence of rib fracture or pneumothorax after chest compression for patients with CPA using computed tomography (CT).

This retrospective study protocol was approved by the review board of Juntendo Shizuoka Hospital. The Department of Acute Critical Care Medicine is located in Shizuoka Hospital, a 552-bed hospital of Juntendo University in the Izu Peninsula in Shizuoka Prefecture (near Tokyo). Our hospital has helicopter landing pads, an emergency medical system utilizing physician-staffed emergency helicopters in Eastern Shizuoka Prefecture, and serves a population of approximately 1,000,000.

From March 2016 to February 2017, a medical chart review was retrospectively performed for all

patients with out-of-hospital endogenous CPA who were treated by our department staff. The exclusion criteria included patients who experienced CPA in the hospital, patients with exogenous CPA (trauma, hanging, suffocation or poisoning), and those who did not undergo a CT examination. In our study, a CT examination and biochemical analysis for blood were routinely performed if a patient was not in the terminal stage of cancer or informed consent count not be obtained to perform the necessary examinations.

The subjects were divided into four groups: a rib fracture (RF) + group, which included patients who had rib fractures identified by CT; an RF – group, which included patients who did not have rib fracture; a pneumothorax (PX) + group, which included patients who had PX identified by CT; and a PX – group, which included patients who did not have pneumothorax. The characteristics of the patients—age, sex, witness collapse, bystander cardiopulmonary resuscitation (CPR), initial rhythm at scene, value of base excess on arrival, method of transportation (air or ground ambulance), duration from commencement of CPR by emergency medical technicians (EMTs) to the CT examination, return of spontaneous circulation and the survival rate—were analyzed between the RF + and RF - groups and the PX + and PX – groups. CT was performed immediately after ceasing resuscitation or obtaining stable circulation at our department. Accordingly, the duration from the commencement of CPR by the EMTs to the CT examination represented the duration of CPR executed by professional medical workers.

Both the chi-squared test and the non-paired Student's *t*-test were used for the statistical analyses. P values of <0.05 were considered to be statistically significant.

## RESULTS

During the investigation period, a total of 163 patients with CPA were treated by the staff of our department. Among these patients, 9 were inpatients who suddenly collapsed. Another 44 patients had exogenous CPA induced by trauma, hanging or poisoning. Another 10 patients did not undergo CT. After excluding these 63 patients, 100 remained and were enrolled as subjects in the present study.

The results of the analyses between the RF + and RF – groups are summarized in Table 1. Rib fracture was observed in 73 subjects. The rates of bystander CPR, initial rhythm, method of transport, return of circulation, value of base excess and the survival ratio were not significantly different between the groups. The rate of female gender, the average age and the rate of witness collapse were significantly higher in the RF + group than in the RF – group. The duration from the commencement of CPR by the EMTs to the CT examination in the RF + group was significantly longer than in the RF – group. In the multivariate logistic regression analysis, female gender was the most significant predictor of RF – (odds ratio [OR], 0.10; 95% confidence interval, 0.01-0.04; p<.001). Other significant predictors included the average age (OR for 1 unit, 0.96; 95% CI, 0.93-0.99; p<0.05) and the duration from the commencement of CPR by the EMTs to the CT examination (OR for 1 unit, 0.96; 95% CI, 0.93-0.99; p<0.05).

The results of the analyses between the PX + and – groups are summarized in Table 2. Pneumothorax was observed in 8 subjects. The gender ratio, rate of bystander CPR, initial rhythm, measure of transport, the duration from the commencement of CPR by the EMTs to the CT examination, return of circulation, value of base excess and the survival ratio were not significantly different between the groups. The average age, rate of witness collapse and existence of rib fracture were significantly higher in the PX+ group than in the PX – group.

**Table−1: The results of the analyses between the rib fracture (RF) + and - groups**

| | RF + (n=73) | RF - (n=27) | p-value |
|---|---|---|---|
| Age (years) | 74.0 ± 1.6 | 63.8 ± 3.7 | <0.05 |
| Sex (male/female) | 43/30 | 2/25 | <0.01 |
| Witness collapse (yes/no) | 27/46 | 16/11 | <0.05 |
| Bystander chest compression (yes/no) | 31/42 | 14/13 | n.s. |
| Initial rhythm at scene | | | n.s. |
| Asystole | 46 | 17 | |
| Pulseless electrical activity | 18 | 5 | |
| Ventricular fibrillation | 9 | 5 | |
| Method of transport (air/ground ambulance) | 56/17 | 20/7 | n.s. |
| Duration of basic life support by EMT (min) | 53.1 + 1.5 | 44.5 + 3.8 | <0.05 |
| Return of circulation (yes/no) | 19/54 | 5/22 | n.p. |
| Base excess (mmol/L) | -20.2 ±1.1 | -18.9 ± 1.6 | n.s. |
| Survival rate (%) | 1/73 (1.3%) | 1/27 (3.7%) | n.s. |

EMTs: emergency medical technicians; n.s.: not significant, Mean ± standard error

**Table−2: The results of the analyses of between the pneumothorax (PX) + and – groups**

| | PX + (n=8) | PX - (n=92) | p-value |
|---|---|---|---|
| Age (years) | 74.0 ± 1.6 | 63.8 ± 3.7 | <0.05 |
| Sex (male/female) | 4/4 | 64/27 | n.s. |
| Witness collapse (yes/no) | 5/3 | 38/54 | <0.05 |
| Bystander chest compression (yes/no) | 5/3 | 40/52 | n.s. |
| Initial rhythm at scene | | | n.s. |
| Asystole | 4 | 59 | |
| Pulseless electrical activity | 3 | 20 | |
| Ventricular fibrillation | 1 | 13 | |
| Method of transport (air/ground ambulance) | 7/1 | 69/23 | n.s. |
| Duration of basic life support by EMTs (min) | 53.1 ± 5.4 | 50.6 ± 1.6 | n.s. |
| Return of circulation (yes/no) | 2/6 | 22/70 | n.p. |
| Base excess (mmol/L) | -13.5±3.6 | -20.2 ± 0.9 | n.s. |
| Rib fracture (yes/no) | 8/0 | 65/27 | <0.05 |
| Survival rate (%) | 0/8 (0%) | 2/92 (2.1%) | n.s. |

EMTs: emergency medical technicians; n.s.: not significant
Mean ± standard error

## DISCUSSION

This is the first report to demonstrate that, among patients with out-of-hospital CPA, female gender, advanced age, witness collapse and a longer duration from commencement of CPR by the EMT to the CT examination were risk factors for rib fractures. In addition, advanced age, witness collapse and complication of rib fractures were risk factors for pneumothorax.

Previous studies have reported that rib fracture, sternum fracture and internal organ injury can occur as complications induced by chest compression. Hoke et al. summarized the findings from previous studies on the incidence of rib and sternal fractures after conventional closed-chest compression in the treatment of CPA in adults and children [4]. Conventional CPR in adults was associated with an incidence of rib fractures ranging from 13% to 97% and of sternal fractures from 15 to 43%. CPR in children was associated with an incidence of rib fractures of 0%-2% and no sternal fractures. Accordingly, they concluded that manual CPR rarely causes skeletal chest injuries in young patients. Koga *et al*. investigated non-traumatic adult cases of out-of-hospital cardiac arrest to determine whether or not mechanical and manual CPR differed only in the occurrence of complications induced by CPR [3]. They found that posterior rib fracture, hemoperitoneum, and retroperitoneal hemorrhaging were significantly more frequent in the mechanical CPR group than in the manual CPR group. In addition, advanced age was also a risk factor for posterior rib fracture in their report [3]. Fragility fractures tend to occur more frequently in females or elderly individuals with osteoporosis [8-10]. Japan is a front-runner among the world's super-aging societies, and females tend to survive longer than males [11]. Accordingly, elderly female patients who receive chest compression for CPA might suffer rib fractures. This report supports the possibility of difficulty with extubation after initial successful resuscitation of elderly female patients with CPA because of frail chest, resulting in the requirement of prolonged support with mechanical ventilation despite patients regaining consciousness [7].

The longer duration from the commencement of CPR by the EMTs to the CT examination increased the risk of rib fracture. This is because the risk of rib fracture increases based on the number of chest compressions, as these are a traumatic insult. Of note, however: the existence of chest compressions executed by a bystander did not affect the risk of rib fracture. This might be because the duration of chest compressions by the bystander was shorter than that of compressions executed by professional health workers (data not shown). The quality of chest compressions may also be related to the risk. The quality of CPR executed by EMTs is presumed to be adequate, based on the training and experience [12]. In contrast, most bystanders executed chest compressions under instructions by telephone from the fire department; their lack of experience might have resulted in them pushing the chest softly so as not to injure the thoracic cage [13]. This difference in CPR quality between bystanders and professional health workers may have resulted in a greater occurrence of rib fractures induced by chest compressions from professional health workers. However, witness collapse was associated with an increased risk of rib fracture, possibly because the professional health workers pushed the chest more aggressively than usual because such patients still had a chance of surviving and achieving social rehabilitation.

Rib fracture can induce pneumothorax. We detected an approximately 10% occurrence of pneumothorax among patients receiving chest

compression, similar to the findings of Koga *et al*.[3]. Accordingly, if a patient underwent chest compression and obtained return of circulation, mechanical ventilation might have resulted in occurrence of tension pneumothorax. Critical care physicians should pay attention to such complications.

The present study is associated with several limitations, including its retrospective design and the small number of patients in the study population. Future prospective studies involving a larger number of patients are therefore needed to further examine this issue.

## CONCLUSION

The present study demonstrated that, among patients with out-of-hospital CPA, female gender, advanced age, witness collapse and a longer duration from the commencement of CPR by the EMT to the CT examination were risk factors for rib fractures. Whether or not such patients should receive careful chest compressions is a clinical question that should be addressed in the future.

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