Comparison of complications secondary to cardiopulmonary resuscitation between out-of-hospital cardiac arrest and in-hospital cardiac arrest

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<TABLE OF CONTENTS>

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

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Objective: The aim of this study was to assess whether there was a significant difference in the complications of cardiopulmonary resuscitation (CPR) between out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA) survivors using multidetector computed tomography (MDCT).

Subjects and methods: We performed a retrospective analysis of prospective registry data. We enrolled both OHCA and IHCA patients who underwent successful CPR. We classified chest injuries secondary to chest compression into rib fractures, sternum fractures, and uncommon complications such as lung contusions and extrathoracic complications. We compared these complications according to CPR locations. We also analysed risk factors for CPR complications using multiple regression analysis and classification and regression tree analysis.

Results: During the study period, a total of 148 patients were included in the primary analysis. Rib fractures were detected more in OHCA survivors than in IHCA survivors (74 patients (83.2%) vs. 37 patients (62.7%), p = 0.05), and frequency of multiple rib fractures was higher in OHCA survivors than IHCA survivors (69 patients (77.5%) vs. 34 patients (57.6%), p = 0.01).

Although other complications were not significantly different between the groups, there was a trend for OHCA survivors to sustain more serious and direct high-energy related complications. Older age, longer CPR, and OHCA were significantly associated with incidence of rib fractures, multiple rib fractures, and number of rib fractures.
Conclusions: Rib fractures were more likely to occur in OHCA survivors, and serious complications tended to occur more often in OHCA compared to IHCA survivors.

Key words : Cardiopulmonary resuscitation, Out-of-hospital cardiac arrest, In-hospital cardiac arrest, Complication

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I. INTRODUCTION

Chest compression during cardiopulmonary resuscitation (CPR) may cause unintended complications consisting mainly of chest injuries. The most common complications are rib fractures and sternum fractures.[1–4] The incidence of rib fractures is 12.9–96.6%, and most often involves the second and sixth ribs along the mid clavicular line.[3] The incidence of sternum fractures is 1.3–43.3%.[1,2,4] Other complications, which are relatively rare but clinically significant, include fractures of clavicles, scapulae, and the vertebral column, flail chest, subcutaneous emphysema, pulmonary oedema,pulmonary haematoma, pneumothorax, haemothorax, lung laceration, pneumomediastinum, cardiac contusion/rupture, pericarditis, liver laceration, and bowel injury.[4] The incidence of these complications varies widely depending on the diagnostic approach.[1,2] Up to now, CPR quality during ambulance transport has not been maintained for various reasons. As the speed of ambulances has increased, excessive depth and the average rate of chest compressions have increased.[5] In a previous study, a high chest compression rate with a wide variability was reported during ambulance transport.[6] Changes in acceleration resulting in jerk force occur frequently during transport, which may throw ambulance personnel off balance.[7] Off-balance personnel may directly affect CPR hands-off time as well as the rescuer’s posture during CPR. If the rescuer is off balance, he/she cannot maintain the correct hand position, and may unavoidably compress the incorrect position on the victim's chest. Therefore, the CPR conducted out-of-hospital, especially during ambulance transport, may lead to more complications than that conducted in-hospital. To our knowledge, there is no study comparing the differences in complications of CPR between out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA) survivors. In most prior studies pertaining to complications of CPR, chest injuries through autopsies or by means of chest radiographs were evaluated.[1,2] However, these methods have limitations in clinical practice. Autopsies cannot be used for survivors after CPR. Chest X-rays can show a large haemothorax or pneumothorax, but some injuries, such as a smaller haemothorax, occult pneumothorax, lung contusion, sternum fracture, or minor rib fracture, could be missed.[8,9] Therefore, in studies utilizing chest X-rays, complications may be underestimated. Multidetector computed tomography (MDCT) enables thinner sections with greater speed, and allows for higher quality axial images and multiplanarreconstructions.[9–11] Given the increasing utilization of MDCT in the trauma setting, MDCT has become a useful diagnostic tool with high diagnostic accuracy.[8–11] Recently, studies using MDCT for detecting chest injuries secondary to CPR have been published.[12–14] Hence, the aim of this study was to assess whether there was a significant difference in the complications of CPR between OHCA and IHCA survivors using MDCT. We hypothesised that complications are more likely to arise in OHCA survivors because of the difficulty of CPR during ambulance transport.

II. MATERIALS AND METHODS

1. Study design and participants

We performed a retrospective analysis of prospective registry data to compare complications of CPR between OHCA and IHCA survivors using chest MDCT. We enrolled both OHCA and IHCA patients who underwent successful CPR in the emergency departments of two academic tertiary care centres from

January 2009 to May 2014. We excluded patients under the age of 18, those who did not undergo chest MDCT within 48 h after return of spontaneous circulation (ROSC), and those with cardiac arrest following a trauma. We also excluded patients who underwent CPR in another hospital before being transferred to our institutions. Each hospital's Institutional Review Board approved this study protocol.

2. Study protocol

One investigator collected data through a retrospective review of medical records. Variables that were recorded included: age, gender, cause of arrest, witnessed or unwitnessed arrest, location of the arrest, whether bystander CPR was provided, and initial rhythm and duration of CPR. In our two institutions, CT scans were performed using one of two scanners: a 64-slice MDCT scanner (Somatom Sensation64; Siemens Medical Solutions), or a 128-slice MDCT scanner (Somatom Definition AS+; Siemens Medical Solutions). A standard scanning protocol was used with 64×—0.6-mm or 128×—0.6-mmsection collimation. The exposure parameters for the CT scans were 100–120 kVp, 110–200 mA, 1-mm or 5-mm slice thickness and 1.25-mm or 5-mm reconstruction increment covering thorax. Image reconstruction for conventional CT scan was performed onthe scanner's workstation. All CT images were sent to the picture archiving and communication system (PACS) (Centricity 1.0; GE Medical Systems, Mt Prospect, IL).We classified chest injuries secondary to chest compression into rib fractures, sternum fractures, and uncommon complications such as lung contusions, lung haemorrhage, pneumothorax, haemothorax, retrosternal haematomas, and mediastinal haematomas. Other extrathoracic complications such aspneumoperitoneum, haemoperitoneum, scapular fractures, and vertebra fractures were also evaluated. These complications were determined based on CT interpretation reports which were con-ducted by each hospital's board-certified radiologist. Rib fractures were also divided according to the following 6 classifications: (1)

side: bilateral, one-side only, or none; (2) single or multiple; (3) number of fractured ribs; (4) level of fractured rib: 1st to 12th; (5) location of fractured rib: anterior (the parasternal line to the anterior axillary line), lateral (the anterior axillary line to the posterior axillary line) and posterior (the posterior axillary line to the paravertebral line)15; and (6) distance from midline to fracture site of rib, defined as the horizontal length from the midline of the sternum to the outermost fractured line of rib. Sternum fractures were sub-divided into the upper, middle, or lower third of the sternal body. The location of fractured ribs, the distance from midline to fracture site on the rib, and the level of sternum fractures were assessed by one emergency physician using the Picture Archiving and Communication System (PACS, Centricity, GE Healthcare, Milwaukee, WI,USA).

3. Data analysis

The statistical analysis was performed using SAS (version9.2, SAS Inc., Cary, NC, USA) and R package (version 3.0.3,http://www.R-project.org–package: party). The categorical variables were described as frequencies (%), and continuous variables were described as mean ± standard deviation. We used independent t-test for comparison of continuous variables and Fisher’s exact test for categorical variables. The generalized estimating equation was used to analyse differences in CPR complications such as level of fractured ribs and location of fractured ribs between OHCA and IHCA survivors because these variables allowed multiple checks. Variables with a $p < 0.05$ from the univariate analyses, and clinically significant variables such as age and gender, were selected as potential risk factors for CPR complications. These variables were assessed with multiple logistic regression or multiple linear regression. The classification and regression tree (CART) analysis was performed to determine interaction patterns for subjects with and without rib fractures, and to determine cut-off points for these parameters. The parameters that were identified as being significant by multivariate analysis were included in the

CART analyses. Statistical significance was defined as p < 0.05.

III. RESULTS

1. Study population

During the study period, a total of 2153 patients were enrolled. Most patients (n = 1214; 56.4%) were excluded because CPR was not successful. Among the 939 patients with ROSC, we excluded 56patients under the age of 18, 24 patients with cardiac arrest following a trauma, and 711 patients that did not undergo chest CT within 48 h. Finally, 148 patients were included in the primary analysis (Figure 1). All patients in our study were resuscitated manually in the hospital and EMS. Of the 148 patients, 89 were categorized as OHCA (60.1%) and 59 were categorized as IHCA (39.8%).Among the 89 OHCA patients, 1 case had only out-of-hospital CPR without in-hospital CPR, because ROSC was achieved during ambulance transport. Demographic characteristics and clinical findings are summarised in Table 1. There were no significant differences in age, gender, cause of arrest, and initial rhythm between OHCA and IHCA survivors. The mean CPR time of OHCA was longer than that of IHCA survivors (28.6 ± 12.4 min vs. 7.9 ± 5.6 min, p < 0.001). In OHCA survivors, out-of-hospital CPR time was 17.6 ± 9.1 min and in-hospital CPR time was 11.0 ± 7.3 min.

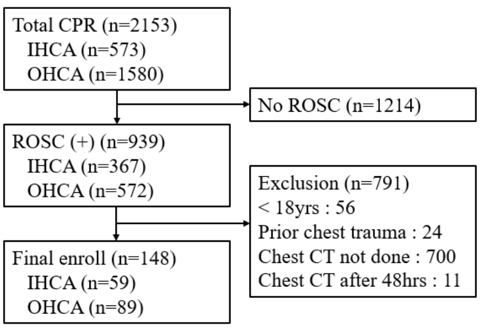


Figure 1. Flow diagram of patient eligibility

Table 1. Patient demographics and clinical findings

Variables	OHCA (N=89)	IHCA (N=59)	*p*-value
Age (yr), mean±SD	62.9±17.3	65.1±15.7	0.43
Gender, N (%)			0.71
Male	51 (57.3)	32 (54.2)	
Female	38 (42.7)	27 (45.8)	
Cause of arrest, N (%)			0.51
Cardiogenic	14 (15.7)	7 (11.9)	
Noncardiogenic	75 (84.3)	52 (88.1)	
Bystander CPR, N (%)	47 (52.8)		
Initial rhythm, N (%)			0.20
Shockable	10 (11.2)	3 (5.1)	
Nonshockable	79 (88.8)	56 (94.9)	
CPR time (min), mean±SD	28.6±12.4	7.9±5.6	<0.001

OHCA : out-of-hospital cardiac arrest
IHCA : in-hospital cardiac arrest
CPR : cardiopulmonary resuscitation

2. The difference in rib fractures between OHCA and IHCA survivors

Rib fractures were detected more often in OHCA survivors than in IHCA survivors (74 patients (83.2%) vs. 37 patients (62.7%), p = 0.005), and the incidence of multiple rib fractures was higher in OHCA survivors than in IHCA survivors (69 patients (77.5%) vs.34 patients (57.6%), p = 0.01). The mean number of fractured ribs was 5.2 ± 3.9 in OHCA survivors and 3.8 ± 4.0 in IHCA survivors (p = 0.05). Bilateral involvement of rib fractures was the most com-mon type of fracture in both groups, with no significant difference (p = 0.07). Rib fractures were most frequent in anterior ribs in both groups, with a higher rate of anterior fractures in OHCA survivors than in IHCA survivors (70 patients (78.7%) vs. 34 patients (57.6%),p = 0.006), followed by lateral ribs, and, rarely, posterior ribs. Distance from midline to fracture site on the rib was not significantly different (9.7 ± 1.9 cm vs. 9.5 ± 1.6 cm, p = 0.68) (Table 2). Fractures were distributed frequently between rib numbers 2nd through 8th in both groups, but occurred more frequently in OHCA survivors. First and 9th to 11th rib fractures were rare, but these fractures developed more frequently in OHCA survivors according to a generalised estimating equation analysis ($p = 0.04$). Twelfth rib fractures did not occur in either group. In OHCA survivors, 47patients (52.8%) underwent bystander CPR which did not affect the frequency of rib fractures, multiple rib fractures, or the number of fractured ribs ($p = 0.60$, $p = 0.43$ and $p = 0.10$, respectively).

3. The difference in other complications between OHCA and IHCA survivors

Sternum fractures occurred in 34 (38.2%) OHCA survivors and18 (30.5%) IHCA survivors ($p = 0.34$). The middle and lower third of the sternum body were the most frequent fracture sites in both groups. Lung contusions and pneumothorax accounted for most lung injuries. OHCA survivors tended to have a higher incidence of both lung contusions and pneumothorax, but the differences were statistically insignificant (34.8% vs. 25.4%, $p = 0.23$, 21.4% vs. 5.1%, $p = 0.08$, respectively) (Table 2). A total of 11 serious complications were reported (8 OHCA survivors, 3 IHCA survivors) (Table 2). Among them, 8 patients underwent emergency operation or embolization and 2 patients with a tension pneumothorax underwent chest tube insertion in the emergency department. Severe complications detected in OHCA survivors were as follows: 3 patients with pneumoperitoneum (one of them had lower oesophageal perforation detected in the operation room), 1 patient with a large haemoperitoneum and alveolar haemorrhage, 1 patient with severe subcutaneous emphysema, 2 patients with tension pneumothorax, and 1 patient with haemomediastinum from active bleeding of the bilateral internal mammary arteries. In IHCA survivors, there was one patient with a pneumoperitoneum and 2 patients with haemoperitoneum.

Table 2. Comparison of complications between OHCA group and IHCA group

Variables	OHCA (N=89)	IHCA (N=59)	*p*-value
Rib fracture, *N* (%)	74 (83.2)	37 (62.7)	0.01
Multiple rib fracture, *N* (%)	69 (77.5)	34 (57.6)	0.01
Number of rib fracture, *N*, mean±SD	5.2±3.9	3.8±4.0	0.05
Side of rib fracture, N (%)			0.07
Unilateral	16 (18.0)	9 (15.3)	
Bilateral	58 (65.2)	28 (47.5)	
None	15 (16.9)	22 (37.3)	
Location of rib, N (%)			
Anterior	70 (78.7)	34 (57.6)	0.01
Lateral	50 (56.2)	26 (44.1)	0.15
Posterior	6 (6.7)	3 (5.1)	>.9999
Distance from midline, cm, mean±SD	9.7±1.9	9.5±1.6	0.68
Sternum fracture, N (%)	34 (38.2)	18 (30.5)	0.34
Upper	10 (11.2)	5 (8.5)	0.59
Middle	20 (22.5)	10 (17.0)	0.41
Lower	22 (24.7)	8 (13.6)	0.1
Lung contusion, N (%)	31 (34.8)	15 (25.4)	0.23
Pneumothorax, N (%)	19 (21.4)	3 (5.1)	0.08
Hemothorax, N (%)	10 (11.2)	3 (5.1)	0.2
Retrosternal hematoma, N (%)	5 (5.6)	0 (0)	0.16
Mediastinal hematoma, N (%)	5 (5.6)	0 (0)	0.16
Vertebral fracture, N (%)	2 (2.3)	0 (0)	0.52
Pneumomediastinum, N (%)	4 (4.5)	2 (3.4)	>.9999
Scapular fracture, N (%)	2 (2.3)	0 (0)	0.52
Serious complications*, N (%)	8 (9.0)	3 (5.1)	0.53
Pneumoperitoneum, N (%)	4 (4.5)	1 (1.7)	
Hemoperitoneum, N (%)	0 (0)	2 (3.4)	
Massive subcutaneous emphysema, N (%)	1 (1.2)	0 (0)	
Tension pneumothorax, N (%)	2 (2.3)	0 (0)	
Hemomediastinum, N (%)	1 (1.2)	0 (0)	

4. Risk factors for CPR complications

We divided the groups according to whether the patients had a specific complication, such as rib fracture, or not, and performed univariate analysis to find the risk factors. Multiple logistic regression or multiple linear regression analyses were conducted using the variables in which $p < 0.05$ after the univariate analysis. Clinically important variables such as age and gender were also included in the multiple logistic regression or multiple linear regression analyses. CPR time and arrest location were highly interrelated with each other, so taking into consideration the multi collinearity between the two variables, we generated models one by one including one of the two variables. The results of the multivariate analyses are shown in Table 3. Older age, OHCA and longer CPR were significantly associated with incidence of rib fracture, multiple rib fractures, number of rib fractures, rib fracture combined with sternum fracture, and rib fracture combined with sternum fracture and serious complications. There were no differences in rib fractures, sternum fractures, and serious complications before and after the change in the 2010 CPR guidelines (Table 4).

Table 3. Multivariate logostic regression analysis of variables associated with CPR complications.

Dependent variables	Independent variables	Without duration		Without location	
		OR (95% CI) or β (SE)	*p*-value	OR (95% CI) or β (SE)	*p*-value
Rib fracture	Age	1.090 (1.057-1.125)	<0.001	1.099 (1.061-1.137)	<0.001
	Gender	1.474 (0.571-3.805)	0.42	1.256 (0.459-3.435)	0.66
	Location of arrest	5.912 (2.177-16.053)	<0.001		
	CPR time			1.123 (1.064-1.186)	<0.001
Multiple rib fracture	Age	1.084 (1.053-1.117)	<0.0001	1.083 (1.052-1.115)	<0.001
	Gender	1.224 (0.515-2.914)	0.65	1.13 (0.466-2.658)	0.81
	Location of arrest	4.418 (1.803-10.825)	0.01		
	CPR time			1.063 (1.024-1.104)	0.001
Number of rib fracture	Age	0.123 (0.017)	<0.0001	0.113 (0.017)	<0.001
	Gender	0.914 (0.569)	0.11	0.872 (0.559)	0.12
	Location of arrest	1.600 (0.577)	0.07		
	CPR time			0.070 (0.019)	<0.001
Rib and sternum fracture	Age	1.062 (1.032-1.093)	<0.0001	1.061 (1.031-1.091)	<0.0001
	Gender	2.245 (0.838-6.013)	0.11	2.103 (0.767-5.764)	0.15
	Location of arrest	4.233 (1.609-11.140)	0.004		
	CPR time			1.084 (1.034-1.135)	<0.001
Rib, sternum fracture and serious complications	Age	1.062 (1.032-1.093)	<0.0001	1.061 (1.031-1.091)	<0.0001
	Gender	2.245 (0.838-6.013)	0.11	2.103 (0.767-5.764)	0.15
	Location of arrest	4.233 (1.609-11.140)	0.004		
	CPR time			1.084 (1.034-1.135)	0.001

CPR : cardiopulmonary resuscitation

Table 4. CPR-related injuries before and after the change in the 2010 guidelines.

Variables associated with CPR complications	Before the change of guideline (*N*=36)	After the change of guideline (*N*=112)	*p*-value
Rib fracture	24 (66.67)	87 (77.68)	0.184
Sternum fracture	14 (38.89)	38 (33.93)	0.588
Serious complications	1 (278)	10 (8.93)	0.296
Rib and sternum fractures	26 (72.22)	94 (83.93)	0.119
Rib, sternum fractures, and serious complications	26 (72.22)	94 (83.93)	0.119

5. CART analysis for the prediction of rib fracture

The decision-tree analyses, denominated as the CART analysis, were carried out using the three predictors identified as being significant by multivariate analysis. In consideration of their multicollinearity, four CART analyses were performed separately for arrest location and CPR time. For rib fracture, each CART analysis consisted of three basic steps based on two variables (age and arrest location (Figure 3A), and age and CPR time (Figure 3B)) for a total of four nodes. With a combination of two variables, we classified the risk of rib fracture. If the patient was under 41 years of age, the probability of rib fracture was relatively low (21.05% patient rate, “Node 2”).On the other hand, if the patient’s age was over 41 years with a CPR time over 10 min, the highest risk of rib fracture was 93.1% patient rate (“Node 7”). For patients over 41 years with a CPR time under10 min, the risk of rib fracture was divided at the age of 66 years(<66 yrs, 27.78% patient rate (“Node 5”) vs >66 yrs, 87.5% patient rate (“Node 6”)). As an example, a 60-year-old man with OHCA, is applicable to “Node 7” in Figure 3A and Exhibits 92.21% patient rate for risk of rib fracture. A 60-year-old man who underwent CPR for 15 min, is applicable to “Node 7” in Figure 3B and Exhibits 93.1%patient rate for risk of rib fracture. In rib fractures combined with sternum fractures or rib and sternum fractures combined with serious complications, each CART analysis consisted of two basic steps based on two variables (age, and CPR time) with a total of three nodes. With combination of two variables, we can classify the risk of rib fractures combined with sternum fractures or rib, and sternum fractures combined with serious complications (Figure 3C and D). The results for

CART analysis in patient with rib, and sternum fractures combined with serious complications were identical to rib fractures combined with sternum fractures because two groups of injured patients were the same.

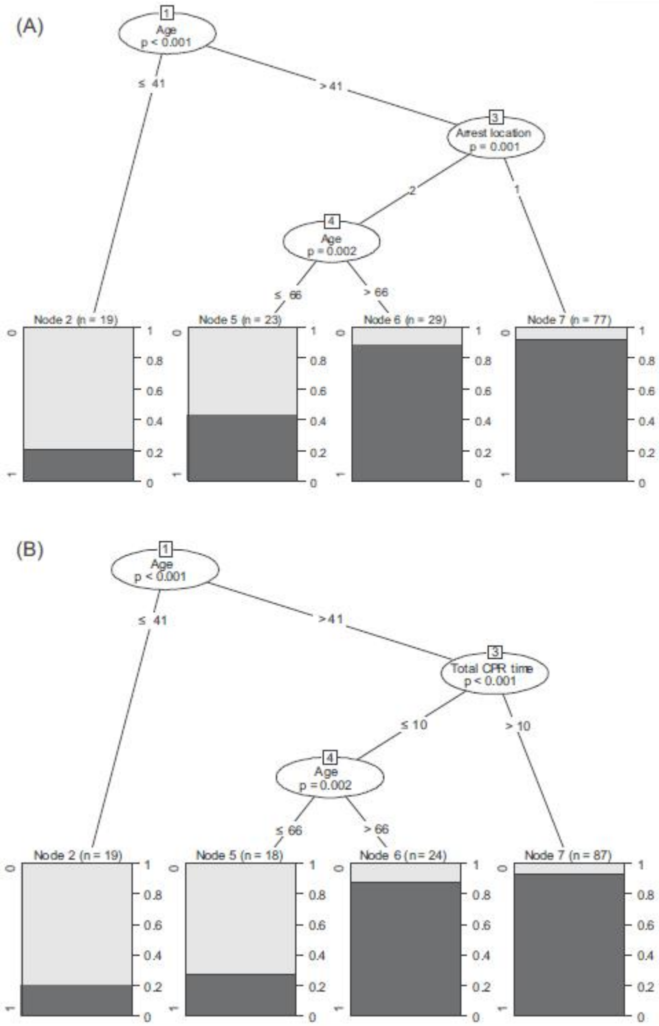
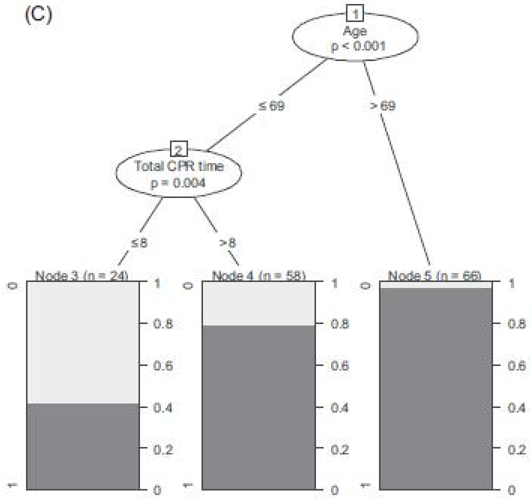


Figure 3. CART model for classification of the risk of rib fracture (models of age and arrest location (A) and models of age and CPR time (B))



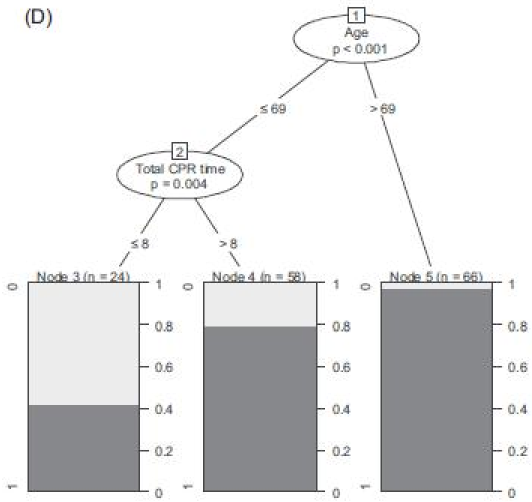


Figure 3. (Continued) CART model for classification of the risk of rib fractures combined with sternum fractures (C) or rib and sternum fractures combined with serious complications (D).

IV. DISCUSSION

This was the first retrospective study to demonstrate that com-plications are more likely to occur in OHCA survivors than in IHCA survivors. In this study, there was a higher incidence of rib fractures, multiple rib fractures, and a higher numbers of rib fractures in OHCA survivors than in IHCA survivors. Although there were no statistically significant differences because of the small number of complications, there was a trend for OHCA survivors to sustain more serious complications than IHCA survivors. Also, there were 2 cases of vertebral fractures and 2 cases of scapular fractures in the OHCA survivors. Scapular and vertebral fractures are very uncommon, and are usually associated with direct high-energy trauma.[5, 16] Therefore, these results suggest that more physical force was applied to the OHCA survivors. A previous study showed that as the speed of ambulances increases, chest compressions with excessive depth, as well as the rate of chest compressions, increase.[5] Increased ambulance speed also causes an increase in high frequency acceleration of chest compressions which suggests the possibility of unnecessary application of force.[5] Another study reported that variability in chest compression rate and depth during transport was significantly greater than that occurring at the scene.[17] Therefore, CPR during transport could lead to unnecessary deeper and faster chest compressions resulting in more damage to the chest wall, including rib fractures, and higher force injuries such as scapular or vertebral fractures. First rib and 9 to 11th rib fractures happened more frequently in OHCA survivors than in IHCA survivors in our study. Lateral portions of the ribs were more frequently fractured in OHCA patients. Theas findings may be difficult to maintain the correct hand position for high quality CPR in OHCA than in IHCA (Figure 2).

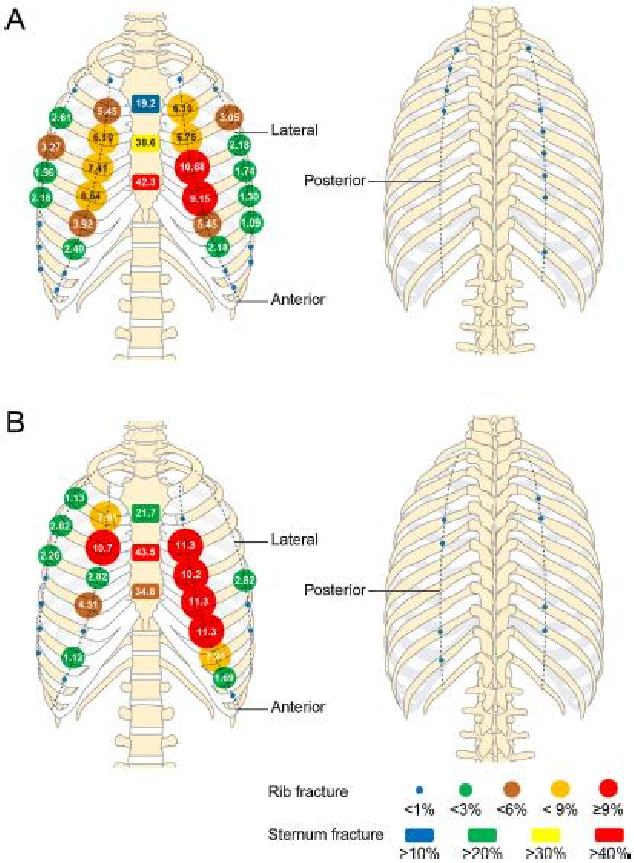


Figure 2. Characteristics of locations of sternum and rib fractures between out-of-hospital (A) and in-hospital (B) cardiac arrest. We noted 52 fractures of the sternum in 89 OHCA patients and 23 fractures in 59 IHCA patients. There were no significant differences in the locations of sternum fractures between OHCA and IHCA patients (p=0.83). In addition, we noted 459 rib fractures in 89 OHCA patients and 177 fractures in 59 IHCA patients. There were significant differences in the locations of rib fractures between OHCA and IHCA patients(p=0.007). In post hoc analysis, rib fractures were frequently found in anterior (83.1%) and posterior portions (4.5%) of the ribs in IHCA patients (lateral portions: 12.4%). However, lateral portopms of the ribs were more frequently fractured in OHCA patients (23.1%; anterior: 74.3%; posterior: 2.6%).

Changes in acceleration and jerk that exceed a critical off-balance threshold occur frequently during transport.[7] Acceleration exceeded the critical off-balance threshold 49% of the time and jerk exceeded critical threshold 26% of the time suggesting that some off-balancing developed during ambulance transport and the rescuers in ambulances could not constantly keep the correct hand position. This off-balancing might cause unintended fractures and unexpected fracture locations such as a 1st rib fractures. Several studies have revealed that the use of devices for ambulance officer posture stabilization can improve the quality of CPR during ambulance transportation. These devices may minimize complications of CPR caused by incorrect hand positions in a movingenvironment.18In our study, 47 (52.8%) of OHCA survivors underwent bystander CPR which did not affect the CPR-related injuries. In a previous study, only 11.5% of patients who underwent bystander CPR suffered from minor injuries thought to be related to bystander CPR.[19] Another study, concerning frequency and severity of injury related to chest compressions in bystander CPR, also reported very low incidence of complications; 12% of patients experienced discomfort, and only 2% of patients had a fracture.[20] Several possible reasons were suggested for the occurrence of bystander CPR related com-plications. Non-trained lay persons tend to be reluctant to perform aggressive CPR because of the fear of CPR-provoked injury and because of inadequate knowledge. The short duration of CPR may be another reason.[19, 20] Also, the real quality of bystander CPR remains suboptimal.[21] For these reasons, bystander CPR in OHCA survivors had a negligible effect on CPR complications. In our study, the incidence of rib fractures, multiple rib fractures, and number of rib fractures were significantly associated with arrest location as well as older age and longer CPR time. Old age is thought to be an important factor in the occurrence of rib fractures secondary to CPR in many studies.[1,2,21–25] Degenerative skeletal changes lead to increased risk of fracture. Longer duration of CPR is another factor that could influence rib fractures.[1, 21, 25]

Increasing tissue stiffness as time passes may contribute to rib fractures.[1] In our case, rib fractures were more common with increasing length of total CPR time with a cut-off value of 10 min regardless of CPR location. There was no increase in rib fractures, sternum fractures, and serious complications after the change in the 2010 guidelines, although the recent guidelines emphasised a deeper and faster chest compression method.[14] However, there were small numbers of patients included in this study before the change of the guide-lines. Prospective studies with a larger number of patients will be needed to confirm our findings that there were significant differences in complications of CPR before and after the change of 2010 CPR guidelines. Using age, arrest location and CPR time as risk factors, we carried out CART analyses. The main advantages of CART analyses are that they are simple, exploratory, and risk can be classified as a tree. We displayed four CART analyses. Each CART model consisted of two variables, age and arrest location and age and CPR time. Using the CART analyses, we can classify the risk of rib fracture, rib fractures combined with sternum fractures or rib and sternum fractures combined with serious complications for any one person one person of certain age depending on his or her arrest location or CPR time. Rib fractures in our study were observed in 75% of total cases, 83.2% in OHCA survivors, and 62.7% in IHCA survivors. This incidence is far beyond the average incidence of previous studies using MDCT (22%, 26% and 62.9%, respectively).[12–14] The difference between our study and the previous study may be due to selection bias; patients with serious complications tended to have undergone chest CT more often. However, a recent study with postmortem CT showed that 70% of patients had rib fractures, similar to ourstudy.[25] We noted 34 fractures of the sternum in 89 OHCA patients and 23 fractures in 59 IHCA patients in this study. Although there was no difference in sternum fractures according to age, gen-der, location of arrest, and CPR time, sternum fractures as well as rib fractures are considered to have a high life-threatening potential. Our study has several limitations. First, we evaluated complications secondary to CPR only for survivors, and only a subset of the patients who had undergone chest CT were included in our study. A total of 2153 CPR were conducted during the study period, but only 148 (6.8%) patients who had undergone chest CT after ROSC were enrolled in our study. This study was a retrospective study based on a small population of patients, which raises the possibility of selection bias. Second, to compare com-plications of CPR between OHCA and IHCA survivors, the ideal method might be comparison between the OHCA patients who were successfully resuscitated before hospital arrival and the IHCA patients. However, only one OHCA survivor achieved ROSC before arriving at the hospital, and the majority of the OHCA group had both out-of-hospital and in-hospital CPR. Third, Complications of CPR will occur in all steps during transportation. However, transition during transportation may only be for short periods of time. The complications in transition steps will be similar to those of results from off-balance CPR in a vehicle. Unfortunately, since this study was retrospectively conducted, we could not evaluate complications of CPR in each step. Fourth, CPR guidelines changed during the study period and emphasised deeper and faster chest compression. Although this change could directly influence our results, both OHCA and IHCA patients would be affected equally.

V. CONCLUSION

Rib fractures were more likely to occur in OHCA survivors, and serious complications tended to occur more often in OHCA than IHCA survivors. In the future, prospective multicentre studies with a larger number of patients are needed to compare the complications from CPR in OHCA patients who achieve ROSC before hospital arrival and IHCA patients, and to facilitate a more appropriate and secure way to conduct CPR during transport in order to reduce complications.

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ABSTRACT(IN KOREAN)

병원 외 심정지 생존자와 병원 내 심정지 생존자에서 심폐소생술 합병증 비교

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성 민 경

서론 : 이 연구의 목적은 병원 외 심정지 환자와 병원 내 심정지 생존자에서 다절편 전산화 단층 촬영을 이용하여 심폐소생술 합병증에 차이가 있는 지 알아보고자 하는 것이다.
방법 : 우리는 레지스트리 데이터를 사용하여 후향적 분석을 시행했다. 우리는 심폐소생술 후 순환회복 된 병원 외 심정지 환자와 병원 내 심정지 환자들을 모두 연구에 포함하였다. 우리는 가슴 압박에 이차적으로 발생한 흉부손상을 늑골 골절, 흉골 골절과 폐좌상과 같이 드문 합병증과 흉곽 외 손상으로 구분하였다. 이러한 합병증을 심폐소생술 장소에 따라 비교하였다. 또한 심폐소생술 합병증의 위험요소를 다중 회귀분석과 회귀 나무분석을 이용해서 분석했다.
결과 : 연구 기간 동안, 전체 148명의 환자들이 일차 분석에 포함되었다. 늑골 골절은 병원 내 심정지 생존자에서 보다 병원 외 심정지 생존자에서 더 많이 발견되었고 (74명(83.2%) 대 37명(62.7%), p=0.05), 다발성 늑골 골절의 빈도 또한 병원 내 심정지 생존자에서 보다 병원 외 심정지 생존자에서 더 높았다. (69명(77.5%) 대 34명(57.6%), p=0.01) 비록 다른 합병증에 있어서는 이 그룹들 간에 통계적으로 유의한 차이는 없었지만 병원 외 심정지 환자에서 좀 더 심각하고 직접적으로 고 에너지와 연관된 합병증이 많이 생기는 경향을 보였다. 고령, 심폐소생술 시간, 그리고 병원 외 심정지는 늑골 골절, 다발성 늑골 골절, 늑골 골절의 개수와 통계적으로 유의한 연관을 보였다.

결론 : 늑골 골절은 병원 외 심정지 생존자에서 늑골 골절이 더 많이 발생하였고 심각한 합병증 또한 병원 내 심정지 생존자와 비교하여 병원 외 심정지 환자에서 더 많이 발생하는 경향을 보였다.

핵심되는 말 : 심폐 소생술, 병원 외 심정지, 병원 내 심정지, 합병증

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