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RESEARCH REPORT

INJURIES ASSOCIATED WITH PREHOSPITAL CPR PROVIDED BY PROFESSIONALS AND NON-PROFESSIONALS IN BANGKOK EMS

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ABSTRACT

Background: This study describes adverse outcomes from cardiopulmonary resuscitation (CPR) performed during out-of-hospital cardiac arrest by trained first responders and professional practitioners by exploring types of injuries and analyzing potential contributing factors.

Methods: Forensic autopsy data from a single center covering almost half of Bangkok, Thailand and its outskirts were retrospectively collected and analyzed from October 2020 to January 2021. The data were divided into two groups: trained first responders and professional practitioners. Thoraco-abdominal injuries to soft tissue, bone, and internal viscera were recorded. Factors including age, BMI, sternal length, and chest circumferencewere categorized in each injury and statistically compared.

Results: 139 cases reported as OHCA with the exclusion of thoraco-abdominal injuries were recruited. The most commonly found CPR injuries were chest wall fractures, especially those of ribs (65.7%). Bilateral anterior rib fractures were more common than unilateral. Age was found to be the only significant associated factor with rib fractures. Other observed injuries were sternal fractures, lung contusions and lacerations, epicardial and subendocardial hemorrhages, cardiac contusions, liver lacerations, and pancreatic and splenic hemorrhages. No statistical difference between injuries generated by trained first responders and professional practitioners is found.

Conclusion: This study may provide useful information for clinicians and forensic physicians to be aware of and investigate for potential injuries and complications from CPR.

BACKGROUND

Out-of-hospital cardiac arrest (OHCA) patients may receive initial CPR from bystanders, trained first responders, or professional practitioners, resulting in different outcomes owing to expertise and experiences (Anderson et al., 2011; Talikowska et al., 2020). In Thailand, trained first responders are volunteers who pass a short-course consisting of a few days of training. Professional pratitioners are physicians, registered nurses, or paramedics who receive advanced cardiac or traumatic life sup-

port (ACLS or ATLS) courses. OHCA patients are usually resuscitated by trained first responders, professional practitioners, or sometimes by automated devices, depending on EMS service availability in each area.

When patients survive to hospital admission, CPR injuries become issues of significant concern. Prior studies have shown a number of thoraco-abdominal injuries, including chest-wall fractures and intrathoracic and intra-abdominal visceral injuries (Boland et al., 2015; Deliliga et al., 2019; Girotti et al., 2022). These injuries not only add to patient suffering but also contribute to prolonged hospitalization.

This study explored and compared CPR-related injuries generated by trained first responders versus professional practitioners during out-of-hospital resuscitation attempts. The study also searched for factors significantly associated with such injuries.

METHODS

The data was retrospectively obtained via forensic autopsy reports and pictures, which were performed from October 2020 to January 2021 at a single center that is responsible fo medico-legal investigations of death for roughly half of Bangkok. The Institutional Review Board approved the study. The cardiac arrest cases recruited into the study must have received only manual chest compression methods. Those who received CPR by both kinds of practitioners or developed decomposition or contained antecedent thoraco-abdominal injuries indistinguishable from CPR were excluded from the study.

The total cases were subsequently divided based on the CPR performer into TFR for those who received manual CPR exclusively by trained first responders and PP for those who received manual CPR only by professional practitioners. Injuries of the chest wall, including skin, subcutaneous tissue, anterior mediastinum, sternal, and rib fractures, were recorded in association with intrathoracic and intra-abdominal injuries. Data were analyzed for the total group and each subgroup based on sex, age range, body mass index (BMI), sternal length (SL), and chest circumference (CC). Age was categorized in decades except for both extreme groups; therefore, the subgroups were ≤ 20, > 20-30, > 30-40, > 40-50, > 50-60, and ≥ 60 years. BMI was classified into five subgroups according to WHO (2004) for the Asian population (WHO Expert Consultation, 2004) that consisted of BMI ≤ 18.5, 18.5-22.9, 23.0-24.9, 25.0-29.9, and ≥ 30. SL and CC in centimeters were categorized based on percentile ranking of the dataset that principally consisted of ≤ P10, > P10-P25, > P25-P50, > P50-P75, > P75-P90, and ≥ P90 subgroups.

Locations of rib fracture were defined as anterior, ranging from the midline to anterior axillary line; lateral, ranging from anterior to posterior axillary lines; and posterior, ranging from posterior axillary line onwards.

Descriptive statistics and graph plotting were performed by Microsoft Excel 2019, while correlation analysis was done by IBM SPSS v.20. Statistical comparison was analyzed by Fisher s exact or Chi-square test via the online platform at https://astatsa.com/FisherTest/. Binary logistic regression analysis was used for determining significance.

An association factor was also calculated online at https://stats.blue/Stats_Suite/logistic_regression_calculator.html. Statistical significance was considered when $p \leq 0.05$.

RESULTS

A total of one hundred thirty-nine cases met the criteria and were recruited. The distribution of cases for the total TFR and PP groups with regard to sex, age, and BMI is presented in Tables 1 and 2. The number of cases in the ≤ 20 group is much lower than the others because it is concordant with the mortality rate of forensic cases.

CPR injuries were found in 85 cases (61.2%), of which the most significant number were rib fractures (55 cases, 64.7%), followed by sternal fractures (27 cases, 31.8%), intrathoracic (19 cases, 22.4%), intra-abdominal (8 cases, 9.4%) visceral injuries, and clavicular fracture (1 case, 1.2%). Lung and heart injuries were found in 7 and 12 cases, respectively, while intra-abdominal organs, i.e., liver and pancreas, were found in 8 and 1 cases, respectively. No splenic injury was observed. All of the lung injuries were contusions, whereas heart injuries were epicardial (10/12 cases) and subendocardial (2/12 cases) hemorrhage. Hepatic injuries were lacerations and contusions, while that of the pancreas was peripancreatic hemorrhage. Only a single injury of intrathoracic viscera was found, while those of intra-abdominal viscera contained a combined injury in one case.

	Age (years)					
	≤20	>20-30	>30-40	>40-50	>50-60	>60
Total (n=139, 100%)						
m (n=105, 75.5%)	n=6 (5.7%)	n=11 (10.5%)	n=28 (26.7%)	n=19 (18.1%)	n=23 (21.9%)	n=18 (17.1%)
f (n=34, 24.5%)	n=2 (5.9%)	n=1 (2.9%)	n=8 (23.5%)	n=6 (17.6%)	n=12 (35.3%)	n=5 (14.7%)
TFR (n=78, 56.1%)						
m (n=66, 84.6%)	n=3 (4.5%)	n=5 (7.6%)	n=18 (27.3%)	n=16 (24.2%)	n=13 (19.7%)	n=11 (16.7%)
f (n=12, 15.4%)	n=1 (8.3%)	n=0 (0.0%)	n=2 (16.7%)	n=3 (25.0%)	n=3 (25.0%)	n=3 (25.0%)
PP (n=66, 38.6%)						
m (n=39, 43.9)	n=3 (7.7%)	n=5 (12.8%)	n=10 (25.6%)	n=4 (10.3%)	n=10 (25.6%)	n=7 (17.9%)
f (n=22, 36.1)	n=1 (4.5%)	n=1 (4.5%)	n=5 (22.7%)	n=3 (13.6%)	n=10 (45.5%)	n=2 (9.1%)

Table 1. Distribution of cases in the age dataset. m = male, f = female.

	BMI				
	<18.5	18.5-22.9	23.0-24.9	25.0-29.9	>30
Total (n=139, 100%)					
m (n=105, 75.5%)	n=11 (10.5%)	n=29 (27.6%)	n=19 (18.1%)	n=35 (33.3%)	n=11 (10.5%)
f (n=34, 24.5%)	n=4 (11.8%)	n=10 (29.4%)	n=12 (35.3%)	n=3 (8.8%)	n=5 (14.7%)
TFR (n=78, 56.1%)					
m (n=66, 84.6%)	n=4 (6.1%)	n=20 (30.3%)	n=13 (19.7%)	n=21 (31.8%)	n=8 (12.1%)
f (n=12, 15.4%)	n=2 (16.7%)	n=3 (25.0%)	n=4 (33.3%)	n=1 (8.3%)	n=2 (16.7%)
PP (n=66, 38.6%)					
m (n=39, 43.9)	n=7 (17.9%)	n=10 (25.6%)	n=5 (12.8%)	n=14 (35.9%)	n=3 (7.7%)
f (n=22, 36.1)	n=2 (9.1%)	n=7 (31.8%)	n=8 (36.4%)	n=2 (9.1%)	n=3 (13.6%)

Table 2. Distribution of cases in the BMI dataset. m = male, f = female.

Of the rib fractures, 37 cases (68.5%) contained bilateral rib fractures, of which 35 cases (94.5%) were located at the anterior part of both sides. A few cases were found equally located at the lateral and posterior parts and were usually combined with those at the anterior part. Unilateral fractures were equally found on either side (9 cases per side). Similarly, anterior fractures were predominant (8/9 for both sides). Fractures commonly occurred in the first to eighth ribs.

The second most common injury was a sternal fracture, mostly found between the second to fifth intercostal spaces. Injuries of intrathoracic viscera, the third most common injury, occurred in the lungs and were of similar number as those in the heart (11 against 12 cases); both of them occurred separately.

Sites commonly found for liver lacerations were located at the right lobe and in the middle part. Peripancreatic hemorrhage was observed around its head.

The SL and CC subgroups were categorized by percentile, as described above. For SL subgroups, data were finally divided as ≤ 15, > 15-17, > 17-19, > 19-21, > 21-23, and ≥ 23 centimeters, while CC subgroups were divided as ≤ 74.9, > 74.9-79.8, > 79.8-87.0, > 87.0-93.0, > 93.0-99.0, and ≥ 99.0 in centimeters as well. Soft tissue injuries involving skin, subcutaneous, and anterior mediastinum were counted together for each age, BMI, SL, and CC subgroup in the total data, TFR, and PP. Bony fractures of the ribs and sternum and intrathoracic and intra-abdominal visceral injuries were also counted similarly. Multivariate binary logistic regression was performed to determine the significant contributing factor(s). Then, the contributing factor(s) were analyzed by Chi-square or Fisher s exact test to define a cut-off point.

Of the total data, only rib fracture showed a statistical significance by logistic regression analysis among different ages ($p < 0.01$). By Chi-square analysis, the age of 30 shows a significant cut-off point ($p < 0.01$). Summary details are in Table 3 and Figure 1.

Independent Variable	Odds Ratio	95% Confidence Interval	*p*
Age	1.05	(1.02-1.08)	<0.01
Gender	1.01	(0.41-2.45)	0.99
BMI	1.07	(0.98-1.18)	0.13
SL	0.96	(0.86-1.08)	0.52
CC	1.00	(0.95-1.06)	0.92

Table 3. Binary logistic regression results assigning rib fracture as a dependent variable.

In TFR, soft tissue injuries were statistically different among age groups ($p = 0.023$), while bony injuries involving rib and sternal fractures were statistically different among SL groups ($p < 0.01$). In PP, soft tissue injuries and rib fractures were both statistically different among age groups ($p = 0.04$ and < 0.01, respectively), while only bony injuries were statistically different among BMI groups ($p = 0.02$).

Prevalence of rib fractures of the TFR was slightly less than those of the PP (27/78 or 34.6% against 26/61 or 42.6%); however, Chi-square or Fisher s exact test showed no significant difference between both groups with regards to the cut-off age. Spearman s rank correlation coefficient showed a significantly strong pairwise correlation of rib

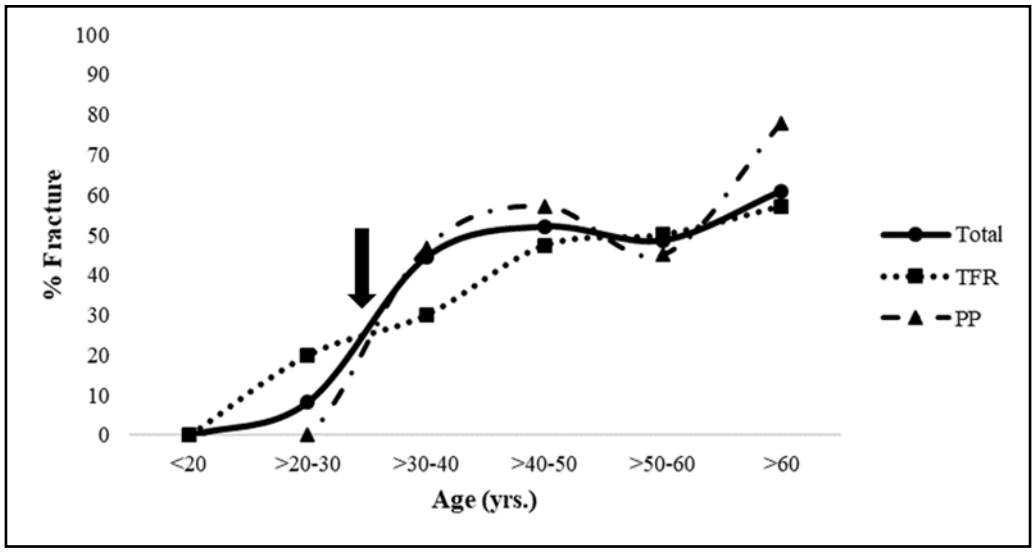

Figure 1. Percent of chest wall fractures. Fracture distribution by age shows the cut-off point at 30 years (black arrow).

fracture only by age. The correlation coefficient (rs) between the total group and TFR is 1.00 ($p < 0.01$), rs between the total group and PP is 0.81 ($p = 0.05$), and rs between TFR and PP is 0.81 ($p = 0.05$).

DISCUSSION

OHCA has been reported to generate CPR-related injuries in association with the duration of chest compression and survival (Boland et al., 2015; Takayama et al., 2018). Victims who fail to gain ROSC usually receive chest compression for more than 10-15 minutes, leading to an increased prevalence of chest injuries (Boland et al., 2015; Takayama et al., 2018). To access a greater possibility of detecting a wide variety of CPR-related injuries, this study examines autopsied cadavers, as previously reported (Deliliga et al., 2019; Girotti et al., 2022). Rib fractures are the most prevalent of complications found after CPR, similar to prior studies (Friberg et al., 2019; Karasek et al., 2021).

This study explores the significant factors associated with rib fractures and finds that older age, similar to those previously described (Takayama et al., 2018; Karasek et al., 2021; Moriguchi et al., 2021; Kralj et al., 2015), is a strong contributor. However, this study defines the cut-off point at the age of 30 to discriminate a statistically significant acceleration of prevalence (Figure 1).

The cut-off age in this study is in concordance with costal calcification staging previously reported (Patyal & Bhatia, 2022; Zhang et al., 2017), which may be one of the factors susceptible to cause fractures. This study cannot identify that BMI could be significantly associated with rib fractures; however, it could affect the performance of CPR in obese patients (Tellson et al., 2017).

This study also finds that bilateral rib fractures are more common than unilateral. The different results from the prior study (Kaldırım et al., 2016) might result from many conditions, such as the varied skills of CPR performers from person to person and from

place to place (Anderson et al., 2011; Talikowska et al., 2020). However, this may help CPR training emphasize substantial points for trainees to reach the satisfying goals. In addition, soft tissue injuries of the chest wall are associated with age, but they are serious complications nonetheless. There is no statistical difference in the other factors, i.e., SL and CC, in association with injuries except for an association between bony fractures of the chest wall and SL only in the TFR group. This finding has yet to be observed further because our sample size is not large enough.

This study could be primarily summarized that there is no significant difference in rib fractures between CPR performance by trained first responders and professional practitioners even though professional practitioners generate a slightly higher incidence of rib fractures than trained first responders. This could be owing to higher CPR quality (Talikowska et al., 2020).

Despite lower incidence, internal visceral injuries are of more concern because they can potentially result in severe morbidities. In this study, lung lacerations, contusions, and liver lacerations are observed. However, most of the heart injuries are found to have very limited severities, which are hemorrhage in the epicardium and subendocardium. However, it is not clear whether subendocardial hemorrhage is directly caused by chest compression or by other factors, such as adrenaline administration during CPR (Charaschaisri et al., 2011). Sites of hepatic injuries are of interest for clinical and forensic aspects. This data may help CPR performers respond more quickly and effectively to life-threatening conditions in severe lacerations. It also guides forensic physicians to concern and distinguish CPR injuries from antecedent trauma. The pancreatic and splenic injuries found here are of less clinical significance because they do not involve organ parenchyma.

LIMITATIONS OF THIS STUDY

We are concerned that as automated CPR devices become more available, even in OHCA, the future direction should focus on the device's effectiveness and outcome, especially between different manipulating skills. Because of better rib recoil, it is of greater interest to have more infant CPR cases enrolled in future studies to investigate possible adverse outcomes.

CONCLUSION

This study describes a landscape of CPR-related injuries performed by personnel with different training backgrounds. Chest wall fractures are the most common complication, followed by intrathoracic and intra-abdominal injuries. Advanced age may significantly contribute to the incidence of rib fractures.

Professional practitioners generate little more incidence of fractures than trained first responders without statistical significance. Lung injuries are found to be severe and most common. Finally, the study also allows forensic physicians to distinguish between injuries caused by CPR and antecedent trauma.

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