Original article

Comparison of chest compression injuries during CPR between the 2010 and 2005 AHA guidelines in autopsy cases in Chiang Mai, Thailand

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Background The 2010 American Heart Association (AHA) Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC) focus more on the importance of chest compressions than the 2005 AHA Guidelines. Observations show that injuries from CPR under the 2010 guidelines are more serious than those that occur under the 2005 guidelines. This may be a contributing factor in the death of these patients.

Objective To study and compare injuries from CPR chest compressions under the 2010 AHA Guidelines with those that occurred under the 2005 Guidelines.

Material and methods Retrospective, prospective and descriptive studies were performed on 254 deceased persons who had received chest compressions under the 2005 or 2010 AHA Guidelines.

Results This study found a higher incidence of injuries from cases of chest compression (2010 guidelines) than in the controls (2005 guidelines). Injuries that were statistically significant (p<0.05) included: skin contusion/abrasion, intercostal muscle contusion, sternal fracture, rib fracture, pericardial contusion, pericardial rupture, hilar and heart contusion, cardiac contusion, and spleen rupture**.**

Conclusion Injuries found from CPR chest compressions, which followed the 2010 AHA guidelines, were statistically greater in quantity and severity than those found in persons following the 2005 guidelines. Chronic liver diseases, such as cirrhosis and fatty liver disease, can cause increased injury from CPR chest compressions. **Chiang Mai Medical Journal 2016;55(2):57-63.**

keywords: AHA guidelines, CPR, ECC, chest compression, injuries, chronic and fatty liver diseases

Introduction

The 2010 American Heart Association (AHA) Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC) focus on the importance of chest compressions, which include achievement of an adequate rate and depth that allow for complete chest recoil, and minimized interruptions.

The guidelines changed from a recommended rate of approximately 100 compressions per minute in the 2005 guidelines to at least 100 compressions per minute in the 2010 guidelines. Increasing the number and speed of chest compressions correlated with

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a higher rate of survival. In order to increase blood flow, the depth of chest compressions changed from approximately four to five cm in the 2005 guidelines to at least five cm in the 2010 guidelines[1]. The objective of this study was to compare post CPR injuries between the 2005 and 2010 AHA guidelines.

However, injuries have occurred from chest compressions during CPR, with the most common being rib and sternal fractures. Krischer *et al*[2] studied 705 deceased persons who had received CPR, of which 63% were found to have more than five broken ribs, and three out of four had broken ribs on both sides of the chest. These fractures in the thoracic region were a result of osteoporosis, which caused the bones to break more easily. Chest compressions that are too forceful or performed in the wrong position also may cause injury to internal organs[3,4].

Cardiac rupture can occur spontaneously in patients with heart diseases, such as myocardial infarction and myocarditis. The left ventricle is the most common location of cardiac rupture during CPR.

Destruction of the liver or spleen from CPR is uncommon [5,6]. Cases of abdominal injury are found mostly in regions close to the ribs and sternum, but this depends on the strength of chest compressions and whether it causes the force to spread through the abdomen[7]. It was first reported that patients who died of a ruptured liver from CPR were pregnant, because their liver is positioned higher in such circumstances[8].

Observations showed that injuries from CPR, when using the 2010 AHA guidelines, are more serious than those that occur under the 2005 guidelines. These injuries may be a contributing factor in these fatalities. However, to address these observations, it is necessary to study the differences first between the internal injuries from the two guidelines, in order to utilize the results.

Materials and methods

The researchers used a retrospective study of deceased persons, who had received chest compressions as a part of resuscitation using the 2010 or 2005 AHA guidelines. Autopsies were performed at the Department of Forensic Medicine of Chiang Mai University School of Medicine. This research used the following inclusion criteria: the deceased persons had received resuscitation according to the 2005 or 2010 AHA guidelines at the Emergency Department, Faculty of Medicine, Chiang Mai University, and were transferred after death to the Forensic Department for an autopsy. The exclusion criteria included: 1) deceased persons under the age of 18 years; 2) persons who died as a result of traffic accidents, falling from heights, or those with a history of injuries in the chest and abdominal regions; and 3) persons with X-rays showing chest injuries before resuscitation. Data were analyzed by descriptive statistics and a comparison of the two guidelines, using the SPSS program to compute a chi-square statistic and perform a Fisher's exact test.

Results

The data were divided into two groups: the study cases and controls. The study case group was composed of deceased persons who had received chest compressions during resuscitation using the 2010 AHA guidelines. Information was collected on 127 cases of this group between January 2011 and August 2012. The control group included deceased persons who had received chest compressions during resuscitation using the 2005 AHA guidelines. Information was collected on 127 of these cases between September 2007 and November 2010, bringing the total number of cases analyzed to 254.

The average age of the study cases and controls was 58.58 and 55.31 years, respectively. The ages of the study cases and controls ranged from 18 to 96 and 19 to 99 years, respectively (Table 1). The distribution of deaths by age group is shown in Table 2. With regard to gender, 72.44% of the study cases were male and 27.56% female, and the control group comprised 66.14% male and 33.86% female. Statistical computations found this study to have no statistically significant differences in age and sex between the two groups (Table 2). The duration of chest compressions for the study cases ranged from 15 to 115 minutes, with an average time of 32.2 minutes. The duration for the controls ranged from 10 to 100 minutes, with an average time of 37.7 minutes

Table 1. Average age and sex of the study and control groups

	Study group N=127	Control group N=127	Chi-square test value	*p*
Age (yrs)*	58.58	55.31	81.044	0.133
Range	18-96	19-99	1.184	0.277
Male	92 (72.44%)	84 (66.14%)		
Female	35 (27.56%)	43 (33.86%)		

N=124

Table 2. Distribution of study and control samples by age group

Range (yrs)	Study group N=124 (%)	Control group N=124 (%)	Chi-square test value	*p*
18-30	10 (8.06)	14 (11.29)	2.956	0.399
31-50	29 (23.38)	38 (30.64)		
51-70	48 (38.70)	41 (33.06)		
>71	37 (29.83)	31 (25.00)		

(Table 3).

The study cases were found to have more incidence of chest compression injuries (2010 guidelines) than the controls (2005 guidelines). Statistically significant injuries ($p<0.05$) included: skin contusion/abrasion ($p=0.002$), intercostal muscle contusion ($p=0.000$), sternal fracture ($p=0.000$), rib fracture ($p=0.000$), pericardial contusion ($p=0.001$), pericardial rupture ($p=0.029$), hilar heart contusion ($p=0.02$), cardiac contusion ($p=0.006$) and spleen rupture ($p=0.006$) (Table 4). The controls had a greater incidence of hilar lung contusion when compared to the study cases ($p=0.014$). No statistically significant differences were found in the analysis of rib fractures on the left, right, or both sides of the sternum. In addition, no statistically significant differences were found in anterior, antero-lateral, and lateral rib fractures and no posterior rib fractures were found in either the study or control group.

Table 3. Range and average duration of chest compressions during CPR

	Range (min)	Mean (min)
Study group (n=50)	15-115	32.2
Control group (n=31)	10-100	37.7

Discussion

This research studied 254 cases of death by comparing between the study group and controls that received injuries from chest compressions according to the 2010 and 2005 AHA guidelines, respectively. This study found a statistically significant ($p<0.05$) difference between the number of injuries in the study group and that in the controls. This difference is attributed to the increased force and speed of compressions during CPR under the 2010 AHA guidelines.

Rib fracture was the chest compression injury reported most commonly. Previous studies have found a rib fracture incidence of 3-89%[9]. This research found a rib fracture incidence of 77.6% and 17.8% in the study group and controls, respectively. Smekal *et al*[10] collected data on 85 cases of chest compression injury during CPR, and reported that those injuries were insufficiently severe to have caused death. However, this research found that deceased persons had ribs fractures in multiple locations after receiving chest compressions, and it could be assumed that the tips of the fractured ribs pierced the heart, as shown in Figure 1.

Table 4. Injuries from CPR chest compressions in the study and control groups

Findings	Study group N=127 (%)	Control group N=127 (%)	Chi-square test value	*p*
Skin contusion/abrasion	40 (31.49)	19 (14.96)	9.736	0.002
Chest				
Intercostal muscle contusion	95 (74.8)	52 (40.94)	29.216	0.00
Sternal fracture	62 (48.81)	19 (14.96)	34.08	0.00
Rib fracture*	97 (77.6)	51 (40.8)	36.438	0.00
Hemothorax	4 (3.14)	4 (3.14)	-	1.00
Pneumothorax	1 (0.78)	0	-	1.00
Thoracic aorta rupture	5 (3.94)	0	-	0.06
Heart				
Pericardial contusion	26 (20.47)	8 (6.29)	11.002	0.001
Pericardial rupture	6 (4.72)	0	-	0.029
Cardiac contusion	19 (14.96)	6 (4.72)	7.498	0.006
Cardiac rupture	9 (7.08)	9 (7.08)	-	1.00
Hilar heart contusion	15 (11.81)	5 (3.93)	5.427	0.02
Lung				
Lung contusion	12 (9.44)	9 (7.08)	0.467	0.494
Hilar lung contusion	4 (3.14)	14 (11.02)	5.979	0.014
Hilar lung laceration	3 (2.36)	6 (4.72)	-	0.5
Abdomen				
Hemoperitoneum	7 (5.51)	3 (2.36)	1.666	0.197
Diaphragm muscle contusion	4 (3.14)	0	-	0.122
Liver rupture	3 (2.36)	2 (1.57)	-	1.00
Spleen rupture	14 (11.02)	3 (2.36)	7.628	0.006

N=125

Table 5. Rib injuries from CPR chest compressions in the study and control groups

	Study group (%)	Control group (%)	Chi-square test value	*p*
Rib fractures	97	51	36.438	0.00
Left side	91 (93.81)	47 (92.15)	0.000107	0.9917
Number of fractured ribs	4.81	3.53		
Right side	81 (83.51)	38 (74.51)	0.827	0.3631
Number of fractured ribs	5.15	3.79		
Bilateral	76 (78.35)	33 (64.71)	1.581	0.2086
Location				
Anterior	70 (72.16)	42 (82.35)	0.987	0.3204
Antero-lateral	16 (16.49)	2 (3.92)	0.336	0.5623
Lateral	35 (36.08)	12 (23.53)	0.196	0.6581
Posterior	0	0	-	-

Factors that increased the likelihood of rib fractures were gender, age, and the length of chest compressions during CPR. Multiple rib fractures also were found to have a high incidence in women with a tendency to develop osteoporosis, and because their pectoral structure is different from men. In addition, age causes bones and joints to deteriorate, which increases the likelihood of injury [9,10]. It is noteworthy that both the study and control

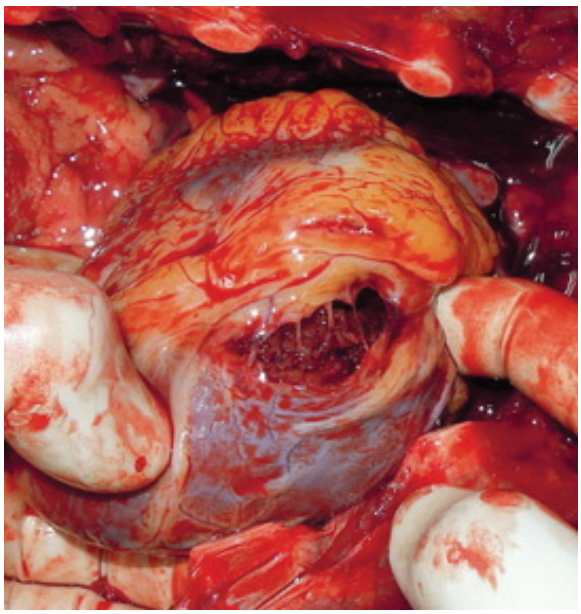

Figure 1. Injury from CPR chest compressions following the 2010 AHA Guidelines. (From the Department of Forensic Medicine, Chiang Mai University School of Medicine).

groups in this research had no deceased persons with posterior rib fractures.

There is reason to believe that the myocardial contusions and hemorrhages found resulted from pressure between the front of the chest and bones of the spine, caused by chest compressions during CPR. Hashimoto *et al*[5] reported 58 cases of deceased persons who had received CPR. They found 23 cases (40%) of myocardial hemorrhages, with five (21.7%) located on the anterior wall of the heart, 13 (56.5%) on the posterior wall, and 7 (30.4%) with both anterior and posterior hemorrhages. In this research, myocardial contusions and hemorrhages were found in only 14.96% and 4.72% of cases in the study and control group, respectively. Eight of the 19 cases (42.1%) in the study group were found on the anterior wall, eight (42.1%) on the posterior wall, and three (15.8%) on both the anterior and posterior wall. All three cases where hemorrhages were found on both sides of the heart were identified in people who had chronic liver disease. Two out of the three cases had chronic cirrhosis of the liver. It is assumed that these persons had abnormal blood clotting that caused more contusions and hemorrhages than in other cases.

Cardiac rupture from CPR had a very low reported incidence. Krischer *et al*[2] studied this phenomenon at the time when CPR guidelines were first introduced and found only one case (0.1%) of cardiac rupture out of 705 deaths. Takada *et al*[11] studied 77 deaths and found no relationship between CPR chest compressions and left ventricular rupture. Baldwin and Edwards[12] also performed a research at the time when CPR guidelines were initiated. Their study found a relationship between right ventricular rupture and CPR, without finding any rib or sternal fractures. During the same time span, Bodily and Fischer[13] studied 2,659 deaths and found only three cases of right ventricular rupture from CPR. In this research, nine cases of cardiac rupture were identified in the study group, with six cases of left ventricular rupture and myocardial infarction or arteriosclerosis. In addition, there were two cases of right atrial rupture, caused either by penetration from sternal fractures during CPR or spontaneous fracture where the pericardium was normal, but with arteriosclerosis. The final case was death by drowning, in which right atrial rupture was found, with normal pericardium and no arteriosclerosis. Therefore, it is likely that this atrial rupture was the result of CPR chest compressions.

It is believed that liver and spleen rupture result from improper placement of hands and too much force used when performing CPR. A report on administering thombolysis and CPR found cases of spleen rupture[14]. The report found a liver and/or spleen rupture incidence of zero to 31 cases out of 100. This research found 14 (11%) and 3 (2%) cases of spleen and liver rupture, respectively, but discovered only two cases of significant abdominal bleeding, which also had cirrhosis of the liver. This research studied only deceased persons that had received CPR chest compressions according to the 2005 and 2010 AHA guidelines. Autopsies were performed exclusively by the Department of Forensic Medicine at the Chiang Mai University School of Medicine. This research did

not study the relationship between the survival rate and CPR chest compression injuries. It is hoped that this information will be beneficial in improving CPR guidelines and furthering research on this topic.

Conclusion

Injuries from CPR chest compressions were statistically greater in quantity and severity in patients following the 2010 AHA guidelines than those following the 2005 AHA guidelines.

These injuries were most notable in areas close to the hand position on impact, for example, rib fracture, intercostal muscle contusion, sternal fracture, and skin contusion/abrasion. This research did not find any posterior rib fractures, but it did discover that chronic liver diseases, such as cirrhosis and fatty liver disease, cause increased injury from CPR chest compressions.

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การเปรียบเทียบการบาดเจ็บที่เกิดขึ้นจากการกดนวดทรวงอกในกระบวนการการช่วยฟื้นคืนชีพระหว่างข้อชี้แนะของสมาคมโรคหัวใจแห่งอเมริกา ปี ค.ศ. 2010 และ 2005 ที่ตรวจพบในศพที่ชันสูตรในเชียงใหม่ ประเทศไทย

ยุตติ อมรเลิศวัฒนา และ ไพฑูรย์ ณรงค์ชัย
ภาควิชานิติเวชศาสตร์ คณะแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่

บทนำ สมาคมโรคหัวใจแห่งอเมริกาได้ประกาศข้อชี้แนะ ค.ศ. 2010 (AHA2010) สำหรับการช่วยฟื้นคืนชีพ (CPR) และการดูแลรักษาโรคระบบหัวใจและหลอดเลือดแบบฉุกเฉิน (ECC) มีการให้ความสำคัญกับการกดนวดทรวงอกมากกว่าข้อชี้แนะฯ 2005 (AHA2005) จากการศึกษาพบว่าการบาดเจ็บที่เกิดจากการช่วยฟื้นคืนชีพตาม AHA2010 มีการบาดเจ็บที่รุนแรงกว่า AHA2005 และการบาดเจ็บดังกล่าวอาจจะเป็นสาเหตุที่สำคัญอย่างหนึ่งของการเสียชีวิตของผู้ป่วยที่ถูกกดนวดเหล่านี้

วัตถุประสงค์ เพื่อศึกษาและเปรียบเทียบการบาดเจ็บที่เกิดขึ้นจากการกดนวดทรวงอกตามข้อชี้แนะแห่งสมาคมโรคหัวใจแห่งอเมริกาปี ค.ศ. 2010 กับ 2005

วิธีการ ศึกษาจากการผ่าชันสูตรพลิกศพจำนวน 254 ศพทั้งแบบย้อนหลังและแบบเดินหน้า ที่ศพเหล่านี้มีการกดนวดทรวงอกตามข้อชี้แนะ AHA2010 และ AHA 2005

ผลการทดลอง การศึกษานี้พบว่าอัตราการเกิดการบาดเจ็บในศพที่เกิดขึ้นจากการกดนวดทรวงอกตามข้อชี้แนะ ฯ AHA2010 สูงมากกว่า AHA2005 อย่างมีนัยสำคัญทางสถิติ และการบาดเจ็บที่เกิดขึ้นดังกล่าว ได้แก่ ผิวหนังฟกช้ำ กล้ามเนื้อระหว่างซี่โครงฟกช้ำ กระดูกทรวงอกหัก กระดูกซี่โครงหัก ถุงหุ้มหัวใจฟกช้ำและฉีกขาด ขั้วปอดและปอดฟกช้ำ หัวใจฟกช้ำและม้ามฉีกขาด

สรุป การบาดเจ็บที่เกิดขึ้นจากการนวดทรวงอกตามข้อชี้แนะ ฯ AHA2010 เกิดขึ้นมากกว่าและรุนแรงมากกว่า AHA2005 อย่างมีนัยสำคัญทางสถิติ สำหรับโรคตับเรื้อรัง เช่น ตับแข็ง และไขมันเกาะแทรกในตับเป็นสาเหตุที่ทำให้เกิดการบาดเจ็บได้ง่ายขึ้น เมื่อมีการกดนวดทรวงอก **เชียงใหม่เวชสาร 2559;55(2):57-63.**

คำสำคัญ: AHA guideline, CPR, ECC, การกดนวดทรวงอก การบาดเจ็บ โรคตับเรื้อรัง และไขมันเกาะแทรกในตับ