World Academy of Science, Engineering and Technology
International Journal of Medical and Health Sciences
Vol:7, No:6, 2013

Could One-Hand Chest Compression for a Small Child Cause Intra-Abdominal Injuries?

Yeon Ho You, Ji Sook Lee, and Jin Hong Min

Abstract—We examined whether children (<18 years old) had risk of intra-thoracic trauma during 'one-handed' chest compressions through MDCT images. We measured the length of the lower half of the sternum ($S_{total/2\sim X}$). We also measured the distance from the diaphragm to the midpoint of the sternum ($S_{total/2\sim D}$) and half the width of an adult hand ($W_{total/2}$). All the 1 year-old children had $S_{total/2\sim X}$ and $S_{total/2\sim D}$ less than $W_{total/2}$. Among the children aged 2 years, 6 (60.0%) had $S_{total/2\sim X}$ and $S_{total/2\sim D}$ less than $W_{total/2}$. Among those aged 3 years, 4 (26.7%) had $S_{total/2\sim X}$ and $S_{total/2\sim D}$ less than $W_{total/2}$, and among those aged 4 years, 2 (13.3%) had $S_{total/2\sim X}$ and $S_{total/2\sim D}$ less than $W_{total/2}$. However, $S_{total/2\sim X}$ and $S_{total/2\sim D}$ were greater than $W_{total/2}$ in children aged 5 years or more. We knew that small children may be at an increased risk of intra-thoracic trauma during 'one-handed' chest compressions.

Keywords—Cardiopulmonary resuscitation, Child, Compression.

I. Introduction

HIGH quality paediatric cardiopulmonary resuscitation CPR is critical when reviving a collapsed child in order to reduce the risk of neurologic sequelae after cardiopulmonary arrest [1]-[4]. To perform high quality CPR, the optimal chest compression site, rate, and depth are necessary [5]-[7]. In accordance with *the 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care*, paediatric CPR in small children involves compression of the lower half of the sternum [8]. However, compressing the lower part of the sternum might cause complications such as cardiac contusion, liver injury, and musculoskeletal injury [9], [10]. Nonetheless, the risk of injury to abdominal organs after one-hand chest compression has not been reported. Here, we address the possibility of compression of intra-thoracic trauma during if one-hand chest compression in small children.

F. Y. H. Y. is with the Chungnam National University Hospital, Daejeon, South Korea (phone: 82-42-280-8081; fax: 82-42-280-8082; e-mail: yyo1003@naver.com).

J.S.L. is with the Ajou University Hospital, Suweon, South Korea .

J. H. M. is with the Chungbuk National University Hospital, , Cheungju, South Korea.

All authors declare that they have no proprietary, financial, professional or other personal interest of nature or kind in any product, service, company that could be construed as influencing the position presented in the manuscript entitled.

II. Method

The medical records including multidirectional computed tomography (MDCT) scans of children who presented to one of 3 hospitals (Chungnam National University Hospital, Ajou University Hospital, Chungbuk National University Hospital) from March 2002 to March 2012 were reviewed retrospectively. Our institutional review board approved the study protocol and deemed it appropriate for exemption from informed consent. Children who were not within normal percentile height and body weight were excluded, as were children who had diseases that could shift mediastinal organs (such as atelectasis, cardiac abnormality, space-occupying mediastinal mass, spinal deformity, ascites, pneumothorax, or haemothorax), those who had had previous chest or abdominal surgery, those whose nipples were not in the same transverse section on the MDCT scan, and those whose height or body weight were not recorded. The MDCT scanners used in this study were the Somatom plus 4 (Siemens, Erlangen, Germany), the Sensation Cardiac 64 (Siemens, Forchheim, Germany), the Hispeed/I (GE Medical Systems, Milwaukee, MN, USA) and the Brilliance 64 (Phillips, Eindhoven, The Netherlands). S_{total} (the length of the sternum, measured between the most superior aspect of the suprasternal notch and the most caudal aspect of the xyphoid process), $S_{total/2\sim X}$ (the length of the lower half of the sternum), and $S_{total/2\sim D}$ (the distance from the diaphragm to the midpoint of the sternum) were measured from the MDCT images (Fig. 1).

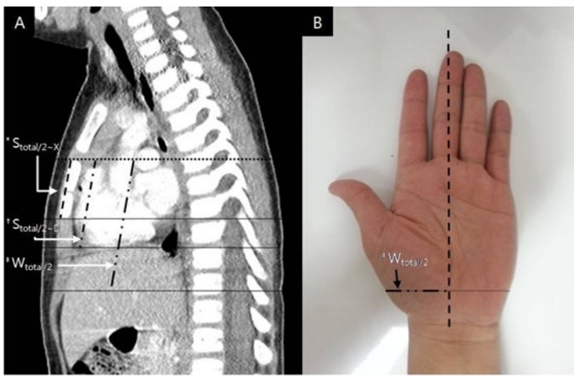

Fig. 1 These images show $S_{total/2\sim X}$, $S_{total/2\sim D}$, and $W_{total/2}$. A) The mid-point of the sternum (··········), $S_{total/2\sim X}$ (– – – –), $S_{total/2\sim D}$ (—— · ——), and $W_{total/2}$ (—— · · —). B) A representative image for the half line for the hand (– – – –) and $W_{total/2}$ (—— · · —)

*$S_{total/2\sim X}$: The length from the midpoint of the sternum to the xiphoid process.
†$S_{total/2\sim D}$: The length from the midpoint of the sternum to the diaphragm.
‡$W_{total/2}$: The half the longest width of an adult hand.

One researcher practiced the extraction of measurement and collected data with Maroview (Infinitt, Seoul, South Korea). Ink stains of the rescuers hand were taken, and they participated in a paediatric CPR simulation on a child manikin covered with paper, in accordance with the *the 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care* [8]. One researcher measured the half of the longest width of the ink stain ($W_{total/2}$). Data were compiled using SPSS for Windows (version 15.0; SPSS, Inc., Chicago, IL, U.S.A.) and are presented as means and standard deviations or percentages. Data were analysed with Mann-Whitney or chi square tests and results were considered significant if the *p*-value was less than 0.05.

III. Results

Of 429 children were reviewed, 128 were excluded as 51 were children whose height or body weight were not recorded, as 72 were not within normal percentile height and body weight, as 5 were children who had diseases that could shift mediastinal organs. This study enrolled 301 children with a mean age of 12.05 ± 5.59 years. Of the studied children, 199 were boys (66.1%). The mean height and body weight were 146.73 ± 30.75 cm and 47.07 ± 22.52 kg, respectively. The mean S_{total} was 14.37 ± 3.50 cm and $S_{total/2\sim X}$ and $S_{total/2\sim D}$ were 7.19 ± 1.75 cm and 7.07 ± 2.11 cm, respectively. The study also enrolled 47 adult rescuers with a mean age of 23.20 ± 2.13 years, of whom 25 were men (53.2%). The mean height and body weight of the rescuers were 170.47 ± 8.41 cm and 62.26 ± 11.30 kg, respectively, and the mean $W_{total/2}$ was 4.62 ± 0.46 cm. The diagnoses of the enrolled children included pneumonia (31.6%), lung contusion (23.6%), viral infection (16.3%), pulmonary tuberculosis (14.6%), leukaemia (6.6%), asthma (3.0%), foreign body in the oesophagus (2.3%), brain haemorrhage (1.0%), lupus nephritis (0.7%), and urinary tract infection (0.3%). The mean subtraction of $W_{total/2}$ from $S_{total/2\sim X}$ and $S_{total/2\sim D}$ in 1-year-old children was 1.25±0.44 and -0.11±0.68, respectively. The mean subtraction of $W_{total/2}$ from $S_{total/2\sim X}$ and $S_{total/2\sim D}$ in 2-year-old children was -0.47±0.69 and -0.49±0.70, respectively. Among the 1-year-old children, 9 (100.0%) had $S_{total/2\sim D}$ less than $W_{total/2}$, and 6 (66.7%) had $S_{total/2\sim X}$ less than $W_{total/2}$. Among those aged 2 years, 6 (60.0%) had $S_{total/2\sim D}$ less than $W_{total/2}$, and 8 (80.0%) had $S_{total/2\sim X}$ less than $W_{total/2}$. Among those aged 3 years, 4 (26.7%) had $S_{total/2\sim D}$ less than $W_{total/2}$, and 7 (46.7%) had $S_{total/2\sim X}$ less than $W_{total/2}$. Among those aged 4 years, 2 (13.3%) had $S_{total/2\sim D}$ less than $W_{total/2}$, and 5 (33.3%) had $S_{total/2\sim X}$ less than $W_{total/2}$. However, $S_{total/2\sim X}$ and $S_{total/2\sim D}$ were greater than $W_{total/2}$ in children aged 5 years or more. The height, body weight, $S_{total/2\sim X}$, and $S_{total/2\sim D}$ of the children at each age, from 1 year to 18 years, are summarized in Table I, I, and III.

TABLE I
Height, body weight, and chest measurements by age (Mean ± S.D.) cm

Age	Number(%)	Height	Body weight	$S_{total/2\sim X}$	$S_{total/2\sim D}$
1	9(3.0)	79.26±3.21	10.05±0.85	3.37±0.44	4.51±0.68
2	10(3.3)	89.93±4.50	13.93±2.77	4.15±0.69	4.13±0.70
3	15(5.0)	97.52±2.34	14.83±1.86	5.05±0.98	4.70±0.82
4	15(5.0)	101.32±6.29	16.34±2.41	5.44±0.94	5.02±0.70
5	9(3.0)	108.00±7.26	20.52±2.56	5.95±0.66	5.41±0.49
6	9(3.0)	117.34±8.71	21.90±3.58	5.80±0.41	5.46±0.86
7	11 (3.7)	124.87±6.30	27.04±3.16	6.15±0.47	5.71±0.81
8	16(5.3)	128.13±7.13	29.45±6.66	6.03±0.51	6.03±1.21
9	10(3.3)	132.95±3.69	30.99±4.95	6.46±0.36	5.56±0.49
10	9(3.0)	138.87±15.14	34.32±8.24	6.52±0.53	6.02±1.27
11	4(1.3)	139.88±13.60	43.55±1.36	6.50±0.61	6.08±1.15
12	11(3.7)	156.07±4.03	54.55±6.55	6.55±0.78	7.83±1.59
13	11(3.7)	153.79±11.59	49.47±11.67	7.68±1.12	7.68±1.36
14	14(4.7)	163.87±6.14	49.41±11.09	8.21±0.76	8.23±1.48
15	18(6.0)	171.29±7.50	63.87±8.29	8.20±1.24	9.05±1.66
16	36(12.0)	168.56±10.74	63.72±10.53	8.19±1.19	8.01±2.04
17	45(15.0)	171.17±7.62	66.38±10.94	8.62±1.24	8.01±1.74
18	49(16.3)	171.91±5.90	67.27±10.40	8.42±0.95	8.36±1.99

*$S_{total/2\sim X}$: The length from the midpoint of the sternum to the xiphoid process. †$S_{total/2\sim D}$: The length from the midpoint of the sternum to the diaphragm.

TABLE II
COMPARISON OF MEASUREMENTS BETWEEN MALE AND FEMALE SUBJECTS BY AGE (MEAN ± S.D.) CM

Age	Sex	Height	*P*	Body weight	*P*	$S_{total/2\sim X}$*	*P*	$S_{total/2\sim D}$†	*P*
1	M	79.09±3.66	0.67	10.09±0.98	0.89	3.37±0.30	0.99	4.36±0.56	0.67
	F	79.85±1.20		9.91±0.13		3.40±0.99		5.05±1.06	
2	M	92.50±3.99	0.10	13.88±1.10	0.42	4.07±0.74	0.84	4.41±0.77	0.31
	F	87.36±3.63		13.98±4.00		4.23±0.71		3.85±0.57	
3	M	99.08±2.80	0.07	15.63±0.66	0.09	5.68±0.51	0.05	5.09±0.59	0.11
	F	96.48±1.29		14.29±2.23		4.63±1.02		4.43±0.88	
4	M	101.87±7.04	0.87	17.05±2.35	0.34	5.85±0.61	0.15	5.11±0.59	0.87
	F	100.84±6.00		15.71±2.44		5.08±1.07		4.95±0.82	
5	M	110.67±3.20	0.26	21.28±1.86	0.26	6.01±0.54	0.91	5.41±0.55	0.91
	F	102.67±11.02		19.00±3.50		5.83±0.99		5.40±0.46	
6	M	114.52±9.50	0.17	21.73±3.68	0.71	5.92±0.41	0.38	5.45±1.08	0.55
	F	123.00±2.50		22.23±4.13		5.57±0.36		5.47±0.20	
7	M	124.07±6.71	0.58	26.44±3.21	0.22	6.08±0.49	0.33	5.81±0.86	0.33
	F	128.50±2.12		29.70±0.42		6.50±0.00		5.25±0.35	
8	M	130.23±6.31	0.18	30.56±7.24	0.15	6.07±0.60	0.71	6.28±1.39	0.49
	F	124.63±7.56		27.60±5.68		5.95±0.35		5.60±0.75	
9	M	133.71±3.64	0.52	32.07±4.57	0.52	6.56±0.36	0.18	5.64±0.54	0.67
	F	131.17±3.82		28.47±5.82		6.22±0.26		5.38±0.34	
10	M	137.88±17.87	0.91	34.58±11.36	0.91	6.40±0.69	0.19	6.48±1.47	0.19
	F	140.10±13.47		34.00±2.94		6.68±0.22		5.45±0.80	
11	M	146.50±3.76	0.50	44.07±1.08	0.50	6.80±0.13	0.50	6.14±1.40	0.99
	F	120.00±0.00		42.00±0.00		5.60±0.00		5.90±0.00	
12	M	155.90±3.12	0.92	54.85±7.55	0.78	6.60±0.91	0.63	7.90±1.75	0.63
	F	156.53±6.83		53.77±3.70		6.40±0.28		7.63±1.37	
13	M	156.58±12.98	0.33	54.26±12.05	0.33	7.95±1.03	0.54	7.41±1.20	0.66
	F	151.47±10.93		45.48±10.67		7.46±1.23		7.91±1.55	
14	M	165.65±3.81	0.37	52.08±11.59	0.19	8.28±0.88	0.99	8.36±1.68	0.95
	F	159.43±9.10		42.73±6.85		8.03±0.36		7.90±0.90	
15	M	173.04±7.49	0.13	64.78±9.22	0.55	8.77±0.90	0.01	9.40±1.65	0.10
	F	167.80±6.77		62.03±6.37		7.06±1.03		8.35±1.56	
16	M	172.66±10.04	<0.01	67.85±9.87	<0.01	8.48±1.28	0.02	8.48±2.27	0.09
	F	161.31±7.91		56.72±7.68		7.68±0.84		7.19±1.22	
17	M	172.12±7.31	0.21	69.37±10.38	<0.01	9.06±0.95	<0.01	8.02±1.71	0.97
	F	168.26±8.15		57.42±7.18		7.28±1.07		7.99±1.91	
18	M	172.71±5.62	0.11	69.92±9.50	<0.01	8.65±0.91	<0.01	8.70±2.01	0.07
	F	169.72±6.33		59.94±9.49		7.79±0.80		7.42±1.64	

*$S_{total/2\sim X}$: The length from the midpoint of the sternum to the xiphoid process.
†$S_{total/2\sim D}$: The length from the midpoint of the sternum to the diaphragm.

TABLE III
RESULTS OF THE DIFFERENCE BETWEEN $S_{TOTAL/2\sim X}$ AND $S_{TOTAL/2\sim D}$ AND $W_{TOTAL/2}$ BY AGE

Age	$S_{total/2\sim X}$ - $W_{total/2}$ (Mean ± S.D.)	$S_{total/2\sim D}$ - $W_{total/2}$ (Mean ± S.D.)	$W_{total/2}$>$S_{total/2\sim D}$ Number (%)	$W_{total/2}$> $S_{total/2\sim X}$ Number (%)
1	-1.25±0.44	-0.11±0.68	9(100.0)	6(66.7)
2	-0.47±0.69	-0.49±0.70	6(60.0)	8(80.0)
3	0.43±0.98	0.08±0.82	4(26.7)	7(46.7)
4	0.82±0.94	0.40±0.70	2(13.3)	5(33.3)
5	1.33±0.66	0.79±0.49	0(0.0)	0(0.0)
6	1.18±0.41	0.84±0.86	0(0.0)	0(0.0)
7	1.53±0.47	1.09±0.81	0(0.0)	0(0.0)
8	1.41±0.51	1.41±1.21	0(0.0)	0(0.0)
9	1.84±0.36	0.94±0.49	0(0.0)	0(0.0)
10	1.90±0.53	1.40±1.27	0(0.0)	0(0.0)
11	1.88±0.61	1.46±1.15	0(0.0)	0(0.0)
12	1.93±0.78	3.21±1.59	0(0.0)	0(0.0)
13	3.06±1.12	3.06±1.36	0(0.0)	0(0.0)

14	3.60±0.76	3.61±1.48	0(0.0)	0(0.0)
15	3.58±1.24	4.43±1.66	0(0.0)	0(0.0)
16	3.57±1.19	3.39±2.04	0(0.0)	0(0.0)
17	4.00±1.24	3.39±1.74	0(0.0)	0(0.0)
18	3.80±0.95	3.74±1.99	0(0.0)	0(0.0)

*$S_{total/2\sim X}$: The length from the mid- point of the sternum to the xiphoid process.
†$S_{total/2\sim D}$: The length from the mid- point of the sternum to the diaphragm.
‡$W_{total/2}$: The half of the longest width of a adult hand

IV. DISCUSSION

To achieve successful high quality CPR, certain conditions are essential to reduce organ injuries by chest compression and to generate a higher cardiac output. Although complications are more common in adults than in children because of the reduced pliability of the adult rib cage in adults compared to children, children can also be at risk of severe organ injuries from chest compressions, including hepatic rupture, chest wall contusion, retroperitoneal haematoma, epicardial haematoma, pneumothorax, pulmonary interstitial haemorrhage, rib fractures, splenic contusion, stomach perforation, and haemoperitoneum [11]-[13]. It has been reported that chest compression should be practiced at the middle one-third of the sternum to reduce liver injury [9], and that complications such as cardiac contusion, liver injury, and musculoskeletal injuries occurred when the lower part of the sternum was compressed [10]. In this study, $S_{total/2\sim X}$, and $S_{total/2\sim D}$ was less than $W_{total/2}$ in children aged up to 4 years. Although there were differences in some data between male and female subjects aged 15 years or more, those differences would not have affected our results because there were no cases of $S_{total/2\sim X}$ and $S_{total/2\sim D}$ being less than $W_{total/2}$ in children aged 5 years or more. Therefore, based on our measurements, we can recommend that rescuers who practice one-hand chest compression can bear in mind that the risk of intra-abdominal organ injuries may be more prevalent in children aged 1 to 4 years.

There are several limitations to this study. First, the retrospective nature of the study did not clarify whether certain data were compiled according to the guardians' statements rather than clinical findings. Second, the only mode of measurement was via MDCT images. More studies are needed to validate an increased risk of intra-abdominal trauma and the findings of the present study. Third, I did not consider the curve of the children's sternums. Fourth, all enrolled children were breathing by themselves without assisted ventilation, and there are differences in the location of intrathoracic structures between spontaneously breathing children and children with positive pressure ventilation. Fifth, I did not consider the distribution of pressure through different areas of the palm/hand when performing CPR on children. Sixth, this study did not consider the difference in sizes between adult dominant and non-dominant hands. Seventh, the sample size of the study population was small for some ages.

V. CONCLUSION

The results presented by this study conclude that children aged four years or less may be at an increased risk of intra-thoracic trauma during 'one-handed' chest compressions. However, further studies examining the risk of intra-thoracic trauma during 'one-handed' chest compressions in paediatric CPR are needed.

REFERENCES

[1] Nadkarni V, Hazinski MF, Zideman D, et al. Paediatric life support: an advisory statement by the Paediatric Life support Working Group of the International Liaison committee on Resuscitation. Resuscitation 1997;34:115-27.
[2] Mogayzel C, Quan L, Graves Jr., et al. Out-of-hospital ventricular fibrillation in children and adolescents: causes and outcomes. Ann Emerg Med 1995;25:484-91.
[3] Kyriacou DN, Arcinue EL, Peek C, et al. Effect of immediate resuscitation on children with submersion injury. Pediatrics 1994;94:137-42.
[4] Hickey RW, Cohen DM, Strasbaugh S, et al. Pediatric patients requiring CPR in the prehospital setting. Ann Emerg Med 1995;25:495-501.
[5] Berg RA, Kern KB, Hilwig RW, et al. Assisted ventilation does not improve outcome in a porcine model of single-rescuer bystander cardiopulmonary resuscitation. Circulation 1997;95:1635-41.
[6] Berg RA, Sanders AB, Kern KB, et al. Adverse effects of interrupting chest compressions for rescue breathing during cardiopulmonary resuscitation for ventricular fibrillation cardiac arrest. Circulation 2001; 104:2465-70.
[7] Berkowitz ID, Gervais H, Schleien CL, et al. Epinephrine dosage effects on cerebral and myocardial blood flow in an child swine model of cardiopulmonary resuscitation. Anesthesiology 1991;75:1041-50.
[8] 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Part 13. Pediatric basic life support. Circulation 2010;122:S862-75.
[9] Orlowski JP. Optimum position for external cardiac compression in children and young children. Ann Emerg Med 1986;15:667-73.
[10] Hoke RS, Chamberlain D. Skeletal chest injuries secondary to cardiopulmonary resuscitation. Resuscitation 2004;63:327-38.
[11] Thaler MM, Stobie GHC. An improved technique of external cardiac compression in infants and young children. N Engl J Med 1963;269:606-10.
[12] Thaler MM, Krause VW. Serious trauma in children after external cardiac massage. N Engl J Med 1962;267:500.
[13] Bush CM, Jones JS, Cohle SD, et al. Pediatric injuries from cardiopulmonary resuscitation. Ann Emerg Med 1996;28:40-4.