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Clinical paper

The effects of thoracic cage dimension and chest subcutaneous adipose tissue on outcomes of adults with in-hospital cardiac arrest: A retrospective study

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Abstract

Background: The associations between thoracic cage dimension, chest subcutaneous adipose tissue (SAT) depth and outcomes of adults with in-hospital cardiac arrest (IHCA) remain unknown.

Methods: We retrospectively evaluated IHCA patients between January 2016 and October 2017. The thoracic cage transverse diameter, internal AP diameter, cross-sectional area, anterior and posterior SAT depths were measured in computed-tomography (CT) images. Using logistic regression models, we determined the adjusted associations between thoracic cage dimension, SAT depths and the prognosis for IHCA. The primary outcome was sustained return of spontaneous circulation (ROSC) and the secondary outcome was survival to hospital discharge.

Results: Among 423 IHCA patients, 258 patients achieved ROSC and 70 survived to discharge. Smaller cross-sectional area and posterior SAT depth were significantly related to ROSC. Smaller posterior SAT depth was associated with ROSC. After multivariate adjustment, the smaller cross-sectional area was independently associated with ROSC (Odds ratio [OR] 0.99, 95% confidence interval [95%CI] 0.99–1.00; p = 0.008) and survival to discharge (OR 0.99, 95%CI 0.98–1.00; p = 0.024), and the smaller posterior SAT depth was independently related to ROSC (OR 0.65, 95%CI 0.44–0.96; p = 0.030), whereas no relation to survival to discharge was found.

Conclusions: In adults with IHCA, the smaller thoracic cage dimension and posterior SAT depth are associated with better survival. An adjustable compression depth based on the thoracic cage dimension might be better than the "one-size-fits-all" compression depth for resuscitating CA patients. In addition, physicians should pay extra attention to compression efficacy when resuscitating obese patients.

Keywords: Thoracic cage dimension, Cross-sectional area, Subcutaneous adipose tissue, In-hospital cardiac arrest, Compression depth

Introduction

Cardiac arrest is one of the major health problems worldwide. The overall survival rate for out-of-hospital cardiac arrest is about 10%.[1] Despite the development of medical care service, the overall survival of IHCA patients is only about 25%.[2,3]

High quality cardiopulmonary resuscitation (CPR) with adequate compression depth is believed to be associated with improved outcomes of adults with cardiac arrest,[4–7] but increasing evidence has revealed that an adequate but uniform compression depth may not be suitable for all adults with various body sizes. Elevated body mass index (BMI) has been found to be related to better outcomes of patients after cardiac arrest, but inconsistent results were described

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between studies.[8–14] Compared to BMI, the thoracic anteroposterior (AP) diameter is a commonly used parameter to reflect the thoracic cage dimension. Delivery of an adjustable compression depth based on thoracic AP diameter is recommended in pediatric resuscitation guidelines,[15–19] but whether the thoracic cage dimension has impact on the prognosis for adult patients with cardiac arrest remains under debate.[8,20]

Besides thoracic cage dimension, the potential effect of chest SAT layer on outcomes of cardiac arrest has been recognized. Secombe et al. demonstrated the relationship between both anterior and posterior SAT depth and BMI.[21] Using a modified manikin to emulate an obese patient, Secombe et al. further revealed the association between increasing SAT depth and compression inadequacy.[22] But to date, whether the SAT-caused compression inadequacy leads to adverse outcomes of patients with cardiac arrest was unknown.

Therefore, we conducted a retrospective study to explore whether the thoracic cage dimension and SAT depth are associated with outcomes of adult patients with IHCA. We hypothesized that under the current compression depth, patients with smaller thoracic cage dimensions and SAT depths were more likely to obtain better outcomes after IHCA.

Methods

Study design and setting

This was a retrospective study conducted in the emergency department (ED) of West China Hospital. This hospital is a tertiary academic medical center with about 4300 beds. An approximate 200,000 patients visit the ED in each year, and more than 500 IHCA events occur per year. ED visits with the suspected or diagnosed respiratory, cardiovascular, thoracic cage or mediastinal diseases were suggested to underwent chest CT scans if necessary. When an IHCA event happens, junior residents will perform manual CPR immediately. Experienced senior residents and attendants will participate in the following CPR process and start the mechanical CPR with LUCAS devices at once. The endotracheal intubation and epinephrine were administrated routinely. After achieving ROSC, patients were treated with the therapeutic hypothermia if they received further treatment in the emergency intensive care unit (EICU). This study in compliance with the Declaration of Helsinki and was approved by the Human Ethical Committee of West China Hospital. The Ethical Committee waived the informed consent before the study (reference number: 2,019,201).

Study population

We retrospectively screened all patients underwent IHCA in the ED from January 1, 2016 to October 31, 2017. Patients who underwent chest CT scans before IHCA were enrolled into the study. Patients with age younger than 18 years, pregnant, major trauma etiology, without essential data, or with severe thoracic cage deformity which led to measurement difficulty were further excluded.

Outcomes

The primary outcome was sustained ROSC and the secondary outcome was survival to hospital discharge. Definitions of the outcomes were based on the Ustein template. The sustained ROSC was defined as patients with persistent circulation for at least 20 consecutive minutes not required for chest compressions, and the survival to hospital discharge was defined as discharged from hospitals regardless of the outcome or neurological status.[23]

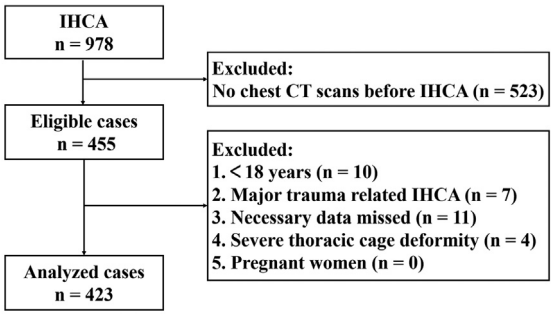

Fig. 1 – Flowchart of the study. IHCA: in-hospital cardiac arrest. CT: computed-tomography.

Data collection

The data of each patient was collected including demographic data, medical history, comorbidities, etiology of IHCA, initial rhythm, and other variables in accordance with the Ustein template.[23] A senior resident checked all the data to make sure the accuracy.

Consecutive CT images of all the patients were transferred into personal computers. Two experienced doctors performed the parameter measurements using the three-dimensional visualization software (Mimics Interactive Medical Image Control System, Version 17.0, Materialize Company, Belgium). Given that the compression position is in the 4th intercostal space level, the measurements were performed in this level. In order to make sure all the measurements were performed in the 4th intercostal space level precisely, the two doctors performed 3D reconstructions of all the thoracic cages before measurement using the Mimics software, and then measured the thoracic cage dimensions and SAT depths respectively (Fig. 2A and B). The final data were calculated out by averaging the data measured by two doctors. The two doctors were skilled in performing 3D reconstruction and dimension measurement with the Mimics software.

Thoracic cage dimension measurements

The measurement tools in the Mimics software were used to measure the following parameters of thoracic cage dimension based on previous studies[24,25]: transverse diameter (A: the maximal distance from the inner surface of rib of one side to the opposite side); internal AP diameter (B: from the inner surface of sternum to the ventral surface of vertebral body); cross-sectional area (C: from the inner surface of the thoracic cage) (Fig. 2B).

SAT depth measurements

SAT depth measurements were taken as follows based on a previous report[21]: anterior SAT depth (D: between the anterior skin surface and sternum); posterior SAT depth (E: between the posterior skin surface and the tip of spinous process). Moreover, we recognized smaller SAT depth from posterior skin surface to rib than to spinous process in some CT images. Considering the whole thoracic cage but not only the

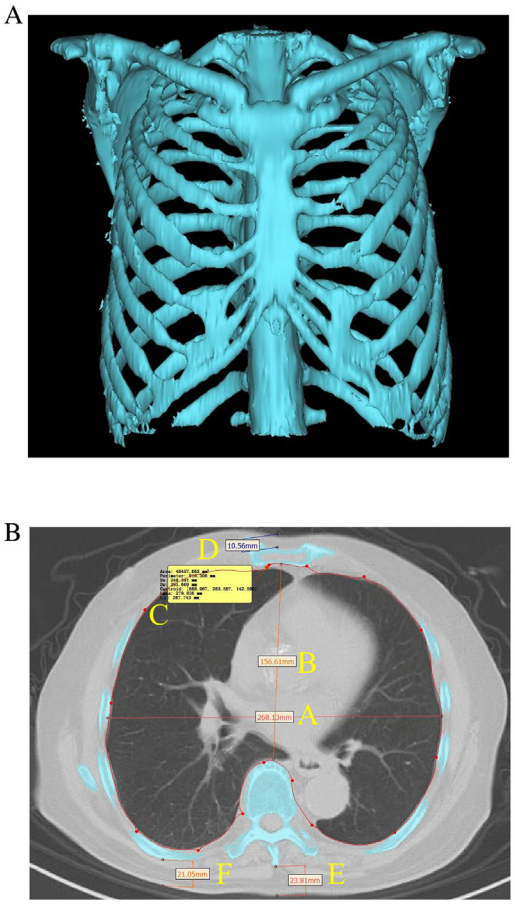

Fig. 2 – (A) Three-dimensional reconstructions of the thoracic cage. (B) Example of the thoracic cage dimension and subcutaneous adipose tissue depth measurement. A. transverse diameter (the maximal distance from the inner surface of rib of one side to the opposite side); B. internal anteroposterior diameter (from the inner surface of sternum to the ventral surface of vertebral body); C. cross-sectional area (from the inner surface of the thoracic cage); D. anterior subcutaneous adipose tissue depth (between the anterior skin surface and sternum); E. posterior subcutaneous adipose tissue depth (between the posterior skin surface and the tip of spinous process). F. subcutaneous adipose tissue depth between the posterior skin surface and rib.

spinous process transmitted the compression force to posterior SAT, we also measured the minimal SAT depth between the posterior skin surface and rib (F) (Fig. 2B).

Statistical analysis

Sample size calculation

We calculated the sample size based on the cross-sectional area as a variable. As the sample size of patient survival to hospital discharge was much smaller than that of ROSC, we selected survival to discharge as the dependent variable. A two-sided significant level was set as 0.05 and the power of the test was set as 90%. Moreover, we expected as least 6 variables could be evaluated simultaneously in the multivariate regression models. Based on the principle that the sample size of dependent variable was required for at least 10 times of variable number, the minimal number of outcome events was 60. Due to an approximate 16% survival to discharge rate was found in our previous studies, at least 375 patients were needed for analysis. We found about 50% of patients underwent chest CT scan before IHCA occurred, therefore, a minimal sample size was about 750. Considering the sample size decrease because of a proportion of patients were excluded before the study, we finally determined a necessary sample size of 950.

The continuous data were expressed as mean ± standard deviation or median and interquartile, and the categorical data were expressed as counts and percentage. The Kolmogorov–Smirnov test was used to assess normality distributions of continuous variables. Normally distributed continuous variables were compared by Student t test, while the continued variables that were not normally distributed were compared by Mann–Whitney U test. Categorical variables were compared by chi-square test. A two-sided p value < 0.05 was considered statistically significant. Logistic regression analysis was used to evaluate outcomes based on variables (odds ratio [OR], 95% confidence interval [CI]). After univariate analysis, variables with p value < 0.15 were considered for multivariate regression analysis to determine the independent factor for outcomes. In multivariate regression model, the p value was set at 0.05. The goodness-of-fit of the logistic regression models were evaluated by the Hosmer–Lemeshow test. All analyses were conducted using SPSS statistical software version 24.0 (IBM Corporation, Armonk, NY).

Results

A total of 978 patients experienced IHCA between January 2016 and October 2017 were screened. Of these, 523 patients without undergoing chest CT scan before IHCA were excluded, 32 patients were further excluded due to the age < 18 years, insufficient data, major trauma etiology, and severe thoracic cage abnormality. No pregnant women with IHCA was excluded. Finally, 423 patients were included in the final analysis (Fig. 1).

Baseline characteristics

Characteristics of patients were shown in Table 1. Among 423 adults, 291 (69%) were male and the mean age was 61.7 (SD, 18.5) years. Total of 258 (61%) patients achieved ROSC and 70 (16.5%) survived to hospital discharge. The younger age and the initial rhythm of ventricular fibrillation were linked with better outcomes, while patients with longer total CPR duration and the initial rhythm of systole were related to worse outcomes. The characteristics of thoracic cage dimension and SAT depth were shown in Table 2. The mean transverse diameter was 23.4 cm, mean internal AP diameter was 10.9 cm and mean cross-sectional area was 324.3 cm^2. The median anterior SAT depth was 0.6 cm. Thicker posterior SAT layer than anterior SAT was found, and both the mean posterior SAT depth at spinal process and rib was 1.0 cm.

Return of spontaneous circulation

Total of 258 (61%) patients achieved ROSC. Patients with younger age ($p = 0.010$), initial rhythm of ventricular fibrillation ($p < 0.001$), and shorter total CPR duration ($p < 0.001$) were more likely to

Table 1 – Baseline characteristics of patients stratified by outcomes.

Variables	All patients (n = 423)	Return of spontaneous circulation			Survival to hospital discharge		
		Yes (n = 258)	No (n = 165)	*p* Value	Yes (n = 70)	No (n = 353)	*p* Value
Male (%)	291 (69)	183 (71)	108 (66)	0.236	45 (64)	246 (70)	0.373
Age (y) (mean, SD[a])	61.7 (18.5)	59.8 (19.0)	64.5 (17.3)	0.010	56.3 (20.4)	62.7 (17.9)	0.016
Initial rhythm							
Ventricular fibrillation, n (%)	55 (13)	48 (19)	7 (4)	<0.001	16 (23)	39 (11)	0.007
Pulseless ventricular tachycardia, n (%)	5 (1)	3 (1)	2 (1)	0.974	2 (3)	3 (1)	0.416
Asystole, n (%)	363 (86)	207 (80)	156 (95)	<0.001	52 (74)	311 (88)	0.002
Total CPR[b] duration (min) (median, IQR[c])	30 (10, 51)	16 (5.5, 48)	38 (30, 58.5)	<0.001	5.5 (2, 10)	34 (18.3, 57)	<0.001
Cardiac cause of cardiac arrest, n (%)	69 (16)	42 (16)	27 (16)	0.982	13 (19)	56 (16)	0.575
Therapeutic hypothermia, n (%)	136 (32)	–	–	–	38 (54)	98 (28)	<0.001
Comorbidities							
Neurological insufficiency, n (%)	98 (23)	57 (22)	41 (25)	0.512	16 (23)	82 (23)	0.946
Heart disease							
Heart failure, this admission, n (%)	56 (13)	37 (14)	19 (12)	0.403	14 (20)	42 (12)	0.068
Heart failure, prior admission, n (%)	31 (7)	16 (6)	15 (9)	0.266	8 (11)	23 (7)	0.150
Myocardial infarction, this admission, n (%)	12 (3)	7 (3)	5 (3)	0.848	2 (3)	10 (3)	0.991
Myocardial infarction, prior admission, n (%)	58 (14)	44 (17)	14 (9)	0.012	12 (17)	46 (13)	0.361
Arrythmia, n (%)	56 (13)	35 (14)	21 (13)	0.804	10 (14)	46 (13)	0.777
Hypertension, n (%)	78 (18)	40 (16)	38 (23)	0.052	9 (13)	69 (20)	0.187
Hypotension, n (%)	8 (2)	4 (2)	4 (2)	0.781	1 (1)	7 (2)	1.000
Coronary artery disease, n (%)	37 (9)	25 (10)	12 (7)	0.391	5 (7)	32 (9)	0.603
Respiratory insufficiency, n (%)	155 (37)	100 (39)	55 (33)	0.259	34 (49)	121 (34)	0.023
Hepatic insufficiency, n (%)	82 (19)	47 (18)	35 (21)	0.447	11 (16)	71 (20)	0.395
Renal insufficiency, n (%)	103 (24)	63 (24)	40 (24)	0.967	14 (20)	89 (25)	0.353
Diabetes, n (%)	83 (20)	56 (22)	27 (16)	0.177	14 (20)	69 (20)	0.930
Sepsis, n (%)	64 (15)	40 (16)	24 (15)	0.788	11 (16)	53 (15)	0.881
Metastatic malignancy, n (%)	49 (12)	33 (13)	16 (10)	0.332	8 (11)	41 (12)	0.965

Abbreviations: [a]SD, standard deviation; [b]CPR, cardiopulmonary resuscitation; [c]IQR, interquartile range.

Table 2 – Thoracic cage dimension and SAT depth parameters of patients stratified by outcomes.

Variables	All patients (n = 423)	Return of spontaneous circulation			Survival to hospital discharge		
		Yes (n = 258)	No (n = 165)	*p* Value	Yes (n = 70)	No (n = 353)	*p* Value
Thoracic cage dimension parameters							
Transverse diameter (cm) (mean, SD[a])	23.4 (2.0)	23.3 (1.8)	23.5 (2.2)	0.398	23.1 (1.6)	23.4 (2.0)	0.093
Anteroposterior diameter (cm) (mean, SD)	10.9 (1.6)	10.8 (1.6)	11.0 (1.7)	0.268	10.7 (1.8)	11.0 (1.6)	0.156
Cross-sectional area (cm^2) (mean, SD)	324.3 (48.7)	317.7 (44.0)	334.5 (53.7)	0.001	308.0 (40.6)	327.5 (49.5)	0.002
SAT[b] depths							
Anterior SAT depth (cm) (median, IQR[c])	0.6 (0.4, 0.9)	0.6 (0.4, 0.9)	0.6 (0.4, 0.9)	0.429	0.6 (0.4, 1.0)	0.6 (0.4, 0.9)	0.895
Posterior SAT depth at spinous process (cm) (median, IQR)	1.0 (0.6, 1.4)	1.0 (0.6, 1.4)	1.0 (0.6, 1.6)	0.278	1.0 (0.6, 1.3)	1.0 (0.6, 1.5)	0.594
Posterior SAT depth at rib (cm) (median, IQR)	1.0 (0.6, 1.4)	1.0 (0.6, 1.3)	1.1 (0.6, 1.5)	0.045	1.0 (0.6, 1.3)	1.0 (0.6, 1.4)	0.416

Abbreviations: [a]SD, standard deviation; [b]SAT, subcutaneous adipose tissue; [c]IQR, interquartile range.

achieve ROSC (Table 1). Adults who obtained ROSC had significantly smaller cross-sectional area ($p = 0.001$), and posterior SAT depth between skin surface and rib ($p = 0.045$), whereas no relationship between the transverse diameter, internal AP diameter and ROSC was found (Table 2). After the confounder adjustment using multivariate regression model, the smaller cross-sectional area (OR 0.99, 95%CI 0.99–1.00; $p = 0.008$) and larger posterior SAT depth between skin surface and rib (OR 0.65, 95%CI 0.44–0.96; $p = 0.030$) remained independently associated with ROSC (Table 3).

Survival to hospital discharge

In patients obtaining ROSC, 70 (16.5%) survived to hospital discharge. Patients with younger age ($p = 0.016$), initial rhythm of ventricular fibrillation ($p = 0.007$), shorter total CPR duration ($p < 0.001$) and therapeutic hypothermia treatment ($p < 0.001$) were more possible to survival to discharge (Table 1). Smaller cross-sectional area was associated with survival to discharge ($p = 0.002$), while no association was found between the transverse diameter, internal AP diameter and survival to discharge (Table 2). After the

Table 3 – Logistic regression models of variables associated with return of spontaneous circulation.

Variables	Univariate regression model			Multivariate regression model		
	Odds ratio	95% Confidence interval	*p* Value	Odds ratio	95% Confidence interval	*p* Value
Age	0.99	0.98, 1.00	0.011	0.98	0.97, 1.00	0.008
Total CPR[a] duration	0.98	0.97, 0.99	<0.001	0.98	0.97, 0.99	<0.001
Ventricular defibrillation	5.16	2.27, 11.71	<0.001	8.12	1.06, 62.05	0.044
Asystole	0.23	0.11, 0.49	<0.001	1.07	0.17, 6.78	0.942
Myocardial infarction, piror admission	2.22	1.17, 4.19	0.014	2.14	1.08, 4.24	0.030
Cross-sectional area	0.99	0.99, 1.00	0.001	0.99	0.99, 1.00	0.008
Posterior SAT[b] depth between skin surface and rib	0.66	0.47, 0.93	0.017	0.65	0.44, 0.96	0.030

The Hosmer–Lemeshow goodness-of-fit test: $p = 0.108$.
Abbreviations: [a]CPR, cardiopulmonary resuscitation; [b]SAT, subcutaneous adipose tissue.

multivariate adjustment, smaller cross-sectional area was independently related to survival to discharge (OR 0.99, 95%CI 0.98–1.00; $p = 0.024$). No association between posterior SAT depth and survival to discharge was found (Table 4).

Discussion

In this retrospective study, we explored the impact of thoracic cage dimension and SAT depth on outcomes of patients with IHCA. Besides the thoracic internal AP diameter, we also used the cross-sectional area at the 4th intercostal space level to evaluate the thoracic cage dimension. We demonstrated that smaller cross-sectional area was independently associated with improved outcomes, while no relation between the thoracic internal AP diameter and the outcomes was found. Moreover, the larger posterior SAT depth between skin surface and rib was found to be related to adverse survival. To our best knowledge, this is the first study that demonstrated the association between cross-sectional area and prognosis for IHCA. Moreover, this is the first study that revealed the potential impact of posterior SAT depth on IHCA outcomes which had been ignored before.

Thoracic cage dimension and outcomes

Several studies demonstrated that a compression depth of one-third of the chest AP diameter was appropriate for children resuscitation,[17–19] while inconsistent results were found in studies of adult patients. Lee et al. showed that a uniform compression depth was not suitable for all adults with various thoracic internal AP diameters. Considering the balance between efficiency and safety, a depth between one-third and one-fourth of external AP diameter was appropriate.[20] On the contrary, Wang et al. found no strong relationship between thoracic external AP diameter and neurological outcomes for IHCA patients, while only the patients with BMI $> 23.2\,kg/m^2 \times$ thoracic external AP diameter $> 18.5\,cm$ were associated with worse outcomes.[8] Similarly, no relationship between thoracic internal AP diameter and survival of IHCA was found in our study, but the smaller cross-sectional area was found to be independently related to improved outcomes of patients experienced IHCA.

The findings of our study can be partially explained in terms of the physiologic principle of CPR. High quality chest compressions lead to intrathoracic pressure augment and then provide systemic blood flow to maintain the threshold levels of coronary and cerebral perfusion.[5,26] For patients with smaller thoracic cage dimensions, adequate compression depth means more of the thoracic cage compression ratio, which causes greater intrathoracic pressure increase and subsequently generates better systemic blood perfusion. But for patients with larger thoracic cage dimensions, current compression depth means a lesser thoracic cage compression ratio which might not generate adequate blood flow to peripheral vital organs.

Although smaller thoracic cage dimension was found to be associated with improved outcomes for IHCA, we do not suggest a deeper compression depth should be performed on patients with

Table 4 – Logistic regression models of variables associated with survival to hospital discharge.

Variables	Univariate regression model			Multivariate regression model		
	Odds ratio	95% Confidence interval	*p* Value	Odds ratio	95% Confidence interval	*p* Value
Age	0.98	0.97, 1.00	0.009	0.98	0.96, 0.99	0.005
Total CPR[a] duration	0.91	0.89, 0.93	<0.001	0.90	0.88, 0.93	<0.001
Ventricular circulation	2.39	1.25, 4.57	0.009	0.30	0.03, 3.34	0.329
Asystole	0.39	0.21, 0.73	0.003	0.09	0.01, 0.95	0.045
Therapeutic hypothermia	3.09	1.83, 5.22	<0.001	1.56	0.80, 3.06	0.196
Respiratory insufficiency	1.81	1.08, 3.04	0.025	2.65	1.33, 5.29	0.006
Cross-sectional area	0.99	0.99, 1.00	0.002	0.99	0.98, 1.00	0.024

The Hosmer–Lemeshow goodness-of-fit test: $p = 0.127$.
Abbreviations: [a]CPR, cardiopulmonary resuscitation.

greater thoracic cage dimensions. Optimal compression strategy was a trade-off between the benefit of systemic blood perfusion and risk of compression-related injuries.[27] Several studies have proved that deeper chest compression leads to a higher incidence of CPR-related injury and adverse outcomes.[28] Therefore, whether CA patients with greater cage dimensions would obtain substantial benefit with a deeper compression depth needs further investigation.

Previous studies have demonstrated that the BMI, a parameter used for obesity assessment and may reflect the body size to large extent, may influence the outcomes of cardiac arrest, but the association between BMI and outcomes of patients surviving cardiac arrest remains controversial.[8–14,29] Some studies showed that CA patients with overweight had better outcomes,[9–11,29] while the other studies found the contradictory results.[8,9–14] These contradictory results indicate that there might be no close relationship exists between BMI and outcomes of patients with cardiac arrest. In terms of the physiologic principle of CPR, we suggest that the cross-sectional area is more appropriate for compression depth guidance when delivery CPR.

SAT depth and outcomes

The SAT layer outside the thoracic cage acts like a layer of soft mattress which may reduce the effectiveness of compression,[30] but its potential role has always been ignored before. Secombe et al. described the correlation between increased anterior SAT depth and the chest compression inadequacy using modified manikin, which confirmed the "mattress effect" of chest SAT layer during the CPR performance.[22] But whether the SAT-related compression inadequacy had impact on survival of CA patients remained unknown. We revealed that increased posterior SAT depth between skin surface and ribs was an independent predictor for ROSC. No relationship between anterior SAT depth and ROSC was found in our study, and the significant smaller depth of anterior SAT than posterior SAT might be the explanation. In addition, we noticed the obese patients had much deeper anterior and posterior SAT depth in another study conducted in Australia.[21] While in our study, most of the included patients were Asians who had lower body mass index (BMI) and smaller anterior SAT depth compared to the Australian population. Given the body size and BMI variation exist across different races, the association between anterior SAT depth and possibility of ROSC in obese patients, such as the Australian or American population, needs further investigation.

Practical implications

First, our findings provided insights into the underlying effect of thoracic cage dimension on prognosis for IHCA patients, which may help to take the form of a thoracic cage dimension-adjusted chest compression depth. Second, based on our findings and physiologic principle, we recommend that the cross-sectional area is more appropriate than thoracic internal AP diameter for thoracic cage dimension evaluation. Moreover, we revealed the underlying impact of increased posterior SAT depth on adverse outcomes. Considering the global high prevalence of overweight and obesity,[31,32] the posterior SAT layer may be a common factor influencing compression effectiveness which has always been ignored before. Our results reminded that clinicians should pay extra attention to compression efficiency when resuscitating obese patients.

Limitations

The limitations of this study are as follows: First, the respiration-caused thoracic cage dimension change may affect the final measurement results. Although all the patients were asked for holding the breath at the end of inspiration before the CT scanning, we did not make sure all the patients followed the request, especially for those who were unconscious or felt difficult to hold breath. We neglected this change due to the respiration-caused dimension change was relatively small. Second, patients in our study were limited to those with normal thoracic cage dimensions, 4 patients with severe thoracic cage deformity were excluded. While we showed great interest in the underlying impact of thoracic cage deformity on compression efficacy and outcomes of IHCA, we did not make comparison due to the extremely small sample size. Third, when comparing the muscular patients with strong back muscle to fatty adults with thick back fat layer, whether the same posterior SAT depth has similar effect is unknown. It was not feasible to calculate the fat and muscle proportion accurately in chest CT images. In addition, as a retrospective study, some unmeasured bias may influence the final results.

Conclusion

Smaller thoracic cage dimension and posterior SAT depth are associated with better survival in adult patients with IHCA. An adjustable compression depth based on thoracic cage dimension might be better than the "one-size-fits-all" compression depth for resuscitating CA patients. In addition, physicians should pay extra attention to compression efficacy when resuscitating obese patients.

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Conflict of interest

None of the authors declared conflict of interest. All authors had read and approved the manuscript.

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