Original article

A comparison of dilatation of the right atrium on post-mortem CT between asphyxial death and non-asphyxial death

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Background: The dilatation of the right atrium and the great vein is one of classical Sign of asphyxial death. The diagnosis of dilatation of the right atrium from the autopsy is difficult due to the unclear criteria and unavailability of measuring the organ size while it is still in the body. Post-mortem computed tomography (PMCT) is useful for the study on the dilatation of the right atrium before autopsy.
Objective: This study aimed to compare the size of right atrium measuring with PMCT between the asphyxial and non-asphyxial death.
Methods: The samples of this observational analytic research were a total of 20 bodies, 10 were asphyxial death and 10 were non-asphyxial death. The samples had been examined through PMCT process to measure the diameter of right atrium prior to the autopsy at the Central Institute of Forensic Science, Ministry of Justice. Statistics that were applied for data analysis included mean, standard deviation, and unpaired *t* - test.
Results: The comparison of the size of right atrium revealed that the mean of the right atrium diameter was 4.98 ± 1.13 and 4.85 ± 0.91, respectively. When testing with the statistic method, there was no significant difference between two groups.
Conclusion: No statistically significant differences in the size of the right atrium was found between asphyxial and non-asphyxial death groups, so the size of right atrium cannot be used as part of the diagnosis of asphyxial death.

Keywords: Asphyxia, dilatation of right atrium, post-mortem computed tomography.

Autopsy is a post-mortem examination process, indicated by law, to determine a cause of death when external examination undetermined the cause of death, according to the Criminal Procedure Section 151 which states that "Whenever there is the necessity to find the cause of death, the official holding the post-mortem inquest shall be able to have the power ordering the dissection of the corpse and then the analysis of any portion thereof, or send the corpse or any portion thereof to the government medical officer or analyst." [(1)]

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Autopsy has been the best method to identify the cause of death since it applies the visual inspection of external evidence and the microscopic biopsies. Currently, the forensic examination is bringing the practice of creating the images by various medical tools, particularly the virtopsy. Around the 70's, when computed tomography scan (CT scan) was introduced to forensic clinic for the first time to use with patients who had a head injury from bullets. Moreover, multislice CT (MSCT) and magnetic resonance imaging (MRI) were applied to study and compare the data obtained from the autopsy. Since then, post-mortem computed tomography (PMCT) has been developed constantly to create the 3-D image for the accurate size measurement and displays the clear injury of organs and bones. For this reason, it has been widely used in an autopsy at the Institute of Forensic Medicine both in Thailand and foreign countries.[(2)]

During asphyxia, the disorder of oxygen supply of vital centers of the brain is in the first period of the development of anxiety, fear, general excitation, euphoria, different motor responses (before seizures). Developing stress increases the tone of the sympathetic nervous system, which ensures the development of tachycardia and hypertension. Until the last period of asphyxia, blood pressure is greatly reduced.

Asphyxia death has several indications from the autopsy such as petechial haemorrhages, congestion and edema, cyanosis, engorgement of the right heart and the great vein, and fluidity of blood. However, none of the indications is specific.[3] One of indications is the dilatation of the right atrium and the great vein which could be found in non-asphyxial death such as death from heath failure that causes the dilatation of the right atrium from the increasing level of venous blood and pressure in the heart.[2, 4] However, it is difficult to diagnose the dilatation of the right atrium from the autopsy currently because there are no distinct criteria and the size measurement is impossible without removing the organ from the body. Thus, the results of interpretation mainly depends on the personal expertise of the forensic physician.

At present there are numbers of researches that investigate the dilatation of the heart and thoracic aorta using PMCT and live CT of the chest. In 2003, Shiotani S, *et al.*[5] from Japan, studied the dilatation of heart of the living and dead persons by comparing the size from the measurement with CT scan. PMCT and live CT data of 50 samples from each group, aged over 20 years old, were examined by measuring the widest and narrowest diameter of the superior vena cava (SVC), inferior vena cava (IVC), pulmonary artery (PA), pulmonary vein (PV), right atrium (RA), and left atrium (LA). They found that PMCT showed the dilatation of the right atrium in spherical shape when compared to live CT. In 2010, Christe A, *et al.*[6] investigated the nature occurrence found from PMCT by applying knowledge of radiology to determine the specific post-mortem signs. The findings showed that the size of right atrium enlarged after death due to the post-mortem congestion except from the corpse died from exsanguination.

In 2011, Eifer DA, *et al.*[7] from Canada, investigated the size of cardiac chambers with chest CT to determine the abnormal dilatation of the cardiac chamber in female and male by comparing to the standard reference of cardiac MRI. They found that right atrium transverse diameter in men (≥ 67 mm) were larger than in women (≥ 64 mm). Later in 2014, Sogawa N, *et al.*[8], from Japan, studied on the application of PMCT to measure the circumference and cross sectional area, and to calculate the vessel flattening index (vFI) of SVC, IVC, thoracic and abdominal aorta to determine the relationship between the measured value and the cause of death with 93 samples that had been performed both a PMCT and an autopsy. The results showed that the vFI of the abdominal aorta and inferior vena cava was low in hyperthermia (heatstroke), but higher in drowning, hypothermia (cold exposure) and sudden cardiac death. Furthermore, Sogawa N, *et al.*[9] studied the application of PMCT to measure virtual volumetry of the heart and lung *in situ* to identify the association of the measured value and the terminal cardiopulmonary pathophysiology in 70 samples that had the autopsy and the hearts and lungs were weighed and the cardiac volume was measured in order to compare with the cardiac volume obtained from PMCT. The findings showed that volume ratio of the lung to heart was higher in drowning, lower in SCD, and intermediate or varied in other groups; high and low ratios can indicate predominant/antecedent pulmonary and cardiac dysfunctions, respectively. In 2016, Michiue T, *et al.*[10] from Japan, examined the data obtained from the autopsy and PMCT by measuring the cardiac weight with PMCT to calculate the difference in the ratio to the actual cardiac weight from the autopsy before calculating cardiac dilatation index (CDI) to identify the terminal central congestion of the various causes of death. The CDI was significantly lower in fatal hyperthermia (heatstroke) than in drowning, fatal methamphetamine abuse, alcohol/sedative hypnotic intoxication and SCD.

It is known that international forensic institutions have implemented PMCT to the researches along with the data obtaining from the autopsy. However widely, there are only few researches in Thailand that apply the use of PMCT. These could cause in the limitation of computed tomography results. Moreover, the autopsy does not have the clear criteria for measuring the size of right atrium. Therefore, the researcher would like to study by comparing the size of right atrium on PMCT between the asphyxial and non-asphyxial death. The research hypothesis is to identify the difference in size of the right atrium between asphyxial and non-asphyxial deaths.

Materials and methods

Research design, population and sample

The research on the comparison of the dilatation of the right atrium on post-mortem computed tomography between the asphyxial and non-asphyxial death applied the observational analytic approach.

The Research Ethics Committee, Faculty of Medicine, Chulalongkorn University, has certified to give the exemption from ethics consideration to the research base on the Institutional Review Board (IRB) no. 822/63, Certificate of Exemption no. 047/2020.

The total numbers of samples were 20 corpses: 10 from the asphyxia death and the other from non-asphyxial death; they had been examined through post-mortem CT before the autopsy at the Central Institute of Forensic Science, Ministry of Justice during 2017 - 2020. The following corpses were not qualified as samples for this study because they met the exclusion criteria.

The exclusion criteria were as follow:

- Corpses with the history of treatment with chest compression, resuscitation procedure or intravenous therapy.
- Corpses with the history of chest injury, severe blood loss or large external wound.
- Corpses with history of heart disease such as heart failure, aortic dissection, abnormal aortic valve, and heart surgery.
- Decomposed body.
- Aged under 20 years old.

Methods

The corpses used in this research involved the corpses that were performed the autopsy without cold storage and those with cold storage at 4°C for not over 24 hours. Then, the corpses were processed with CT scan using Toshiba, Aquilion Lightning with the setting as shown in Table 1, in the room with the temperature at 20 - 25°C and projecting the image via RadiAnt DICOM Viewer before processing the standard autopsy.

The diameter of the right atrium of each corpse was measured starting from locating a position of aortic valve where the right coronary artery split off in the plane axial view (Figure 1).

Then, the area under the aortic valve was identified for 3.0 cm. in the plane coronal view (Figure 2) to measure the widest diameter of the right atrium to be vertical with the atrioventricular septum in the plane axial view (Figure 3).

Data collection

Coordinated with the Central Institute of Forensic Science, Ministry of Justice to obtain the data, which was the statistic of the dead person during 2017 – 2020, their background, cause of death, CT scan images, and photos during the autopsy process.

Statistical analysis

The minimum and maximum value, the average paired mean with the standard deviation were analyzed using Microsoft Excel 2019. Then, the data distribution was illustrated with box plot and the difference of mean of both population group was assessed using unpaired t – test from Microsoft Excel 2019 was tested. Data were expressed as mean ± standard deviation (SD). P - value < 0.05 was considered statistically significant.

Results

Demographic data

From the total of 20 selected corpses, eight of them in the group of asphyxia death were male and two were female. Nine of them were identified the age while the only one was unidentified. For the group of non-asphyxia death, 3 of them were male while 7 were female. The average and standard deviation of the age, height, weight, body mass index, and cardiac weight obtained from the autopsy are detailed in Table 2.

Table 1. Settings of CT scan.

	Rotation time (s)	Tube voltage (kV)	Tube current (mA)	Slice collimation (mm)	Pitch	Total scan time (s)
Head and neck	0.6	120	200	0.5 x 16 x 0.3	0.69	37
Body	0.6	120	150	1 x 16 x 0.8	0.94	34

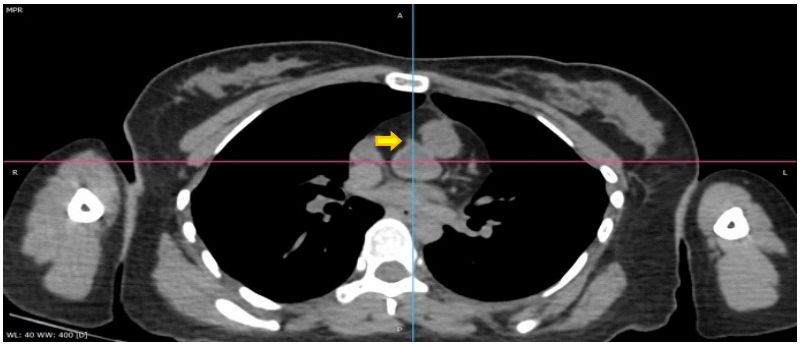

Figure 1. The position of aortic valve where the right coronary artery split off (the yellow arrow) in the plane axial view.

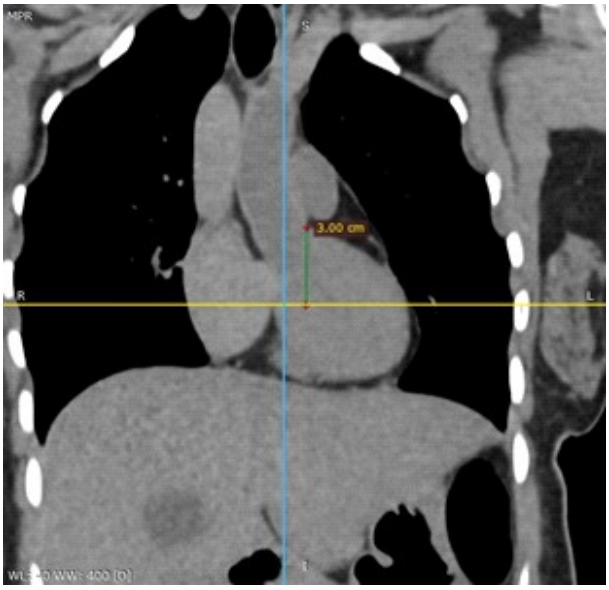

Figure 2. The area of 3 cm. under the aortic valve in the plane coronal view.

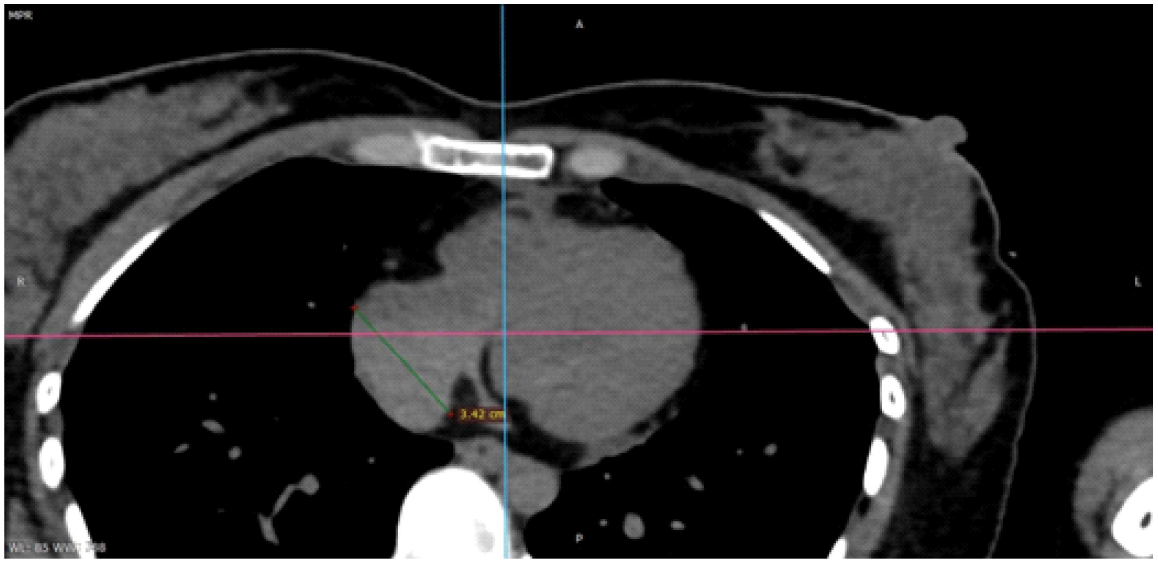

Figure 3. Measuring the widest diameter of the right atrium to be vertical to the atrioventricular septum in the plane axial view.

Table 2. Average and standard deviation of age, height, weight, body mass index, cardiac weight, and diameter of the right atrium obtained from the autopsy and CT scan.

	Corpses from asphyxia death		Corpses from non-asphyxia death	
	Average	Standard deviation	Average	Standard deviation
Age (year)	47.8	10.6	37.9	8.6
Height (cm.)	162.9	10.1	159.1	19.4
Weight (kg.)	46.4	6.3	55.3	6.7
Body mass index (kg./m²)	17.4	0.8	21.5	5.8
Cardiac weight (g.)	265.7	29.4	341.6	135.4
Diameter of the right atrium (cm.)	4.98	1.13	4.85	0.91

All selected corpses were processed with CT scan prior to the autopsy at the Central Institute of Forensic Science, Ministry of Justice. The causes of death that the physician diagnosed were analyzed using the data from autopsy and CT scan analysis, as well as causes of death are shown in Table 3.

Size of the right atrium diameter

The mean and standard deviation of the widest diameters of the right atrium in the plane axial view of the corpses from asphyxial and non-asphyxial death were distributed as shown in Table 2.

Comparison of the diameters of the right atrium of the corpses from asphyxial and non-asphyxial death

The data of diameters of the right atrium of the corpses from both groups were tested to identify the mean difference. Subsequent analysis revealed that the mean of diameters of the right atrium of the corpses from both groups was not significantly different (Table 4).

Table 3. Causes of death identified from the autopsy and CT scan analysis.

Cause of death	No. (prs.)
Asphyxial death	
Asphyxia due to neck vessel compression	10
Non-asphyxial death	
Severe head injury	3
Non-traumatic intracranial hemorrhage	2
Pesticide intoxication	2
Pneumonia	1
Sepsis	1
Electrocution	1
Total	**20**

Table 4. Results of unpaired *t* - test to compare the mean of data from both groups.

	N	Mean	SD	*P* - value	Mean difference	95% confidence interval of the difference	
						Lower	Upper
Corpses from asphyxia death	10	4.98	1.13	0.76	0.13	-0.82	1.10
Corpses from non-asphyxia death	10	4.85	0.91				

Discussion

This comparative research compared the size of the right atrium by measuring its diameter from the total of 20 corpses, 10 from the asphyxial death and another 10 from non-asphyxial death. It revealed that the mean of diameter of the right atrium of each group was 4.98 and 4.85 cm. respectively. Further analysis showed that there was significant difference between these two group, which was inconsistent with the hypotheses; the diameter could identify the difference of the right atrium size of the corpse from asphyxia and non-asphyxial death. Because of the post-mortem congestion might lead to the dilatation of right atrium which was in line with the study of Shiotani S.[5] and Christe A.[6]

Generally, the cardiac weight varied to the body weight which affected the size of the right atrium. This research found that the average body weight and cardiac weight of the corpses from non-asphyxial death was 55.3 kg. and 341.6 g. respectively, which were more than those of the corpses from asphyxial death, which were 46.4 kg. and 265.7 g. respectively. Thus, this might be one possible variables that did not cause the difference with a statistical significance to the mean of diameters of the right atrium of the corpses from both groups.

Furthermore, there were some limitation on CT scan without using the contrast media as it is not necessary to use this substance with all post-mortem corpses before the autopsy in Thailand. For this reason, the inaccuracy in the diameter measurement of the right atrium was possible because the septum wall of the right atrium could not be apart from the lumen of the right atrium. Consequently, the septum wall must be measured as well. In general, the average thickness of the septum wall of the right atrium was 2 mm.[11] The researchers measured the diameter of the right atrium in the vertical angle to the axial view, which was the standard anatomical position, not in the 4-chamber view that could view the 4 chambers of the heart at the same time and measure the diameter of the right atrium precisely since it measured in the vertical angle to the apex. However, the plane adjustment required the details of cardiac structure which could not be seen from the CT scan without the contrast media enhancement.

Another limitation was the corpse selection for CT scan before the autopsy which depended on the discretion of the forensic physician. Thus, not all corpses from the aspyxial death were processed with the post-mortem CT, or only the head and neck part that would be processed along with the autopsy of the rotten corpses at the Central Institute of Forensic Science. Therefore, the number of the corpses from asphyxial death was limited. The last limitation is the number of cases of both group is too small to be statistically significant.

Conclusion

No statistically significant differences in the size of the right atrium were found between asphyxial and non-asphyxial death groups. Therefore, the size of right atrium cannot be used as part of the diagnosis of asphyxial death.

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Conflict of interest

The researcher has not received any fund and do not have any conflict of interest in terms of financial or non-financial interest with any authorities.

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