Dokkyo Journal of Medical Sciences
44(1)：25～30，2017

Original

Cerebral-localized Low Density Area on Post-mortem Computed Tomography Images : Retrospective Analysis of the Forensic Autopsy Cases

Kanto Ishii, Shinobu Yamauchi, Akira Kurosu

Department of Legal Medicine, Dokkyo Medical University

SUMMARY

Post-mortem computed tomography (PMCT) can noninvasively visualize abnormal organic findings, and is also often applied in the investigation of the cause of death. We have experienced autopsy cases in which we observed abnormal findings on PMCT images unrelated to the direct cause of death such as cerebral-localized low-density area (CLLDA) without having a history of intracranial disease before death. In this study, we investigated the characteristics of CLLDA in deceased cases. We retrospectively reviewed the autopsy records and police reports provided for 1248 forensic autopsy cases performed at the Dokkyo Medical University School of Medicine, between 1 February 2011 and 28 February 2014. We found 58 autopsy cases that were over 20 years old and had been performed PMCT. Subjects having a history of intracranial disease before death were excluded.

We divided autopsy cases into two groups, one for those with confirmed CLLDA on PMCT images (CLLDA group) and the other for those with no confirmed CLLDA on PMCT images (Control group). The variables obtained from the autopsy records and police reports for each group, and were compared and statistically analyzed.

The prevalence of basilar artery sclerosis and coronary artery stenosis was higher in the CLLDA group ($p=0.022$ and $p=0.005$ respectively). There was no significant difference in left and right ventricular thickness and cardiac weight between the two groups. It was suggested that the finding of CLLDA indicated the probable presence of vascular abnormalities in forensic autopsy.

Key words : forensic autopsy, post-mortem computed tomography, vascular abnormality

INTRODUCTION

Post-mortem imaging can noninvasively visualize abnormal organic findings, and is also often applied in the investigation of the cause of death. There are several post-mortem imaging techniques currently available, such as post-mortem computed tomography (PMCT), and post-mortem magnetic resonance imaging (PMMRI). PMCT is one of the most prevalent techniques used for several reasons : PMCT was reported to more accurately help identify the cause of death than PMMRI[1] ; PMCT can be carried out more quickly and cheaply than PMMRI[1]. PMCT has attracted attention in the fields of pathology, forensic medicine, clinical medicine, and so far, several reported studies have used this tool to investigate the cause of death. It was found that determining cause of death

Received November 8, 2016 ; accepted November 18, 2016
Reprint requests to : Kanto Ishii
Department of Legal Medicine, Dokkyo Medical University, Tochigi 321-0293, Japan

in certain traumatic cases has been done equally accurately with both PMCT and standard autopsy[2]. Observations indicating fatal bleeding disorders, such as intracranial vascular lesions and intra-thoracic hemorrhage, have reportedly been confirmed by PMCT[3]. In addition, PMCT helps ensure the safety of the autopsy operator, since they confirm the presence of internal injury or its by-products, an inferior vena cava filter or weapon debris using PMCT. However, few previous studies focus on abnormal findings on PMCT images unrelated to the direct cause of death.

We have observed in autopsy cases a cerebral localized low-density area (CLLDA) on PMCT images without having a history of intracranial disease before death. However, there has been little reported about CLLDA on PMCT images at forensic autopsy. In this study, we investigate the characteristics of CLLDA using the autopsy findings, police records, and PMCT images in forensic autopsy.

MATERIALS AND METHODS

The Ethics Committee of the Dokkyo Medical University approved this study (Approval number was dmu27004). All data of the autopsy cases were strictly archived in the department database based on autopsy code number. The autopsy records, provided police reports, and PMCT images were perused. In this study, the provided types of post-mortem images were PMCT and post-mortem X-ray. PMCT was performed in all cases from the head to the lower limbs. In this study, since post-mortem X-ray cannot evaluate the cerebral parenchyma, it was excluded. The necessary data were collected and analyzed anonymously without consent due to the retrospective nature of this study.

When the cause of death is unclear from the medical history, circumstances of death, post-mortem imaging or external observations, a forensic autopsy is required to investigate the cause of death. Post-mortem imaging is performed at the neighboring hospital as required by the police or the doctor after confirming death. Because we don't have the CT instrument, we used PMCT images provided by the police as the reference material.

We compared CLLDA on PMCT images with anatomical and pathological findings at the same site. On the other hand, because the imaging conditions such as the slice thickness is different in each autopsy, we analyzed the slice thickness.

Study Subjects

We retrospectively reviewed the autopsy records and related police reports of 1248 forensic autopsy cases from the Dokkyo Medical University School of Medicine, recorded between 1 February 2011 and 28 February 2014. We selected 58 autopsy cases for which the deceased were over 20 years old and performed PMCT. The exclusion criteria were as follows : (1) severe cranial injury ; (2) severe cranial air lesions ; (3) advanced post-mortem change ; (4) neurological abnormalities such as paralysis being subjectively or objectively recognized before death ; and (5) history of intracranial disease.

Data evaluation

PMCT images were interpreted before reviewing the details of the autopsy and police records. Lesions of more than 5 mm in diameter were considered as CLLDA. Detection of CLLDA was performed in the cerebrum, cerebellum and brain stem. We excluded air lesions by the computed tomography (CT) number.

We divided autopsy cases into two groups, one for those with confirmed CLLDA on PMCT images (CLLDA group) and the other for those with no confirmed CLLDA on PMCT images (Control group). The following variables were obtained from autopsy records and police reports, and the two groups were compared for each variable.

(1) Background factors : We examined the physical features at the time of death, including sex, height, weight, body mass index (BMI), age and resuscitation attempts. We also examined the slice thickness which may affect the detection rate of CLLDA used for PMCT.

(2) Autopsy findings : whether the cause of death was classified as a disease or external events. We examined autopsy findings related to the heart and brain as follows : coronary artery stenosis ; basilar artery sclerosis ; left and right ventricular thickness ; cardiac weight ; and presence of intramyocardial white scar. Coronary artery stenosis was defined as

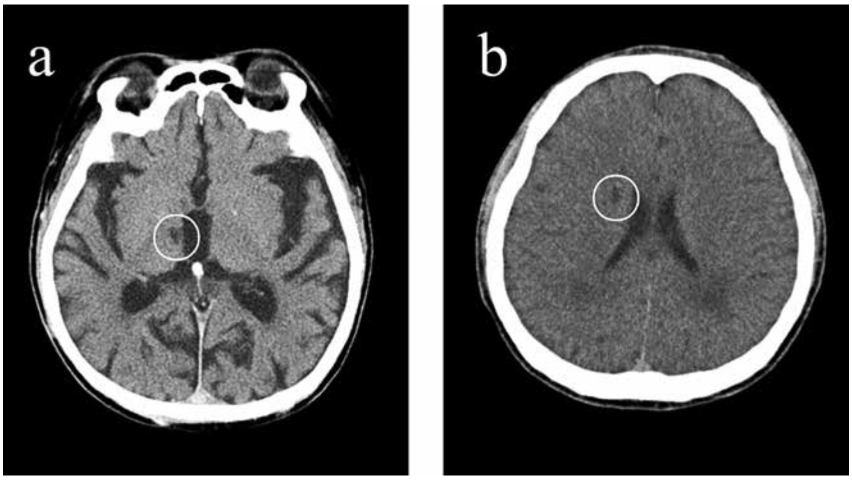

Fig. 1 CLLDA on PMCT images
(**a**) PMCT images from an 84-year-old man. PMCT was performed that slice thickness was 5.0 mm. The cause of death was determined in the autopsy to be freezing. CLLDA was detected in the right thalamus (circled). (**b**) PMCT images from a 42-year-old man. PMCT was performed that slice thickness was 2.0 mm. The cause of death was diagnosed by autopsy as choking. CLLDA was detected in the right corona radiata (circled).

significant stenosis (50% or more stenosis in actual measurement) if observed in any of the left main trunk, left anterior descending coronary artery, left circumflex coronary artery or right coronary artery. We classified basilar artery sclerosis as no sclerosis, mild sclerosis, moderate sclerosis or severe sclerosis, with the last two categories being classed as significant sclerosis.

Imaging conditions for PMCT (slice thickness), cause of death (disease or external events), and resuscitation attempts may affect the interpretation of PMCT. We therefore included a statistical evaluation of the differences in these variables between the two groups in this study.

Statistical Analysis

Categorical data were analyzed using Fisher's exact test. Continuous data were assessing the equality of variances for a variable using Levene's test. Subsequently, the data found to equal variance were analyzed using Student's t-test, or the data found not to equal variance were analyzed using Welch's t test. Data were expressed as a mean ± standard deviation (minimum - maximum). A $p\text{-value} < 0.05$ was considered statistically significant. All statistical analyses were performed with IBM SPSS software version 21.0 for Windows (IBM Japan, Ltd., Tokyo, Japan).

RESULTS

General aspects

The 58 cases had a mean age of 57.8 ± 18 years. The mean height was 162.8 ± 10 cm, mean weight was 61.6 ± 16 kg, and mean BMI was 23.0 ± 5 kg/m^2. Forty-three cases (74.1%) were male. The mean of the slice thickness of PMCT was 5.4 ± 2 (2.0-10.0) mm with the exclusion of one case for which the thickness was not documented. Thirty-four cases (58.6%) were diagnosed in forensic autopsy as death due to disease, and 44 cases (75.9%) included resuscitation attempts. Twenty-six cases (44.8%) showed coronary artery stenosis, and six cases (10.3%) had an intramyocardial white scar. The mean left ventricular thickness was 13.6 ± 2 mm, mean right ventricular thickness was 3.5 ± 1 mm, and mean cardiac weight was 375.5 ± 89 g. Eighteen cases (31.0%) exhibited significant basilar artery sclerosis. Only one autopsy case of 58 cases was found in which CLLDA on PMCT images was pathologically observed as cavitation and gliosis at the same site.

The CLLDA group was made up of 14 cases in total, and the Control group included the other 44 cases. Representative PMCT images from cases in the CLLDA group are shown in Fig 1.

Table 1 Comparison of the CLLDA and Control groups based on PMCT images, conditions and case circumstances

Variables	CLLDA group (N=14)	Control group (N=44)	p-value
Slice thickness of PMCT (mm)	5.4±2 (3.0-10.0)	5.4±2 (2.0-10.0)	1.000
Cause of death (n)			0.218
Disease	6	28	
External events	8	16	
Resuscitation attempts (n)			0.725
Yes	10	34	
No	4	10	

*Statistical significance indicated if $p<0.05$.
The mean of the slice thickness in the Control group was calculated excluding one case for which this information was unknown.

Table 2 Results of variables analyzed for a detailed comparison of the CLLDA and Control groups

Variables	CLLDA group (N=14)	Control group (N=44)	p-value
Height (cm)	158.7±11	164.1±10	0.089
Weight (kg)	50.8±10	65.1±16	0.002*
BMI (kg/m^2) **	20.0±3	24.0±5	0.005*
Age (years)	70.5±16	53.8±17	0.002*
Sex (n)			0.484
Male	9	34	
Female	5	10	
Basilar artery sclerosis (n)			0.022*
Yes	8	10	
No	6	34	
Coronary artery stenosis (n)			0.005*
Yes	11	15	
No	3	29	
Intramyocardial white scar (n)			0.319
Yes	0	6	
No	14	38	
Left ventricular thickness (mm)	14.1±1	13.4±2	0.220
Right ventricular thickness (mm)	3.3±1	3.5±1	0.222
Cardiac weight (g)	354.6±60	382.2±96	0.317

*Statistical significance indicated if $p<0.05$
**Calculated BMI = Weight (kg)/Height (m^2)

Detailed comparison of the CLLDA and Control groups

We examined whether there was bias in the slice thickness of PMCT, cause of death, and resuscitation attempts found in the two groups (Table 1). Post-mortem changes may have hypostasis effects and resuscitation attempts may cause traumatic changes on the interpretation of PMCT images. Additionally, the slice thickness of PMCT may affect the detection of CLLDA. We found no significant differences for these factors. Therefore, we continued with a detailed comparison of other variables for the two groups.

The comparison of physical features and autopsy findings is summarized in Table 2. The prevalence of mean weight and mean BMI were higher in the

Table 3 Comparison of the CLLDA and Control groups in elderly cases (over 60 years)

Variables		CLLDA group (N=10)	Control group (N=17)	p-value
Basilar artery sclerosis (n)				0.237
	Yes	7	7	
	No	3	10	
Coronary artery stenosis (n)				0.001*
	Yes	10	6	
	No	0	11	

* Statistical significance indicated if $p < 0.05$

CLLDA group. There were no significant differences in the mean height for the two groups.

Basilar artery sclerosis and coronary artery stenosis were also more common in the CLLDA group than the Control group, but there was no significant difference in the prevalence of intramyocardial white scar but there were no significant differences in the mean right and left ventricular thicknesses and cardiac weights of the two groups. The number and size of CLLDA in each subject were unrelated to basilar artery sclerosis and coronary artery stenosis.

Since there was significant difference in the mean age between the two groups, we examined basilar artery sclerosis and coronary artery stenosis in elderly subjects (over 60 years old) (Table 3). The prevalence of coronary artery stenosis was observed to have a significant difference. There was no significant difference in the prevalence of basilar artery sclerosis, however, it showed a higher prevalence in the CLLDA group than the Control group (70.0% vs. 41.2%).

DISCUSSION

In this study, it was suggested that the finding of CLLDA indicated the probable presence of vascular abnormalities such as basilar artery sclerosis and coronary artery stenosis in forensic autopsy, however, relation of the presence of intramyocardial white scar was not admitted. Since the facility is limited to perform PMCT using contrast medium[4], in cases where contrast medium cannot be used in PMCT, CLLDA may suggest the need for a detailed anatomical investigation about the vascular abnormalities. PMCT is a useful complement to autopsy by the detection of lesions prior to autopsy and lead to improve the anatomical accuracy. Understanding CLLDA on PMCT images and history before death in advance suggests the regions that need forensic anatomically detailed investigation such as coronary artery and basilar artery.

PMCT is affected by post-mortem changes from immediately after cardiac arrest. Circulatory arrest, starting from the time of death, results in overall brain ischemia. The contrast between white matter and gray matter decreases over time and gradually obfuscates the visible cerebral sulcus[5,6]. The circulation of blood also stops, and the force of gravity causes post-mortem hypostasis throughout the body. This is observed as a high-density area on PMCT images[7]. It was reported that even if the deceased is diagnosed as having a subarachnoid hemorrhage from the findings on PMCT images, false-positive findings are caused by increasing density from hypostasis in the intracranial sinus and dural hemorrhage caused by hypostasis in the tentorium vessels and subsequent bursting[8,9]. The formations of CLLDA exclude air lesions as post-mortem changes. Air lesions have been often observed on PMCT images, caused by resuscitation, putrefaction gas by advanced post-mortem change, and skull base fractures. These lesions can be differentiated from cerebrospinal fluid on PMCT images using the difference in the CT number.

CLLDA is considered to be the imaging findings, such as expanding perivascular space, brain cyst and cerebral infarction, and magnetic resonance imaging helps differentiate them[10]. Liebetrau et al reported that detection rate of CLLDA on ante-mortem CT images was 8.6% in a study of 239 subjects of 85-year-olds living in Sweden[11], although there has been little research of CLLDA using PMCT. Shinkawa et al reported that the prevalence of asymptomatic cerebral infarction, which is one of the pathogenesis indicating CLLDA, was 12.9% in a study of 996 autopsy cases in Japan[12]. Detection rate of CLLDA in our study was 24.1% and was higher than the results of these study, because the slice thickness in the study of using ante-mortem CT was thicker as compared with our study (10 mm vs about 5 mm), and the study of autopsy did not include expanding perivascular space and brain cyst.

In this study, only one autopsy case of 58 cases was found in which abnormal macroscopic and pathologic findings consistent with CLLDA was observed. There was a possibility to be overlooked in cases where cross-section of the lesion was not exposed at autopsy. There was a possibility that CLLDA had not been recorded as an abnormal finding in the case where this was confirmed as perivascular space in forensic autopsy. However, if PMCT is performed correctly and interpreted under appropriate conditions for the study, it can be valuable in detecting micro lesions.

This study had some limitations. We could not diagnose the cause of CLLDA excluding one subject. Because of this study targeting the deceased cases, detailed living conditions such as arteriosclerosis factor while alive were unknown. Further studies are required to confirm diagnosis of detailed CLLDA by PMCT and anatomical and pathological examinations.

In conclusion, this study was the first investigation that suggested an association between CLLDA on PMCT images and coronary artery stenosis, basilar artery sclerosis in forensic autopsy. PMCT is a useful complement to autopsy by the detection of lesions prior to autopsy and lead to improve the anatomical accuracy.

Acknowledgements This work was supported by a grant-in-aid from Dokkyo Medical University, Young Investigator Award (Grant No. 2015-12)

REFERENCES

1) Roberts IS, Benamore RE, Benbow EW, et al : Post-mortem imaging as an alternative to autopsy in the diagnosis of adult deaths : a validation study. Lancet **379** : 136-142, 2012.
2) Le Blanc-Louvry I, Thureau S, Duval C, et al : Post-mortem computed tomography compared to forensic autopsy findings : a French experience. Eur Radiol **23** : 1829-1835, 2013.
3) Takahashi N, Higuchi T, Shiotani M, et al : The effectiveness of post-mortemmultidetector computed tomography in the detection of fatal findings related to cause of non-traumatic death in the emergency department. Eur Radiol **22** : 152-160, 2012.
4) Sakamoto N : Zouei shigo CT. Autopsy imaging guideline third edition, Vectorcore, Tokyo, pp147-151, 2015. (in Japanese)
5) Ishida M, Gonoi W, Okuma H, et al : Common post-mortem computed tomography findings following atraumatic death : differentiation between normal post-mortem changes and pathologic lesions. Korean J Radiol **16** : 798-809, 2015.
6) Shirota G, Gonoi W, Ishida M, et al : Brain swelling and loss of gray and white matter differentiation in human post-mortem cases by computed tomography. PLoS One **10** : e0143848, 2015.
7) Shiotani S, Kohno M, Ohashi N, et al : Post-mortem intravascular high-density fluid level (hypostasis) : CT findings. J Comput Assist Tomogr **26** : 892-893, 2002.
8) Kibayashi K, Shojo H, Sumida T. Dural hemorrhage of the tentorium on post-mortem cranial computed tomographic scans in children. Forensic Sci Int **154** : 206-209, 2005.
9) Takahashi N, Satou C, Higuchi T, et al : Quantitative analysis of intracranial hypostasis : comparison of early postmortem and antemortem CT findings. AJR Am J Roentgenol **195** : 388-393, 2010.
10) Kwee RM, Kwee TC.Virchow-Robin spaces at MR imaging. Radiographics **27** : 1071-1086, 2007.
11) Liebetrau M, Steen B, Hamann GF, et al : Silent and symptomatic infarcts on cranial computerized tomography in relation to dementia and mortality : a population-based study in 85-year-old subjects. Stroke **35** : 1816-1820, 2004.
12) Shinkawa A, Ueda K, Kiyohara Y, et al : Silent cerebral infarction in a community-based autopsy series in Japan. The Hisayama Study. Stroke **26** : 380-385, 1995.