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Case Report

Hypothermic death resulting from extreme freezing with characteristic postmortem computed tomography findings: A case report and review of the literature ☆,☆☆

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ABSTRACT

We report a case of hypothermic death that resulted from extreme freezing, with characteristic postmortem computed tomography (PMCT) findings. A 75-year-old man died in a deeply frozen state. In PMCT, there was a lack of increase in the bilateral lung-field attenuation. Urinary retention, with a hypodense area of frozen urine, was observed in the bladder. Changes that appeared to involve the crystallization of serum in frozen blood were observed in the aorta. Based on the scene and his circumstances, it was speculated that he died of hypothermia. Present case and our review revealed that although PMCT findings from hypothermic death that resulted from deep freezing are very rare, the characteristic PMCT findings may help determine the cause of death.

Introduction

Hypothermic death refers to the endpoint of behavioral and physiological changes caused by a reduction in body temperature. Hypothermic death is usually accidental and results from exposure to extreme environmental temperatures. While the postmortem computed tomography (PMCT) findings associated with hypothermic death have previously been compared with autopsy results [1–8], the PMCT findings of hypothermic death have not been adequately investigated.

Abbreviations: PMCT, postmortem computed tomography; HU, Hounsfield unit.

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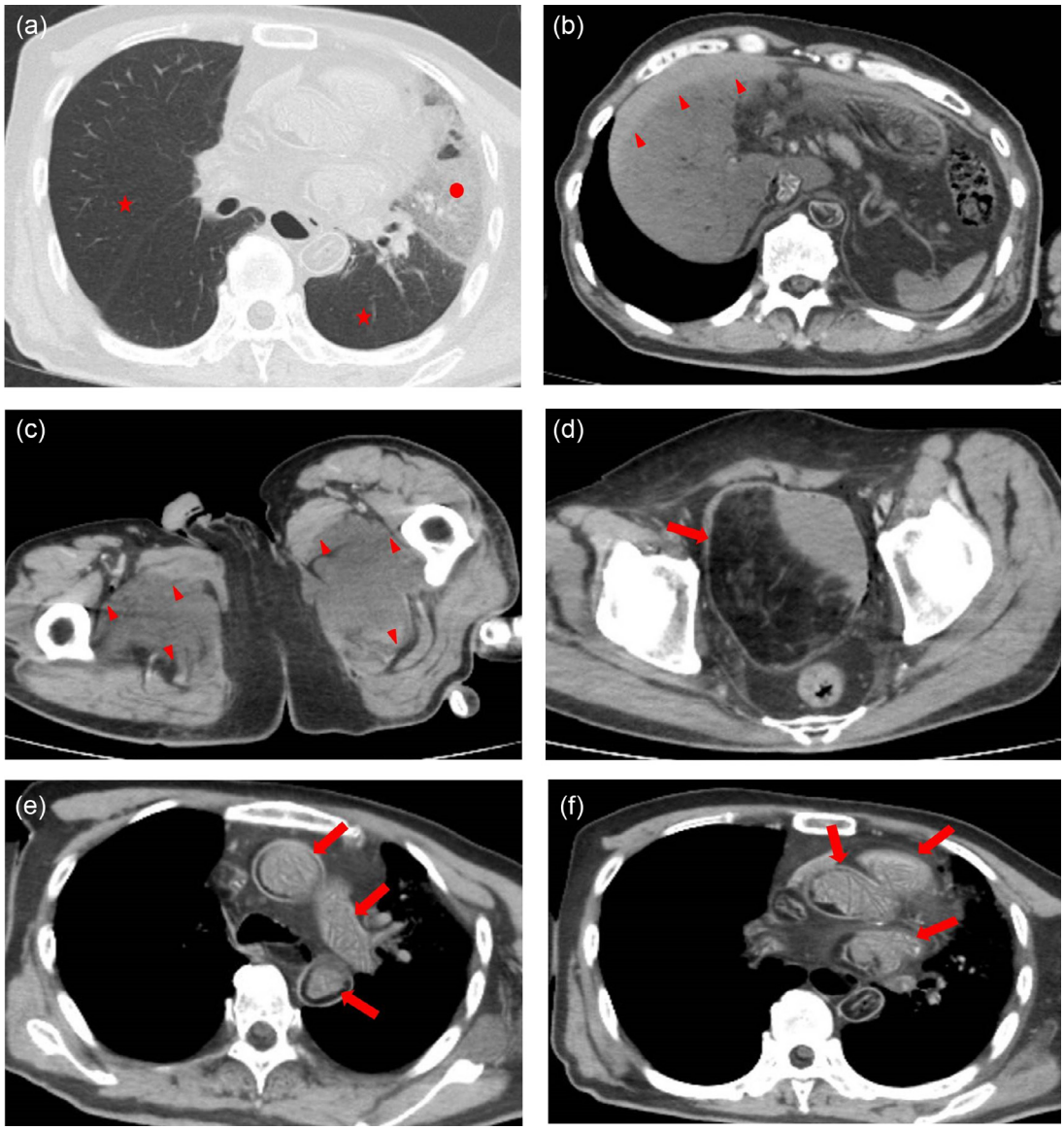

Fig. 1 – A 75-year-old man was found dead in a deeply frozen state. (A) There was an increase in attenuation in the left lung due to hypostasis in the left lateral decubitus position (circle) and a lack of increase (−1000 to −750 HU) in bilateral lung-field attenuation (stars). (B, C) Areas of hypodensity were observed in the central part of the liver (−15 to 55 HU) (arrowheads) and thighs (−10 to 45 HU) (arrowheads) and were linear in appearance. (D) Urinary retention with a hypodense area (−105 to −2 HU) (arrow) of approximately 350 cc was observed in the bladder. (E, F) Changes that appear to reflect serum crystallization in frozen blood are seen in the aorta, pulmonary artery, and heart (arrows).

Herein, we report a case of hypothermic death that resulted from extreme freezing, with characteristic PMCT findings. And we reviewed the available literature on PMCT findings in hypothermic death. Present case and our review revealed that although PMCT findings from hypothermic death that resulted from deep freezing are very rare, the characteristic PMCT findings may help determine the cause of death.

Case presentation

A 75-year-old man was found dead in the left lateral position at a campsite. The campsite was covered with snow, and there were no footprints. He was identified by his belongings. The man had been missing since he had told his family that he was going shopping two weeks ago. He recently experienced symptoms of dementia, was forgetful, and often lost his way home. His car, wrecked in an accident, was found approximately 600 meters from where he was found. He had no apparent injuries, and his body was frozen. He was undressed, and his clothes lay near him, suggesting paradoxical undressing. When he was found, his rectal temperature was −1°C and the ambient temperature was 10°C. A toxicological examination of his urine was performed, and illegal drugs were not detected. Frozen state may have affected the estimation of time of death; however, the condition of his body suggested

Table 1 – A literature review of PMCT findings in hypothermic death.

Author	N	Organ	PMCT findings
Kawasumi [1]	2 (frozen)	Brain	Hypodense areas (15-30 HU) resembling infarction
Kawasumi [2]	12/24	Lung	lack of an increase in lung field attenuation
	15/24	Vascular	Blood clotting in the heart, thoracic aorta or pulmonary artery
	24	Bladder	Increase uterine retention (207 mL)
Schweitzer [3]	14	Lung	Lower attenuation (−762 HU) compared to age-sex matched controls (−546 HU)
Chatzaraki [4]	14	Spleen	Higher attenuation (54 HU) compared to multiple organ failure (43 HU)
Michiue [5]	8	Lung	Transparent with slight hypostatic ground glass opacification
Sogawa [6]	7	Lung	Higher estimated air/gas content and higher effective lung ratio compared to sudden cardiac death Lower attenuation (−678 HU) compared to sudden cardiac death (−477 HU)
Hyodoh [7]	13	Lung	Higher aerated lung volumes (1565 mL) and higher percentages of aerated lung volume (62%) compared to control (739 mL, 31%)
Schober [8]	4	Lung	lower attenuation and homogeneous distribution (−880 HU)
Present case	1 (frozen)	Lung	Lack of increase (−1000 to −750 HU) in bilateral lung-field attenuation
		Vascular	Changes that appear to reflect serum crystallization in frozen blood are seen in the aorta, pulmonary artery, and heart
		Bladder	Urinary retention with hypodense area (−105 to −2 HU) of approximately 350 cc was observed in the bladder.
		Liver, thighs	Areas of hypodensity were observed in the central part of the liver (−15 to 55 HU) and thighs (−10 to 45 HU), and were linear in appearance

an estimated time of death of approximately 24 hours after death. Twelve hours after discover of his body, PMCT was performed to investigate the cause of death. The cadaver was defrosted before scanning at room temperature; however, the body was still frozen. An increase in the attenuation in the left lung due to hypostasis in the left lateral decubitus position was noted, as well as a lack of increase (−1000 to −750 HU) in the bilateral lung-field attenuation (Fig. 1A). Areas of hypodensity were observed in the central part of the liver (−15 to 55 HU) and thighs (−10 to 45 HU) and were linear in appearance (Figs. 1B and C). Urinary retention with a hypodense area (−105 to −2 HU) of approximately 350 cc was observed in the bladder. The hypodense area was considered the area where the tissues and fluids were frozen (Fig. 1D). Changes, which appeared to be crystallization of serum in frozen blood, were observed in the aorta, pulmonary artery, and heart (Figs. 1E and F). No findings suggestive of traumatic changes were observed on PMCT including his brain. A difference in the color of the blood from the right and left ventricles was noted.

Based on the scene and his circumstances, it was speculated that he died of hypothermia while being lost, and an autopsy was not performed.

Discussion

Hypothermic death is a lethal condition in which body temperature declines along with life support functions due to the cold. In general, autopsy findings of hypothermia are as follows: gastric mucosal hemorrhagic spots (Wischnewski spots), differences in the color of the left and right heart blood, soft blood clots, chicken fat clots in the heart and large blood vessels, lungs without edema, and a large amount of urine retention [9]. However, it is difficult to detect PMCT findings that are positive for hypothermic death during autopsy.

The use of PMCT is becoming increasingly common and plays an important role in forensic medicine. PMCT findings of hypothermic death, including a lack of an increase in lung-field attenuation, blood clotting in the heart, thoracic aorta, or pulmonary artery, and urine retention in the bladder, have been more frequently identified in cases of hypothermic death than in non-hypothermic death cases [9]. We searched PubMed and Google Scholar to review the available literature (published until December 2022) on PMCT findings in hypothermic death using the key terms “hypothermia,’’ and “PMCT.”

Table 1 shows a literature review of PMCT findings in individuals who experienced hypothermic death. Pulmonary PMCT findings are most commonly reported, which most studies mentioning preservation of the aerated lungs [2,3,5–8]. A previous study measured the CT range volume (−1000 to −700 HU) close to the air in the lungs and calculated its ratio to the total lung volume. Hypothermic death was associated with significantly less elevated lung attenuation than other causes of death [7]. In our case, a lack of lung-field attenuation increase was observed, in agreement with previous reports and supportive of hypothermic death [2]. However, PMCT findings in the lungs are not specific to hypothermia. Other postmortem cases, such as dehydration, starvation, blood loss due to trauma, neck hanging, or obstructive pulmonary disease, should be considered in the differential diagnosis when PMCT with air retention in the lung-field is observed [5].

In PMCT, high-attenuation bodies are often found in individuals with a long agonal period (prolonged death) [10]. This finding is usually observed 2-6 hours after death and is observed in the heart and large blood vessels as a “template” structure of pulmonary artery thrombus. PMCT showed that the number of high-attenuation bodies was significantly higher in the hypothermia group than in the non-hypothermia group [10]. However, the high-attenuation body was not a specific finding for hypothermia because it is often observed in cases of prolonged (non-acute) death, such as intracranial hemorrhage, toxic poisoning, infectious disease, or malignant tumors [2].

In this individual, changes that appeared to reflect serum crystallization in frozen blood were observed in the aorta. A similar PMCT finding has not been previously reported, and it was presumed that the agonal period was long and slow circulating blood flow caused the serum to gradually freeze and undergo a crystallization process, producing the appearance of linear icicles.

A large amount of urine is often found in the bladder following hypothermic death [2], and it is considered to be caused by the long time leading to death and diuresis due to hypothermia. However, even in cases of hypothermia, there may be little fluid in the bladder due to incontinence during the agonal period. Therefore, when evaluating the amount of urine in the bladder, it is necessary to confirm the presence and degree of urinary incontinence with an investigative agency that understands the site and condition of the clothes. In our case, a large amount of urine accumulated and it was speculated that part of the urine was frozen, since the ice has fewer molecules per unit volume than water [1]. Consequently, the number of electrons per unit volume of ice is less than that of water, such that the X-ray transmittance of ice is higher [1]. On PMCT, frozen parenchymal organs and frozen urine have a lower density than normal organs and urine. However, knowledge of PMCT findings of frozen organs is difficult to obtain from the clinical literature.

Conclusions

A diagnosis of lethal hypothermia should be based on macroscopic, microscopic, and biochemical observations and can be established by ruling out all other possible causes of death. Such a multidisciplinary approach would allow for a more accurate diagnosis of hypothermia. In addition, knowledge of PMCT findings in frozen cadavers may help clinicians determine the cause of death.

Author contributions

Conceptualization, H.T., A.T. and Y.Ts.; Methodology, H.T.; Investigation, H.T.; Resources, H.T.; Data curation, H.T. and A.T.; Writing—original draft preparation, H.T.; Writing review and editing, H.T., A.T. R.S., Y.Ta, A.K., H.F. and Y.Ts.; Visualization, H.T.; supervision, A.T. R.S., Y.Ta, A.K., H.F. and Y.Ts., All authors have read and agreed to the published version of the manuscript.

Data availability statement

The data presented in the present study are available on request from the correspondent author.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Patient consent

Written informed consent was obtained from the patient's legal guardians for publication of this case report and any accompanying images. A case report is not required institutional review board (IRB) in our institution.

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