



Usefulness and limitation of postmortem computed tomography in bath-related death: Four case reports



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ABSTRACT

Bath-related death occurs relatively frequently in Japan; however, there is room for improvement in the investigation of such deaths. Here, we describe four autopsy cases of bath-related death (one case of drowning; one of drowning under the influence of drinking; and two cases of sudden cardiac death without drowning) in which postmortem computed tomography (PMCT) was performed before autopsy. Based on analysis of autopsy and PMCT findings of these cases, we further discuss the utility and limitation of PMCT when applied to bath-related death. Comparison of the autopsy findings and PMCT findings between the cases suggests that combinations of several PMCT findings in bath-related death cases (e.g., signs suggestive of overinflated lungs, hemodilution, and excessive water intake in the gastrointestinal tract) can serve to distinguish drowning cases from non-drowning cases. Many bath-related deaths have been reported to have drowning signs at autopsy, although elderly victims with cardiovascular diseases tend to be diagnosed as death due to disease without employing PMCT or autopsy. Therefore, this case series suggests that implementation of PMCT in bath-related death might prevent underestimation of drowning as a cause of death. Although PMCT alone has several limitations, such as inability to evaluate toxicology or heart pathology, implementation of PMCT may trigger a more detailed investigation of the background regarding bath-related death, especially in drowning cases. Based on this case report, we emphasize that PMCT should be performed routinely in bath-related death for compilation of accurate mortality statistics of bath-related death for developing future prevention strategies.

1. Introduction

Traditional Japanese bathing manners differ considerably from those associated with the Western style of bathing. Japanese people pour hot water of approximately 40–42 °C into a bathtub up to shoulder depth and soak in the sitting position [1]. Therefore, tubs are sufficiently deep for submersion of the face if persons lose consciousness during bathing. Unfortunately, sudden death in a bathtub (i.e., bath-related death) occurs relatively frequently in Japan, particularly among elderly people [2–7]. The annual mortality rate for fatal drowning in Japan is higher than in other developed countries, and this is mainly attributable to bath-related deaths among elderly people [5]. However, many bath-related deaths are not autopsied in the current Japanese death investigation system, unless the police or the relatives of the deceased desire detailed examination [8]. Therefore, there is room for further improvement in the investigation of bath-related death.

Recent advances in forensic radiology include postmortem imaging using computed tomography (CT) and magnetic resonance imaging

(MRI), which are used as a supplement in determining cause of death with or without conventional autopsy [9,10]. Postmortem CT (PMCT) can provide quantitative data regarding various organs in situ, such as radiodensity and volume of tissues, and there are many reports regarding application of PMCT findings to interpreting terminal pathophysiology of unnatural death [11–15]. There are also many reports of PMCT findings of drowning [16–20]; however, characteristics of the PMCT findings associated with bath-related death or application of PMCT to bath-related death have heretofore not been reported. In this report, we describe four autopsy cases of bath-related death in which PMCT was performed before autopsy. From the comparison of autopsy findings and PMCT findings in these cases, we discuss the utility and the limitation of PMCT when applied to bath-related death.

2. Radiological measurements of PMCT

Whole-body PMCT was performed before autopsy using a 64-row CT scanner (Somatom Definition AS, Siemens Healthcare, Forchheim,

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Germany) with the following parameters: 120 kV, quality reference mAs: 535, thickness: 64 × 0.6 mm, and field of view: 500 mm. Image data were analyzed by forensic pathologists using syngo.via software (Siemens Healthcare).

Several radiological parameters used in the previous studies of PMCT findings of drowning, including density of the fluid in the maxillary sinus, density of airway contents, distance between lungs (anterior mediastinum), rib level of the diaphragm dome, density of the right and the left atria, the approximate stomach volume, density of the gastric and the duodenal contents, were measured in each case [16–18]. Distance between the lungs and rib level of the diaphragm dome were measured using a pulmonary window setting (window level, –600; window width, 1500). Density of the maxillary sinus, airway contents, and right and left atria, as well as the approximate stomach volume and density of the gastric and the duodenal contents, were measured under a mediastinal window setting (window level, 40; window width, 300). The approximate volume of the stomach was calculated using the product of stomach length, height, and depth and a multiplication factor of $\pi/6$, as reported previously [16]. The density of the contents was calculated as the means of three measurements in the corresponding areas (measured in HU). The results are shown in the Table 1.

3. Case report

3.1. Case 1

A woman in her 80 s who lived alone was found dead in a bathtub with her face submerged beneath the water. Her past history included hypertension and osteoporosis. According to her son, she had been well, but she complained that she sometimes fell asleep in a bathtub. The deceased was 150 cm tall and weighed 51 kg. External examination was performed approximately 12 h after her death and revealed that fresh watery fluid with microbubbles flowed out of the mouth at the lateral position. There were no injuries. PMCT was performed approximately 14 h after her death, and major findings included a mosaic pattern of lung perfusion (Fig. 1a) and a pooling of fluid in the trachea (5 HU). A pooling of fluid was also observed in the sphenoidal sinus (–10 HU) and the maxillary sinus (9 HU). The mean radiodensity of the contents of the stomach and duodenum was –1 HU and 2 HU, respectively (Fig. 1b). An autopsy revealed emphysema aquosum (Fig. 1c) and pooling of fresh watery fluid with microbubbles in the trachea (Fig. 1d) and watery gastric content (400 mL) (Fig. 1e). The heart was moderately enlarged (403 g), but neither necrosis of cardiomyocytes nor stenosis of coronary arteries was observed. No other pathological findings were observed, and drugs or ethanol were not detected from toxicological analysis. From the autopsy findings, the cause of death was determined to be drowning.

3.2. Case 2

A woman in her 70 s living with her husband was found dead in a

Table 1
Radiological measurements of PMCT in each case.

	Case 1	Case 2	Case 3	Case 4
Density of the contents in the maxillary sinus (HU)	9	12	34.7	29.3
Density of airway contents (HU)	5.0	24.0	38.0	30.0
Distance between lungs (anterior mediastinum, cm)	0.1	1.5	8.4	6.7
Rib level of the diaphragm dome	5	5	4.5	4
Density of the right atrium (HU)	46.3	45.0	54.0	56.0
Density of the left atrium (HU)	49.0	41.0	65.0	69.0
Stomach volume (mL)	779.1	1320.6	605.3	657.0
Density of the gastric contents (HU)	–1.0	14.0	40.0	24.0
Density of the duodenal contents (HU)	2.0	18.0	38.0	21.0

bathtub with her mouth submerged beneath the water. She started bathing after dinner, but did not finish bathing after 50 min passed. According to her husband, she did not have any complaint before bathing. It was unclear whether she had consumed alcohol before bathing. Her past history included hypertension and hyperlipidemia. The deceased was 149 cm tall and weighed 66 kg. External examination was performed approximately 14 h after her death, and revealed a small amount of dark red-colored fluid with microbubbles flowing out of the mouth at the lateral position. Injuries were not evident. PMCT was performed approximately 15 h after her death, and major findings included a mosaic pattern of lung perfusion (Fig. 2a), microbubbles in the trachea, and calcification in the coronary arteries. A pooling of fluid was observed in the main bronchus (24 HU), sphenoidal sinus (4.3 HU), and maxillary sinus (12 HU). The mean radiodensity of the contents of the stomach and duodenum was 14 HU and 18 HU, respectively (Fig. 2b). An autopsy revealed emphysema aquosum (Fig. 2c) and a pooling of vomitus and red-colored fluid with microbubbles in the trachea (Fig. 2d). A fresh watery fluid was separated in the upper layer of the gastric content (Fig. 2e). The heart weighed 433 g, but neither necrosis of cardiomyocytes nor significant stenosis of coronary arteries was observed. There were no pathological findings, except for fatty deposits in the hepatocytes. Toxicological analysis revealed that the blood ethanol level was 1.48 mg/mL. From the autopsy findings, the cause of death was determined to be drowning under the influence of the ethanol.

3.3. Case 3

A man in his 60 s who lived in a dormitory with his colleagues was found dead in a bathtub. According to his colleague, his mouth was not submerged beneath the water, and he did not drink before bathing. He had no past medical history. The deceased was 175 cm tall and weighed 73 kg. External examination was performed approximately 24 h after his death, and a small amount of red-colored fluid without microbubbles flowed out of the mouth at the lateral position. There were no injuries. PMCT was performed approximately 26 h after his death, and major findings included calcification in the coronary arteries, diffuse ground glass opacities in the lungs, a small amount of fluid in the right thoracic cavity (Fig. 3a), and a pooling of fluid in the trachea (38 HU), sphenoidal sinus (26.7 HU), and maxillary sinus (34.7 HU). The mean radiodensity of the contents of the stomach and duodenum was 40 HU and 38 HU, respectively (Fig. 3b). An autopsy revealed congestive and edematous lungs, but the findings did not resemble emphysema aquosum (Fig. 3c). A pooling of brown-red-colored fluid was observed in the trachea, but microbubbles were not evident. The stomach contained dark brown-colored liquids, but fresh watery fluid was not separated in the upper layer (Fig. 3d). The heart was significantly enlarged (672 g) with significant stenosis of the anterior descending branch and the circumflex branch of the left coronary artery (Fig. 3e). There were no pathological findings or injuries except for severe atherosclerosis of the aorta and other organs. Histopathological findings showed a proliferation of collagen fibers and the appearance of a contraction band in the cardiac muscle tissue (Fig. 3f). Drugs or ethanol were not detected from toxicological analysis. From the autopsy findings, the cause of death was determined to be sudden cardiac death due to severe cardiomegaly and coronary atherosclerosis.

3.4. Case 4

A man in his 40 s who lived alone was found dead in a bathtub of a public bath. According to the staff in a public bath, he seemed drunk when he came to the public bath, and his face was not submerged beneath the water at the time of the detection. His past history included diabetes mellitus and gout. The deceased was 174 cm tall and weighed 75 kg. External examination was performed approximately 29 h after his death, and brown-red-colored fluid without microbubbles flowed

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