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# Postmortem computed tomography findings in cases of bath-related death: Applicability and limitation in forensic practice

Satoko Mishima[a,b], Hideto Suzuki[a,*], Tatsushige Fukunaga[a], Yoko Nishitani[b]

[a] Tokyo Medical Examiner's Office, Tokyo Metropolitan Government, Japan
[b] Department of Forensic Medicine, Faculty of Life Sciences, Kumamoto University, Japan

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ABSTRACT

*Purpose:* Bath-related deaths occur frequently in Japan, and many of these deaths are diagnosed as death from disease without autopsy in the current Japanese death-investigation system. Therefore, we aimed to examine the postmortem computed tomography (PMCT) findings of bath-related deaths to determine if PMCT can differentiate between real cases of drowning and sudden deaths not related to drowning.
*Methods:* Bath-related deaths were sampled from all autopsies conducted at the Tokyo Medical Examiner's Office from September 2015 to August 2016. A total of 90 bath-related deaths (77 drowning cases and 13 non-drowning cases) and 50 controls (sudden cardiac deaths non-related to bathing) were included in this study. We investigated factors contributing to drowning and measured PMCT parameters (presence/density of fluid in the maxillary sinus/trachea, distance between the lungs, lung patterns [ground glass opacities, consolidation], position of the right diaphragmatic dome, density in the right atrium, stomach volume, and density of the gastric/duodenal contents).
*Results:* The analysis of the factors contributing to drowning showed that alcohol intoxication was the most frequent (n = 25), followed by cardiac pathology (n = 22), and psychotropic drug intoxication (n = 6). Radiological evaluation showed that measurements of all parameters differed significantly between the drowning group and the controls. In addition, significant differences were observed between drowning and non-drowning cases in three radiological parameters (i.e., distance between lungs, stomach volume, and density of gastric contents).
*Conclusions:* Majority of bath-related deaths in this study showed signs of drowning at autopsy, and we observed a range of factors that contributed to drowning. By using several radiological parameters (e.g., the distance between the lungs, stomach volume, and the density of the gastric contents), PMCT for the investigation of bath-related deaths might indicate that drowning as opposed to other factors unrelated to drowning (e.g., sudden cardiac death) was the cause of death. This might allow for calculation of accurate mortality statistics on bath-related deaths.



## 1. Introduction

Although cultural practices related to baths vary across countries, baths are overall considered a mode of relaxation worldwide [1]. Unfortunately, many cases of sudden deaths during bathing have been reported thus far [2–14]. In most cases, death occurs in a bathtub, and victims are found unresponsive with their faces immersed or completely submerged under water [1]. These deaths are a critical social issue, especially in Japan, where approximately 19,000 sudden bath-related deaths are estimated to occur annually [1]. The annual mortality rate for fatal drowning in Japan is higher than that in other developed countries and is mainly attributable to bath-related deaths among elderly people [5]. Japanese people pour hot water of approximately 40–42 °C into a bathtub up to shoulder depth and soak in it in the sitting position [5,15]. Therefore, the tubs are manufactured with such depth; if a person loses consciousness during bathing, this depth allows for submersion of the face. Determining the cause of death in cases of bath-related deaths (e.g., drowning or disease) is generally difficult by only external examination; however, many bath-related deaths do not undergo an autopsy in the current death-investigation system of Japan [8]. Therefore, there is room for further improvement in the investigation of bath-related deaths.

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

* Corresponding author at: Tokyo Medical Examiner's Office, Tokyo Metropolitan Government, 4-21-18 Otsuka, Bunkyo-ku, Tokyo 112-0012, Japan.
*E-mail address:* hideto-@qk9.so-net.ne.jp (H. Suzuki).

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imaging (MRI), which are used as supplementary investigations in determining the cause of death with or without conventional autopsy [16]. Postmortem CT (PMCT) imaging can provide quantitative data regarding various organs in situ, and many studies have reported the application of PMCT findings to interpreting the terminal pathophysiology of unnatural death [17–20]. In addition, several studies have evaluated the PMCT findings in cases of drowning [21–25]; however, the characteristics of PMCT findings associated with bath-related death or possible application of PMCT to bath-related deaths have not been reported. Therefore, in this study, we investigated PMCT findings of autopsied cases of bath-related death to determine if PMCT can differentiate between cases of real drowning and those of non-drowning-related sudden death (e.g., cardiac death) and discuss the applicability and limitations of PMCT for investigating bath-related death in forensic practice.

## 2. Materials and methods

### 2.1. Study sample

We examined bath-related deaths from all autopsies conducted at the Tokyo Medical Examiner's Office from September 2015 to August 2016. Exclusion criteria were as follows: the presence of pneumothorax, massive pleural effusions, significant putrefactive changes, and prolonged death in the hospital after temporary recovery by cardiopulmonary resuscitation. Finally, a total of 90 cases of bath-related death were included. In addition, we selected a control group of 50 cases of sudden cardiac death unrelated to bathing, because a previous study reported that the most-frequent pathological finding in bath-related death was heart disease [5,6]. The control samples were selected to match the age distribution of those with bath-related deaths (mean ± standard deviation [SD]: 69.0 ± 14.0).

### 2.2. Autopsy data

Data regarding age, gender, the cause of death, major autopsy findings including drowning signs (e.g., hyper-inflated lungs, emphysema aquosum, water in the trachea, and water in the stomach), and the results of the toxicological analysis were collected from the autopsy records. Bath-related deaths were categorized into two groups based on the presence of drowning signs: drowning and non-drowning cases. In all cases showing signs of drowning (n = 77), the direct cause of death was determined to be drowning. Among these cases, the cause of death was determined as disease-related in 22 cases (28.6%); the most common pathology was coronary arteriosclerosis with or without cardiomegaly, followed by arteriosclerosis of the cerebral arteries. Reviews of the autopsy findings revealed that all these findings were based on arteriosclerotic changes with or without old myocardial/cerebral ischemic changes, but without findings of thrombi in the coronary/cerebral arteries or fresh necrosis of the tissues. Therefore, we defined these findings as factors contributing to drowning in this study and investigated these factors for all drowning cases.

### 2.3. Imaging analysis

Whole-body PMCT was performed before autopsy, using a 64-row CT scanner (Somatom Definition AS; Siemens Healthcare, Forchheim, Germany) with the following parameters: 120 kV; quality reference, 400 mAs; thickness, 64 × 0.6 mm; and field of view, 500 mm. Image data were analyzed using syngo.via software (Siemens Healthcare). The density of the contents (e.g., maxillary sinus) was measured using a region of interest (ROI) and calculated as the means of three measurements in the corresponding areas.

### 2.4. Measured variables

A list of all variables measured by PMCT is shown in Table 1.

#### 2.4.1. Respiratory system

We evaluated the presence and density of fluid in the maxillary sinus. Cases with contents in the maxillary sinus were included when the contents were observed in more than one side of the sinus. The presence and density of fluid in the trachea and the main bronchi were also assessed. The distance between the lungs (anterior mediastinum) and lung patterns were evaluated. Lung patterns were divided into two subcategories: ground glass opacities (GGO) and consolidations, as reported previously [22]. The location of each lung pattern (diffuse, patchy, apical, hypostatic, anterior, and posterior) was also determined.

#### 2.4.2. Thoracic cavity, non-respiratory

The height of the right diaphragmatic dome was measured according to the position of the anterior ribs. Moreover, the density of the blood in the right atrium was analyzed.

**Table 1**
Measured variables.

| | | | |
|---|---|---|---|
| Respiratory system | | | |
| 1. Maxillary sinus | Presence of fluid | | |
| | | Fluid density | ROI (HU) |
| 2. Trachea and main bronchi | Presence of fluid | | |
| | | Fluid density | ROI (HU) |
| 3. Lungs | Distance between the lungs | Anterior mediastinum | |
| | | Patterns – types | Ground glass opacities<br>Consolidations |
| | | Patterns – localization | Diffuse – patchy<br>Hypostatic – apical<br>Posterior – anterior |
| Thoracic cavity | | | |
| 1. Right diaphragmatic dome | Position | According to position of anterior ribs | |
| 2. Right cardiac atrium | Blood density | ROI (HU) | |
| Digestive system | | | |
| 1. Stomach | Volume | Product of the stomach length, height, depth and π/6 | |
| | | Density of content | ROI (HU) |
| 2. Duodenum | Density of content | ROI (HU) | |