Case Report

Sudden Death During Bathing: Autopsy Reveals Cerebral Arteriovenous Malformation

Mone Amagasu[1], Hideto Suzuki[2], Toshinori Omi[2,3], Takeshi Inagaki[2]

[1] School of Medicine, Jichi Medical University, 3311-1 Yakushiji, Shimotsuke, Tochigi 329-0498, Japan
[2] Division of Forensic Medicine, Department of Anatomy, Jichi Medical University, 3311-1 Yakushiji, Shimotsuke, Tochigi 329-0498, Japan
[3] Department of Basic Science, Faculty of Veterinary Medicine, School of Veterinary Nursing and Technology, Nippon Veterinary and Life Science University, 1-7-1 Kyonancho, Musashino, Tokyo 180-8602, Japan

Abstract

Arteriovenous malformations (AVMs) in the brain can induce seizures, potentially leading to fatal accidents. Here, we present an autopsy case of sudden death related to bathing, wherein a cerebral AVM may have been the precipitating factor. A man in his seventies, with no significant medical history, was discovered deceased in a bathtub. Notably, he had a history of methamphetamine use and admitted to consuming the drug 2 days before his demise. Initially, authorities suspected methamphetamine involvement in his death, prompting a forensic autopsy. Post-mortem examination revealed indications of drowning along with an AVM located on the basal surface of the left frontal lobe. Histopathological analysis revealed gliosis in the surrounding brain parenchyma, indicative of tissue ischemia resulting from vascular stealing. Additionally, hemorrhaging was observed around the right dorsal metacarpal vein, identified as the drug injection site. However, toxicological analysis and histopathological findings suggested methamphetamine was unlikely to have contributed to his death. The cause of death was determined to be drowning, with the cerebral AVM potentially precipitating seizures preceding the event. Despite frequent occurrences of bath-related deaths in Japan, autopsies in such cases are uncommon. This case underscores the significance of conducting autopsies in bath-related fatalities to uncover underlying pathologies.
(Keywords: arteriovenous malformation, bath-related death, drowning, forensic autopsy)

Introduction

Arteriovenous malformation (AVM) is a congenital vascular anomaly characterized by a tangled network of malformed arterial vessels and draining veins lacking an intervening capillary network [1, 2]. AVMs can manifest in various regions of the central nervous system, with a majority located along the middle cerebral arteries and involving the hemispheric convexities contiguous with the overlying leptomeninges [2]. Symptoms of cerebral AVMs commonly include hemorrhage, seizures, and headaches [3, 4]. Additionally, cerebral AVMs may precipitate vascular steal phenomena leading to a spectrum of neurological deficits [5-8]. Here, we present a case study of an individual who died during bathing, wherein a cerebral AVM is posited as a potential underlying cause. Initially, law enforcement attributed the death to illicit drug usage; however, autopsy findings revealed indications not only consistent with drowning but also an undiagnosed cerebral AVM. Subsequently, we explore the potential causal relationship between cerebral AVMs and mortality.

Case

A man in his seventies, with no significant medical history, was found deceased in a seated position in a bathtub at home. The water in the bathtub was discolored with bloody discharge from the external nostrils and mouth. According to his wife, although he had complained of a headache prior to bathing; otherwise, he appeared normal. Although an ambulance was requested, the patient was not transported to the hospital due to the presence of rigor mortis upon the

Correspondence to: Hideto Suzuki, Division of Forensic Medicine, Department of Anatomy, Jichi Medical University, 3311-1 Yakushiji, Shimotsuke, Tochigi 329-0498, Japan. Tel: +81-285-58-7342 Fax: +81-285-40-8304 E-mail: suzuki.hideto@jichi.ac.jp
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arrival of emergency medical services. Subsequently, the police initiated an investigation into his death. The deceased had a history of multiple arrests for methamphetamine use and had reportedly used methamphetamine with a friend approximately two days before his death. A urine drug screening test using DRIVEN FLOW®M8-Z (Alfa Scientific Designs Inc., Poway, USA) tested positive for methamphetamine. The police then ordered a judicial autopsy to determine if methamphetamine intoxication was related to his death.

An autopsy was conducted approximately two days postmortem. The decedent was 168 cm tall and weighed 78.3 kg. Putrefactive discoloration was noted on the chest wall, with blisters scattered across the trunk. Postmortem lividity appeared dark purple with petechiae on the dorsal trunk. The face exhibited congestion, and red-colored fluid leaked from the external nostrils. Except for a pinhole-sized purple discoloration on the dorsal surface of the right hand, no other injuries were observed. The autopsy revealed emphysema aquosum, pulmonary edema, and pleural effusion (135 mL on the left and 235 mL on the right). The left lung weighed 690 g, and the right lung weighed 678 g. Gastric contents consisted of a pale yellowish liquid (350 mL) containing food residues. Additionally, a vascular ectatic lesion was identified on the basal surface of the left frontal lobe **(Fig. 1a, b)**. Brain cross-sections revealed cirsoid vascular components and aneurysm-like dilatation, with the brain parenchyma surrounding the vascular lesion showing yellowish discoloration **(Fig. 1c)**. The heart weighed 378 g without scarring, and the coronary arteries showed no significant stenosis or thrombi. Other autopsy findings included a hemorrhage around the right dorsal metacarpal vein **(Fig. 2a)**. No findings related to the cause of death were observed in other organs.

Histopathological examination of the vascular lesions in the brain revealed vessels with architectural disarray, such as marked fluctuation of medial thickness and aneurysmal dilatation. Vessels displaying both arterial and venous characteristics were observed **(Fig. 1d-f)**. Based on these findings, the vascular lesion was diagnosed as an AVM. Gliosis was also noted in the brain parenchyma surrounding the AVM **(Fig. 1g)**. An area in the hemorrhagic site around the right dorsal metacarpal vein was stained with Berlin blue **(Fig. 2b)**. Other histological findings included pulmonary edema and fatty liver infiltration.

Toxicological analysis of blood (12 mL) and urine (1 mL) samples collected at autopsy was performed using gas chromatography and gas chromatography-mass spectrometry at the Forensic Science Laboratory, Criminal Investigation Department of the Tochigi Police. Methamphetamine was detected in the urine, while no drugs or ethanol were detected in the blood.

Discussion

Based on the autopsy findings, drowning was determined to be the direct cause of death. The major autopsy findings associated with death from drowning include emphysema aquosum, lung edema, and watery gastric content [9]. Emphysema aquosum is caused by an influx of water pushing air toward the peripheral side of the lungs during drowning [9] and as a consequence of water inhalation and congestion, the weight of the lungs increases. With a progression of postmortem changes, pleural effusion is observed due to effusion of inhaled water into the pleural cavity [9]. Several autopsy findings in this case are consistent with those associated with death from drowning. Previous research on autopsy findings of sudden death in the bathroom (bath-related death) indicates that drowning may play a crucial role in the final process of death [10]. While cardiovascular disease is the most common cause, bath-related deaths can also result from various factors, including alcohol or drug intoxication, seizure disorders, and intracranial injuries [10-13]. In this case, methamphetamine use and AVM were identified as potential underlying causes of drowning. We discuss the involvement of each factor in his death below.

Intoxication with amphetamine-related derivatives (AMPs) induces symptoms such as hyperthermia and cardiac arrhythmias. AMPs may also be indirectly related to accidental deaths, including traffic accidents and drowning incidents [14]. The effects of methamphetamine can last for approximately 8–24 hours. However, methamphetamine can still be detected in the body for hours to months after the last use, depending on the testing method employed [15]. Blood and oral fluid testing are more useful and accurate than urine testing for detecting recent ingestion, whereas urine tests usually detect methamphetamine for up to 72 hours after the last dose [15, 16]. Therefore, the toxicological analysis results in this case suggest that the deceased might not have used methamphetamine near the time of death. Additionally, the autopsy revealed that the deceased had been injected with methamphetamine via the right dorsal metacarpal vein. Stainable iron in the form of hemosiderin does not usually appear within the first 2 or 3 days [17]. Histopathological findings at the hemorrhagic site were also compatible with the deceased's statement that he used methamphetamine approximately 2 days before death. Consequently, it was concluded that methamphetamine use was unlikely to be associated with his death.

An autopsy revealed an AVM at the bottom of the left frontal lobe, accompanied by gliosis in the surrounding parenchyma. Vascular steal is an angiographic phenomenon characterized by the failure of distal vessels supplying normal brain tissue adjacent to AVMs to opacify due to the shunting of blood into the AVM. In this context, blood is diverted into the low-resistance network of the AVM,

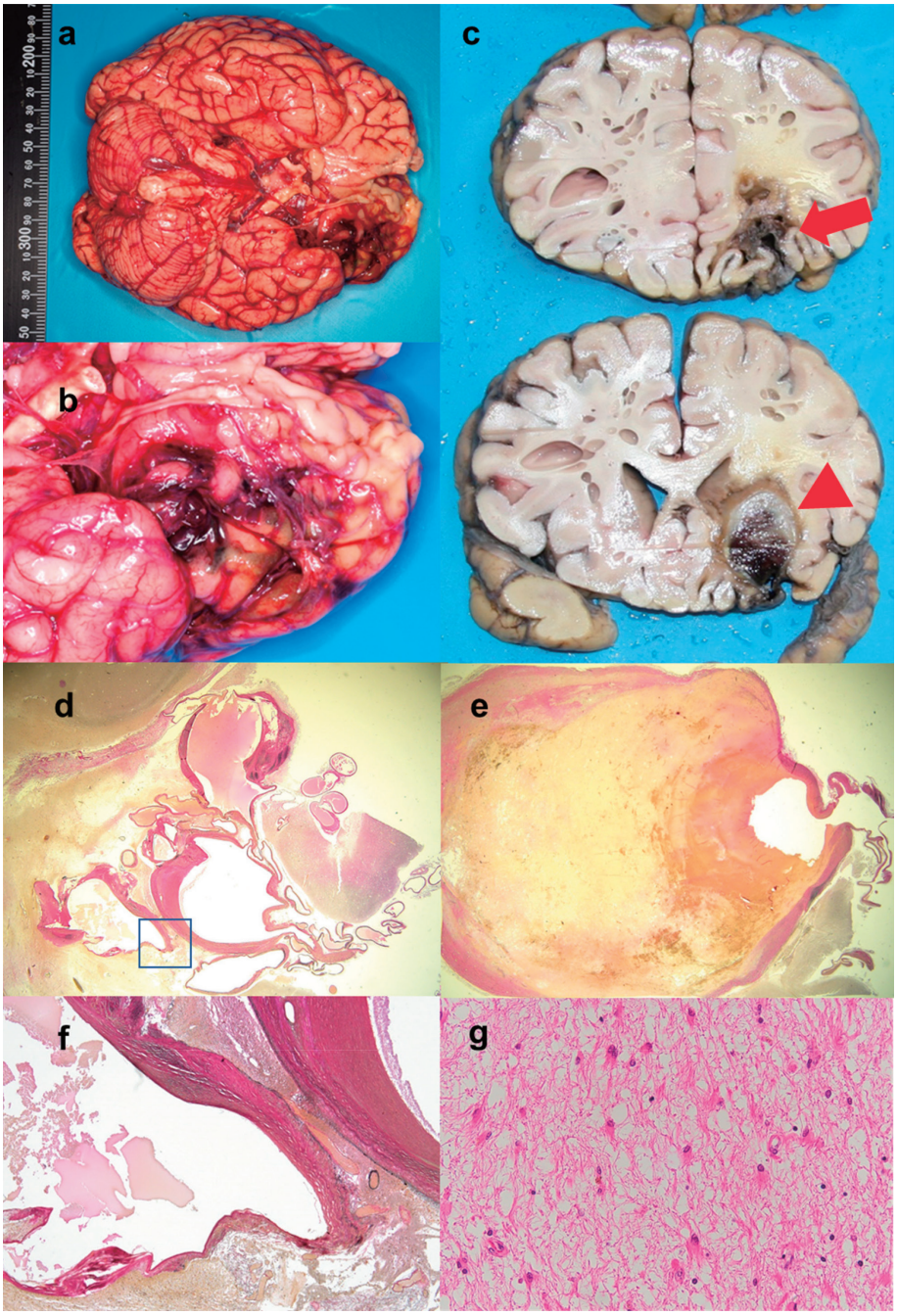

Fig. 1. Macroscopic and histopathological findings of the brain

(a, b) A vascular ectatic lesion was observed on the basal surface of the left frontal lobe.

(c) Cirsoid vascular components (arrow) and aneurysm-like dilatation (arrowhead) were observed in the cross-section of the brain.

(d-f) Histopathological findings showed vessels with architectural disarray, such as marked fluctuation of medial thickness and aneurysmal dilatation (d: magnified image of the area marked with an arrow in Fig. 1c, e: magnified image of the area marked with an arrowhead in Fig. 1c, f: magnified image of the boxed area in Fig. 1d) (Elastica van Gieson stain)

(g) Gliosis was observed in the brain parenchyma surrounding the AVM (Hematoxylin and eosin stain).

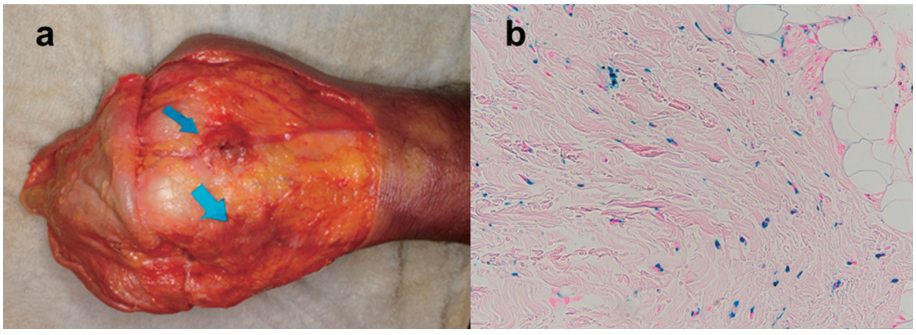

Fig. 2. Macroscopic and histopathological findings of the subcutaneous layer of the right hand

(a) Arrows indicate the sites of hemorrhage, with the upper arrow showing hemorrhage around the right dorsal metacarpal vein.

(b) An area in the hemorrhagic site around the right dorsal metacarpal vein stained positive with Berlin blue.

resulting in relative hypoperfusion in the surrounding brain tissue, which may lead to ischemia [5-8]. Additionally, high AVM pressure may promote venous hypertension, impairing venous drainage in the surrounding brain and reducing cerebral perfusion pressure [8]. This ischemia can result in clinical sequelae such as transient or progressive focal neurological deficits and seizures [7, 8, 18]. Seizures are the most common symptom of unruptured AVM [3, 4], and previous reports suggest that accidental deaths (e.g., trauma and drowning) may be induced by epileptic seizures due to AVM [19, 20]. We consider that the gliosis surrounding the AVM in this case resulted from vascular steal and that seizures due to the AVM might have occurred before drowning. The onset of AVM generally occurs at a relatively young age; in this regard, Tong et al., who investigated 3299 AVM patients in their prospectively maintained database, have reported that 80.1% and 92.3% of these patients were diagnosed prior to the ages of 40 and 50 years, respectively [21]. However, 109 (3.3%) of these patients were 60 or more years of age, among whom the initial presentation was a seizure in 13 cases [21]. Fuwa et al. have similarly reported the cases of seven patients with AVM, in whom the initial symptoms occurred at an age of over 60 years (3.5% of all AVM cases), and among these, one patient showed seizures as an initial symptom [22]. However, although this patient may have developed seizures due to AVM in his 70s, details of the symptoms prior to death were not established owing to limited information obtained from the forensic autopsy.

Bath-related deaths are more common in Japan, where approximately 14,000 such deaths occur annually [23]. Unlike other countries, Japan has a bathing style in which people soak in shoulder-deep hot water (42 °C or higher) to warm themselves, especially during cold winters. These Japanese habits are thought to be closely related to the high incidence of bath-related deaths [11-13]. Diagnosing the correct cause of bath-related death is difficult without autopsy because such deaths are thought to result from several factors [13]. However, very few bath-related deaths are subjected to autopsies under the current Japanese death investigation system [13]. The decision to conduct an autopsy is typically made by the police from a criminal standpoint, except in areas with a medical examiner system (e.g., Tokyo and Osaka). Most bath-related deaths occur in the elderly [10], many of whom have a history of medical conditions such as hypertension [13], leading to a low priority for autopsies. In this case, an autopsy was ordered due to the suspicion of methamphetamine use before death. However, the autopsy revealed an unexpected pathology (AVM) as a possible underlying cause of death. Based on this case, we emphasize the need for autopsies in bath-related deaths to avoid missing underlying pathologies that might cause drowning. Furthermore, the current police-oriented system in Japanese death investigation has significant limitations in investigating non-criminal causes of death. The overall autopsy rate for unnatural deaths has remained around 10% in recent years [24], despite the introduction of a new autopsy system in 2013 based on the Act for Investigations into the Cause of Death or Identity of Corpses handled by the Police. Therefore, a system allowing autopsies at the discretion of forensic pathologists and police is required to obtain accurate mortality statistics for public health.

In conclusion, we present an autopsied case of bath-related death in which cerebral AVM might be the underlying cause of death. The police initially suspected that the deceased died from methamphetamine intoxication based on the history of drug use and the drug screening test results. However, the toxicological analysis and histopathological findings suggested that the involvement of methamphetamine in the patient's death was unlikely. Alternatively, an autopsy revealed a cerebral AVM with gliosis in the brain parenchyma, which may have caused the seizures before drowning. This case is not only a rare presentation but also emphasizes the need for performing autopsies of bath-related deaths to avoid missing the underlying pathology.

Declaration of interest

The authors declare that they have no competing financial interests or personal relationships that may have influenced the work reported in this study.

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脳動静脈奇形を認めた入浴中突然死の一剖検例

天春　萌音[1]，鈴木　秀人[2]，近江　俊徳[2,3]，稲垣　健志[2]

１．自治医科大学　医学部
２．自治医科大学　解剖学講座法医学部門
３．日本獣医生命科学大学獣医学部獣医保健看護学基礎部門

要　　約

緒言：脳動静脈奇形は痙攣発作を惹起し，重大な事故の契機となることがある。今回生前未診断の脳動静脈奇形の関与が推定された入浴中の突然死例を経験したので報告する。
症例：70歳代男性。某日早朝に自宅浴槽内で死亡しているのを発見された。死亡数日前に覚醒剤使用を示唆する言動を認めたため，法医解剖となった。剖検所見として，（１）水性肺気腫，（２）左前頭葉底面の脳動静脈奇形と周囲脳実質のグリオーシス，（３）右背側中手静脈周囲の出血と同部組織のベルリン青染色による青染を認めた。薬毒物検査にて尿中にはメタンフェタミンが検出されたが、血液中からは検出されなかった。
考察：剖検所見より本屍の死因は溺死と診断した。溺水に関与した要因としては組織学及び薬毒物検査結果より，脳動静脈奇形による意識障害を推定した。入浴中の突然死には生前未診断の病変が死に関与している事例もあり，慎重に死因究明を行う必要がある。
（キーワード：脳動静脈奇形，入浴中突然死，溺死，法医解剖）

連絡先：鈴木　秀人，自治医科大学　解剖学講座法医学部門，〒329-0498　栃木県下野市薬師寺3311-1.
Tel：0285-58-7342　Fax：0285-40-8304　E-mail：suzuki.hideto@jichi.ac.jp
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