Forensic Science International: Synergy 1 (2019) 68–70

Contents lists available at ScienceDirect

Forensic Science International: Synergy

journal homepage: https://www.journals.elsevier.com/forensic-science-international-synergy/

Evaluation of L/D ratio in a water-related case for the differentiation between drowning and postmortem immersion

Zhigang Li [a], Bo Wu [a], Xiao Cheng [b], Yunying Wu [c], Pingping Zhang [c], He Shi [a], Dongyun Zheng [a], Jianding Cheng [d, ***], Chao Liu [d, **], Jian Zhao [d, *]

[a] Guangzhou Forensic Science Institute & Key Laboratory of Forensic Pathology, Ministry of Public Security, Baiyun Avenue 1708, Baiyun District, 510000, Guangzhou, China
[b] Southern Medical University, Shaitai Road South 1023-1063, Baiyun District, Guangzhou, 510515, China
[c] Kunming Medical University, Chunrong Road West 1168, Chenggong District, Kunming, China
[d] Faculty of Forensic Medicine, Zhongshan School of Medicine, Sun Yat-Sen University & Guangdong Province Translational Forensic Medicine Engineering Technology Research Center, Zhongshan 2nd Road 74, Yuexiu District, 510080, Guangzhou, China

ARTICLE INFO

Article history:
Received 14 January 2019
Received in revised form
31 March 2019
Accepted 1 April 2019
Available online 10 April 2019

Keywords:
Forensic pathology
Drowning
Diatom test
L/D ratio

ABSTRACT

It is a difficult task to determine the cause of death for decomposed bodies found in water. Diatom test has been shown to provide supportive evidence for the diagnosis of drowning. According to our previous studies, the ratio of diatom content in lung tissue to diatom content in drowning medium (L/D ratio) is a very useful indicator to distinguish between drowning and postmortem immersion. In this article, we presented a case of a highly decomposed body being recovered from water with no significant findings on its cause of death. We applied the microwave digestion-vacuum filtration-automated scanning electron microscopy method (MD-VF-Auto SEM) to detect diatoms in the organs and suspected drowning medium. In this case, positive results are found in diatom tests of lung tissue, liver tissue and kidney tissue, while the L/D ratio analysis suggested that the victim was more likely to suffer from postmortem immersion. Taking the result of L/R ratio and other findings into consideration, we can eliminate the possibility of drowning. With continuous study, the L/D ratio analysis would be a valuable tool in diagnosis of drowning.

1. Introduction

Diatoms found in distant organs, such as liver and kidneys, are considered as the supportive evidence for the diagnosis of drowning [1–3]. No matter drowning or not, diatoms are always found in the victim's lung which directly communicates with the drowning medium by tracheas. Few diatoms recovered in the lung could not be used as an indicator of drowning [4].

For an effective quantitative analysis of diatoms in organs, we have developed a sensitive diatom test method called “Microwave Digestion-Vacuum Filtration-Automated Scanning Electron Microscopy (MD-VF-Auto SEM)” [5]. A number of cases were tested by this new method, and the quantitative analysis results revealed the importance of the ratio of the diatom content in lung and drowning medium (L/D ratio) [6]. In the review of 64 water-related cases [6], we found that there were statistical differences in L/D ratios between the drowning and the postmortem immersion groups. The drowning cases were more likely to get higher L/D ratios than the postmortem immersion cases. We illustrated that the L/D ratio analysis would provide supportive evidence for the diagnosis of drowning.

In this article, we provided the L/D ratio as an indicator of determining postmortem immersion for a water-related case.

2. Material and methods

2.1. Case history

A highly decomposed female body was found floating in a farmland brook in Autumn (Fig. 1). According to the police investigation, the victim was a 50-year-old woman lived in the nearby

* Corresponding author.
** Corresponding author.
*** Corresponding author.
E-mail addresses: chengjd@mail.sysu.edu.cn (J. Cheng), liuchaogzf@163.com (C. Liu), zhaojian0721@163.com (J. Zhao).

https://doi.org/10.1016/j.fsisyn.2019.04.001

Fig. 1. A highly decomposed female body was found floating in a farmland brook.

village. She was reported missing 2 weeks ago.

2.2. Autopsy findings

There were no wounds or injuries to the body. 200 g of gastric content was found in the stomach without any obnoxious odors. The hemorrhage of gastric mucous membrane was observed. No foreign matters were found in the bronchi and tracheae. Both thoracic cavities were empty without any fluid in them.

50 g of liver tissue, the whole kidney and 50 g of lung tissue samples were removed in the prescribed sequence at autopsy for diatom test.

The gastric content, liver tissues and bladder flushing fluid (no urine found in the bladder) were obtained for toxicological analysis.

2.3. Diatom test

10 g of the liver tissue, 10 g of the kidney tissue, 1 g of the lung tissue and 30 ml of the water sample obtained from the site where we found the body were tested using the MD-VF-Auto SEM method [5]. The tissues were digested with the microwave digestion system, enriched in the vacuum filtration device and automatically scanned by the SEM at 400 × magnification.

The result of the diatom test was 302 valves/10 g of lung tissue, 10 valves/10 g of the liver tissue, 17 valves/10 g of the kidney tissue and 33028 valves/10 ml of the water sample. The L/D ratio is 0.009.

Diatom species detected in the samples were listed in Table 1.

Table 1
Diatom species detected in the samples.

Diatoms	Lung	Liver	Kidney	Drowning medium
Amphora	−	−	−	+
Coscinodiscus	+	−	+	−
Cyclotella	+	−	−	+
Eunotia	−	−	−	+
Gomphonema	+	−	+	−
Gyrosigma	−	−	−	+
Melosira	+	−	−	+
Navicula	+	+	+	+
Nitzschia	+	+	+	+
Pinnularia	−	−	+	−
Surirella	−	−	−	+
Synedra	+	−	−	+
Thalassiosira	−	−	−	+

+: Present; -: Absent.

2.4. Toxicological analysis

Tetramine was positive in the liver tissue and the gastric contents while common hypnotics (phenobarbital, clozapine, triazolam, etc.) and pesticides (dimethoate, dichlorvos, parathion, etc.) were negative.

Common hypnotics (phenobarbital, clozapine, triazolam, etc.), pesticides (dimethoate, dichlorvos, parathion, etc.) and drugs (morphine, benzedrine, MDMA, etc.) were negative in the bladder flushing fluid.

3. Discussion

In forensic pathology, it is difficult to determine the cause of death for bodies recovered from water, especially for highly decomposed bodies [3,7]. Typical drowning signs disappear in the process of body putrefaction [7]. During drowning, diatoms in the water will be inhaled into the pulmonary alveolus by breathing [8]. Some of them penetrate into the bloodstream, and lodge in the liver, kidneys and bone marrow. The finding of diatoms in distant organs indicate death by drowning [1,3,9,10].

At present, there are several principles that were followed by the forensic pathologists to diagnose drowning [3,9]. Amongst these, the two regardings to diatom test are: (1) Diatoms should be found in the distant organs such as the liver, kidneys, or bone marrows, and (2) Certain numbers of diatoms to be discovered in the diatom test, viz. 20 diatoms/100 μL of sediment taken from 10 g of lung tissue and 5 diatoms/100 μL of sediment taken from 10 g tissue from at least one other organs. With the application of sensitive MD-VF-Auto SEM method in water-related cases, we found that it was not uncommon to get a result from an organ with diatom content higher than the abovementioned principles, even in those postmortem immersion cases.

In the drowning cases with decomposed bodies, we may find some supportive signs for or against the positive diagnosis of drowning. But in this case, while tetramine was positive in the liver tissue and the gastric contents, there was not a single sign of drowning being found in autopsy. Considering the autopsy findings and toxicological analysis results, we could infer that the victim is postmortem immersion.

However, the diatom test seems to provide a contradictory result from the conventional perspective. As we can see, the diatom contents meet the abovementioned two principles for determining a drowning death. For a body recovered from water, diatoms are frequently detected in the lung tissues no matter the victim is drowned or not [11]. In this case, the diatom species detected in the lung tissue are inconsistent with those of the water sample (*Coscinodiscus* and *Gomphonema*). One of the possible reasons is that the water we analyzed was not sampled on the day that the body entered into the water [12]. Potential false positive results in the distant organs, such as liver and kidney, have been controverted for a long time [2]. According to our study [12], few diatoms were observed in the liver and kidney tissues of non-drowned bodies though they were not in all cases. In this case, diatoms were found in both liver and kidney tissues. Moreover, the spectrum of diatom species detected in the kidney tissues was not concordant with the lung tissue (*Pinnularia*) and the water sample (*Coscinodiscus, Gomphonema* and *Pinnularia*). This result indicates the diatoms found in the distant organs are unlikely coming from the water of the brook where the body was found.

In our previous studies [6,11], all the cases with L/D ratio > 2 were from the drowning group. In the region of L/D ratio <2, some drowning cases and postmortem immersion cases shared in this range. It is possibly the severe physical injuries before drowning that has decreased respiration movement and lead to a

low capacity for diatom enrichment. It seems that using the L/D ratio alone is not sufficient for identifying postmortem immersion. In the case reported here, the L/D ratio was 0.009, which was much smaller than the value that we normally encountered in the drowning cases. Wounds, injuries and drowning signs were not found in the autopsy. Though diatom tests were positive in the liver and kidney tissues, the very small L/D ratio, when excluding the physical injuries and other factors affecting diatom counting, should not be regarded as evidence for drowning. It indicated that the victim was probably not alive and without any respiratory movements as she got into the water. Therefore, drowning was excluded to be the cause of death of the victim in this case.

The MD-VF-Auto SEM method, which is much more sensitive than the conventional method, improves significantly the recovery of diatoms from the tissue samples, hence increases a lot in the number of diatoms in quantitative diatom analysis. With the new sensitive method, the current practice and guidelines on how to diagnose drowning based on the diatom test results should be critically reviewed and updated. In the past, forensic pathologists in China always struggled with the potential false positive results in the diatom tests of closed organs due to the difficulty in ascertaining the source of diatoms detected in the organs was from drowning or life intake [13]. Therefore, we are exploring other ways to determine whether the victim have breathing movement or not in the water. As illustrated in our previous studies [6,11], the L/D ratio is a very good indicator for the diagnosis of drowning. Taking the autopsy findings together with the toxicological analysis results into consideration, the L/D ratio gave us confidence to conclude in the case that the victim had suffered from postmortem immersion. The L/D ratio would be more and more valuable in the diagnosis for drowning.

One thing to note here is that the L/D ratio should not be used to diagnose drowning singly, the diatoms in the closed organs should also be taken into due consideration.

Conflict of interest statement

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work, there is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled, “Evaluation of L/D Ratio in a water-related case for the differentiation between drowning and postmortem immersion”.

CRediT authorship contribution statement

Zhigang Li: Validation, Methodology, Writing - original draft, Formal analysis. **Bo Wu:** Validation, Investigation. **Yunying Wu:** Validation. **Pingping Zhang:** Validation. **He Shi:** Resources, Methodology. **Dongyun Zheng:** Validation, Data curation. **Jianding Cheng:** Methodology. **Chao Liu:** Methodology, Writing - review & editing, Project administration.

Acknowledgments

This study was financially supported by Grant-in-Aids for Scientific Research from China Public Security Ministry & Guangdong Province (2017GABJC07; 2015JSYJA03; 2015A020217001), and grant from National Natural Science Foundation of China (81430046).

References

[1] B. Ludes, M. Coste, N. North, S. Doray, A. Tracqui, P. Kintz, Diatom analysis in victim's tissues as an indicator of the site of drowning, Int. J. Leg. Med. 112 (1999) 163–166.
[2] M.S. Pollanen, Forensi Diatomology and Drowning, Elsevier Science BV, Amsterdam, 1998.
[3] M.H.A. Piette, E.A. De Letter, Drowning: still a difficult autopsy diagnosis, Forensic Sci. Int. 163 (2006) 1–9.
[4] A. Auer, M. Mottonen, Diatoms and drowning, Z. Rechtsmed. 101 (1988) 87–98.
[5] J. Zhao, C. Liu, S. Hu, S. He, S. Lu, Microwave digestion-vacuum filtration-automated scanning electron microscopy as a sensitive method for forensic diatom test, Int. J. Leg. Med. 127 (2013) 459–463.
[6] J. Zhao, Y. Ma, C. Liu, J. Wen, S. Hu, S. He, et al., A quantitative comparison analysis of diatoms in the lung tissues and the drowning medium as an indicator of drowning, J. Forensic Leg. Med. 42 (2016) 75–78.
[7] R.W. Byard, Drowning deaths in rivers, Forensic Sci. Med. Pathol. 13 (2017) 388–389.
[8] P. Lunetta, A. Penttil, G.H. Llfors, Scanning and transmission electron microscopical evidence of the capacity of diatoms to penetrate the alveolo-capillary barrier in drowning, Int. J. Leg. Med. 111 (1998) 229–237.
[9] R.B. Dettmeyer, M.A. Verhoff, H.F. Schütz, Forensic Medicine: Fundamentals and Perspectives, Springer-Verlag, Berlin Heidelberg, 2014.
[10] J. Hürlimann, P. Feer, F. Elber, K. Niederberger, R. Dirnhofer, D. Wyler, Diatom detection in the diagnosis of death by drowning, Int. J. Leg. Med. 114 (2000) 6–14.
[11] J. Zhao, C. Liu, A.S.A. Bardeesi, Y. Wu, Y. Ma, S. Hu, et al., The diagnostic value of quantitative assessment of diatom test for drowning: an analysis of 128 water-related death cases using microwave digestion-vacuum filtration-automated scanning electron microscopy, J. Forensic Sci. 62 (2017) 1638–1642.
[12] X Shen, Y Liu, C Xiao, C Zheng, J Huang, He Shi, et al. Analysis of false-positive results of diatom test in the diagnosis of drowning—would not be an impediment, Int. J. Leg. Med., https://doi.org/10.1007/s00414-019-02021-4
[13] N. Foged, Diatoms and drowning-once more, Forensic Sci. Int. 21 (1983) 153–159.