

## Letters to the Editor

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### Commentary on F. T. Zugibe and J. T. Costello, "The Iceman Murder: One of a Series of Contract Murders" (J. Forensic Sci., Vol. 38, No. 6, pp. 1404–1408, 1993)

Dear Sir:

The remarkable report on the "Iceman Murder" by Zugibe and Costello needs—in my opinion—some questions answered from a methodological (point 1 below) as well as from a physical (points 2 and 3 below) point of view.

1. The authors cite experimental procedures from histology textbooks [Refs. 4–6]. These procedures were developed to avoid tissue alterations which are usually caused by freezing and freeze-drying. From the fact that the examined body has been subjected to very different freezing conditions, it does not seem conclusive to postulate that morphological alterations (their Fig. 1) are necessarily due to ice crystal formation during freezing and/or thawing.
2. Although probably firm by its outer appearance, the body of the victim was scarcely completely solidified at the reported storage temperature of  $-17^{\circ}\text{C}$ . Both extra- and intracellular spaces contain significant amounts of dissolved electrolytes ( $\text{Na}^+/\text{K}^+$ ,  $\text{Cl}^-$ , etc.) and proteins. During freezing, ice crystals form from pure water, thereby increasing the concentrations of all dissolved substances. From the phase diagram for NaCl, it becomes clear that at  $-17^{\circ}\text{C}$  the ice crystals are in equilibrium with a concentrated NaCl-solution (20.5% by wt.) and that complete solidification will not occur until the eutectic temperature ( $-21.1^{\circ}\text{C}$ ) is reached. For other dissolved substances, the temperatures for complete solidification (whether eutectic or amorphous) are even lower. In a system where liquid and crystalline phases coexist, any pressure which might be exerted by ice crystals during their growth would be alleviated by fluid flow. It seems hard to perceive a pressure which the authors present as an explanation for the observed nuclear distortions. In histology, where specimens completely solidify during cooling to  $-130^{\circ}\text{C}$  and below, such pressures might in fact arise due to different crystallization kinetics in the intra- and extracellular spaces and due to the volumetric expansion of water during crystallization.
3. The observation that decomposition was greater externally than internally is attributed to microorganisms reaching the body from outside since the enteric flora was supposedly killed or altered after freezing. However, the fate of the enteric flora is not as certain as the authors' statement indicates, since numerous microorganisms are known to survive low temperatures. On the other hand, if it is in fact true that all microorganisms have been killed or altered during freezing, it seems a difficult venture for external microorganisms to migrate through the 20 layers of plastic in which the body was wrapped. Thus, the reason for

the peculiar decomposition seems open and not easily correlated with its freezing history.

In light of the above comments, the physical basis for the observed "ice crystal artifacts" (Fig. 1) seems dubious, while the so-called "ancillary studies" (such as clothing) deserve more attention in the discussion of the case. Basic research on the governing principles of freezing damage to bodies seems necessary before the authors' concluding queries become indicative of an "Iceman Murder."

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### Authors' Response

Dear Sir:

In response to Mr. Spieles letter regarding our article in the Journal of Forensic Sciences, Vol. 38, No. 6, November 1993, pp. 1404–1408, we disagree with both his comments and his conclusions which are based on mere speculation and a lack of experience in critically examining tissue from individuals who froze to death. Our conclusions are based on our experience over the past 25 years in the medical examiner's office concomitant with an extensive knowledge of the effects of freezing on tissues gained after having spent over ten years in histochemical research, with extensive experience in freeze-dry and cryomicrotomy techniques and a complete familiarity with the various cellular distortions that are associated with ice crystal effects. Over the past twenty five years, we have investigated numerous cases where individuals were found frozen to death and have regularly observed ice crystal artifacts in the tissue sections that are similar to those reported in our paper. Contrary to Mr. Spieles comment, many of our cases involving individuals found dead in below zero temperatures were indeed quite solid and sometimes had to be thawed over two days prior to autopsy.

It is important to understand that most of our current understanding of the effects of freezing on tissues was primarily derived from the results of histochemical research in the area of freeze drying. As we previously indicated, the principles of freeze-drying are based on the rapid freezing of tiny specimens at about  $-160^{\circ}\text{C}$  so that the water in the tissues is converted to a non-crystalline form in an attempt to avoid ice crystal formation which occurs at higher temperatures causing characteristic tissue distortions; the tissue is subsequently desiccated with a strong vacuum while kept frozen to remove all of the water. Prior to the introduc-

tion of freeze drying techniques, the old cold knife and freezing microtome techniques caused severe artifactual distortions, frequently making interpretation of surgical specimens very difficult. This problem was well known to older pathologists who used these methods for frozen section biopsies. Fortunately, newer cryostat techniques have obviated many of these problems making many pathologists unaware of them. To requote the warning by renowned pathologist and histochemist, Dr. R. D. Lillie (reference 6 in our paper) "*Slow freezing of unfixated tissue at temperatures near the freezing point is to be scrupulously avoided: relatively enormous ice crystal artifacts are produced.*"

In regard to Mr. Spieles third comment, unfortunately, our paper was remiss in not including information regarding the condition of the plastic wrappings. The autopsy report states, "There were holes in the plastic consistent with insect and animal activity and a garden snake crawled out of the bundle." Moreover, myriads of insects were present throughout. This should readily explain how many of the organisms were able to traverse the plastic layers. It is of interest that three years after our autopsy, Micozzi (ref. 2 in

our paper) reported the results of his experimental studies, where he froze rats and observed their decomposition. His findings were similar to ours in that *decomposition was more marked externally than internally, and there was a lack of distension*. He reported that the frozen thawed animals were more susceptible to invasion by insects and microorganisms from the outside, that it appeared that the freeze thaw cycle diminished the capability of the enteric organisms to grow and participate in postmortem putrefaction and that the mechanical disruption of the skin by freezing weakens the skin, connective tissue and joints.

We trust that this will clear up any misconceptions regarding our paper.

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