Forensic Science International 272 (2017) 150–153

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Technical Note

# Toward a universal equation to estimate postmortem interval

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ARTICLE INFO

*Article history:*
Received 19 September 2016
Received in revised form 9 January 2017
Accepted 10 January 2017
Available online 18 January 2017

*Keywords:*
Medicolegal death investigation
Postmortem interval
Forensic taphonomy
Decomposition
Temperature
Relative humidity

ABSTRACT

Estimating postmortem interval is an important goal in medicolegal death investigations. Although several methods have been developed to achieve this goal, many of these require significant time and advanced expertise to generate a reliable estimate. Unfortunately these techniques do not provide much insight during the early stages of an investigation when critical decisions must be made regarding the allocation of investigative resources. An equation was recently developed to address this problem: provide a preliminary estimate of postmortem interval to initiate an investigation while more advanced techniques are conducted. To evaluate this equation, we used it to estimate postmortem interval at multiple indoor death scenes with known PMI in Nebraska and Hawai'i. This equation allowed us to accurately estimate PMI at 15 of 19 (79%) indoor death scenes. In Nebraska, this equation was accurate at 100% of the scenes. In Hawai'i, this equation was accurate at 60% of the scenes. All inaccurate estimates of postmortem interval were associated with at least 20% mass loss and a postmortem interval of ≥4 days. Although this equation was accurate at the majority of the death scenes attended, we conclude that more research is warranted, particularly the effect of climate on decomposition and the investigators' ability to accurately estimate soft tissue mass loss.



## 1. Introduction

Establishing postmortem interval (PMI), or time elapsed since death, is a key component of every medicolegal death investigation. Postmortem interval plays various important roles to different parties involved in a death investigation. Postmortem interval may corroborate witness statements, support the credibility of other physical evidence, provide intelligence information for developing leads, facilitate information management regarding decisions on the allocation of investigative resources, and serve as evidence for subsequent prosecutorial action. In most death investigations the estimation of PMI is relatively straightforward because it is already known, or it can be established within a narrow time frame using witness statements and emergency services data. However, there are cases where PMI is unknown, and these cases are usually associated with unattended deaths or bodies that have decomposed for some period of time. In these cases it is very important to estimate PMI so that the investigation can proceed in a timely and appropriate manner.

Estimating PMI is a difficult responsibility, which is reflected, in part, by the numerous methods that have been developed over the years [1]. Oftentimes the first estimate of PMI is based on testimonial statements provided by neighbors, family members, and coworkers. Since these statements can be unreliable, investigators will also base PMI estimates on antemortem physical evidence such as newspaper delivery, daily/monthly calendars, cell phone activity, social networking (e.g. Facebook, Twitter) as well as medicine reminders and medical records from recent doctor visits. When those forms of evidence are not available, however, estimating PMI becomes quite difficult and often relies on postmortem changes and decomposition processes. These include the predictability of postmortem changes such as rigor mortis, livor mortis, algor mortis [2,3] as well as the chemical composition of the vitreous humor [3,4]. One particularly effective means to estimate PMI is forensic entomology, which uses the development of fly larvae, insect community succession [5], and fly larval gene expression [6].

Other recent methods to estimate PMI use postmortem microbial succession [7–10] or gene expression [11,12] and nucleic

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http://dx.doi.org/10.1016/j.forsciint.2017.01.013

acid degradation [13] of decedent cells. These methods are particularly promising because microbial and decedent cells should always be associated with remains and these processes also have a potentially high level of precision. For example, Metcalf et al. [14] used the structure of postmortem microbial communities to estimate the PMI of mouse carcasses to within approximately 3 days of actual PMI. Furthermore, these postmortem changes in microbial community structure appear to be similar across carcass species (mouse, swine, human) and geography [8], which means that postmortem microorganisms have a great potential as predictors of PMI. However, these methods require advanced instrumentation, extensive personnel training, and extended periods of time. As a result medicolegal death investigation still lacks a method to reliably estimate PMI that allows an investigation to proceed appropriately while providing time for more complex analyses. To address this gap in the medicolegal toolkit, Vass [15] proposed a universal method to estimate PMI (Eq. (1)).

$$\text{Aboveground PMI} = \frac{1285 \times (\text{decomposition}/100)}{0.0103 \times \text{temperature} \times \text{humidity}} \qquad (1)$$

where ***1285*** is a constant, representing the Accumulated Degree Days at which loss of soft tissue mass ceases, as observed at the Forensic Anthropology Center at the University of Tennessee-Knoxville. ***Decomposition*** is a value or range of values between 1 and 100, which represents a visual estimation of the percentage of soft tissue mass loss. ***0.0103*** is a constant, which adjusts for the effects of moisture on decomposition rate. ***Temperature*** is the value in degrees Celsius (°C) of the average temperature at the site on the day that the body was discovered. ***Humidity*** is a value between 1 and 100, representing the average relative humidity (%) at the site on the day that the body was found.

Eq. (1) was formulated to provide an investigator with a reliable preliminary estimate of PMI to progress an investigation while more detailed analyses are conducted. The development of a method to do so would be a significant advancement in medicolegal death investigation. To test the aboveground PMI equation, 19 death scenes were attended in Lancaster County, Nebraska, and the City and County of Honolulu, Oʻahu, Hawaiʻi. All death scenes used in this study had a reliable known PMI that allowed us to verify accuracy.

## 2. Materials and methods

### *2.1. Death scenes*

A total of 19 indoor death scenes were investigated. Ten death scenes were located in the City and County of Honolulu, Oʻahu, Hawaiʻi and nine death scenes were located in Lancaster County, Nebraska. The death scenes investigated in Nebraska occurred between March 2011 and February 2012 while the death scenes on Oʻahu, Hawaiʻi, were investigated between January and April 2014. These scenes had a known, reliable PMI based on several forms of evidence including witness statements, telephone activity, and electronic correspondence.

#### *2.1.1. Climate and environmental data collection*

Lancaster County, Nebraska, is located in a Cold climate (Dfa) characterized by hot summers and the lack of a dry season [16]. The island of Oʻahu is associated with two primary climates, Tropical Rainforest (Af) and Tropical Savanna (Aw) [16]. Following the completion of all necessary investigative documentation, temperature (°C) and relative humidity (%) at all death scenes were collected using a datalogger (Onset Computer Corporation, HOBO U23 Pro v2, Product #U23-001, Bourne, MA, USA). The datalogger was placed as close to the body as possible, always within 1 m. The datalogger was removed just prior to the body being removed from the scene to the morgue. The average time the dataloggers remained on scene in Lancaster County was 120 min and the temperature and relative humidity was recorded every minute. The average time the dataloggers remained on scene in Oʻahu was 60 min and the temperature and relative humidity was recorded every 30 s.

#### *2.1.2. Estimating soft tissue mass loss*

A visual evaluation of the body was made, taking into account the appearance, including discoloration, marbling, blistering, bloating, and skin slippage, and the amount of decomposition fluid and other bodily fluids released from the body. These estimates were similar to the calculation of Total Body Score [17], where a number is associated with a physical characteristic. Estimating soft tissue mass loss was quite difficult and we associated decomposition stage [see Ref. [18]] with soft tissue mass loss so that Fresh (0.1%–5%), Bloat (5%–10%), Active Decay (10%–50%), and Advanced Decay (>50%) were used as the basis for these estimates. Because estimations of soft tissue mass loss were inexact, difficult, and subjective, a range of percentages was established rather than a single value. For example, rather than estimate soft tissue mass loss equaled 5%, an estimated range of 1%–10% was used. For all death scenes in Nebraska, two individuals estimated soft tissue mass loss independently and then the average mass loss was determined.

#### *2.1.3. Statistical analyses*

Descriptive and inferential statistics were generated using Prism 7.0a for Mac OS X (GraphPad Inc., La Jolla, CA). Mean temperature, relative humidity, and soft tissue mass loss (±standard error) were calculated to describe the decomposition environments. These data were then compared using an unpaired t-test when datasets had similar variance or an unpaired t-test with Welch's correction when datasets had significantly ($P < 0.05$) different variances.

## 3. Results

Mean temperature and relative humidity at the nine death scenes in Lancaster County, Nebraska, equaled 24.6 °C ± 0.9 °C and 46.3% ± 7.4%, respectively. Mean temperature and relative humidity at the ten death scenes on Oʻahu, Hawaiʻi equaled 25.3 °C ± 0.6 °C and 67.8% ± 2.4%, respectively.

Table 1displays the data collected for the death cases in Lancaster County, Nebraska. The estimated PMI for all cases (100%) in Nebraska was consistent with the known PMI using Eq. (1). Table 2 displays the data collected from ten death scenes on Oʻahu. For six of the ten cases (60%), the estimated PMI was consistent with the known PMI. All of these cases had a known PMI of five days or less and estimated soft tissue mass loss was 15% or less. The cases in which the estimated PMI was inaccurate had a known PMI ranging from four to sixteen days. In four of these five cases the estimated percentage of soft tissue loss was 20% or greater. Mean temperature ($P = 0.82$) and relative humidity ($P = 0.44$) were not significantly different between accurate and inaccurate death scenes. In contrast, accurate death scenes were associated with significantly ($P < 0.05$) less mass loss than inaccurate death scenes.

Two significant differences were observed when we compared the datasets from Nebraska to Oʻahu. First, the relative humidity at the Nebraska death scenes was significantly ($P = 0.01$) less than at the accurate Oʻahu death scenes. Second, soft tissue mass loss in Nebraska was significantly ($P = 0.04$) less than at the inaccurate Oʻahu death scenes. In other words, inaccurate PMI estimates were associated with significantly greater soft tissue mass loss.