

Regression Models for Postmortem Interval Estimation by using Accumulated Degree Hours and Potassium in Vitreous and Blood

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Abstract

The biochemical changes of corpse are used for the postmortem interval (PMI) estimation, but decomposition is varied due to many factors. Ambient temperature is believed to be the most important factor which is related to biochemical change in the human corpse by using accumulated degree hours (ADH). The aim of this research was to develop exponential formula to estimate the PMI based on a potassium and ADH as the parameters. The secondary data analysis is conducted on 3 articles published in Thailand. The correlation data were analyzed by potassium, ADH, and time of death in each experiment. The temperature data was provided by the Thailand Meteorology Department (TMD). These results suggested that this developed method can use for PMI estimation. The additional step, namely to calculate the ADH from the finding date back until the predicted day of death from case reported and TMD. The regression analysis had a high reliability. The potassium level significantly estimates the PMI ($R^2 = 0.9183, 0.8296$ and 0.7142 for pig vitreous, corpse vitreous and corpse blood, respectively). When using the ADH in pig vitreous, the R^2 increased to 0.9931 . The developed potassium regression models are a practical method to measure PMI. The PMI can be estimated using this method, but caution is advised in case with a long PMI. It can be used to estimate the mortality time of the fresh-early decomposition stage, up to 48 hours. Due to the longer mortality, there may be a gradual rate of change and samples cannot be collected.

Keywords: Ambient temperature; Accumulated degree hours; Postmortem interval; Potassium.

Introduction

The time of death is extremely important to forensic medicine. There are various methods used to assessment, but often raise a question of the accuracy and precision in the PMI evaluation. The biochemistry postmortem changes after death are used to estimate

the time of death or PMI. The elements in vitreous humor (VH) are used to evaluate time since death, especially, potassium. The studies were performed on the VH^{1,2}, probably slowly autolytic changes to its being anatomically protected and isolated by its own structure.³ One method that forensic scientists have

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been explored for decades is the evaluation of the rise in potassium concentration in the VH.⁴ The several studies have found that the positive correlation between potassium concentration and PMI.⁵ Basically, most of previous equations are based on the approximation of the vitreous potassium according to both of a linear regression⁶⁻⁸ and exponential model.⁴

The various physicochemical changes of the corpse start immediately or shortly after death and continue in an orderly manner until the body decays. Each physiochemical and biochemical change has its pattern. Unfortunately, postmortem changes are strongly influenced by many unpredictable endogenous and exogenous, especially, environmental factors. Consequently, the longer the postmortem interval, the wider is the range of estimate as to when death probably occurred. In the other words, the less precise is the estimate of the time of death. The postmortem changes are a continuous process and are influenced by multivariable factors.^{9,10} The climatic differences between circumstantial regions, such as a hot or cold environment, influence the decomposition rate.¹¹ It is known from literature that temperature^{12,13}, body weight^{14,15} and clothing¹⁶ also have an effect on the decomposition process. It is said that ambient temperature is the most important variable, because it is the primary factor for all biological activity and biochemical reactions.¹⁶

In various studies, the relationship between the rise of potassium concentration in the VH and the time since death has been studied. There are many obstacles for using potassium as a tool for the time since death estimation, including some limitations and sample sizes given by different authors. Despite the numerous studies done in this field, there is still no consensus as to what formula or method is most accurate to estimate PMI from increased potassium in VH.⁴ The concentration of potassium increase in direct variable pattern with PMI.⁶ There are certain conditions that affect the methodology: correct sampling of VH, ambient temperature, body weight and temperature, metabolic status, agony preceding death, and even the cause of death are factors that can modify the results of PMI estimation.¹⁷⁻²⁰ The recent methods have been designed to determine the PMI based on the biochemistry of the VH as well as correctional factors such as ambient temperature with apparently good results.^{4,21} Nevertheless, it is essential to continue research in this field and to develop new methodologies that enable this calculation when the necessary data to apply existing

methods is not available, as well as improving the predictive power of these models. The availability of different methods of validation that integrate different parameters makes their use in daily practice more feasible and the option to choose one or another method. Based on the available data and the particular circumstances of each case helps to establish PMI in a more reliable way. In order to develop a methodology capable of estimating PMI with an easily, a quickly, and reliability obtained for tropical region. Therefore, the aim of this research was to develop exponential formula to estimate the PMI by using a potassium level and ADH.

Materials and Methods

The secondary data can be obtained from published reports, completed research papers, case studies, or published research articles about temperature changes in potassium levels and report the time of death of the corpse from papers published in journals in a manner consistent with the research objectives. The secondary data analysis is conducted from 3 articles published in Thailand. The research articles consist of time and date, ambient temperature, and potassium levels report.

Temperature collection

Ambient temperature was collected from Thai Meteorological Department (TMD) at that time in secondary data reported.

Potassium level and postmortem interval analysis

Pig vitreous carcass

The pig carcass data was obtained from Wohandee's research report.²² The objective was to study the relationship between the rate of change of various heavy metals in the VH for PMI predictable pattern. The study used 20 pig carcasses to observe the rate of body change after death and to assess the amount of electrolyte VH in 0, 1, 3, 6, 12, 24, 36, 48 hours. The researchers reported postmortem body changes as the time after death increased, environmental and body temperature, electrolytes in VH at the postmortem period increased. Therefore, these potassium data in the pig VH were used to estimate the postmortem period. The data were analyzed for new the relationship of changes in potassium levels and time after death with changes in ambient temperature. The exponential equation can be applied for estimating the time of death in corpses.

Human vitreous autopsy

The autopsy data was obtained from Soontorn’s thesis.²³ In this study, the amount of potassium, sodium and chloride ions were measured in the vitreous fluid to determine the relationship between electrolyte content and the time of death. The vitreous fluid from 50 corpses with the exact time of death was examined.

Human blood autopsy

Research data was obtained by Samroay’s thesis modification.²⁴ The research entitled “Estimation of death of dead bodies based on sodium, potassium and chloride levels in the blood”. The aim of the study was to determine the change in serum sodium, potassium and chloride levels at different times after death for use in estimating the time of death of a corpse.

Statistical analysis

The data were analyzed using GraphPad Prism 6 version 6.01 (GraphPad Software Inc. La Jolla, CA. USA). The data were analyzed for potassium, ADH and PMI. The values are displayed in the form of mean and standard deviation, linear and exponential regression.

Results and Discussion

The secondary data of Wohandee’s research report, the potassium data unit were modified from conventional unit to SI unit (mmol/L) shown in Table 1. The results shown that the potassium concentration in the VH was found to increase correlation with the time after death and ADH (Figure 1).

Table 1: potassium, PMI and ADH in pig carcass

PMI (Hours)	Potassium (Mean±SD) (mmol/L)	Accumulated degree hour (Hours)	Postmortem change
0	0.49±0.05	0.00	Fresh
1	0.67±0.11	6.60	Fresh
3	0.77±0.08	19.80	Fresh
6	1.08±0.07	39.60	Fresh
12	1.26±0.16	79.20	Early decomposition, dark skin
24	1.62±0.13	158.40	Dark brown skin,
36	1.69±0.18	237.60	Marbling
48	1.75±0.23	316.80	Late decomposition, fully bloat, bleb

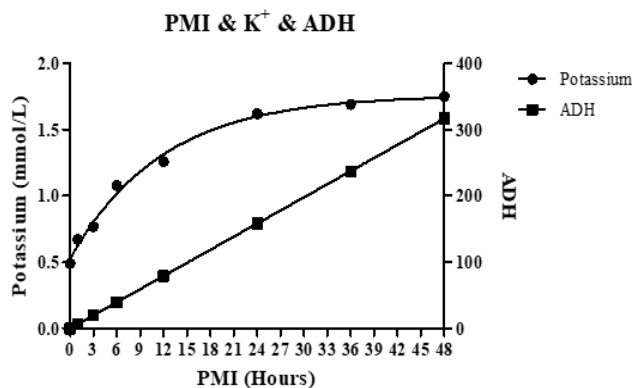


Figure 1: The relationship of potassium in pig VH, PMI and ADH

The relationships of potassium levels in pig carcass VH, PMI and ADH were shown as Figure 1. The linear regression of ADH and PMI was $Y = 6.600x - 0.0000002284$, $R^2 = 1.0000$. The exponential curve of

potassium and PMI is $Y = 0.5252 + 1.762(1 - \exp^{-0.0847X})$, R^2 is 0.9183 in Table 2. When Plateau was the Y value at infinite times, expressed in the same units as $Y = 1.762$ and K was the rate constant, expressed in reciprocal of the X axis time units = 0.0847. The relationship of exponential equation of potassium, ADH, and PMI was shown $R^2 = 0.9931$ (data not shown). The data were characterized by the correlation of potassium levels in the VH with different time periods of increased mortality consistent with the Zilg’s study.⁴ The exponential regression features have different slopes of curves at several points. The curve was initially steep and gradual, and the Y-intercept when entering fixed at Y_0 was 1.762 mmol/L during the 48 hours postmortem study period. When comparing the potassium levels of pig carcass vitreous humor at time 0, the unchanged potassium level was 7-10 times lower than that of the human

blood and vitreous humor. Comparison of initial potassium concentrations in pig VH were 1.99-2.84 times lower than human vitreous potassium levels. When applying this computational model to corpses, estimates of the duration of death may be inflated.

Table 2: Equation for postmortem interval estimation

Factors	Formula	R ²
Pig VH		
PMI-K ⁺	$Y = 0.5252 + 1.762(1 - \exp^{-0.0847X})$	0.9183
PMI-ADH	$Y = 6.6X - 0.0000002284$	1.0000
Corpse VH		
PMI-K ⁺	$Y = 2.779 + 7.491(1 - \exp^{-0.1159X})$	0.8296
Corpse blood		
PMI-K ⁺	$Y = 4.596 + 41.404(1 - \exp^{-0.06603X})$	0.7142

R² = Correlation coefficient

The secondary date of Soontorn's research report, the results shown that the potassium concentration in the VH was found to increase correlation with the time after death of corpse (Figure 2). The exponential curve of group vitreous potassium and PMI was $Y = 2.779 + 7.491(1 - \exp^{-0.1159X})$, R² = 0.8296 (Table 2). Forensic medicines estimate the time of death based on a several factors. The changes after death depend on the circumstantial environment. If the death environment was different, the change in the corpse condition would be completely different.

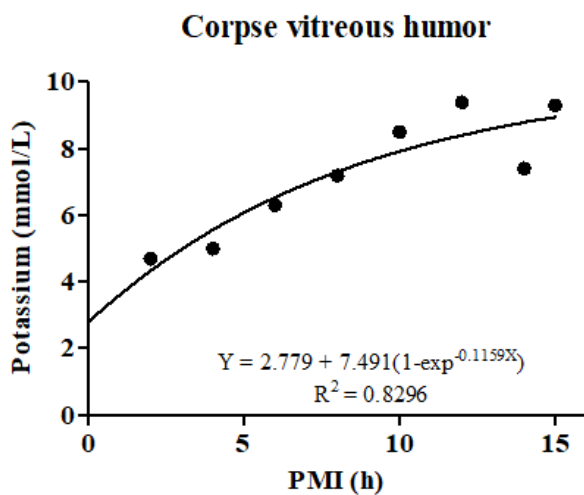


Figure 2: The exponential curve of potassium and PMI in corpses VH

The secondary data of Samroay's thesis report, the results shown that the potassium concentration in the blood was found to increase correlation with the time after death of corpse (Figure 3). The exponential curve of blood potassium and PMI was $Y = 4.596 + 41.404(1 - \exp^{-0.06603X})$, R² = 0.7142 (Table 2).

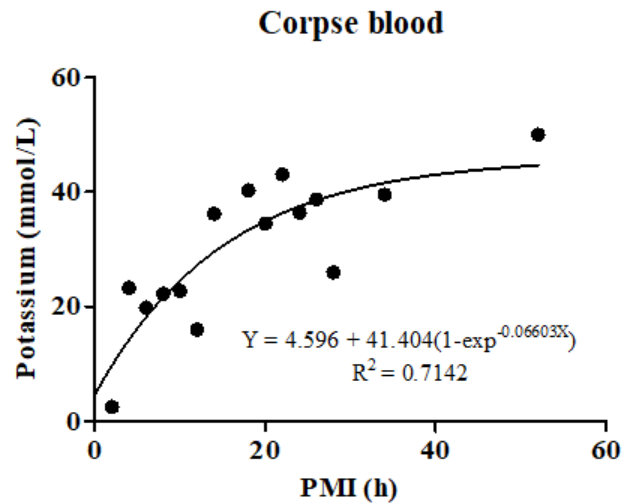


Figure 3: The exponential curve of potassium and PMI in corpse blood

The relationship of potassium levels in corpse blood and time since death was shown as Figure 3. The exponential curve of blood potassium and PMI is $Y = 3.795 + 39.575(1 - \exp^{-0.1047X})$, R² is 0.5476 in Table 2. The mean blood potassium concentration in humans was 4.14±0.46 mmol/L, which was within the reference range of 3.5-5.0 mmol/L. Comparing the equations, it was found that the exponential had better coefficients than the linear regression equations. It is suitable for early changes in potassium levels characterized by a steep curve and slows down as the mortality time increases to near constant.⁴ Potassium levels increased after death following a non-linear curve. Age factors and ambient temperature influence changes in potassium levels. The duration of injury and the high alcohol content at death were less than 1%, and the additional factors investigated did not affect the increase in potassium levels in the VH. Reported causes of death include intrathoracic hemorrhage, asphyxia from strangulation, stroke, asphyxia from choking, circulatory failure, trauma from a gunshot wound to the brain, a brain contusion, a torn lung, a torn liver and left kidney. These causes of death may be a factor in abnormal potassium levels in the blood. This is different from the concentration of potassium in the VH.

Conclusion

The present study collects data from published research on postmortem changes in biochemicals in the vitreous humor of pig carcasses and in the blood and vitreous of human corpses that can determine the timing of death. Our result can be use as data to create an equation model for estimating the time of death of dead bodies in Thailand which is characterized by a humid tropical climate. The regression equation has relationship of accumulated-degree hour to biochemical changes and decomposition processes of corpses. It can be applied to the death period after the onset of death up to 48 hours. Therefore, the PMI can be estimated using this method. However, caution is advised in the event of a prolonged death period and accumulated-degree day (ADD) is not indicative of the total heat present in the transition or decay that persists, which can be biased.

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Ethical clearance: Ethical committee Nation University, Thailand clearance was obtained before conducting the study (NTU.EC.1-005/2564).

Conflict of interest: None

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