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Experience in Creating Methods for Determining the Age of Death

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Abstract

The article provides thirty years of experience in solving the problem of establishing the age of the onset of human death in the early post-mortal period and with the onset of late cadaveric changes. The main stages of the defended dissertation studies that made it possible to create mathematical models are given. Most of the work is based on the features of postmortem thermodynamics and on the study of changes in various biophysical parameters of the corpse and its biological fluids in the early and late post-mortal periods. Mathematical models were implemented in devices to determine the age of death at the scene for forensic experts traveling to incidents with police officers. Sharing the experience of creating methods for establishing the age of death, the authors point to problems and possible ways to solve them.

Keywords: Age of Death; Human Corpse; Forensic Medicine; Forensic Medicine; Forensic Examination; Post-Mortem Thermodynamics of the Corpse

Introduction

The paradox of the last 20 years of crime, according to criminologists, is that traditional crime indicators currently do not fit into the established ideas for which their registration is carried out. It is more advantageous for criminals to commit acts that are not considered a criminal offense in a particular country, but which do not cease to be illegal in essence. A contradiction arises: the worse the situation in the country (local wars, social and economic crises), the better the legal statistics of legal crime [1]. Crime is known to require the participation of the police, the investigation and the trial, the establishment of the circumstances necessary for the disclosure of the wrongful act and measures to prevent it in the future.

Forensic medical examination is an important tool in the disclosure, and even more so in the investigation of unlawful acts against the person. The activities of forensic physicians can be procedural and extraprocessional in nature (the latter is increasingly prevalent in the activities of a forensic physician in the Russian Federation with sudden death, etc.) [2].

When solving and investigating crimes against the person, only forensic medicine is able to answer a number of specific questions of the investigation and the court. One of the significant questions that the police and the court are interested in: "When did death occur?." An important scientific area of activity of the Department of Forensic Medicine with a forensic histology course of the Faculty of Advanced Training and Retraining of the Izhevsk State Medical Academy is the study of issues of determining the date of death. It is known that objective specification of the statute of limitations of the exhaustion of death (the age of death - AOD) can provide significant assistance to the bodies of investigation, inquiry and trial in solving the crime and exposing the offender. In 2024, Viter VI [2], professor at the

Department of the Izhevsk State Medical Academy, was in Florida at a police school, where he was also interested in determining the age of death and the methods then carried out in the United States.

During the work of the forensic expert at the scene, in the process of sectional examination of the corpse, as one of the leading methods for fixing post-mortem changes, the organoleptic method is mainly used Kononenko VI, et al. [3]. Nevertheless, since the organoleptic method operates on features that cannot be quantified, it has some subjectivity, a high dependence of the result on the expert's qualifications and, as a result, a relatively high error in determining the AOD as a whole. Naturally, the efforts of many researchers in the field of forensic medicine were focused on the search and study of dynamic processes that could be numerically characterized and laid the basis for the definition of AOD Botesatu GA [4] and Novikov PI [5].

In the works of the staff of the Department of Forensic Medicine, the solution to the issue of determining the AOD is developed on the basis of the study of the features of postmortem thermodynamics and on the methods based on the study of changes in various biophysical parameters of the corpse and its biological fluids in the early and late postmortal periods. A feature of scientific works for the development of methods for establishing the age of death were facts based on the phenomena of intravital disruption of the mechanisms of regulation of body temperature from the standpoint of systemic disintegration of homeostatic mechanisms. It recommends actively using the data of a sectional study, which, in the context of the theory of functional systems (in relation to the dying process), can make it possible to determine the sequence of death of structural levels that ensure the vital activity of an integral organism. Based on the studies, a mathematically describing diagnostic process formula was obtained by Viter VI, et al. [6].

Later, research on post-mortem cooling was continued in the works of students of VI Viter, et al. [6]. So Ramishvili AD [7], according to the results of rectal and hepatic thermometry, showed an exponential nature of the cadaver temperature dynamics, which depends more on the thanatogenetic sign and less on the nosological sign [7]. As a model of the body of Viter VI, et al. [6], it was proposed to use a two-layer structure, where the inner layer (the body itself) is formed by internal organs that have close values of thermophysical parameters, and the outer surface layer (including fat layer, skin, clothing) is significantly different from the parameters of internal organs. According to this model, the law of measuring the current (postmortem) body temperature is obtained with a known dependence of the temperature of the surface layer of the surface temperature, which is a more general solution of the formula Viter VI, et al. [8] of the thermal problem for a two-layer object [8].

Subsequent scientific work has shown that the AOD is influenced by individual signs that cannot be mathematically described at this stage and therefore it is proposed to establish confidence intervals for the onset of death [9]. Being a technical specialist (Department of Computer Engineering, Izhevsk State Technical University named after M.T. Kalashnikov), Kulikov VA, et al. [9] devoted a dissertation study creation of original needle-type temperature sensors. This study made it possible to create and establish the industrial production of portable electronic thermometers with a high rarefactive ability to measure temperature (0.1-0.001 C).

In the future, all scientific work at the Department of Forensic Medicine, carried out as part of the thermometric approach, was carried out with temperature sensors developed by Kulikov VA, et al. [9], which made it possible not only to significantly increase the accuracy of measuring the temperature of the corpse and, therefore, determining the AOD, but also to recommend the use of new diagnostic zones not used for thermometry earlier. So Shchepochkin OV [10] developed an original method for measuring the temperature of the brain in its central part and created a computer program "CranioTemp," to determine the AOD from a number of measurements of the temperature of the corpse and the environment [10]. At the same time, the shape of the head is more accurate than all other parts, including successive layers of the meninges, bones of the skull, muscles, skin and hair, in contrast to the subcutaneous fat of the body, brings a smaller error to the measurements. Based on the analysis of the error of the thermometric study, for the first time, the ranges of applicability of the method were also identified, justified by the possibility of achieving the maximum accuracy of determining the AOD in these diagnostic zones [11] with the time of death in the range from 2 to 13 hours, the AOD error was not more than 30 minutes.

Somewhat unconventional (from the point of view of previously developed mathematical models of post-mortem cooling) is the approach to the problem from the standpoint of assessing the values of thermophysical parameters of biological tissues of the human body. In order to move from relative values characterizing the rate of postmortem cooling of the body to specific values of its thermophysical characteristics, Vavilov AY [12] proposed using the definition of the thermal conductivity coefficient of a number of biological tissues and organs of a human corpse. In the course of the studies, both the actual values of the thermophysical parameters of the human body and their dependence on a number of factors taken into account in the study were established.

In addition, the peculiarities of the methodology developed by the author made it possible to use it in other

scientific developments of the department, devoted both to the possibility of establishing the age of death by the biophysical method of KA Babushkin and to resolve the issue of lifetime and age of injury, on the basis of signs that previously could not be quantified. The laws revealed by Vavilov AY [12] were mathematically described, with the possibility of using the given equations to analyze the rate of postmortem cooling of the human body and determine the AOD from the standpoint of the theory of thermal conductivity [12].

So Blagodatskikh AV [13] for the first time in medical practice approaches the process of cooling the human body on the basis of solving the marginal problem of thermal conductivity [13]. The application of this approach made it possible to significantly increase the accuracy of determining the AOD, reducing the error interval of the obtained values to 8% of the calculated value. Nevertheless, some inherent disadvantages of the method (the high complexity of the mathematical apparatus used, the need to establish a number of additional characteristics of the corpse - according to the method of Vavilov AY [12]- limited its practical use.

In the work of Ali LHM [14], analyzing the results of thermometry of classical diagnostic zones (liver, rectum), it was concluded that it is necessary to study the thermodynamics of the corpse from the standpoint of a variant of the thanatogenetic mechanism [14]. The author points out that the variant of thanatogenesis is of important diagnostic value and recommends, along with thermometry, to carefully study the data of the examination of the corpse and its sectional study, on the basis of which it is possible to determine the variant of thanatogenesis. Pathophysiological changes accompanying the onset of human death also did not remain out of the field of view of the researchers. The study of them, with an emphasis on variants of circulatory disorders, was devoted to the candidate work of Khalikov AA [15]. Using the data of hepatic and rectal thermometry, the author mathematically modeled the features of cooling corpses with various variants of pathophysiological disorders, developed recommendations for practical experts, created a computer program "Termo" to calculate the age of death by the temperature of the corpse [15].

The analysis of the above works convincingly indicates a fairly detailed study of the issue of cooling the corpse at its regular stage. Nevertheless, the conditions of such a stage can be fully created only in thermal chamber conditions - stable ambient air temperature, no air flows. In real conditions, such conditions are practically not found. Much more often, a forensic expert meets with the option of staying a corpse in conditions of variable ambient temperature. However, even if such changes are known, the conventional mathematical apparatus developed to date cannot be applied.

In this regard, noteworthy is the study by Swede EF [16], which resulted in the creation of an original two-exponential model of post-mortem cooling, which the author recommends to apply step by step. The start point of each step is the time of change of the ambient temperature, and the duration of the step is selected so that during its given temperature can be considered unchanged. The possibility of separate launch of exponents, which is provided by the proposed model, is important to minimize the calculation error, because it avoids the formation of a "temperature plateau" at the beginning of each of the steps, which inevitably accompanies the use of traditional mathematical models. In addition, appropriate computer programs have been created to facilitate the practical application of the methods developed by him Swede EF [16].

To more adequately model the features of post-mortem thermodynamics of a particular object (corpse), the researcher needs to know some of its individual characteristics - body weight, as a parameter that determines the amount of stored heat and, accordingly, largely determines the dynamics of corpse cooling. However, not all institutions of the forensic medical service have conditions for weighing the corpse and, moreover, this event is impossible when examining the corpse at the place of its detection. In many regions of Russia, the autumn-winter-spring period is characterized by low subzero temperatures. At the same time, the corpses of people in these conditions are subjected to glaciation in some cases, which greatly complicates the diagnosis of the age of their death. Meanwhile, in forensic practice to date, there has been no method to establish the age of death in the study of an icy corpse, which greatly reduces the effectiveness of examination and investigation in the development of criminal cases related to an icy corpse.

In his scientific work, Natsentov EO [17], in relation to the definition of AOD during the examination of icy corpses, identifies three processes that have the appropriate duration:

- Cooling of the corpse - from the moment of death until the phase transition temperature is reached;
- Cooling of corpse tissues in a phase transition state - from the moment of reaching the phase transition temperature to achieving complete glaciation;
- Cooling of the icy body - from the moment of achieving complete icing to the moment of reaching the ambient temperature [17].

The author found that the type of temperature curve in the first phase (body cooling) fully corresponds to the modern theoretical ideas of such a region of "plus" temperatures (Celsius), which allows you to use mathematical modeling for its description using a two-point model, which has proven itself in establishing AOD under variable environmental conditions. Nevertheless, due to the fact that the duration

of various phases (corpse cooling, phase transition, icy body cooling) for superficial and deep parts of the body are different, the mathematical expression reflecting the individual thermophysical features of the corpse was adjusted, which allowed the author to more correctly describe the dynamics of post-mortem temperature at negative ambient temperatures. When analyzing the second stage - the phase transition of the tissues of the corpse - it was established that the duration of this phase is directly dependent on the ambient temperature, body weight and the nature of the clothes on them. To calculate the duration of this phase, the corresponding mathematical expressions were created, and for the examination of the icy corpse as a whole - the original method of thermometric research.

In the work of Vavilov AY [12] "Forensic medical diagnosis of the age of death by thermal methods" on the basis of the studies carried out, it was shown that the values of the thermophysical parameters of the tissues and organs of the human body that make up the "temperature core" and "body wall" of the diagnostic zones under study, determining the rate of cooling of the corpse, are values depending on the cause of death of a person and the presence of ethanol in his blood. Instrumental error of temperature measurement, "diagnostic miss" by a temperature sensor past the center of the examined diagnostic zone, turning the corpse over to its thermometric study, lead to the formation of an error in determining the age of death, reducing the evidentiary value of the expert's conclusion. The assessment of the adequacy of existing models of post-mortem cooling of the corpse, carried out using the developed methodology based on a large practical material, makes it possible to recommend for use in expert activities only models based on the exponential dependence of the fixed indicator, since only they adequately describe the observed process, having similar characteristics in terms of accuracy. The use of optimization methods according to the developed algorithm is accompanied by an increase in the accuracy of establishing the age of death in conditions of incomplete initial information - in the absence of information about the temperature of a person at the time of his death and fluctuations in the temperature of the environment during the stay of the corpse at the place of his detection. The determination of the error of the thermometric method of determining the age of death is made on the basis of the use of the developed method by establishing boundaries in which, with a probability of more than 95%, the true value of the age of death of a person is found.

In the work of Malkov AV [18] "Thermometric diagnosis of the onset of death in the early post-mortal period" [18], for the first time, individual values of thermal constants (coefficient K) were established during thermometry of the dead body, characterizing the duration of the non-stationary cooling regime of the corpse recorded in the brain tissue, liver, rectum. The influence of a complex of external and internal conditions (body weight, external temperature, the cause of death of a person and the presence of alcohol in his blood) on the duration of the initial "temperature plateau" of the corpse has been studied. The duration of the initial "temperature plateau" cooling of the studied diagnostic zones (brain, liver, rectum) is different, and therefore, when calculating the age of death of a person, the duration of the transient thermal cooling regime of the dead body should be set differently, based on which diagnostic zone the corpse thermometry is performed. Using the developed algorithm for optimizing the value of the thermal constant (K), due to taking into account the individual characteristics of the studied dead body, during cranioencephalic thermometry allows you to achieve the accuracy of the method at the level of ±11 minutes, with liver thermometry - ±13 minutes, with rectal thermometry - ±12 minutes in the interval of the postmortal period lasting no more than 12 hours.

In the work of A.V. Lahno "Photocolorimetric objectification of the age of death, based on the dynamics of cadaveric spot restoration," the digital characteristics of the color of the cadaveric spot in the dynamics of its recovery after dosed exposure were studied, discretely quantified in the form of color coordinates in the spaces RGB and YCrCb. The author determined the numerical values of the color characteristics of cadaveric spots and made a mathematical description of the dynamics of their recovery by regression equations, taking into account the complex of factors that determine the individuality of the subject of forensic medical research. Mathematical models have been created that quantitatively characterize the dynamics of restoring the coordinates of the color of the cadaveric spot recovering from standardized pressure on it, depending on the duration of time preceding the diagnostic procedure. A method of objectifying a diagnostic procedure for establishing the age of death of a person by a quantitative method is developed - colorimetric examination of digital indicators of the color of a cadaveric spot in the color spaces RGB and YCrCb, using calculated methods of expert judgment.

The department devoted a number of works to the diagnosis of the age of death in the late post-mortal period. In the work of N.V. Korshunov "Diagnosis of the age of death in the study of corpses in the stage of putrefactive their transformation" (2007), the stage of macroscopically recorded morphological manifestations of putrefactive biotransformation is first described, taking into account the processes associated with postmortem bacterial heat production recorded in an objective quantitative way. Various types of putrefactive biotransformation have been identified with a description of the critical microflora mass, referred to as "putrefactive potential." It has been

established that cadaver decay is characterized by a clear stage of macroscopically fixed morphological manifestations of the process, based on the complex of which it is possible to reliably diagnose the stage of putrefactive decomposition and, accordingly, the decay period of the object. Decay of a biological object, accompanied by intense gas formation ("explosive" type of decay), begins when the cadaveric microflora reaches the "critical mass," for which it is advisable to use the concept of "putrefactive potential," expressed in degrees-hours (°S×chas). One of the necessary conditions for the active activity of cadaveric microflora and, accordingly, "explosive" decay is the preservation by the biological tissue of a minimum optimal ("base") temperature of 16.5 ° C for a certain time. Using the specified "reference" temperature value and the corresponding average value of the "putrefactive potential," it is possible to estimate the length of the time interval necessary for the appearance of signs of rotting of the corpse, based on the specific values of its temperature and individual thermophysical characteristics that determine the individuality of the dynamics of its cooling. The author developed an algorithm for forensic research of a putrefactively changed corpse, which is accompanied by an increase in the accuracy of diagnosing the age of death in the late stages of the post-mortem period, due to the use of objective quantitative methods of accounting for the degree of bacterial heat production.

To improve the quality of diagnosis of the age of death in the late postmortem period, A.M. Onyanov in his work "Dynamics of Impedance Parameters of the Vitreous Body in the Late Postmortal Period" proposed to take into account the dynamics of changes in the ability of the vitreous body to polarize with alternating electric current. The author shows the features of the polarization of the vitreous body by alternating electric current, developed a method of objective (quantitative) calculation of the age of death of a person, and carried out in the late stages of the posthumous period. It has been found that the vitreous body of a person is an object with high stability of electroconductive characteristics, which facilitates accounting for changes detected during biophysical research. The coefficient of polarization (dispersion of electrical conductivity) of the vitreous body depends on the age of the person under study, and does not depend on his gender, the cause of death and the fact of alcohol intoxication. The calculated determination of the error of the method, for a confidence interval of 95%, allows you to recommend it for practical use when the object of the study is located in conditions of external temperatures + 4 ° - + 20 ° C, at which the highest accuracy is achieved.

In the work of A.S. Emelyanov "Diagnosis of the age of death by the magnitude of the electrical resistance of peripheral nerves" (Scientific Director, Doctor of Medical Sciences, and Professor Proshutin Vladimir Lvovich), the characteristics of the dynamics of the electrical resistance of the median and sciatic nerves in the early and late stages of the postmortem period were first studied. It was established that the electrical resistance of the median and sciatic nerves in the dynamics of the postmortem period have similar threads, but different values by observation groups and measured frequencies (100 Hz; 1, 10 and 100 kHz). These values can be used as an additional diagnostic criterion for the age of death within 2 months of the postmortem period. The electrical resistance of the median and sciatic nerves is independent of exogenous (ethanol, types of death) and endogenous factors (gender, age, cross section), and therefore, such can be ignored when establishing the age of death.

Conclusion

It is possible to conclude about the fundamental theoretical study of the thermometric method in the works of employees of the Department of Forensic Medicine with a course in forensic histology, which significantly expanded the understanding of the problem in general and the thermodynamics of the corpse in particular. This gave rise to a number of leading scientists of the Russian Federation to make a judgment on the creation of a scientific school under the guidance of professors Viter VI [2] and Vavilov [12]. The methods created are widely used in institutions of the forensic medical service of Russia and neighboring countries, and the data obtained with their help contribute to increasing the evidence value of the judgment of practical experts in terms of their opinion about the time of death. Meanwhile, research on this problem is not completed, and despite the fact that the Department of Forensic Medicine with a course of forensic histology already occupies one of the leading places in scientific developments to determine the age of death, the continuation of scientific research makes it possible to consider the appearance of new results, new methods that objectivize the diagnosis of the age of death both thermometric and other instrumental methods.

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