Survey on Prediction of Post Mortem Interval using Artificial Intelligence in Forensic Examination

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Abstract: *There is very much of importance of estimation of time since death as it is important aspect in the field of forensics and criminal investigations. Data processing through the artificially intelligent device is the method used to predict the time. As there are many biochemical components present in blood, urine which are helpful for post-mortem interval (PMI) estimation. Mainly femoral vein blood must be collected for measuring the PMI. Artificially intelligent devices are trained to learn and solve the problems. The concept of device used is just for providing the profile of different metabolites in blood such as Lactate dehydrogenase (LDH), cholesterols, triglycerides, etc. and finding out the time of death by just analysing different statistics and graphical study. pH of blood is also the factor which we need to take into consideration, generally in Early PMI estimation and factors like temperature, decomposition, etc. in Late PMI estimation. Use of artificial intelligence is due to its comprehensiveness, efficiency and automation. Use of biomarkers, biological fluids is the powerful and efficient tool in forensic death and crime investigation process.*

Keywords: Post-mortem interval (PMI), time since death, biomarkers, biological fluids, metabolites, artificial intelligence (AI), lactate dehydrogenase (LDH), cholesterols, triglycerides, Early PMI, Late PMI, pH.

Motivation: In upcoming days, there will be very good scope for artificial intelligence in the field of medical science, forensic report generations, health care data processing, etc. From the recent developments, forensic field is benefitting from artificial intelligence. Post mortem interval prediction is the need for crime investigation, to determine the cause of death and investigation of suspicious death which all are the part of forensics. Due to the use of AI, many tasks related to forensics has been automated such as forensic report generation, evaluation of different metabolites in blood and urine, fingerprints matching, etc. Artificial intelligence is also used for health care alerts, health care assistance, etc. And hence the accuracy and error free work is also established.

1. INTRODUCTION

Artificial intelligence has acquired the area almost in all the fields including forensic science. There is an impact of Artificial intelligence in everybody's life.

Whenever investigator encounters a deceased, then to find out the time between the death and discovery of death body, is the primarily task. Post mortem interval is nothing but the time since death. This PMI and forensic report will assist the court, whether to accept or reject the statements of suspects and witnesses [13].

Prediction of time of death methodologies are mainly divided into 2 groups: Early PMI and Late PMI. Until tissue decomposition has not started, the period is called an Early PMI. And Late PMI is also defined as skeletonization [16]. In Early PMI, biochemical changes are the factors to predict the time whereas decomposition, temperature are the factors for Late PMI. But, to predict the time of death is more difficult with longer PMI [10].

There are many ways to define the longer and shorter PMI. Biomarkers like brain, blood, urine, pancreas, etc. have been studied [6],[17],[18]. Biological markers is also classified into proteins and metabolites. Metabolites such as NaCl (sodium chloride), K (potassium), NH3 (ammonia), urea, etc. and proteins such as lactate dehydrogenase (LDH) and Aspartate aminotransferase (AST). Biochemical changes will be there until body decomposes completely. But many researches claimed that blood is an ideal tissue to use for estimation of time of death [5],[15]. Body cooling, settling of blood in lowest placed parts of the body, limbs stiffening and eye chemistry are some changes, one can see in Early PMI. Whereas in Late PMI different levels of decay and decomposition, one can observe.

Potential of hydrogen (pH) is also being used while determining the time. Determining the concentration of H+ ions i.e. pH of blood, which is changed after the death. And by comparing all the parameters with the standard values, we can proceed for analysis.

The concept of estimating the time of death during forensic examination is based on the use of AI device measuring biological markers in blood such as LDH and AST as protein and cholesterols as lipid, as well as pH of blood. Once the profile is provided to the device, it will analyses the data and gives us the correct result with the prediction of time of death. And then report will helpful

to take further actions in court or to declare the cause of death. Figure below demonstrates the process of forensic examination with prediction of post mortem interval.

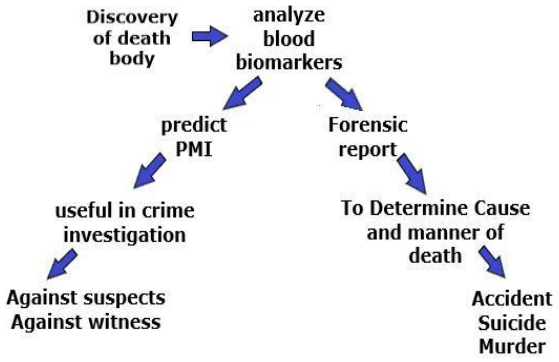

Fig- 1: Process of forensic examination in post mortem interval prediction.

2. LITERATURE SURVEY

In 1965, J. A. Payne [1] was conducted the carrion study on baby pig, Sus scrofa Linnaeus where they studied the different stages of decomposition. When carrion exposed to arthropods, they found 6 stages of decomposition as fresh, bloated, active decay, advanced decay, dry, and remains. Whereas, 5 stages were recognized for carrion which is not exposed to arthropods as, fresh, bloating and decomposition, flaccidity and dehydration, mummy, and desiccation and disintegration. But that study was limited to only the factor 'decomposition' which is useful for estimation of Late PMI.

Glucose and urea nitrogen determinations were made on blood and cerebrospinal fluid by F. John, et al on the research topic "Post mortem Blood Sugar and Blood Urea Nitrogen Determinations" where they claimed that, blood is unsuitable for post mortem glucose determination and samples taken from cerebrospinal fluid gave more uniform values than blood samples and hence post mortem interval should be carefully estimated [2].

J. I. Coe, has been done a great work on post mortem chemistry of blood, cerebrospinal fluid and vitreous humor with the hope that biochemical abnormalities which can exist during life can be demonstrated from post mortem examination [3].

In the research topic, "Cardiac blood pH as a possible indicator of postmortem interval", William R. Sawyer, et al were evaluated the changes in the pH of blood and selected tissues in rats at interval upto 96 hours. And later on study in human subjects suggested that this is the quick and convenient method to estimate PMI [4].

Several years of intense research have been compiled by J. I Coe in 1993 and studied the enzymes, biochemicals, serum, body fluids, blood, pigments, hormones, time of death, blood gases, metabolic disorders, etc. They studied all bio-chemical components related to PMI but consideration of environmental factors was not there [5].

To improve the possibilities to delimitate the time of death, it was examined, if PMI prediction is possible by immunohistochemical insulin detection. Result produced was, pancreatic beta-cells of upto 12 day-old corpses produce positive immunoreaction against insulin whereas corpses older than 30 days do not show such a reaction. These results will be helpful for estimation of post mortem interval prediction. But the time or interval limits which were produced during research may change according to the surrounding condition and it would be body composition specific because of the immunity. [6]

In 2001, the book published named 'Corpse: nature, forensics, and the struggle to pinpoint time of death.' In which J. S. Sachs said that, chemicals, insects found near the body will be weapon in our crime fightening arsenal. And there will always be a linking of decomposition process, scenario at the location where crime has happened and the results of forensics [7].

In 2002, Arpad A. Vass, et al [8] was carried out the study of decomposition chemistry of human remains with the aim of identifying time dependent biomarkers of decomposition. Purpose was to develop the precise method for measuring PMI. During the 4 years of period, analysis of biomarkers like amino acids, neurotransmitters and by-products has been done in various organs like liver, kidney, heart, muscle, brain, etc. which revealed different patterns useful for determining PMI when based on cumulative degree hour (CDH). But limitation which should overcome is to obtain the correct temperature data at crime scene rather than variability in sample. And then analysis of gathered data is required.

M. S. Megyesi, et al [9] has demonstrated a supplemental method to determine the PMI based on scoring decomposition and taken into account temperatures in which the remains were exposed. This method has already implemented and by analysing the data, it was observed that the decomposition is best modelled as dependent on accumulated temperature, not just time. The decomposition state can provide much information about the PMI when used with accumulated degree days.

In the case study of "The effect of body size on the rate of decomposition in a temperate region of south africa", A. Sutherland, et al [10] said that there are many factors influenced on the rate of decomposition, such as temperature, rainfall and exposure of the body. And after observing the rate of decay on pigs of variable body size, the relation established that rapid decomposition occurs in early stages of decomposition. And finally results came out was small pigs decomposed faster than larger

ones; Indicated that body size does have an effect on the rate of decomposition.

Traditional method of identifying metabolites that change post mortem have not been adapted widely to estimate PMI. But the use of biochemical markers and different methods gives precise and accurate result. Main focus was on biochemical changes and cellular changes occurring in the blood. And hence methods described related to Early PMI estimation in this particular research topic [11].

In 2013, M. J. Buchan, et al [12] , have published their paper in which they listed out the different methods to estimate the PMI. Current status was included in that paper including all the types viz. Early PMI and Late PMI. They have noted the problems related to methods also. And future scope to overcome the demerited areas.

In 2015, D. L. Cockle, et al [13], they proposed the study to find out the reliable method to estimate the accurate PMI. Many formulas they have implemented to estimate the time since death but results found as there are many factors affect the body after death and to consider all the factors is difficult, and concluded that neither their results support the proposition of universality for PMI estimation nor any universal formula claimed.

The PMI estimation is based mainly on the visual observation like algor, livor and rigor mortis, etc. The aim of the study was to evaluate the kinetic alterations of several biochemical parameters (i.e. proteins, enzymes, substrates, electrolytes and lipids) during putrefaction of human blood. By studying this, we can develop the mathematical model to achieve more accurate PMI, proposed by I. Costa, et al [14].

In 2016, Y. Meng et al [15], was carried out the study of correlation between blood oxidation-reduction potential (ORP) values and PMIs. After implementing the idea, the results got, was a strong positive correlation between the blood ORP values at different temperatures and the PMI and hence provided the another tool to estimate the PMI.

3. LIVE SURVEY

Various formulae have been developed over the past few years using statistical method and concentration found in vitreous humor. In this paper, 5 simple models are used to estimate PMI by using analysis of potassium, hypoxanthine and urea in the vitreous humor are presented. These five models are established based on the formula derived. Corrective factors as, body weight, rectal temperature, ambient temperature, which can influence the estimation of this time interval, have been incorporated into the formulae. Then R^2 and mean squared error have been calculated for the every model to select best amongst five. Free software program can easily calculate PMI from model and provide quick and reliable results [19].

Received : 13 July 2018
Revised : 30 November 2018
Accepted: 10 December 2018

Natalie R. Langley, et al [20] was conducted lipidomic analysis of human skeletal muscle tissue to test predictive capacity of lipids in human skeletal muscle cell membranes.For this analysis, small amount of tissue is only the requirement. And this is less subjective than the visual methods for estimating PMI. Sophisticated quantitative methods for estimating PMI from biomolecules unique to the corpse, and the human microbiome may provide a means of overcoming the geographic limitations of methods based on subjective visual observations of decomposition changes.

In their research " '2_n Analytical Platform' To Update Procedures in Thanatochemistry: Estimation of Post Mortem Interval in Vitreous Humor", Roberta risoluti, et al [21] developed a novel multiway approach by spectroscopy and thermogravimetry by providing parametric characterization of vitreous humor as a function of the time since death. ICP-OES (Inductively coupled plasma optical emission spectrometry) were found to be diagnostic in predicting PMI which is used to determine micro and macro vitreous specimens. In that study, It was observed that many elements play the significant role in determining PMI.

In early of 2020, Liu R, et al [22], have studied how microbial community sequences help in determining the PMI. In that study, they combined microbial community characterization, microbiome sequencing from different organs (i.e. brain, heart and cecum) and machine learning algorithms [random forest (RF), support vector machine (SVM) and artificial neural network (ANN)] to investigate microbial succession pattern during corpse decomposition and estimate post mortem interval in a mouse corpse system. In that process, microbial communities exhibited significant differences between death point and decay stages. Then ANN combined with post mortem microbial data set from the cecum which was the best combination. And then this integrated model can serve as accurate and reliable post mortem interval estimation.

4. METHODOLOGY SURVEY

4.1 Immediate PMI

Due to the loss of blood circulation and loss of regulatory mechanisms, body undergoes rapid biochemical and physiological changes. These changes are detectable in the eyes and skin. Trucking of retinal blood vessels and losing elasticity and luster of the skin are the observable changes. This phase can be termed as PMI between

somatic and cellular death, within 2 to 3 hours after death.

4.2 Early PMI

This period is of 3 to 72 hours after the death. And this is estimated using algor mortis, rigor mortis and livor mortis.

4.2.1 Algor Mortis

This is the cooling of the body after death and loss of heat to the environment by conduction, convection and radiation. This is the most accurate method of estimating time since death in early post mortem phase.

4.2.2 Rigor Mortis

It is stiffening of muscles, caused by the depletion of ATP from the muscles, post mortem. The cessation of oxygen supply causes the stoppage of aerobic respiration in the cell and causes lack of production of ATP. Rigor mortis appears approximately 2 hours after death and complete after 6 to 8 hours after death. It will appear for next 12 hours and then disappear.

4.2.3 Livor Mortis

In this phase discoloration of skin occur, due to the collection of blood in skin vessels, caused by gravitation

pull. And it will take half an hour to 2 hours. Colorimetric methods are useful to estimate the PMI by using this livor mortis.

4.2.4 Histo-morphological analysis

Microscopic morphological examination of blood is important in this method, whereas histological study required for the skin. By studying this, PMI estimation will be carried out.

4.2.5 Biochemical assessment

This is useful to estimate the PMI from vitreous humor, synovial fluid, pericardial fluid, urine, and cerebrospinal fluid. And few biochemical markers are taking into consideration namely potassium, sodium, urea, chloride, magnesium, etc. then according to the concentration PMI will be estimated. [2][3][11]

4.2.6 Supra-vital reactions

Supra-vital period is the period immediately after cessation of the heart and circulation during which the body remains responsive to some stimuli. And to measure these stimuli is the estimation of time of death.

4.3 Late PMI

This period starts when body tissue starts disintegrating. There are different methods based on the stages of decomposition such as, fresh, early decomposition, advanced decomposition, skeletonization and extreme decomposition.[1][9][10]

4.3.1 Fresh phase

This phase can start as early as 24 hours and as late as 7 days after death. There is no insect activity in this phase.

4.3.2 Early decomposition phase

This begins with skin slippage and hair loss. Body also appearing greyish green. Maggots also begin to appear on the body in this phase and decomposition sign is clearly observed.

4.3.3 Advanced Decomposition phase

This phase begins with the collapse of abdominal cavity. Decomposition may progress rapidly in remains left in an environment with high humidity resulting in extreme maggot activity.

4.3.4 Skeletonization phase

Continuation of decomposition leads to exposure of all osseous material, with exposing dry bones; this is usually seen after six months of exposure, though it has been reported to have occurred as early as the third week.

4.3.5 Extreme decomposition phase

This phase is seen only in remains that have been exposed and leads to erosion of skeletal elements. As it will start appear after 2 months of death.

4.4 Forensic Entomology

There are two methods of estimation of PMI using this forensic entomology, based on succession and development. In a succession based approach, model is chosen which corresponds to environmental condition, including circumstances of death. And in development based approach presence of different stages of the insect on the body as well as in the surrounding area are the factors taken into consideration. [8]

4.5 Molecular Assessment

This is the recent method to estimate the PMI in which degeneration of mRNA, DNA and proteins are evaluated. And linear correlation is there in between PMI and degeneration. But this correlation was found to be temperature dependent and tissue dependent.

5. CONCLUSION

From the above conducted survey and reviews, It can be concluded that the use of artificial intelligence, machine learning algorithms acquired the field of medical science as well as forensics resulting accurate and precise output. In upcoming days, it may possible that each and every field has the influence of AI with great use. In this conducted survey, Data processing is the main key factor used for the interpretation of data and comparison with the database to estimate the PMI. Providing profile to the AI machine and getting the desired output is the only process. Practicality of such devices should be evaluated and decision made with regard to using this device.

6. REFERENCES

[1] J. A. Payne, “A summer carrion study of the baby pig sus scrofalinnaeus,”Ecology., vol. 46 (5), pp. 592–602, 1965.

[2] F. John and A. K. Norbert, "Postmortem Blood Sugar and Blood Urea Nitrogen Determinations,"Canad. Med. Ass. J., vol. 92, 1965.

[3] J .I. Coe,"Postmortem chemistries on Blood with particular reference to urea nitrogen,electrolytes and bilirubin,"J Forensic Sci., vol. 19(1), pp. 3342, 1974.

[4] W. R. Sawyer, D. R. Steup, B. S. Martin, and R. B. Forney, "Cardiac blood pH as a possible indicator of postmorteminterval,"J Forensic Sci., vol. 33, pp. 1439-1444, 1988.

[5] J. I. Coe, "Postmortem chemistry update. Emphasis on forensic application,"Am JForensic Med Path., vol. 14(2), pp. 91–117, 1993.

[6] F. Wehner, and H. D. Wehner, "Schieffer MC, Subke J. Delimitation of the time of death by immunohistochemical detection of insulin in pancreatic [beta]-cells, "Forensic Sci Int., vol. 105 (3), pp. 161–169, 1999.

[7] J. S. Sachs, Corpse: nature, forensics, and the struggle to pinpoint time of death. New York: Basic Books, 2001.

[8] A. A. Vass, S. A. Barshick, G. Sega, J. Caton, J. T. Skeen, J. C. Love, and J.A. Synstelien, "Decomposition chemistry of human remains: a new methodology for determining the postmortem interval", J Forensic Sci., vol. 47(3), pp. 542–553, 2002.

[9] M. S. Megyesi, S. P. Nawrocki, and N. H. Haskell, "Using accumulated degree-days to estimate the postmortem interval from decomposed human remains,"J Forensic Sci., vol. 50(3), pp. 618–626, 2005.

[10] A. Sutherland, J.Myburgh, M.Steyn, P. J. Becker, "The effect of body size on the rate of decomposition in a temperate region of South Africa,"Forensic Sci Int., vol. 231(1–3), pp. 257–262, 2013.

[11] E. D. Andrea and I. L Iain, "Estimation of post-mortem interval using biochemical markers,"Australian Journal of Forensic Sciences., vol. 46(1), pp. 1-19, 2013.

[12] M. J. Buchan and G. S. Anderson, "Time since death: a review of the current status of methods used in the later postmortem interval,"Can Soc Forensic Sci J., vol. 34(1), pp. 1–22, Nov. 2013.

[13] D. L. Cockle and L. S. Bell, "Human decomposition and the reliability of a 'Universal' model for post mortem interval estimations,"Forensic Sci Int.,vol.253, pp. 136.e1–136.e9, Aug. 2015.

[14] I. Costa, F. Carvalho, T. Magalhães, P. Guedes de Pinho, R. Silvestre, and R. J.Dinis-Oliveira, "Promising blood-derived biomarkers for estimation of the postmortem interval,"Toxicol. Res., vol. 4, pp. 1443-1452, 2015.

[15] J. Zhuqing, Y. Meng, W. Xu, L. Di, Z. Haidong, D. Shengli, Z. Fengqin, G. Zhaoming, E. Xiaofei, C. Lin, X. JiaN, B. RufenG, and Y. Tiantong, "Estimation of the Postmortem Interval by Measuring Blood Oxidation reduction Potential Values,"Journal of Forensic Science and Medicine., vol. 2(1), pp. 8-11,2016.

[16] B. Swift, The timing of death. In: Rutty GN, editor. Essentials of autopsy practice. London: Springer, 2006, pp. 189–214.

[17] F. Musshoff, H. Klotzbach, W. Block, F. Traeber, H. Schild, and B. Madea, "Comparison of post-mortem metabolic changes in sheep brain tissue in isolated heads and whole animals using H-MR spectroscopy- preliminary results,"Int J Legal Med.,vol. 125(5), pp. 741-744, May. 2010.

[18] Y. O. Poloz, and D.H. O'Day, "Determining time of death: temperature-dependant post-mortem changes in calcineurin A, MARCKS, CaMKII, and protein phosphatase 2A in mouse,"Int J Legal Med., vol. 123, pp. 305–314, 2009.

[19] https://doi.org/10.1016/j.forsciint.2018.12.007

[20] http://dx.doi.org/10.5744/fa.2019.1011

[21] https://doi.org/10.1021/acs.analchem.9b01443

[22] https://doi.org/10.1111/1462-2920.15000