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Algor Mortis Pattern in Dogs, a Guide to Estimation of Time of Death

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ABSTRACT

Although differing methods of estimation of time of death in human forensics have been well documented, there exists paucity of information in the veterinary field. With little accuracy, veterinary pathologists rely on gross post-mortem changes which include autolysis, rigor mortis, livor mortis, and putrefaction in estimating time of death in animals. This study assessed the pattern of temperature drop in six mongrel dogs using commonly available thermometer. Rectal and hepatic temperatures were taken for eight to eleven hours after death at an average ambient temperature of 29 °C (24 °C to 34 °C). Both organs revealed strong regression models which were harnessed to provide a mathematical guide to estimating time of death in the early hours (six to seven hours). Linear model of temperature drop pattern change was considered less cumbersome for field use. The rates of drop were extremely irregular during the study period. This work substantiates the use of algor mortis as an adjunct in estimating time of death in dogs.

Keywords: Algor mortis, dog, hepatic, pattern, rate, rectal, time of death

INTRODUCTION

Estimation of time of death has been a widely investigated area in the human forensic field for a very long time with varying approaches and results. Thus, Mathematical equations and models have been studied by researchers to explain the dynamics of heat exchange between the body and surrounding after death. Earlier studies considered such interactions to follow the Newton's law of thermodynamics which was truer for spherical bodies than the human or animal's. Subsequent work, however, showed unique nature of human and animal bodies thermodynamic properties in life and after death which revolve around a wide range of variables such as surface conductance, wind speed and direction, as well as body weight, ambient temperature, and temperature at death. Marshall's two-exponential model was the first concrete and concise work on such relationship (Baccino *et al*., 1996) which presumes that post-mortem rectal temperature fall follows a thumb rule of 1.5 °F per hour. This formed the basis for improvement by Henssge (1988) that culminated in the development of the nomogram based on a single rectal measurement.

However, Henssge considered other variables, including body weight and varying degrees of ambience, as well as effect of wind, clothing, surface conductance, and irradiation. Though his work is currently the most widely accepted and practical of all on time of death estimation, the nomogram is still opened to questions of precision and repeated accuracy on single rectal measurements (al-Alousi *et al*., 2002) at different ambience. Inevitable flaws in

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any method proffered have pushed researchers to think of more accurate, practical, and relatively inexpensive methods of estimating time of death. The other methods employed include post-mortem biochemical assays (Myo-Thaik-Oo *et al*., 2002) and changes in proteomics such as calmodulin concentration. Leucogram histological changes (Dokgoz *et al*., 2001), nucleic acid (Haas *et al*., 2009), eye orbit and epaxial muscle temperature (Kaliszan *et al*., 2005) changes have been deeply studied over time.

Nevertheless, time of death estimation has received little attention in the veterinary field until quite recently with the emergence of veterinary forensics as a new field (Cooper and Cooper, 2008; Cooper, 2008). Information on this particular subject in animals is thereby rare, with those available being either impractical or requiring sophisticated temperature measuring instruments such as the thermocouple (Erlandsson and Munro, 2007; Kaliszan *et al*., 2005) microwave (Mall *et al*., 2005) and infrared thermometers. There is also insufficient information on the rate of temperature drop of these organs in animals. However, the overwhelming reliance on gross post-mortem changes, including autolysis, rigor mortis, livor mortis and putrefaction, for the estimation of time of death in animals is marred with gross inaccuracy. This study is designed to aid field veterinary forensic pathologists in estimating time of death in animals within early hours with a reasonable degree of accuracy using commonly available and inexpensive thermometers. The authors also intended to bring forth the pattern of temperature changes after death and this was done by assuming that there is no impact of external factors.

MATERIALS AND METHODS

Six mongrel dogs were utilized for the study under an average ambient temperature of 29 °C, after barbiturate euthanasia. Stirring thermometer (AST 5C, Malaysia), with a temperature range of -20 °C to 50 °C (error ± 0.2 °C), was used for rectal and hepatic temperature measurements every thirty minute for seven to eleven hours post-mortem. Animals were placed on the left lateral recumbency, while hepatic temperature readings were obtained following a stab wound on the mid-ventral half of the right thoraco-abdominal wall along the costo-chondral length of the last rib. Thermometers were inserted to a depth of 4 cm (rectal) and 5 cm (into the costo-chondral incision). Individual organ temperature drop pattern was plotted against time as well their mean values and rates of drop. Relevant regression analysis and equations (exponential and linear) which best fit the pattern were generated for each data acquired using the Microsoft Excel 2007 software. Verification of the formulae was done using the random necropsy cases with known time of death. Necessary correction factor, based on the findings from seven random tests, were introduced to the formulae using the mean differences in the actual and calculated times. All the protocols used in this study were approved by the institution's animal care and use committee (ACUC 08R30/July 08–Jun 09).

RESULTS AND DISCUSSION

Both the rectal and hepatic temperature drop patterns revealed strong exponential and linear regression relations (*Figs. 1-4*). In this study, peaks and short plateaus existed in all organs studied and lasted for an average of seventy minutes at periods which were closely matching the ambient temperature. It took a total of 26 ± 8 hours for the body temperature to reach ambience. The general irregularities observed in the rates of drops of all the organs studied which consisted of spikes and very short plateaus might be due to the inconsistent fluctuations in the environmental temperature (24 °C to 34 °C).

An exponential equation which best fitted the changes in the temperature of the rectum post-mortem was with a strong coefficient of correlation (R^2) value of 0.991 (*Fig. 1*); however, the difference in the strength compared to the linear pattern was very small and it hence enabled us to choose a linear model equation for estimating the time of death in dogs for its

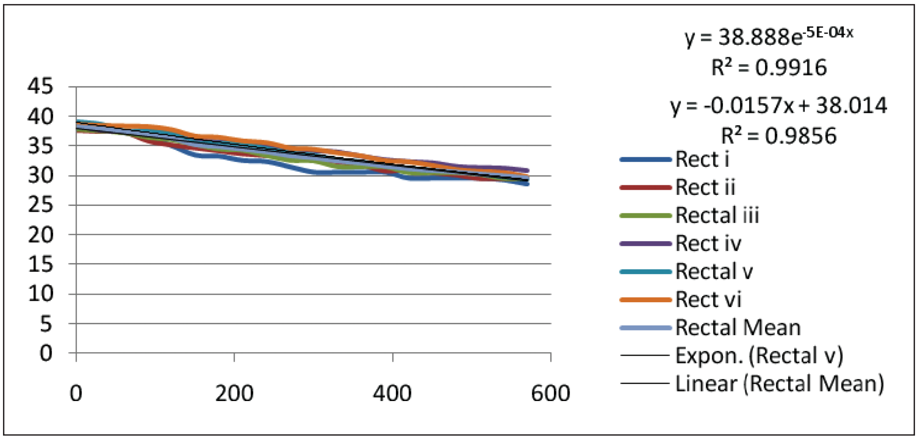

Fig. 1: Post-mortem rectal temperature pattern for six dogs at 29 ⁰C ambient temperature over time

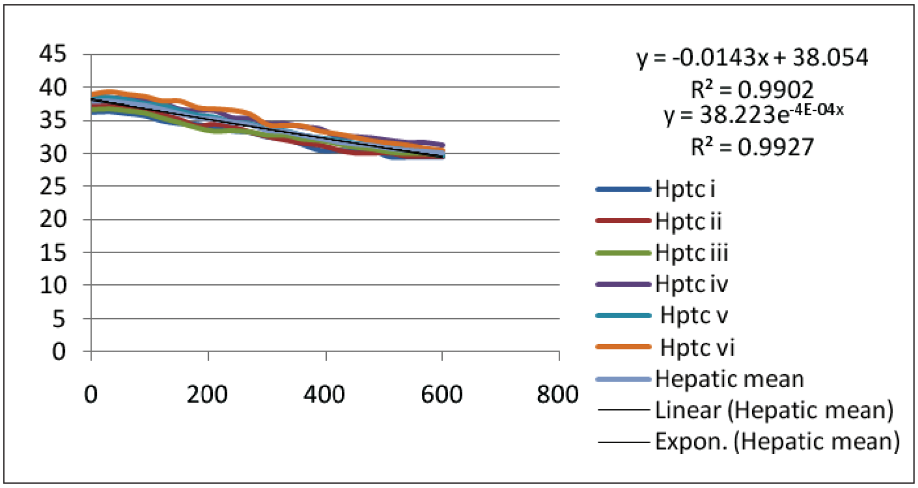

Fig. 2: Post-mortem hepatic temperature pattern for six dogs at 29 °C ambient temperature over time

mathematical and practical ease. The equations are represented as follows;

$Y = 38.18e^{-5E\text{-}0x}$ $R^2 = 0.991$
(Exponential equation)

$Y = -0.015X + 38.01$ $R^2 = 0.985$
(Linear equation)

[If Y is the measured rectal temperature R and X is time of death T], then T can be rewritten as:

$$T = 2534 - 0.015R$$

The exponential pattern of drop for the rectal temperature is similar to the findings of Erlandsson and Munro (2007) and Kaliszan (2005) in beagle dogs and pigs, respectively. However the rates of drop were inconsistent with their findings and did not follow the 1.5 °F

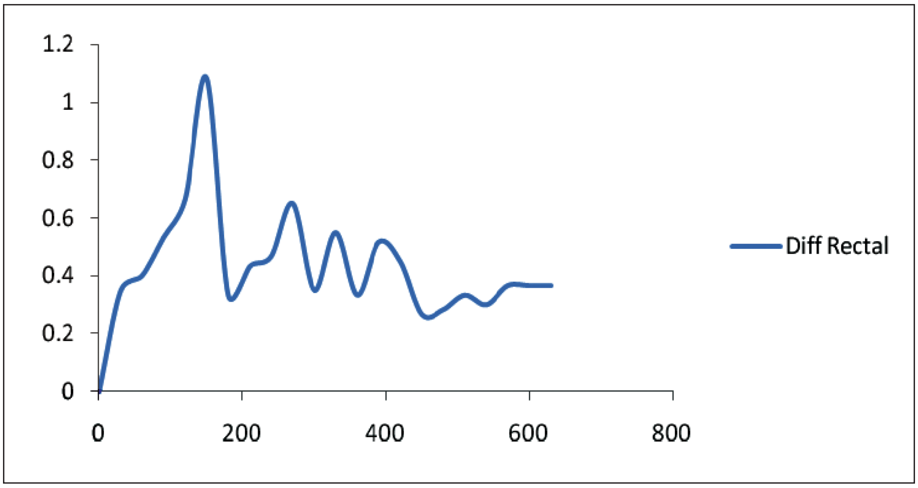

Fig. 3: Mean rate of drop of the post-mortem rectal temperature over time showing an irregular pattern and a polynomial model

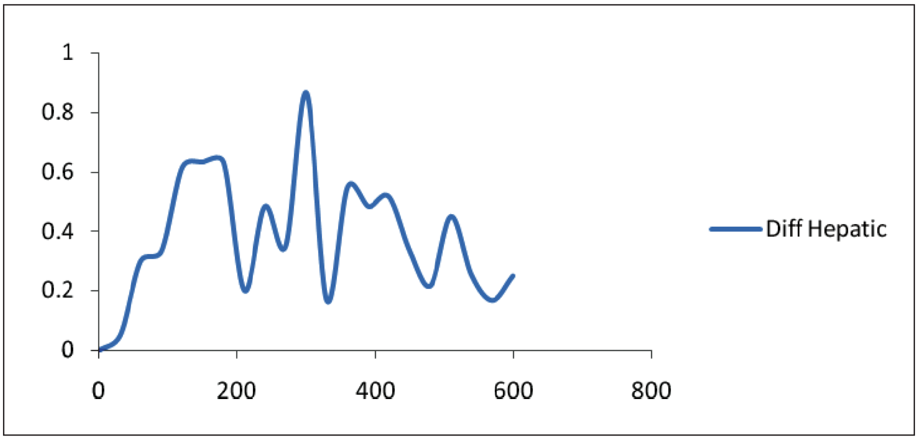

Fig. 4: Mean rate of drop of postmortem hepatic temperature over time showing an irregular pattern and a polynomial model

per hour drop rate rule of thumb. This may have resulted from the different measuring instrument types used, thus thermocouple versus stirring thermometer (our study) as well as the region where the studies were done, temperate for the former and topics for ours. It is well documented that the rate of drop in the temperate regions may be faster and relatively more consistent than those of the tropics, where a possible rise in post-mortem body temperature may be noticed, coupled with very short plateaus or log periods (al-Alousi, 2002). However the resulting equations generated from this study may prove to be more useful in estimation of time of death at the early hours (≈ 7 hours).

Hepatic temperatures appeared to be more insidious in the pattern of drop and might be helpful in cases where both rectal and external auditory canal temperatures are already at par with the ambient temperature. It expressed an

TABLE 1
Calculated time of death using linear regression equation and corrective factor of mean difference for the rectal temperature

Rectal temperature °C	Calculated time (min)	Actual time (min)	Difference (min)	Corrected time (min)
35	201	120	81	117
32.7	354	270	84	270
32.1	394	300	94	310
31.4	441	270	171	186
29.5	567	450	117	483
34.2	254	300	46	170
31.3	447	540	93	363

Mean difference = 84.1 minutes

TABLE 2
Calculated time of death using linear regression equation and corrective factor of mean difference for the hepatic temperature

Hepatic temperature °C	Calculated time (min)	Actual time (min)	Difference (min)	Corrected time (min)
34.9	225	120	105	142
33.2	347	270	77	264
32.8	375	300	105	292
33.2	347	270	77	270
30.5	539	450	89	456
34.5	253	300	47	170
31.6	461	540	79	382

Mean difference = 82.7 minutes

exponential fall over time ($R^2 = 0.992$), and a strong linear correlation coefficient which was summarized by the following equations:

$Y = 38.22e^{-4E-0x}$ $R^2 = 0.992$
(Exponential equation)

$Y = -0.014X + 38.05$ $R^2 = 0.990$
(Linear equation)

[If Y is measured hepatic temperature H and X is time of death T] then T can be rewritten as:

$$T = 2718 - 0.014H$$

The liver being a large well vascularized and highly metabolic abdominal organ may account for higher core temperature values over time and resultant insidious drop rate in comparison to the rectal and external auditory canal. Its inconsistent rate of drop, as well as technical problems of accessibility and possible crucial forensic evidence distortion rendered it less practical for field purposes, though it showed a stronger correlation with time and ability to get a reading even at points where rectal and external auditory canal temperatures are at par with the ambient temperature.

Therefore, factors such as post-mortem anaerobic metabolism, bacterial gas and heat production, hypothermia, hyperthermia, as well as pre-mortem dietary, and biochemical values might play a vital role in such observed irregularities. This is also the view of Henssge (1988) and Erlandsson and Munro (2007).

Therefore, the authors theorized that the short plateaus observed might have resulted from a balanced interaction of the heat production due to the post-mortem anaerobic metabolism and the rate of heat loss to the surrounding. In addition, this might coincide with the period where the body temperature closely matched the actual ambient temperature in the present study. The subsequent seemingly linear drop pattern which might be observed could be as a result of the fall in the ambient temperature forcing the body to cool in proportion to that fall till it attained ambience.

Verification of the formulae showed a good estimate of the time of date in the early hours, with the widest error gap observed in the rectal finding. The mean difference from all the calculated values and the actual time of death was calculated and introduced to the formulae as a negative corrective factor. This enabled a near accurate approximation of time since death calculation at 29 °C, which could be further substantiated by gross post-mortem changes, was observable at the early periods. The formulae were then re-written as follows;

$$T = 2450 - 0.015R$$

$$T = 2635 - 0.014H$$

Tables 1 and 2 show the estimated times of death using the corrected and un-corrected linear models. Its margin of accuracy is limited to early post-mortem periods (five to seven hours) for the rectal and hepatic methods. Errors from these estimations were largely due to the pulling of values towards the extremes of the mean used as the corrective factor. It is therefore advised that both the corrected and un-corrected models be utilized at a given point in time and further validated by gross findings.

CONCLUSIONS

Algor mortis rate could be used as a good index for the estimation of time of death in dogs. Both exponential and linear regression equation models showed a strong correlation between the organ temperature cooling patterns and time at an average ambient temperature of 29 °C. A linear model appeared mathematically easier for quick use in the field to calculate an estimated time since death in dogs using commonly available thermometers for the rectal and post-mortem temperatures.

These models are based on a constant ambient temperature of 29 °C and a weight range of 12 to 16 kg for logistic reasons, especially that of controlling and maintaining ambient temperatures at conceivable practical ranges. Such errors of temperature rounding and those attributable to the measuring thermometer would require further studies to rationalize.

Meanwhile, the rate of drop of body temperature post-mortem is irregular at an average ambience of 29 °C, thereby rendering its use ineffective and largely inaccurate in the estimation of time of death in dogs. The temperature drop plateau existed at intervals for a very short period lasting barely two hours in dogs. More intense studies are required to establish the use of algor mortis rate in the estimation of time of death in dogs and other species in order to standardize the use of the drop patterns and rates.

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