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Estimating the Postmortem Interval in Big Game Animals

REFERENCE: Edge, W. D., "**Estimating the Postmortem Interval in Big Game Animals,**" *Journal of Forensic Sciences,* JFSCA, Vol. 29, No. 4, Oct. 1984, pp. 1144-1149.

ABSTRACT: Methods for estimating the time since death in big game animals are needed to identify animals that are killed during illegal periods. Currently used methods include rigor mortis, eye appearance, carcass cooling, and potassium levels in the vitreous humor. The application and limitation of each method is discussed. The current state of available methods necessitates using several criteria when estimating the postmortem interval.

KEYWORDS: pathology and biology, postmortem examinations, big game animals, postmortem interval, rigor mortis, eye appearance, carcass cooling, vitreous humor potassium levels

Forensic science studies related to problems of specific interest in wildlife law enforcement have been slow to develop. Research in wildlife forensics makes up a very small proportion of wildlife studies conducted yearly by private, state, federal, and university personnel. Law enforcement in wildlife is often considered a necessary evil [*1*]. Research on wildlife forensics is generally given a low funding priority because of lack of interest or because the need for such studies has not been documented [*2,3*]. Enforcement of wildlife laws may be a limiting factor in future game management systems and warrants increased funding for forensic science studies [*4*].

Estimating the postmortem interval for big game animals is one of several forensic science techniques that have attracted the attention of wildlife law enforcement officials. Beattie and Giles [*5*] ranked the estimation of time since death as the top priority in state fish and game agencies' enforcement research. Estimates of time since death are needed primarily to identify animals that were killed just before or after the legal hunting season and to identify animals that were killed at night. The technique may also aid as an investigational tool in any number of cases involving wildlife, such as wildlife caused automobile accidents.

Although several states use various methods of estimating the postmortem interval in game animals, few of these techniques have been published. In the first extensive study of postmortem changes in white-tailed deer (*Odocoileus virginianus*), Gill and O'Meara [*6*] cautioned that knowledge of such techniques should be suppressed to prevent game violators from altering carcasses to avoid detection. This cautionary note may be partly responsible for the lack of published material on the subject. A critical review of the methods used to estimate the time since death in big game animals has not been attempted since Morrow's 1968 review of postmortem changes [*7*]. The purpose of this paper is to review the methods currently being used by state fish and game agencies to estimate the time since death in big game animals.

Estimating the postmortem interval in game animals presents several special problems. De-

Received for publication 25 Aug. 1983; revised manuscript received 2 March 1984; accepted for publication 6 March 1984.

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pending on whether or not the animal was killed for consumption, game animals may or may not be eviscerated. Carcasses may be skinned and be in various states of dismemberment. The head may or may not accompany the body. Carcasses may be transported inside or outside of vehicles over a wide range of distance and time. Environmental conditions under which an animal was killed, especially temperature and wind, can be expected to vary substantially. The agonal period may be short or quite prolonged. This variety of conditions is further compounded by the number of species for which this information is needed. In spite of these problems, several attempts have been made at estimating the postmortem interval in big game animals. In general, these methods have been adapted from human forensics.

Rigor Mortis

At the moment of death, the muscles relax and are highly extensible. The onset of rigor is associated with biochemical changes within the muscle tissue. Muscle rigidity occurs as adenosine triphosphate (ATP) levels decrease because of dephosphorylation [*8, 9*], which usually progresses rapidly after death. However, a "delay period" is associated with initially high levels of ATP [*9*] or through decomposition of glycogen into lactic acid [*10*]. In humans, rigor usually begins to develop about 2 h after death and reaches its maximum extent within 10 to 12 h [*11–13*], and is generally considered to follow a predictable pattern. However, the generally accepted pattern of rigor development proved to be inexact [*14, 11, 13*].

Two studies have examined postmortem changes in rigor mortis of white-tailed deer [*6, 15*]. Rigor begins to develop on the average between 1½ to 2 h postmortem. Rigor usually develops first in the mandible, followed by the tarsal joints, neck, and metatarsal joints. The pattern and time of rigor development is influenced by activity prior to death, location of the wound, differences in ambient temperature, and handling methods. Because of the broad range of variation in the development of rigor mortis, it can be considered only a rough approximation of the postmortem interval [*13, 14*] and should be used only in conjunction with other criteria [*6*].

Changes in Eye Appearance

Several postmortem changes have been described for the human eye. Only a few of these have been applied to game animals. Clarity and color are two observations used on human subjects. The cornea and fundus oculi lose transparency with an increase in the postmortem interval [*16, 11*]. Gill and O'Meara [*6*] reported that the eye of white-tailed deer progressively loses its luminosity from ½ to 18 h. The pattern of change in human eye color was described by Kevorkian [*16*]. Eye color in white-tailed deer changes from green or blue immediately postmortem, to gray 6 to 12 h after death, and may appear hazy blue after 30 h [*6*]. Freezing was reported to change deer eye color to milky white.

Postmortem changes in pupil diameter have also been used to estimate the time since death. The pupil fully dilates immediately after death, associated with the relaxation of iridal muscles. With the onset of rigor, the pupil contracts gradually over a period of several hours [*6, 11, 15, 17*]. Pupil diameter has been correlated with the postmortem interval in white-tailed deer [*17*], mule deer (*Odocoileus heminous*), and elk (*Cervus elaphus*).[2] Woolf et al [*17*] reported that pupil diameter was of marginal use when considered alone. Pupil diameter, although significantly correlated with time since death, did not significantly improve regression models already containing other predictive variables.[2] Variations in ambient temperature, body weight, and handling methods have been suspected to cause variation in the rate of decrease in pupil diameters [*6, 15*]. Animals that have been head-shot show large variations in pupil diameters [*15*]. In spite of these problems, pupil diameter has been suggested as supportive evidence in estimating the postmortem interval [*6, 17*].

[2] W. D. Edge and B. Slott, "Estimating Time Since Death of Mule Deer and Elk," 1983, unpublished paper.

Carcass Cooling

Postmortem temperature change has been the most widely applied technique in both human and wildlife studies. In humans, rectal, skin surface, thigh, cranial, subhepatic, and intrahepatic temperatures have been examined in a effort to find the site giving the most reliable results [*11,13,18-20*]. The naso-pharyngeal cavity, front quarter, and thigh muscles are the sites of temperature measurement used in game animals [*6,17,21,22*].[2] Studies on the estimation of the postmortem interval in humans have been directed toward an improved mathematical expression of the cooling curve. Shapiro [*14,20*] recognized the existence of a postmortem temperature plateau, which imparts a sigmoidal shape to the cooling curve. Fiddes and Patten [*23*] proposed expressing the cooling curve as a percentage of the virtual cooling time. A formula containing two exponential terms, one explaining modifying factors prior to the "breakpoint" [*24*], and the other explaining the cooling curve after a temperature gradient has been established, was reported by Marshall [*25*].

Neubrech [*21*] was the first to recognize the application of temperature as a measure of the postmortem interval in wildlife studies. Cooling curves for nasal and thigh temperatures have been presented for white-tailed deer [*6,17,22*], mule deer [*26*][2] and elk[2] of various body weights under various ambient temperatures. The need to place forensic science methods in a scientific basis by defining statistical probabilities [*7,27*] has resulted in the application of regression analysis to postmortem observations [*17,22,26*]. Log transformations of the predictive variables have been used to coax the data into a linear relationship [*17*], and polynomial models were developed where the linearity assumption was violated [*26*]. Most recently, Kienzler et al [*22*] have reanalyzed Gill and O'Meara's data [*6*] using a weighted nonlinear least squares approach. This refinement was necessary because of nonhomogeneous variance and because multiple observations on each individual cause dependence within the error structure of the model. These models have limited applicability because of the small degree of biological and environmental variation encompassed in the data.

Numerous factors modify cooling curves in both humans and game animals. The most important appear to be environmental factors, especially temperature, wind, and humidity [*6,11,13-15,19,22,25,27*], but handling, weight, body size, and location of the wound may also cause sizable variations [*6,11,13-15,17,19,20,22,27*].[2] Inferences concerning the time since death based upon temperature measurements should be critically examined to avoid a miscarriage of justice.

Vitreous Humor

Many biochemical clues to the postmortem interval have been examined in human forensic science studies [*13*]. Coe [*28*] reviewed the postmortem chemistry of blood, cerebrospinal fluid, and the vitreous humor. Although several chemical constituents of the vitreous humor are potential estimators of the time since death, only the level of potassium has been critically evaluated for game animals. As autolysis proceeds, cellular potassium is released into the vitreous humor. Jaffe [*29*] first recognized the value of potassium levels for estimating the time since death. This technique is advantageous because samples are easy to obtain, are free from contamination and are less influenced by environmental factors [*13,28-31*]. Large differences in confidence limits for the postmortem interval have been noted when this technique is used on humans [*13,32,33*]. Results from game animals have also been inconsistent. Johnson et al [*31*] found a significant correlation between potassium levels and the postmortem interval that was independent of temperature, sex, and weight of mule deer. Other studies have found no consistant relationship between potassium levels and the time since death [*15,34*]. However, in one of these studies [*34*], the authors reported a cloudy precipitate in their samples. Sturner and Gantner [*30*] recommended the deletion of samples with cloudy precipitates, and Woolf and Gremillion-Smith [*34*] acknowledge that such a precipitate may have caused a continual release of potassium into the sample.

Problems and inconsistencies with this technique are primarily a function of sampling and laboratory methods. Excessive force during aspiration may detach retinal cells, resulting in abnormally high potassium levels [*28-30*]. Jaffe [*29*] also found that small samples gave unrepresentative results, and postulated that potassium is not uniformly distributed within the vitreous body. Johnson et al [*31*] reported significant variation in results from different laboratories. In addition, potassium levels within the vitreous humor of dogs have been shown to be dependent upon temperature [*35*]. However, a more fundamental problem with this technique is the lack of knowledge concerning the biochemistry of the eye and normal levels of potassium in the vitreous humor [*13,28,34*].

Field Procedures and Legal Action

According to the Tenth Amendment to the U.S. Constitution, all powers not delegated to the federal government nor denied the states default to the states, respectively. Responsibility for wildlife, with a few exceptions, therefore falls under the jurisdiction of the states. All state fish and game agencies have trained conservation officers vested with powers common to all law enforcement personnel. Most states have statutes requiring sportsmen to stop at game "checking stations." Game animals are inspected to determine species, sex, and age class. At that time, the conservation officers may suspect a violation. For example, a hunter may arrive at the checking station early in the morning of opening day with a game animal showing advanced stages of rigor mortis. This might lead the officer to suspect that the animal was taken before the legal hunting season. The officer may then take additional observations as an aid in establishing probable cause. Most states use the methods detailed by Gill and O'Meara [*6*] for making observations on pupil diameter and carcass temperatures. Procedures for extracting vitreous humor fluid have not been standardized. Depending upon the state, conservation officers in the field may have manuals which present cooling curves or regression equations for game animals of various weights under specific sets of environmental conditions [*36*]. The officer may also have radio access to computer programs [*22*] that calculate point and interval estimates for the time since death.

In many cases where the violator is presented with the scientific "evidence" for the time of death, he will confess to the violation. The game is confiscated and the violater is either issued a citation or placed under arrest. In most cases, however, additional investigations such as interviews of witnesses or suspects and examinations of kill sites and hunter camps will be required to establish probable cause. The author is not familiar with any convictions based solely upon estimation of the time of death.

When the conservation officer has probable cause to believe the game animal has been killed outside legal hunting periods, the suspect is charged with illegal posession of game. The large majority of fish and game violations are misdemeanors. If convicted, the defendent usually forfeits bond or is fined and loses his hunting privileges. Rarely do convictions result in imprisonment [*37*].

Conclusions

Estimation of the time since death in game animals is fraught with the same inconsistencies that have hampered such evaluations in humans. This is further compounded by the number of species for which such information is needed. At present, methods have been developed for only three species of big game animals: white-tailed deer, mule deer, and elk. Rigor mortis and eye pupil diameters will give only rough estimates of the postmortem interval. Regression equations based upon carcass temperatures are applicable only to the specific conditions under which the data were collected, and these models need validation testing [*17*]. Potassium levels in the vitreous humor are subject to major sampling errors and suffer from a basic lack of information concerning eye physiology of game species. Given these inconsistencies, I must concur with the many other authors who have recommended the use of several criteria in evaluating the time since death. The current state of the available techniques limits their use to investigational rather than evidential applications. Future research on the postmortem changes in big game animals should be designed to encompass as much variation in environmental conditions as possible, and should be directed toward techniques that show the greatest potential for meeting specific research objectives.

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