

Cooling of the Carcasses for Veterinary Medico Legal Use

GABRIELA VARGOVÁ*, DANIELA TAKÁČOVÁ

Institute of Forensic and Public Veterinary Medicine and Economy, University of Veterinary Medicine and Pharmacy in Kosice, Komenského 73, Slovakia - 04181.

Abstract | Knowing the time of death of companion animals as well as monitoring the cooling curve of a cadaver can be helpful for forensic determination of the time of death of animals that died due to cruelty, poaching, etc. The subject of our interest were carcasses of dogs and cats (24 animals) divided into 7 groups according to weight, species and environmental conditions that would best imitate the real conditions to which the dead animals may have been exposed. Differences in body temperatures measured and displayed as temperature curves showed the dependence of temperature drop on the weight of carcasses, character of the base on which the animal had rested and internal and external environmental conditions. According to the general rule the cooling rate ranges from 0.6°C to 0.8°C /hour. Within the first hour the temperature in the monitored groups dropped from 1. 2°C to 4°C in all groups. The temperature of cadavers reached the ambience within 27 - 117 hours after the death of animals in dependence on environmental conditions.

Keywords | Animals, Body weights and measures, Carcasses, Temperature, Time

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***Correspondence** | Gabriela Vargová, Institute of Forensic and Public Veterinary Medicine and Economy, University of Veterinary Medicine and Pharmacy in Kosice, Komenského 73, Slovakia 04181; **Email:** Gabriela.Vargova@student.uvlf.sk

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In veterinary practice there has been an increase in cases of animal deaths which necessitate establishing of grounds for law enforcement action. This increase is related to increased interest in both companion and farm animal breeding. These animals are living creatures capable of feeling pain and suffering and are an object interest of owners who may commit illegal acts. This may involve widely different incidents, including damage to someone's property, out-of-season shooting of game animals, poaching and death of livestock during transportation and cases of neglect or deliberate injury to companion animals. Establishment of the approximate time of death of protected species can serve the purpose of determining alibi, opportunity and circumstances of animal death. The issues of time and duration of the pathological process are common in human and veterinary practice. It includes e.g. determination of the time of death, incurring and duration of healing of injuries that may have occurred *ante-* or *post-mortem*, especially in cases of cruelty to animals. Forensic veterinary pathology uses a spectrum of pathological changes that are

helpful when determining duration of pathological processes. Determining the time of death by measuring the temperature of the cooling cadaver requires the mapping of all external and internal factors which could influence the cooling.

Although, time is constant by which we are used to measuring change, *decomposition – autolysis* plus putrefaction – is not constant over time but influenced by myriad factors such as the temperature of the body at time of death, the ambient temperature, the surrounding environment (air, water, ground), ambient pH, (water, soil), disease state (*fever, bacteraemia*, etc.) at the time of death (TOD), and scavenging by animals or insects, to name just a few. However, a thorough discussion of methods used to determine the TOD, types of evidence used in determining TOD include corporal evidence such as drying of mucous membranes, sclera and skin slippage; environmental evidence such as species and stages of insects presents; and anamnestic evidence, such as a last time the animal was

seen alive (Pounder, 2013). Only several authors dealt with measuring of the drop of body temperature in animals to determine the time of death. Abdulazeez and Noordin (2010) studied the drop of temperature in dogs after death (in their rectum or liver) in tropical conditions (24°C – 30°C). The rate of drop was extremely irregular and lasted for an average of 70 minute at period which were closely matching the ambient temperature. It took total of 26 ± 8 h for the body temperature to reach ambience. Erlandsson and Munro (2007) conducted study on dogs of the same breed, of similar weight and held under identical conditions for medico legal purpose. They found that combination of rectal temperature, environmental temperature and gross pathology, histological changes as well can provide a scientifically based estimate of the post mortem interval during the first 10 h following death, of up to one day, one to three days, three to seven and three weeks. Proctor (2007) demonstrated useful the time of death of dogs for forensic investigators from crime scene of households. Study was conducted indoor in still condition, approximately room temperature, monitored the post mortem reduction in rectal, liver, brain and aural temperatures on 16 dogs for 32 h after death. Proctor (2007) concluded that sex, body mass, hair coat density do not affected post mortem temperature change, while body weight and body volume do. Assumed a dog is found death in still air at approximately room temperature with rectal temperature of 34.5°C the mean time of death would be 3, 2 hours. We used formulas for establishing TOD (time of death), which are usually used as a rule of thumb by forensics pathologists in our study:

$$TOD = T0 - T_{rect}. (^{\circ}C + 3 \text{ hour})$$

$$TOD = T0 - T_{rect}. / 1.5^{\circ}F (0.8^{\circ}C)$$

$$T = T_e + (T0 - T_e) e^{-Zt} \text{ (Newton's law of cooling)}$$

$$t = -10 \ln \{T - R_t / T0 - R_t\}$$

Where;

T0: physiological temperature of body by species

T rect.: temperature measured in rectum at scene at time

TE: external or ambient temperature

These formulas give us results about time, when the death probably occurred, but do not offer all information about cooling curve (the temperature plateau and natural temperature condition of cooling, circadian rhythm of the day and floating the temperature). To eliminate errors or false interpretation of results about establishing the TOD it is important to involve all factors and corrections which affect cooling process and to draw a nomogram. The first nomogram was designed by Dr. Clause Henssge and it was used in human forensic science (Institute f. Gerichtliche Medizin, Humboldt Universitat Berlin, 1980). The nomogram for establishing TOD in Veterinary practice can be

drawn. Our study does not cover pathological analyses, we used only external examination of the body and anamnestic information obtaining from internal practice at University where animals were euthanized. Our aim of the study was to establish the TOD by nomograms. During this study we obtain final hours of the body cooling. Measuring was performed in natural conditions and our results were 2 or 3 times longer when comparing results obtained by using formulas, because of floating the temperature during the day that can affected a cooling process. For comparing cooling process during seasonal changes for now, we have not got enough carcasses from each group yet. For better interpretation of our results it seems to have from five to ten carcasses of each group. This fact about amount of carcasses is dependent on owner's choice whether to take away the pet after euthanasia and bury them or let the carcass at the university (according the rules regulating waste disposal in Slovakia). Cooling is a principally natural process of heat conduction and is therefore depend on many factors. That does not occur at the same rate throughout the body. When the heartbeat stops, blood circulation and thermoregulation stops, too. Cooling involves processes of convection, conduction, radiation and evaporation. The mathematical basis of heat conduction is done by Newton's law of cooling, which predicts an exponential decay in the temperature from its initial to some later value, over time (Craig, 2010). Post mortem exchange of heat between the body core and body surface takes place only by conduction. The heat is lost first from superficial layers and the internal parts of the body cool later, until the body temperature reached the ambient level. Cooling of parts that are not in contact with surface area takes place by convection. Exchange of heat by radiation is important only during the first hours and decreases later, depending on skin temperature. Only a small amount of heat is lost by evaporation.

In certain circumstances the process of cooling could be influenced by a lot of factors as following (Algor Mortis, 2012). In case of fat or air embolism, certain infections, septicemia, heatstroke, thyrotoxicosis, psychotic (emotional) stress, administration of neuroleptic medication, intoxication a sharp rise in temperature occurs. Exercise or struggle prior to death may raise the rectal temperature up to 1.5 – 2.0°C. Low temperature occurs in case of collapse, congestive cardiac failure, hypothermia, hypothyroidism, administration of muscle relaxants, secondary shock, etc.

The difference in temperature between the body and the medium, the temperature fall is rapid when difference is great. In tropical climates the heat loss is roughly 0.5 – 0.7°C per hour.

The rate of heat loss is proportional to the weight of the

body to its surface area. Thus children and old people cool more rapidly than adults.

The fat is bad conductor of heat, fat bodies goes through *algor mortis* slowly and lean bodies rapidly (Algor Mortis, 2012).

A body kept in well ventilated room will cool more rapidly than one in a closed room. Moist air is a better conductor of heat than dry air, so that *algor mortis* is more rapid in humid atmosphere than in dry atmosphere. Cooling in the water is most rapid, water is a far better conductor of heat (Algor Mortis, 2012).

The rate of *algor mortis* is slow when the body is clothed, as clothes are bad conductors of heat. If the body is exposed to a source of heat for a few hours shortly after death, its temperature will rise (Algor Mortis, 2012).

Our investigations were carried out on cadavers of companion animals (5 cats and 19 dogs). They were euthanized and allocated to 7 groups (Table 1).

Table 1: Groups of companion animals

Group 1	dog b.w. $\leq$ 5 kg, T amb. 18 – 20 °C
Group 2	cat b.w. $\leq$ 1.9 kg, T amb. 18 – 20 °C
Group 3	dog b.w. $\leq$ 6.3 kg, T amb. 4 – 6 °C, outside
Group 4	dog b.w. $\leq$ 5.1 kg, T amb. 18 – 20 °C, moving air
Group 5	dog b.w. $\leq$ 39.5 kg, T amb. 18 – 20 °C
Group 6	cat, dog bw. $\leq$ 9.04 kg, T amb. 16–18 °C, water, sink
Group 7	dog b.w. $\leq$ 52 kg, T amb. – 3.8 °C, winter outside

W –weight; T amb – ambient temperature

Animals were euthanized at the internal clinic of the University of Veterinary Medicine and Pharmacy (UVMP) in Košice because of old age or incurable disease which would cause suffering and pain to survivors. The decrease in body temperature was measured by a special thermometer, with one probe inserted in the animal rectum and the other used for measurement of ambient temperature (Figure 1). The initial 10 min measuring interval proved to be insufficient so we used 30 min interval to obtain one temperature recording (until the temperature of cadaver dropped to ambient level) (Table 1) (Figure 1).

Our observations proved that the main factors influencing the course of cooling are the animal weight and the temperature of the environment where the cadaver was located. According to the general rule, animal cadavers cool at the rate of 0.6 – 0.8°C per hour, though this does not consider all factors influencing the cooling, e.g. air flow which can speed up the cooling or immersion in water causing 3-fold faster cooling. In our experiment we recorded the fastest

cooling of cadavers in group 2 (1.2°C within the first 4 hours). Cadavers from group 1 cooled at a rate of 2.5°C/hour, those from group 3 at a rate of 2.4°C/hour on average, and cadaver from group 7 (body weight 56 kg, placed outside in winter) cooled within the first hours at a rate of 1.7°C/hour.



Figure 1: Measuring of the body temperature by using of thermometer Testo 175 T3

The temperature drop 2.8°C /hour was recorded in cadavers from group 4, which were exposed to air flow. The cadavers from group 6 exposed to conditions which imitated drowning cooled at a rate of 4°C/hour during the first hours of cooling. After 15 hours, the temperature decrease has stabilised in individual groups and reached the rate of 0.7 – 0.5°C/hour. We recorded also occurrence of the so-called plateau phases (several hours without drop of temperature), but in time intervals differing from those recorded in human corpses. The plateau phase was followed by a decline (0.3 – 0.2°C/ hour). During the last hours of cooling, the cadavers cooled at a rate of about 0.1°C until the temperature of both the cadaver and environment became equal which occurred within 27 – 117 hours. When comparing with the results obtained by human forensic pathologists, the temperature measured in the rectum drops very slightly or not at all for about half an hour after death (*post mortem temperature plateau*). This is followed by a linear rate of cooling (between 0.5 to 1°C per hour) for the next 12 to 16 hours. Then the cooling rate is relatively uniform in its slope. Then it gradually becomes slower, and when the temperature is within about 4°C of the environment, rate of *algor mortis* cooling becomes very slow (Algor Mortis, 2012).

Comparison of the values presented in (Table 2) shows that the rate of cadaver cooling is affected by both the carcass weight and the environmental conditions to which the cadaver was exposed. We observed that the temperature drop was slower in cadavers with higher weight. This indicates that the rule determining the cooling rates of cadavers equal to 0.6 to 0.8°C per hour is very general. Information obtained from crime scene are useful for establishing the

Table 2: Decline of body temperature in hours in each group separately

Group 1	Hour	0 - 4	6	10	15	19	20	22	25	30	< 30
	Decline °C	2.5	1.4	1.0	0.9	0.7	0.5	0.4	0.3	0.2	0.1
Group 2	Hour	0 - 4	4 - 7	7 - 10	10 - 16	16 - 24	24 - 32	< 32			
	Decline °C	2.2	1.0	0.9	0.7	0.5	0.2	0.1			
Group 3	Hour	0 - 12	13	18	19	22	23 - 27	27 - 37	< 38		
	Decline °C	2.4	0.9	0.5	0.4	0.3	0.5	0.2	0.1		
Group 4	Hour	0 - 7	11	17	21	25	26	27	44		
	Decline °C	2.8	0.9	0.6	0.5	0.4	0.3	0.1	0.1		
Group 5	Hour	0 - 4	8	14	18	20	23	24 - 30	33	< 33	
	Decline °C	1.2	1.0	0.9	0.5	0.5	0.3	0.3	0.2	0.1	
Group 6	Hour	0 - 4	7	9	13	15	25 - 32				
	Decline °C	4	3	1.5	0.6	0.2	0.1				
Group 7	Hour	0 - 14	20	20 - 31	31 - 34	41	43	50	59	62	62 - 71
	Decline °C	1,7	1,0	0,9	0,6	0,5	0,3	0,4	0,3	0,2	0,1

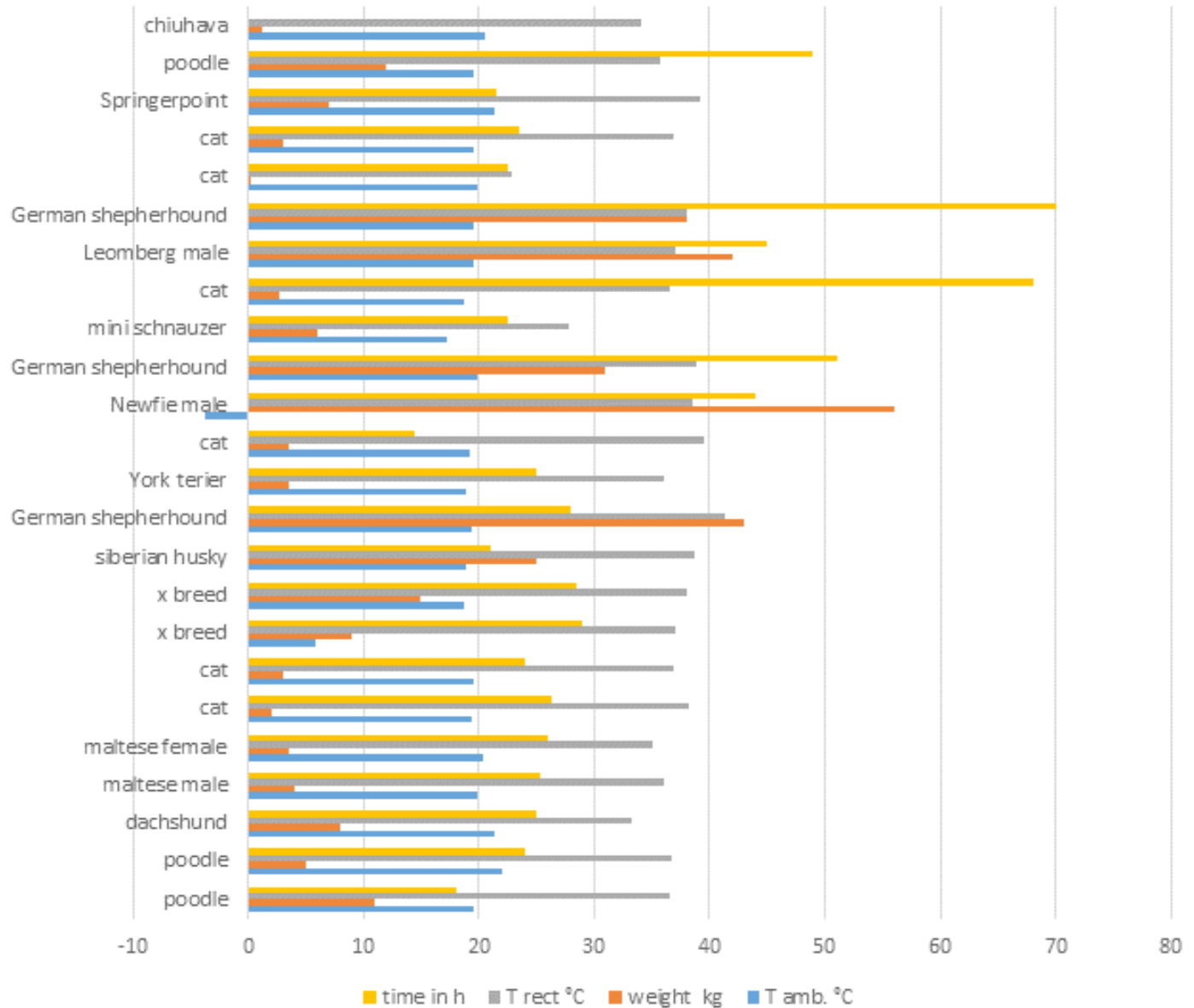


Figure 2: Time of death
T amb – ambient temperature; T rect (°C) – initial temperature at the time of euthanasia

time of death (Figure 2). The values determined in this study will be used to draw nomograms for later use by veterinarians when performing reconnaissance as well as for procuring the grounds for determining the time of animal's death.

Establishing an accurate and precise TOD persist as the holy grail of forensic pathology, despite decades of research. Determining time of death is a constantly evolving research area. In summary, the amount of information available for determining TOD in veterinary species is extremely limited. Given the limited amount of information, as well as the persistently imperfect and inexact science of time of death determination, currently veterinary pathologists may be as well served by personal experience as by sophisticated rectal probes (Gerdin and McDonough, 2013). Potentially pertinent information may be gleaned from some human research based on animal models such as decomposition scoring. Veterinary forensic pathologists should strongly consider documenting and developing a database of known decomposition findings associated with known environmental conditions in their area based on all necropsies performed, not just forensic (Merck, 2014).

AUTHORS' CONTRIBUTION

Gabriela Vargova carried out the experiments and wrote the draft of manuscript. Daniela Takáčová checked the experimental design and supported in English writing manuscript.

The authors have no conflict of interests.

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