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Temperature based forensic death time estimation: The standard model in experimental test

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ABSTRACT

The determination of the time since death is essential to forensic homicide investigations since the time of death represents the presumed time of the offence. Erroneous death time estimates may lead to false acquittal or conviction of suspects. Since its introduction 30 years back, the nomogram method by Henßge has been established as the standard procedure of temperature-based death time determination in the early post-mortem period. The present study provides an independent investigation of the validity of its death time estimates and their corresponding 95%-confidence intervals.

Comparison to post-mortem cooling curves recorded under controlled conditions of 84 suddenly deceased with known death times yielded the following results:

(1) Violations of the predicted 95%-confidence intervals by the nomogram method were observed in 48 of 84 cases (57.1%).
(2) The standard deviations computed from our experimental data considerably exceed those presupposed in the nomogram method for 95%-confidence interval derivation.
(3) The nomogram method shows a clear trend to over-estimate the post-mortem interval in cases with high body mass and large surface area.

Since in the light of our experiments the validity of the nomogram method seems to be problematic, death time estimates – and particularly their 95%-confidence interval limits – have to be interpreted carefully and should only be restrictively used as court evidence to support or refute alibis. Systematic overestimation of the post-mortem interval in bodies of high mass and large surface area must be taken into account.

1. Introduction

Death time determination is essential to medico-legal investigations since the time of death represents the presumed time of the offence. Knowledge of the death time is required to check alibis of suspects. When used in court, erroneous death time estimates may lead to false acquittals or convictions. Temperature back-calculation based on the post-mortem cooling process provides the most accurate death time estimates in the early post-mortem period. The temperature of the deceased is measured at the crime scene commonly in the rectum. Fig. 1 illustrates the typically sigmoid shape of a post-mortem rectal temperature–time curve.

The length of the post-mortem interval (PMI) can be determined from the position of the temperature–time measurement. The correctness of PMI determination depends on the correctness of the model cooling curve. If the curve is too flat, the PMI will be over-estimated. If the curve is too steep, the PMI will be under-estimated.

The model developed by Henßge [1,2] is widely used for temperature-based death time determination. It is founded on the double-exponential model of post-mortem rectal cooling by Marshall and Hoare [3]:

$$\frac{T - T_A}{T_0 - T_A} = \frac{p}{p - Z} e^{-Zt} - \frac{Z}{p - Z} e^{-pt}$$

where T_0 is the core temperature at death time and T_A stands for the ambient temperature at the scene. The original parameter definition, in which parameter Z depended on body mass and surface area, was simplified by Henßge:

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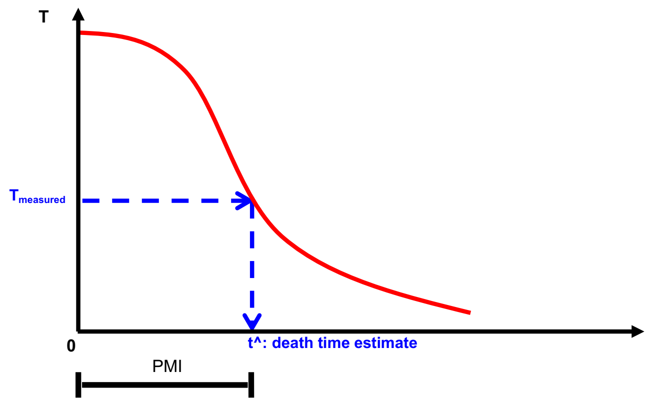

Fig. 1. Temperature based death time determination. Graph: Rectal cooling model curve, $T_{measured}$: Measured rectal temperature, $t^{\wedge}$: Estimated death time by reverse diagram evaluation, PMI: Post-mortem interval.

$Z = 1.2815m^{-0.625} - 0.0284$ with m: body mass [kg].
$p = 5Z$ for ambient temperatures $\leqslant$23.2 °C.
$p = 10Z$ for ambient temperatures $\geqslant$23.3 °C.

The model parameters were fitted to curves of 41 post-mortem standard cooling experiments (body mass 9–112 kg, time elapsed between death and experiment 1–6 h, bodies naked in prone position on thermally indifferent ground, approximately constant ambient temperature around 9 °C in winter and 17.4 °C in summer with fluctuations of ±2 °C). Henßge introduced the body mass correction factor c based on 25 non-standard cooling experiments (dry and wet clothing, air movement). In case of insulating environmental conditions, a correction factor $c > 1$ is chosen to increase virtual body mass resulting in slowed down cooling. In case of non-insulating environmental conditions, a correction factor $c < 1$ is chosen to decrease virtual body mass and hence speed up cooling. Stipantis and Henßge [4] defined the normalized temperature $Q: = (T - T_A)/(T_0 - T_A)$ stating: "by normalizing to essential influencing factors systematic errors in death time back-calculation can be avoided". They derived 95%-confidence-intervals for three Q-ranges (Q1: early, Q2: medium, Q3: late cooling phase). The model can be applied at the crime scene using a nomogram or a special software (www.amasoft.de). Correction factors can be determined following the guidelines in current textbooks on forensic pathology [5–7].

As goes for all empirical models the validity of the Henßge-model strongly depends on the experimental sample and settings used for calibration. Only two studies so far investigated the precision of the nomogram method. Both studies are based on real forensic cases with a single rectal temperature measurement at the crime scene. In 1990 a multi-center study [8] collected 76 cases. In 46 cases the environmental conditions were relatively certain and true death time could be narrowed down to short time intervals based on the results of police investigations. In the other 30 cases environmental conditions were uncertain and the true death time spans relatively wide. A closer look at the 46 'reliable' cases reveals that in 35 cases the time since death was below 10 h and therefore in the early cooling phase. In 2000 further 72 cases were presented [9]. In only 27 of these cases the true death time spans could be narrowed down to <0.5 h, in 10 cases to >0.5–1.0 h, in 5 cases to >1.0–2.0 h, in 7 cases to >2.0–5.0 h, in 6 cases to >5.0–10 h and in 8 cases to >10.0–25 h. In the remaining cases no reliable death time interval was available.

Although implausible results by the nomogram method can be observed in practical case work [10], a study on the precision of the nomogram method on the basis of consecutive experimental rectal temperature measurements under controlled conditions has not been published so far. In the light of the importance of the nomogram method as forensic standard procedure of death time determination, the aim of the present study was to investigate the precision of the method in 84 controlled postmortem cooling experiments with the bodies of suddenly deceased persons with known death times [11].

2. Method and terminology

$N = 84$ postmortem cooling experiments a_n in bodies of recently and suddenly deceased with known times since death $t_{n,k}$ were performed under controlled conditions in a climatic chamber [11]. Rectal-temperature–time-measurements $M_{n,k} := (t_{n,k}, T_{n,k})$ were recorded every minute. Depending on the experiment duration the number K of measurements differed. Experimental boundary conditions were ambient temperature $T_{A,n}$, initial body core temperature $T_{0,n}$, body mass m_n and correction factor c_n. The experiments were conducted in standard conditions, the correction factors c_n – selected according to the general recommendations [5–7] – in the range of 1.0–1.4 had to account for dry clothing only. The Henßge-model cooling curve is computed for each cooling experiment a_n with temperature values $T^H_{n,k}$ at time $t_{n,k}$.

Depending on its first recorded rectal temperature $T_{n,0}$ an experimental case a_n is classified initially hyperthermic if $\Delta T_{0,n} = T_{0,n} - T^H_n(t_{n,0}) > 0.5°C$ and initially hypothermic if $\Delta T_{0,n} = T_{0,n} - T^H_n(t_{n,0}) > -0.5°C$. The experimental sample G_0 of 84 cases is subdivided in subgroup G_1 of 38 definitely normothermic cases and subgroup G_2 of 46 potentially non-normothermic cases. G_2 is further subdivided in subgroup G_{2A} of 18 potentially hyperthermic cases and subgroup G_{2B} of 28 potentially hypothermic cases.

We adopted the solution of choosing arbitrary thresholds of ±0.5 °C + 37.2 °C to discriminate the potentially hypo-, hyper-, and normothermal group with three ideas in mind:

(1) That the time difference between death and measurement start in case of hypothermia was relatively short and thus should not have led to a decline of the core temperature T under 37.2 °C at time of measurement. On the other hand we assumed, that hypothermia means a rise in the body core temperature of at least 1–2 °C.
(2) The body core temperature in the group of normothermal subjects is subjected to statistical deviations. This fact, as well as the natural decline of body core temperature after death and before measurement begin forces the use of a time interval containing the regular core temperature of 37.2 °C.
(3) In case of hypothermia the subjects should have had a initial core temperature of at least 37.2– 0.5 °C to be detectable.

Certainly it is not possible to derive the thresholds from the soft criteria (1)–(3) so we had to introduce some arbitrariness at this point. This very fact as well as statistical deviations surely lead to some cases of misclassification and a blurring of the results. Since the results are highly significant we do not think that they would be changed by the misclassification of some cases.

Death time back-calculation according to the Henßge-model is performed for each cooling experiment a_n and all rectal temperatures $T_{n,k}$ recorded during that experiment, resulting in K Henßge death time estimates $t^{\wedge}_{n,k}$, that can be compared to the (known) true death time $t_{n,k}$. The difference between the estimated and the true death time is the error $e_{n,k}$:

$$e_{n,k} = t^{\wedge}_{n,k} - t_{n,k}$$

As $t^{\wedge}_{n,k}$ is a realization of a random variable $t^{\wedge}$ and $t_{n,k}$ a realization of the fixed value t, we can compute the expectation value $E(e)$