The use of continuous post-mortem temperature measurements for estimating the time of death

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Introduction

Temperature-based techniques are commonly used in forensic medicine to describe the early post-mortem interval and to estimate the time of death. Hennsge [1] introduced a practical and robust algorithm based on single body and ambient temperature measurements. Two well known shortcomings are the need of corrective factors and the assumption of a constant ambient temperature during the cooling process.

We propose a non-linear regression model to describe the characteristics of the body cooling curve considering variable ambient temperatures. The main advantage of the presented model is the discard of corrective factors which depends on the investigator's subjective choice.

Body Cooling Model

It was observed early on that the cooling of the dead human body does not sufficiently conform to Newton's Law of Cooling

$$T'(t) = z \cdot (T(t) - Ta)$$

with body temperature *T(t)* at time *t* and constant ambient temperature *Ta* due to the "plateau" phase during the early post-mortem period (~6h). Marshall and Hoare [2] stated this effect to be exponential in a form which decays with time:

$$T_{MH}'(t) = z \cdot (T_{MH}(t) - Ta) + C_{MH} \cdot e^{-pt}.$$

Solving this differential equation yields

$$T(t) = (T(0) - Ta) \cdot \left(a \cdot e^{bt} + (1 - a) \cdot e^{\frac{ab}{a-1} \cdot t} \right) + Ta$$

with constants *a* and *b* which forms the basis for Hennsge's *Nomogram method.*

Nomogram Method

Assuming the body temperature *T(0) = 37.2°C* at time of death *t = 0,* Hennsge experimentally determined values for the constants *a* and *b.* His approach requires single body and ambient temperature measurements, the body weight *w* and a corrective factor *C* to account for non-standard cooling conditions (e.g. covered body):

$$a = \begin{cases} 1.25, & \text{if } Ta < 23^\circ C, \\ 1.11, & \text{if } Ta > 23^\circ C, \end{cases} \qquad b = 1.2815 \cdot (C \cdot w)^{-0.625} + 0.0284$$

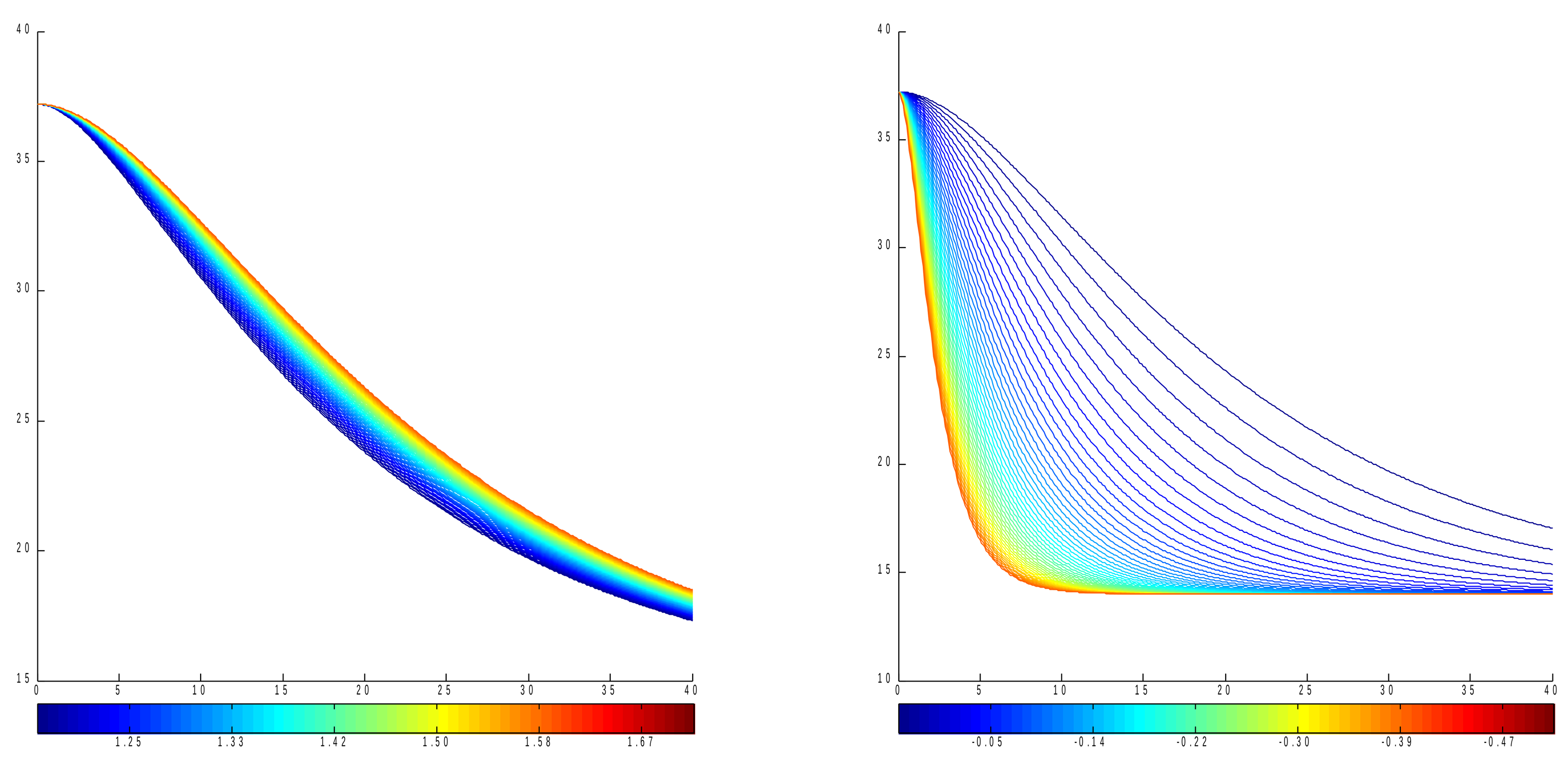

Figure 1: Cooling curves for body weight w = 80 kg, corrective factor C = 1, parameters a ∈ [1.25, 1.75] (left) and b ∈ [-0.05,-0.55] (right).

Variable Ambient Temperature

Normally, temperature data is limited to a few or single-point measurements at the scene of crime. Small electronic button-like data loggers provide a new, easy and automatic way to measure and record continuous temperature data (intervals from 1/sec to 1/273h) over a long period of time (maximum 4094 values).

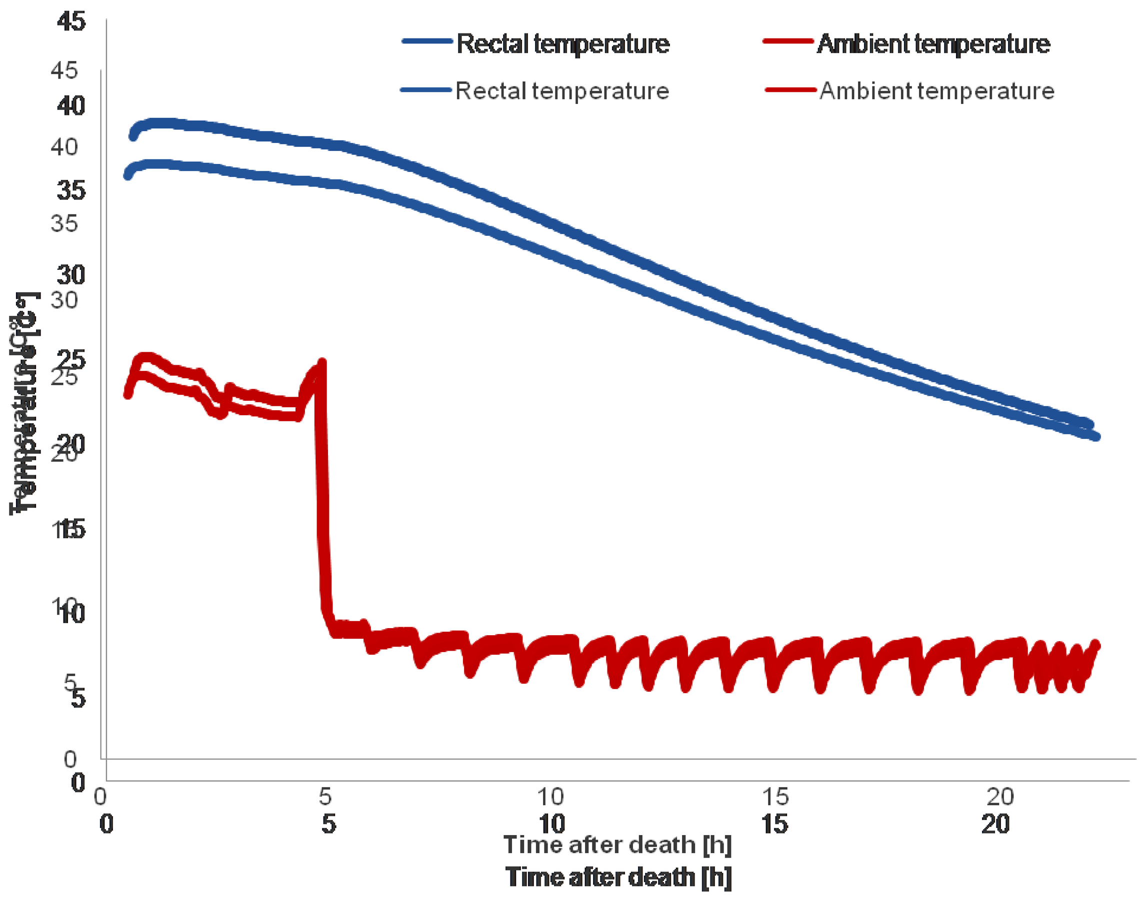

Figure 2: Continuous (rectal) body and ambient temperature during 22 hours after death

The majority of cooling models are based on the assumption that the ambient temperature remains constant which in practice rarely holds true. We suggest to generalise Hennsge's and Marshall and Hoare's approach using a non-linear regression model by solving the nested initial value problem

$$T'(t) = b \cdot \left((T(t) - Ta(t)) - (T(0) - Ta(0)) \cdot e^{\frac{ab}{a-1} \cdot t} \right),$$
$$T(0) = T_0,$$

where *Ta(t)* denotes the linear inter- and extrapolating function through the measured ambient temperatures.

Results and Conclusion

We used a least squares approach for non-linear parameter estimation and the explicit Runge-Kutta method for solving the ordinary differential equation. Model validation was performed by comparing the reported and predicted time of death in 11 cases. We achieved an improvement of accuracy by approximately 1.5h on average compared to the algorithm proposed by Hennsge.

This is the starting point for a new algorithm to estimate the time of death using continuous temperature measurements. After revisiting basic facts on body cooling models and discussing their limitations, we showed that the main advantages of the presented method are the discard of corrective factors and allowing for a change in ambient temperature. The next steps will be presenting more numerical results, identifying the optimum number of model parameters and determining confidence intervals for the time of death.

References

[1] Hennsge C. (1988), Death time estimation in case work. I. The rectal temperature time of death nomogram, Forensic Science International, 38, pp 209-236

[2] Marshall T. and Hoare F. (1962), Estimating the time of death - the rectal cooling after death and its mathematical representation, Journal of Forensic Sciences, 7, pp 56-81