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The role of intestinal bacterial heat production in confounding postmortem temperature measurements

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Summary. To assess the influence of anaerobic bacterial heat production in human stools as a confounding factor in postmortem rectal temperature measurements, in vitro experiments were carried out with human stools incubated at 37°C for 6 h and at decreasing temperatures simulating a postmortem body cooling. Although a statistical significant heat production was observed, it was not relevant enough to explain a postmortem temperature plateau or a substantial rise in the postmortem body temperature. The experiments suggest that stools merely reflect the environmental thermal changes rather than producing bias and confounding by a bacterial heat production.

Key words: Body temperature – Postmortem heat production, in human stools – Time since death, body temperature

Zusammenfassung. Proben menschlicher Faeces wurden anaërob für 6 h bei 37°C und bei abnehmenden Temperaturen in vitro untersucht, um festzustellen, ob eine etwaige postmortale Wärmeproduktion in den Exkrementen einen Einfluß haben kann bei postmortalen rektalen Temperaturmessungen. Obwohl eine signifikante Wärmeproduktion beobachtet wurde, reicht sie nicht aus, um ein postmortales Temperaturplateau oder eine Zunahme der Körpertemperatur zu erklären. Die Experimente zeigen, daß die Faecesproben vielmehr die durch Umgebungsfaktoren bestimmte Temperaturänderungen widerspiegeln, als daß sie aufgrund ihrer bakteriellen Wärmeproduktion zu Irrtümern und Fehlern bei der postmortalen Temperaturmessung führen.

Schlüsselwörter: Körpertemperatur – postmortale Wärmeproduktion in Exkrementen – Todeszeitbestimmung, Temperaturmessung

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Introduction

Since the development of scientific forensic medicine, investigators have studied the postmortem changes in the human body, first to discern death from apparent death, and later on to assess the biochemical, physical, and physiologic mechanisms that underlie these changes. One of the major fields of ongoing study in this area is the postmortem body cooling (Madea and Henßge 1985). A century ago, Seydeler (1869) and Rainy (1869), amongst others, already observed an initial temperature plateau and even a postmortem rise in body temperature. These phenomena again attracted attention in the past decades, and suggestions were made as to the corrections needed in estimating the time of death from temperature measurements (Marshall and Hoare 1962; Marshall 1962a, b, 1969; Reimann 1968; Brown and Marshall 1974; Brown et al. 1985; Henßge 1979, 1981). This has led to complex mathematical formulas, nevertheless still based on several assumptions (James and Knight 1965; Simonsen et al. 1977; Henßge 1981; Brown et al. 1985; Nokes et al. 1985). Despite this ample attention to the postmortem temperature plateau, less is known as to the exact mechanisms that underlie this phenomenon and the temperature rise sometimes observed.

A recovery of the body tissues from a local cooling after the insertion of a thermometer, or from environmental changes during transportation to the morgue, has been put forward as a possible cause of bias (Marshall and Hoare 1962; Marshall 1962a, b; Henßge 1981). Although the heat capacity of the mercury reservoir of a traditional thermometer might indeed have an influence on the tissues deprived from circulation, the temperature plateau has also been observed for durations exceeding this effect (Marshall and Hoare 1962), and in experiments where small electrodes were used (Henßge et al. 1984). These observations make a simple bias due to a thermal effect of a thermometer bulb unlikely. Recovery from environmental changes, on the other hand, is possible and was demonstrated already by Marshall and Hoare (1962), but is difficult to quantify because of the difficulties to control pre-experimental variables and to reduce the lag between death and measurements. The postmortem temperature plateau further shows interaction with factors, such as body weight, natural and artificial insulation, premortem body temperature, and the cause of death (Simonsen et al. 1977; Nokes et al. 1985). It has also been suggested that ongoing metabolism and intestinal bacterial heat production might influence the initial postmortem body cooling (Lyle and Cleveland 1956; Shapiro 1965; Nokes et al. 1985; Hutchins 1985). On theoretical grounds, both hypotheses are worth considering, as there is no reason why biochemical or microbiological reactions should cease at the very moment of death.

As time of death in routine forensic casework normally is estimated from rectal temperature measurements, next to other signs, the eventual role of intestinal bacterial heat production as confounder might be important since its influence could be ruled out by using sterile measurement sites. The consequence (to change an easy-to-access body cavity for less practical measurement sites) that would result if this confounding were real, stresses the importance of such an evaluation even more. This article discusses the results of in vitro experi-

ments on human stools to assess the eventual additional influence of postmortem bacterial heat production in postmortem temperature measurements and its possible role as a confounder in estimating the time of death.

Materials and methods

A total of 15 samples of fresh human stools (mean weight 83 ± 15 g) were collected from the same individual in prewarmed (37°C) 600-ml glass containers with plastic top and were immediatly covered with paraffin oil of the same temperature (Merck). A prewarmed (37°C) stainless steel thermocouple needle (DGT Viking 10*1 mm) was brought into the core of the stools and they were brougt back at 37°C in a waterbath. Plastic tape pressure valves were installed in the top of the containers to ensure them from exploding in case of gas production. After drying the outer surface of the containers mechanically, they were transferred to a hot-air incubator set at 37°C, and were given 30 min to adapt to this new environment before temperature readings were started. Ten of the samples remained at 37°C for 6 h. The other five were treated by simulating a postmortem body cooling: they stayed at 37°C for only 1 h, were then transferred to an incubator set at 30°C for another 5 h, and were finally left at room temperature for 3 h. During the whole experiment all containers were kept closed and the stools' core temperature was measured by a wired remote reading. In the first experiment, temperature measurements took place every 30 min during the first 3 h and every hour afterward. In the second experiment, measurements were made at 30-min intervals during the whole experiment. At that time, the environmental temperature was recorded, too, using top-inserted mercury thermometers for the incubators and electrical thermometry for room temperature (scale 1°C). The gas production was evaluated visually by the appearance of gas bubbles on the interline between feces and paraffin and within the paraffin.

Results

In the experiment with constant 37°C incubation temperature, all but two samples showed a rise in temperature, and all samples showed a gas production. The mean temperature difference after 6 h of incubation was +0.30°C (SD 0.39°C) ($t = 2.433$; $P < 0.05$). The temperature evolution in the stools' core was best estimated mathematically by an exponential regression with formula $Y = 0.31*e^{(-0.51*x)}+36.6$ ($r^2 = 0.949$) (Fig. 1). The temperature changes between

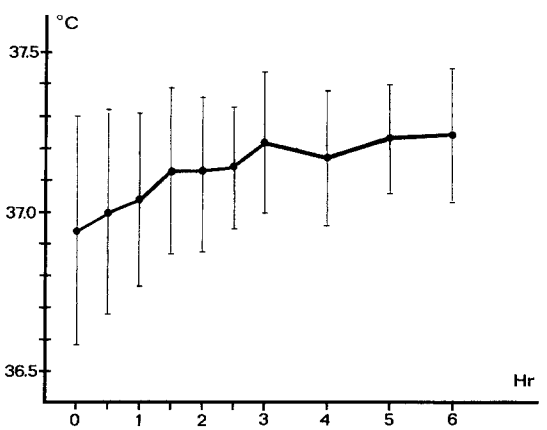

Fig. 1. Temperature evolution in human stools incubated at 37°C for 6 h (mean ± SD)

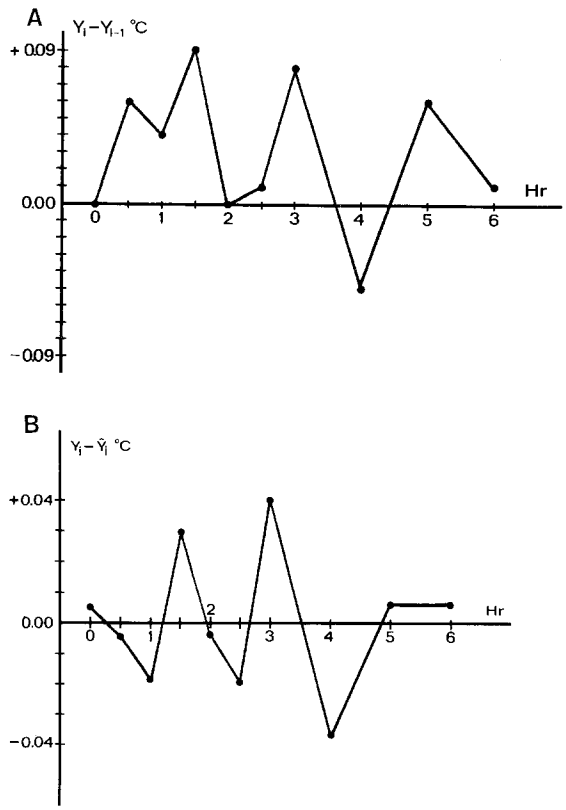

Fig. 2A, B. Evolution of the mean temperature differences between measurements ($Y_i - Y_{i-1}$) during incubation of human stools at 37°C for 6 h (**A**), and of the residuals of the exponential regression ($Y_i - \hat{Y}_i$) (**B**)

two measurements and the residuals of the regression followed a remarkable undular pattern (Fig. 2), which in a more accurate monitoring of the incubator's temperature fluctuation (scale 0.1°C) later on showed to be similar to the effect of the incubator's built-in thermoregulator switching on and off.

In the experiment with decreasing incubation temperatures, all five samples showed gas production, but no significant heat production was recorded. After removing the samples from 37°C to 30°C, the stools' temperature dropped fast to reach the environmental temperature after 60–90 min. During the last 3.5 h of incubation at 30°C, however, a mean temperature rise of +0.12°C was observed (SD 0.30°C) ($t = 0.894$; n.s.). Temperature changes between two measurements were negative during the first 60–90 min and were flat to slightly undular afterward. An undular pattern of the mean differences, as observed in the first experiment, was not seen. After removing the samples to room temperature (ranging from 17° to 23°C), the core temperature again dropped fast to reach room temperature in less than 1 h. During the next 2 h no further temperature changes were observed in any of the samples.

Discussion

Both experiments described above show that there is indeed a capacity for heat production in human stools, resulting in a mean temperature increase of 0.3°C

when they are incubated at 37°C for 6 h. In the experimental set-up used, this must be the result of an anaerobic fermentation. On mathematical expression, this heat production shows not to be linear but to have some saturation point whereafter the heat gain becomes zero. Although the temperature increase observed in the first experiment is statistically significant, it is not relevant enough to confound an estimation of the time of death from rectal temperature measurements. Even if one were so unlucky to measure the body temperature in a rectum filled with stools, it would be improbable that these were kept under standard conditions for 6 h at an environmental temperature of 37°C. Whatever cooling formula further is used, the observed 0.3°C rise in temperature over 6 h could not compensate the heat loss in the dead body, which has been estimated to be 35–70 kcal/h for a 70-kg body (Lundquist 1956).

Secondly, the experiment with decreasing incubation temperatures shows that the bacterial heat production in human stools depends on the environmental temperature, and it decreases when this temperature is lowered, to become negligible below 30°C. In addition, human stools in vitro showed to adapt very quickly to minor changes in the environmental temperature too, as could be seen from the undular pattern superimposed on the temperature curve by the effect of the incubator's built-in thermoregulator.

All these observations suggest that stools do not have a great heat buffer capacity, and merely reflect the impact of the thermal environmental changes, rather than producing bias or confounding in the estimation of the time of death from rectal temperature measurements by their bacterial heat production.

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