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Rectal temperature-based death time estimation in infants

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ABSTRACT

In determining the time of death in infants based on rectal temperature, the same methods used in adults are generally used. However, whether the methods for adults are suitable for infants is unclear. In this study, we examined the following 3 methods in 20 infant death cases: computer simulation of rectal temperature based on the infinite cylinder model (Ohno's method), computer-based double exponential approximation based on Marshall and Hoare's double exponential model with Henssge's parameter determination (Henssge's method), and computer-based collinear approximation based on extrapolation of the rectal temperature curve (collinear approximation). The interval between the last time the infant was seen alive and the time that he/she was found dead was defined as the death time interval and compared with the estimated time of death. In Ohno's method, 7 cases were within the death time interval, and the average deviation in the other 12 cases was approximately 80 min. The results of both Henssge's method and collinear approximation were apparently inferior to the results of Ohno's method. The corrective factor was set within the range of 0.7–1.3 in Henssge's method, and a modified program was newly developed to make it possible to change the corrective factors. Modification A, in which the upper limit of the corrective factor range was set as the maximum value in each body weight, produced the best results: 8 cases were within the death time interval, and the average deviation in the other 12 cases was approximately 80 min. There was a possibility that the influence of thermal isolation on the actual infants was stronger than that previously shown by Henssge. We conclude that Ohno's method and Modification A are useful for death time estimation in infants. However, it is important to accept the estimated time of death with certain latitude considering other circumstances.

1. Introduction

Estimating the time of death has long been an important task for forensic pathologists. Several methods using body cooling have been reported for early postmortem examination in forensic practice [1–3]. Among them, methods based on rectal temperature are commonly used.

Henssge's nomogram method [4] is well established and one of the most practical guides currently available [1,5]. Alternatively, a computer simulation program of rectal temperature based on the infinite cylinder model [6] was developed by Hiraiwa et al. [7,8]. Because the source program was written in the FORTRAN language, Ohno et al. [9] subsequently modified it using the C language for personal computers.

In many forensic institutions, rectal temperatures are measured only a few times before autopsy using bar thermometers. The rectal measuring positions differ each time, even under a similar ambient temperature. Therefore, the results are sometimes markedly different from the actual death time. To solve this problem, Kanetake et al. [10] introduced button-type thermo data loggers to measure postmortem rectal and ambient temperature continuously. Kanetake also developed a computer program that approximates continuous rectal temperature measurements by Marshall and Hoare's double exponential equation with Henssge's parameter determination (Kanetake, unpublished communication).

Few reports on determining the time of death in infants using rectal temperature have been published, and whether the methods for adults are suitable for infants is unclear.

In this report, we assessed the time of death in infants using the following three methods: computer simulation of rectal temperature based on the infinite cylinder model, computer-based double exponential approximation based on Marshall and Hoare's double exponential model with Henssge's parameter determination, and computer-based collinear approximation based on extrapolation of the rectal temperature curve.

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2. Materials and methods

2.1. Cases (Table 1)

In total, 2141 autopsies were performed in our institution from January 2009 to December 2014. Of these, 20 cases involving infants were selected according to the following inclusion criteria: <2 years of age, a ⩽6-h interval between the last time the infant was seen alive and the time he/she was found in cardiopulmonary arrest, insertion of a thermo data logger into the rectum, storage of the body at room temperature in the mortuary for at least 2 h before placement in the refrigerator, and performance of postmortem computed tomography (CT) scan to measure the pelvic circumference of the corpse and the distance between the anus and rectally placed thermo data logger. The exclusion criteria were a rectal temperature of >37.2 °C when the thermo data logger was inserted and cooling of the corpse in the refrigerator as soon as the thermo data logger was inserted.

2.2. CT machine

Postmortem CT was performed with an eight-channel scanner (Aquilion 8; Toshiba Medical Systems, Tokyo, Japan).

2.3. Image management

All CT image data were sent to a digital imaging and communication in medicine (DICOM) server (POP-Net Server; ImageONE, Tokyo, Japan). The pelvic circumference of the corpse and the distance between the anus and rectally placed thermo data logger were measured using a three-dimensional image workstation (Ziostation2 ver. 2.1.5.0; Ziosoft, Tokyo, Japan).

Table 1
Details of the cases evaluated in this study.

Case	Height (cm) / Weight (kg)	Cause of death	Comments
1	58.6/5.3	SUD	Resuscitation (+)
2	71/8.2	SUD	Resuscitation (+), RSV (+)
3	62/6.6	SUD accompanied with mild myocarditis	
4	62.5/6.4	SUD	
5	65/6.5	SUD	Resuscitation (+)
6	48.5/2.8	SUD	Resuscitation (+)
7	77/8.7	SUD	Resuscitation (+)
8	60/5.6	SUD	
9	53/3.8	Hypertrophic cardiomyopathy	Resuscitation (+)
10	54/3.9	SUD with suspicion of viral infection	Resuscitation (+)
11	80.5/10.5	Acute bronchitis and bronchiolitis	
12	68/7.7	Asphyxia due to aspiration of vomited milk	
13	50/3.3	SUD	Resuscitation (+)
14	75.5/10.3	Drowning	Resuscitation (+)
15	71/8.3	SUD	Resuscitation (+), RSV (+)
16	75/8.3	SUD	Resuscitation (+), RSV (+)
17	56/5.5	SUD	Resuscitation (+), RSV (+)
18	61/6.2	SUD	Resuscitation (+)
19	60/5.3	SUD	Resuscitation (+)
20	62/6.4	SUD	Resuscitation (+)

SUD: sudden unexpected death including sudden infant death syndrome. Case 14 was a drowning case, but it was not excluded because the required time for discovery was short (within 15 min). Cases 2, 15, 16, and 17 were respiratory syncytial virus (RSV)-positive at autopsy using a rapid test kit (QuickNavi™-Flu + RSV; Denka Seiken, Tokyo, Japan), and some infections were suspected in Cases 10 and 11, but they were not excluded because there was no evidence indicating antemortem fever.

2.4. Continuous recording of rectal and ambient temperature [10]

Rectal and ambient temperature were continuously recorded using button-type thermo data loggers (model 3650; Hioki E.E. Corporation, Nagano, Japan) (Fig. 1, Table 2). These battery-powered thermometers automatically measure the temperature at time intervals set in advance and save them. We set the measuring interval to 5 min in overwrite mode, and they can save temperature data of approximately last 7 days. The saved data were sent to the computer through the data reader (model 3920; Hioki E.E. Corporation) and output as a time–temperature graph. These thermo data loggers have been distributed to all police stations in Miyagi prefecture. Two devices are used together; one is inserted into the rectum to record the rectal temperature, and the other is set in the holder and placed on the ankle of the deceased to record the ambient temperature. In the summer season, the corpse is stored at room temperature in the mortuary for at least 2 h before it is put in the refrigerator.

2.5. Selection of the approximation section

The start and end points of the approximation section were visually determined on the graph. When the thermo data logger is inserted into the rectum, the rectal temperature curve rises rapidly and then stabilizes. This point was set as the start point. The end point depends on the ambient temperature. When the corpse is placed in the refrigerator, the ambient temperature curve drops immediately. The end point was set just before this point (Fig. 2). When the corpse was stored at room temperature, the end point was set at the point where the thermo data logger was retrieved from the anus (Fig. 3).

2.6. Methods of death time estimation

All computer programs in this study were developed using C++Builder XE3 (Embarcadero Technologies, Tokyo, Japan).

2.6.1. Computer simulation of rectal temperature based on the infinite cylinder model (Ohno's method) [7–9]

Two rectal temperature measurements are required for this program, and those at the start and end points of the approximation section are used. The ambient temperature is regarded to remain constant at the average ambient temperature throughout the approximation section. Measurement of the pelvic circumfer-

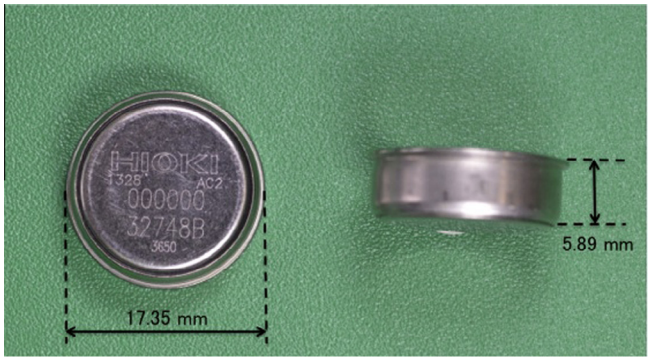

Fig. 1. Appearance of the button-type thermo data logger.