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An experimental evaluation of electrical skin conductivity changes in postmortem interval and its assessment for time of death estimation

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ABSTRACT

In forensic medicine, estimation of the time of death (ToD) is one of the most important and challenging medico-legal problems. Despite the partial accomplishments in ToD estimations to date, the error margin of ToD estimation is still too large. In this study, electrical conductivity changes were experimentally investigated in the postmortem interval in human cases. Electrical conductivity measurements give some promising clues about the postmortem interval. A living human has a natural electrical conductivity; in the postmortem interval, intracellular fluids gradually leak out of cells. These leaked fluids combine with extra-cellular fluids in tissues and since both fluids are electrolytic, intracellular fluids help increase conductivity. Thus, the level of electrical conductivity is expected to increase with increased time after death. In this study, electrical conductivity tests were applied for six hours. The electrical conductivity of the cases exponentially increased during the tested time period, indicating a positive relationship between electrical conductivity and the postmortem interval.

1. Introduction

Time of death (ToD) estimation is one of the most critical concepts in forensic medicine, and ToD studies are ongoing worldwide. ToD estimation is used to predict the elapsed time after death using different physical and chemical techniques. One of the legal criteria for ToD determination is the availability of witnesses who witnessed the death. If there are no witnesses, or witness declarations must be verified, scientific methods are employed to reveal the ToD.

ToD is crucial from various perspectives, especially in the criminal justice system. Precise ToD determination helps identify perpetrators and decreases the number of suspects. In some cases, ToD determination may be essential to verify witnesses' declarations. ToD can clarify whether suspects were at the site of the murder or not. Additionally, death order, even if different by only a few seconds, is important for determining inheritance in cases where the corpses of two or more related persons are found at the same time [1].

In the literature, various physical and chemical techniques have been proposed to estimate ToD within some error margins. Some of the physical techniques are algor mortis [1–12], rigor mortis [13–17], supravital reactions [18–20], livor mortis [21–23], and postmortem decomposition [24–27]. For some chemical methods [28–32], body fluids (e.g., blood, vitreous humour) are taken and changes in the electrolytes are evaluated with respect to time [33]. Scientists have fit curves to the data obtained from these physical and chemical methods to try to predict ToD [34].

Since ToD estimation is challenging and obtaining real data is difficult, ToD estimation has not been adequately studied in the literature. The results of previous studies based on conventional methods are not satisfactory [1], and there is a need to develop new techniques to more accurately estimate ToD. The physical methods are not easy to evaluate quantitatively; natural disintegration of the body can be easily altered by environmental factors, like humidity and temperature. Additionally, since chemical methods are based on taking body fluids multiple times, natural postmortem progress is likely to be disrupted. All these methods need significant amounts of time and experienced researchers.

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In this study, changes in electrical conductivity were experimentally investigated in the postmortem interval in human cases. Electrical conductivity measurements give some promising clues about the postmortem interval. An alive human has natural electrical conductivity; however, in the postmortem interval, intracellular fluids gradually leak out of cells. These leaked fluids combine with extracellular fluids in tissues, and since both of these fluids are electrolytic, this mixing of intracellular and extracellular fluids helps to increase conductivity and thus the level of electrical conductivity is expected to increase after death. In this study, a clinical electrical conductivity test was applied to corpses that were within the early postmortem period (24 h after death) at the Istanbul Council of Forensic Medicine (ICFM).

The rest of the paper is organized as follows. The experimental procedure and information about the cases are discussed in the Materials and Methods section. The experimental results are detailed in Section 3 and discussed in Section 4. The paper is concluded in Section 5.

2. Materials and methods

2.1. Materials

Cases transferred to ICFM were kept in a cold room (5 °C). Corpses received during working hours were taken to autopsy. The ones received after working hours were kept in the cold room until the next day. The cases that came after working hours comprised our experimental group because only the corpses received after working hours stay overnight at the institution.

Electrical conductivity was measured in 32 cases. In order to have the same environmental conditions, we selected only the corpses that passed away between the times of 14:00–15:00 in July and August in Istanbul, when the weather conditions and average temperatures are very similar; cases that passed away in other months were eliminated from the research group. Additionally, we only examined cases that were under the same weather conditions (27 °C temperature, sunny days). Therefore, the study group consisted of cases that died under identical environmental and temperature conditions. Additionally, corpses with edema were excluded. The measurements were started at 16:30 and finished at 22:30 for all cases.

Having the same environmental factors among the cases is important because environmental factors may affect electrical conductivity. According to the case selection criteria, 11 cases that satisfied the conditions were included in the research group; information about these 11 cases is given in Table 1. The stimulating voltage level and temperature of the room were assumed to be fixed during the experiment. Finally, eiet and fluid intake prior to death may have a small influence on conductivity; since this situation of cases prior to death was unknown, it was assumed to be the same in all cases.

2.2. Methods

A computer-aided automation system (see Fig. 1) was designed to measure electrical conductivity changes. The Biopac MP150 data acquisition unit was utilized to record the signals. Electrical stimulation signals were generated by an isolated linear stimulator. The system was automated to produce rectangular pulse signals every 15 min for six hours. The stimulating signals had a magnitude of 10 V and duration of 1 ms because short pulses are generally preferred to long pulses in clinical tests [35].

The polarity of the stimulator and recording electrodes were arranged as shown in Fig. 1. Positive electrodes were placed closer to each other than the negative electrodes were. In this system, stimulations were delivered above the elbow. Response signals were recorded 25 cm away from the stimulating electrodes. To determine the distance, the mid-points of the recording and stimulating electrodes were taken as reference points. Needle electrodes (0.3 mm in diameter) were used for stimulation after being inserted 1.5 cm through the skin, and surface electrodes were utilized for recording. Surface electrodes were pre-gelled single Ag/AgCl electrode conductors, 11 mm in diameter, with a 95 mm^2 conductive contact area. Since stimulation was delivered by needle electrodes under the skin, this experiment can also be called a tissue conductivity measurement.

Table 1
Information about the cases.

	Gender	Age	Height (cm)	Weight (kg)	Cause of death
Case 1	Male	22	180	70	Drugs
Case 2	Male	50	176	60	Fall from height
Case 3	Male	42	165	80	Remaining under rubble
Case 4	Male	29	166	55	Drugs
Case 5	Male	30	174	80	Car accident
Case 6	Male	27	172	58	Drugs
Case 7	Male	55	170	65	Hanging
Case 8	Female	38	166	59	Stab wounds
Case 9	Male	25	175	66	Drugs
Case 10	Male	44	175	56	Alcohol
Case 11	Female	47	168	57	Car accident

After the response signals were perceived by the recording electrodes, they went into a signal amplification unit. Since these signals had low magnitudes, they were amplified in this unit. Response signals were automatically recorded and monitored on a computer. Fig. 2 demonstrates the utilized rectangular pulse signal generated by the stimulator and the response signal, which was recorded by the recording unit. The stimulating signal had one phase of a rectangular wave. The response signal was biphasic, i.e., it had parts on both the positive and negative cycles.

3. Results

The results of 11 cases, depicted in Fig. 3, demonstrate that as the time in the postmortem interval increases, tissue conductivity continues to increase. As mentioned in Section 2, the response signal has portions in both the positive and negative cycles. As the postmortem interval increases, the amplitude of the response signal continues to go up in both cycles, and thus we calculated the integrals of the cycles for each case and for each measurement. In Fig. 3, the *X*-axis is elapsed time (h) after we started the measurements. The *Y*-axis shows the integrals of the signals (mV × s). As shown in Fig. 3, there is a rapid change in electrical tissue conductivity for the initial parts of the graphics. Afterward, this rapid change slows down for the latter parts of the time axis. The graphics do not start from a zero point because a living human has natural electrical conductivity. After death, the level of electrical conductivity starts to go up gradually. During the experimental time, the conductivity levels of the cases increased. Since we took periodic measurements at discrete times, Fig. 3 denotes the measurement values that were taken at those times; increments in the graphics for all cases were continual but their change percentages were different. Electrical conductivity tests were applied for six hours; the increases in conductivity for the first three hours were greater than last three hours. Although the average percentage change in conductivity was 15.2% at the end of one hour with respect to the initial conductivity levels, it reduced to almost 4% after five hours.

Fig. 3 also depicts 11 cases with fitted curves. Measurements were conducted every 15 min across six hours; therefore, the number of measured points for each case was 25. Polynomial

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