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Utilization of bone impedance for age estimation in postmortem cases

Noboru Ishikawa [a, b], Hideki Suganami [c], Atsushi Nishida [d], Daisuke Miyamori [a], Yasuhiro Kakiuchi [a], Naotake Yamada [c], Kim Wook-Cheol [d], Toshikazu Kubo [d], Hiroshi Ikegaya [a, *]

[a] Department of Forensic Medicine, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, Kyoto, 602-8566, Japan
[b] Department of Forensic Odontology and Anthropology, Tokyo Dental College, 101-0061, Japan
[c] Department of Clinical Trial Data Management, Graduate School of Medicine, The University of Tokyo, Tokyo, 113-0033, Japan
[d] Department of Orthopedics, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, Kyoto, 602-8566, Japan

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ABSTRACT

In the field of Forensic Medicine the number of unidentified cadavers has increased due to natural disasters and international terrorism. The age estimation is very important for identification of the victims. The degree of sagittal closure is one of such age estimation methods. However it is not widely accepted as a reliable method for age estimation.

In this study, we have examined whether measuring impedance value (z-values) of the sagittal suture of the skull is related to the age in men and women and discussed the possibility to use bone impedance for age estimation.

Bone impedance values increased with aging and decreased after the age of 64.5.

Then we compared age estimation through the conventional visual method and the proposed bone impedance measurement technique. It is suggested that the bone impedance measuring technique may be of value to forensic science as a method of age estimation.

1. Introduction

In recent years age estimation is a method commonly used when piecing together information to identify bodies. Most of these methods are dependent on forensic anthropological and forensic odontological methods.[1–12] The However, the limitations of this subjective method are well documented.[13–21] The degree of sagittal closure is one of such age estimation methods. However it is also not widely accepted as a reliable method for age estimation because of the dependence upon visual analysis and subjective evaluation.

Recently, in the field of orthopedics, positive results have been shown from attempts to investigate increasing impedance values as bone fractures heal.[21–24] The impedance value is the ratio of electrical current and the electrical voltage that flows through a conductor (in this case bone) when energized by a conductor (direct current or alternating current).[25–28]

In contrast to the subjective elevation and necessity of great experience when performing the conventional age estimation method, because of its simple empirical methodology, conversion to the objective scientific bone impedance measurement technique would lead to more accurate age estimation. For this reason, the impedance values of sagittal sutures of humans were measured, and the effectiveness and reliability of this method was compared with the conventional age estimation method.

2. Materials and methods

2.1. Subjects

The bodies of one hundred people whose age was established following identification of the deceased by their family were used in this study (male: n = 66, female: n = 34, 6–89 years old). The bone impedance value between two points across the sagittal suture was measured. The data was finally divided into four age groups; under 30 (male: n = 8, female: n = 5), from 31 to 50 (male: n = 16, female: n = 9), from 51 to 70 (male: n = 26, female: n = 11) and over 71 (male: n = 16, female: n = 9) (Table 1), after the

* Corresponding author. Department of Forensic Medicine, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, 465 Kajiicho, Kawaramachi, Kamigyo, Kyoto, 602-8566, Japan. Tel./fax: +81 75 251 5343.
E-mail addresses: hoi@koto.kpu-m.ac.jp, ikegaya@koto.kpu-m.ac.jp (H. Ikegaya).

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Table 1
Subject details and results of analyses in humans.

Gender	z-value (kΩ)		
	Age	Average	SD
Male	Under 30 y	13.87	1.98
	31–50 y	14.79	1.31
	51–70 y	15.14	1.04
	71 y and over	15.48	0.8
Female	Under 30 y	13.75	1.18
	31–50 y	15.2	1.15
	51–70 y	15.26	1.02
	71 y and over	14.72	0.93

statistical evaluation of the relationship between age and bone impedance value.

2.2. Human skull bone impedance measurement

Two steel screw pins (15 cm in diameter, 0.2 cm in width), electric device (MES Co., Ltd., Japan) and alternating-current (AC) stimulation device (MES Co., Ltd., Japan) were used in this study (Fig. 1). These pins were used as electrodes, and AC current was passed between the two screw pins using the AC stimulation device with a constant current of 30 ± 6 μA, and loading resistance of 0–60 kΩ.

First, after the skin of the skull was peeled away, two pins were inserted into the skull (centriciput) to a depth of 3 mm. The pins were inserted in line with each other at a distance of 0.5 mm from the sagittal suture. Next, an electrical current of I μA was applied between the electrodes and the voltage E mV was measured, and then bone impedance values (z-values) were calculated through the following formula; of z = E/I. The numerical value displayed on the impedance measurement device was recorded 15 s after galvanic stimulation in order to standardize the method.

2.3. Age estimation through the conventional visual method

The grade of bone closure of each case used in the measurement of impendence values was classified into one of five (0–4) categories using a standardized visual reference criteria (Table 2).[29] Then a comparison of results using the two methods was made.

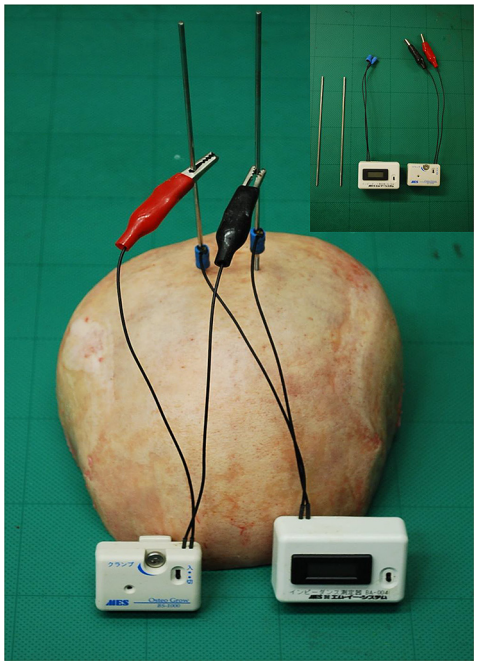

Fig. 1. Impedance values measuring instrument (upper right) and demonstration of usage with a human cranial bone.

2.4. Statistical analysis

The relationship between the impedance and age was analyzed using polynomial regression model. This statistical analysis was performed using SAS version 9.4 software (SAS Institute, Cary, NC, USA). Each parameter in polynomial regression model was examined by two-sided t-test, and $P < 0.05$ was considered statistically significant.

All research protocols in this study were approved in advance by the university medical and ethical committee for the use of human and animal samples (C-569).

3. Results

3.1. Impedance of the human skull bones

Fig. 2 shows the relationship between age and bone impedance of sagittal suture. The first polynomial regression model included age (linear, squared and cubed form) and sex. The model was reduced until all term were statistically significant. The final model has only linear and squared form of age.

When the data was divided into four age groups, the average bone impedance value of males under 30 was 13.87 ± 1.98 kΩ, 14.79 ± 1.31 kΩ for males between 31 and 50, 15.14 ± 1.04 kΩ for males between 51 and 70 and 15.48 ± 0.80 kΩ for males of 71 and over. In females under 30 the average impendence value was 13.75 ± 1.18 kΩ, 15.20 ± 1.15 kΩ for females between 31 and 50, 15.26 ± 1.02 kΩ for females between 51 and 70 and 14.72 ± 0.93 kΩ for females of 71 and over. We have shown the average impedance value in each age groups in Fig. 3.

3.2. Age estimation using the conventional visual method

Autopsy cases were classified into one of five categories using the conventional visual method. The results are as follows: 38.5% of the under 30 bracket fell into category 2, 56% of the 31 to 50 bracket fell into category 3, 36.1% of the 51 to 70 bracket fell in to category 2 and 56% of the 71 and over bracket fell into category 2 (Fig. 4).

4. Discussion

The bone impedance value increased with age, however, it decreased after the age of 64.5 (Fig. 2a and b). It is well known that in the females, the menopause-causing secretion of ovarian hormones and reduced bone density caused by reduced osteoblast activity are among possible explanations.[29–33] However, not only in the females but also in the males, bone impedance decreases after the age of 64.5. Recently it is reported that sex hormone is also responsible for male osteoporosis and other factors, like genetic reasons and chronic diseases induce osteoporosis in the elderlies.[34] Therefore, we could obtain similar regression curve in male in addition to female (Fig. 2b). We could show the apparent relationship between age and bone impedance value of sagittal suture.

Age classification of human autopsy cases through the conventional visual method, while finding that the cranial suture generally closed with age, also showed that the degree of closure varied greatly within age brackets (Fig. 4) as the same as in other reports. And it is also believed to be the result of this method's reliance upon individuals' subjective evaluation of suture closure,[13–21,29] Supporting this notion is Fig. 5, which shows examples of the degree of suture closure not correlating with age. In other words, a skull may show a high bone impedance value even if the skull is