Measurement of Bone Electrical Impedance in Cadavers

INTRODUCTION

In the experimental external fixator model, such as the fractured or lengthening rabbit tibia, we reported an increase in bone electrical impedance (Z values; kΩ) during callus maturation, and that the measurement of Z values makes it possible to evaluate bone union2. We applied this concept to estimate the time to remove external fixators and the diagnosis of delayed union. However, Z values might vary by sex, age, affected extremity, and physique (e.g., body mass index; BMI). Therefore, we measured Z values of the extremities of cadavers, to investigate the validity of this technique. We also evaluated the effects of sex, age, and physique on Z values. This study investigated the potential utility of measuring Z values to evaluate the properties of bone.

METHODS

We measured the Z values of the extremities (humerus, radius, femur, tibia) in 31 cadavers (16 males and 15 females) during autopsies performed at the Kyoto Prefectural University of Medicine. This study was approved by the local research ethics committee. Z values were measured in 159 bones, including the humerus (8), radius (43), femur (48) and tibia (60). The mean age of the cadavers was 59.2 years old (range, 26 – 96 years). Fractured cases were excluded from the analysis.

We prepared two stainless steel Kirschner wires with thread (Synthes Inc.), and inserted one wire into the diaphysis, and the other into the proximal metaphysis. Except for a 1-cm section, the tips of these Kirschner wires were covered with plastic tubes to insulate the wires from soft tissue conductivity (Fig. 1). After inserting the wires, we confirmed that they were inserted distal from the plastic tubes. We measured the Z values between these two wires using an alternating current devise (MES, Co., Ltd., Tokyo) in each bone.

We compared Z values in terms of sex, age and BMI, and determined correlations between these factors. Statistical analysis was performed using Mann-Whitney’s U test. P values <5% were considered statistically significant (p<0.05).

RESULTS

Z values for the individual bones and groups of bones are presented in Table 1. The mean Z value was significantly lower in females than in males (7.5 ± 2.90 vs. 8.86 ± 2.73 kΩ, respectively; p=0.0091). However, this difference was due to a significant difference Z values for the tibia (p=0.0020), but not other bones, between males and females. In males, the mean Z value for non-weight-bearing bones (i.e., humerus and radius) was 7.30 ± 2.45 kΩ, and was significantly lower than that of weight-bearing bones (femur and tibia) (8.75 ± 2.93 kΩ; p=0.0034). By contrast, in females, there was no difference in Z values between weight-bearing and non-weight-bearing bones (p=0.5016). We also found a significant difference in Z values between the femur and tibia in males (p=0.0035), and a small, non-significant difference in females (p=0.0891).

For weight-bearing bones in males, age was negatively correlated with Z values, with correlation coefficients of -0.422 and -0.382 for the femur and tibia, respectively (Fig. 2). However, age was not correlated with Z values in females. Furthermore, there was no correlation between Z values and BMI in males and females.

DISCUSSION

This is the first report to evaluate bone electrical impedance in cadavers. In this study, the Z value only represents the electrical impedance of bone itself because the electrodes were fully isolated from the soft tissues by plastic tubes. Electrical resistance is generally lower in material with higher water content. Bone consists of cortical bone, cancellous bone, and bone marrow. Of these, the electrical current flows through the bone marrow, which has higher water content than the other components. Therefore, the Z values might be influenced by bone density, which may play a role of resistance to the electrical current.

We found that Z values were higher in males than in females, consistent with the notion that bone density is lower in females than males. Also, Z values were higher in weight-bearing bones than in non-weight-bearing bones, indicating that bone density is higher in weight-bearing bones than non-weight-bearing bones.

Z values were negatively correlated with age in males, implying that bone density decreases with age. However, in females, Z values did not decrease with age, although bone density often decreases in females after menopause. This may be because fatty degeneration of the bone marrow might have a greater influence on Z values than bone rarefaction in females, as the electrical resistance of fat is high.

Based on these results, Z values are influenced by sex, age in male, and upper or lower extremities, so that Z values should be compared and evaluated in view of these factors.

REFERENCES