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SURGICAL MEDICAL SCIENCES / CERRAHİ TIP BİLİMLERİ

Evaluation of Odontoid Process Bone Quality with Hounsfield Unit Values in the Adult Population

Erişkin Popülasyonda Hounsfield Ünitesi Değerleri ile Odontoid Proses Kemik Kalitesinin Değerlendirilmesi

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Abstract

Objectives: In this study, the aim is to investigate the changes in bone density and quality of the odontoid tip, neck and second cervical vertebral body located beneath the base of odontoid with advancing age.

Materials and Methods: Seven study groups were formed, each consisting of healthy individuals in the age ranges of 18-29, 30-39, 40-49, 50-59, 60-69, 70-79, and 80 years and above. The odontoid bone structure of each individual was identified on cervical computed tomography images in both sagittal and coronal planes. Mean Hounsfield unit (HU) values were calculated for the odontoid tip, odontoid neck, and the C2 body portion below the odontoid base areas in both midsagittal and midcoronal planes. The HU values were compared and analyzed.

Results: There is a significant, negative correlation between age and the HU values measured in the sagittal plane for the odontoid tip, odontoid neck, and C2 vertebral body portion under the odontoid base (the correlation coefficients are -0.795 r, -0.766 r, and -0.789 r, respectively). Similarly, there is a significant, negative correlation between age and the HU values measured in the coronal plane for the odontoid tip, odontoid neck, and C2 vertebral body portion under the odontoid base (the correlation coefficients are -0.836 r, -0.680 r, and -0.802 r, respectively). These results indicate that as age increases, the quality of the odontoid bone decreases.

Conclusion: The assessment of bone quality through computed tomography, based on HU values, reveals a significant decrease in the bone quality of both the odontoid bone and C2 vertebral body with increasing age.

Keywords: Odontoid bone, odontoid fractures, Hounsfield unit

Öz

Amaç: İlerleyen yaş ile birlikte odontoid proses fraktürlerindeki artışın kemik kalitesinin zaman içinde azalması ile ilişkili olabileceği gösterilmektedir. Bu çalışmada, ilerleyen yaşla birlikte odontoid proses, boyun ve ikinci servikal vertebra gövdesindeki kemik yoğunluğu ve kalitesindeki değişikliklerin araştırılması amaçlanmıştır.

Gereç ve Yöntem: Her biri 18-29, 30-39, 40-49, 50-59, 60-69, 70-79 ve 80 yaş ve üzeri sağlıklı bireylerden oluşan yedi çalışma grubu oluşturuldu. Her bireyin odontoid kemik yapısı bilgisayarlı tomografi görüntülerinde tanımlandı. Ortalama Hounsfield ünitesi (HU) değerleri odontoid proses, odontoid boynu ve C2 gövde kısmı için hem midsagittal hem de midkoronal planlarda hesaplandı. Elde edilen veriler söz konusu 7 grup arasında karşılaştırıldı ve istatistiksel olarak analiz edildi.

Bulgular: Yaş ile odontoid proses, odontoid boynu ve C2 vertebra gövdesi kısmı için sagital düzlemde ölçülen HU değerleri arasında anlamlı, negatif bir korelasyon vardı (korelasyon katsayıları sırasıyla -0,795 r, -0,766 r ve -0,789 r'dir). Benzer şekilde, yaş ile odontoid ucu, odontoid boynu ve odontoid tabanının altındaki C2 vertebra gövdesi kısmı için koronal düzlemde ölçülen HU değerleri arasında anlamlı, negatif bir korelasyon vardı (korelasyon katsayıları sırasıyla -0,836 r, -0,680 r ve -0,802 r'dir). Bu sonuçlar, yaş arttıkça odontoid kemiğin kalitesinin azaldığını göstermektedir.

Sonuç: HU değerlerine dayalı olarak bilgisayarlı tomografi ile kemik kalitesinin değerlendirilmesi, artan yaşla birlikte hem odontoid kemiğin hem de C2 vertebra gövdesinin kemik kalitesinde önemli bir düşüş olduğunu ortaya koymaktadır.

Anahtar Kelimeler: Odontoid kemik, odontoid kırıklar, Hounsfield ünitesi

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Introduction

The odontoid process is a specific bony projection of the second cervical vertebra (C2), also known as axis, and it projects superiorly from the C2 vertebral body to articulate with the anterior arch of the first cervical vertebra (C1), also known as atlas (1). The joint between C1 and C2 is stabilized by numerous special and strong ligament structures, including the tectorial membrane, transverse ligament, alar ligaments, apical ligaments, and accessory ligaments (2). Bone and ligament structures located in the atlantoaxial region are crucial for maintaining the stability of this segment (3).

Fractures in the upper cervical region are a frequent consequence of cervical trauma, and odontoid fractures are present in approximately 18% of all cervical trauma cases (4). This percentage rises to over 50% in the population aged >80 years (4). The most commonly used classification for odontoid fractures today is the Anderson and D'Alonzo classification (4,5). Odontoid fractures are categorized as type 1 for odontoid tip fractures, type 2 for odontoid base fractures, and type 3 for fractures extending into the C2 vertebral body (4,5). Type 2 odontoid fractures represent the most prevalent subtype among these injuries (6).

The management of odontoid fractures is still not definitively established, and treatment selection varies depending on factors like fracture type, patient age, and the quality of the odontoid bone (7,8). The increased life expectancy has resulted in a higher prevalence of osteoporosis, leading to an elevated risk of fractures, particularly in the elderly population, due to the reduction in odontoid bone quality (8).

There are various radiological methods used to assess bone quality and strength, and one of the most commonly used and gold standart method is dual X-ray absorptiometry (DXA) (9). However, in recent years, the success and reliability of measuring bone Hounsfield unit (HU) values on computed tomography (CT) for assessing bone quality have been demonstrated, and calculating HU values has confidently become a method used to measure bone quality (10). There is a correlation between low bone HU values and osteoporotic fractures, screw loosening, and the development of pseudarthrosis risks. Therefore, in spinal surgery, HU values play a significant role in diagnosis, determining the treatment method, and follow-up (10). In this study, the age-related changes in odontoid bone HU values in the adult age groups will be investigated. Consequently, the alteration of odontoid fracture risk with age in adult population will be elucidated.

Materials and Methods

Study Population

This retrospective study was approved by Ankara University Human Research Ethics Committee (decision no.: İ10-705-23, date: 21.11.2023). The study population consists of 70 healthy adults (35 males, 35 females). The individuals included in the study were randomly selected. In the study, there are a total of 7 groups based on age: Group 1 (18-29 years), Group 2 (30-39 years), Group 3 (40-49 years), Group 4 (50-59 years), Group 5 (60-69 years), Group 6 (70-79 years), and Group 7 (80 years and older). For each group, 10 healthy individuals were randomly selected and included in the study.

Measured Parameters

The odontoid bone structure of each individual was identified on cervical CT images in both sagittal and coronal planes. Mean HU values were calculated for the odontoid tip, odontoid neck, and the C2 body portion below the odontoid base areas in both midsagittal and midcoronal planes (Figure 1). The obtained HU values were compared among the mentioned 7 groups, revealing intergroup differences and demonstrating the changes in odontoid bone quality with advancing age.

Statistical Analysis

The statistical analysis was conducted using the SPSS 22.0 software program for Windows. The results were evaluated at a 95% confidence interval, and a p value less than 0.05 was considered statistically significant. To investigate the correlation between age and odontoid bone HU values, both Pearson's correlation test and Spearman's rho correlation test were utilized.

Results

Groups 1, 2, 3, 4, 5, 6, and 7 consist of patients in the age groups of 18-29, 30-39, 40-49, 50-59, 60-69, 70-79, and >80, respectively. Each group includes 10 subjects, with 5 females and 5 males. The mean age values for individuals in groups 1, 2, 3, 4, 5, 6, and 7 are, respectively, 25, 34.9, 45.1, 54.7, 64.5, 73.9, and 84.3 years with standart deviations of groups were as follows: 2,9; 2,7; 2,8; 2,7; 2,2; 2,2; 2,2 respectively. The mean age value for all patients in the study population is 54.6.

For all patients in the study population, the mean sagittal plane HU values are 806.4 for the odontoid tip, 568.8 for the odontoid neck, and 561.6 for the C2 vertebral body area below the odontoid base. The mean coronal plane HU values for the same areas are 800.3, 559.2, and 563.1, respectively.

The distribution of mean HU values for the odontoid tip in the sagittal plane is examined based on groups, the values are

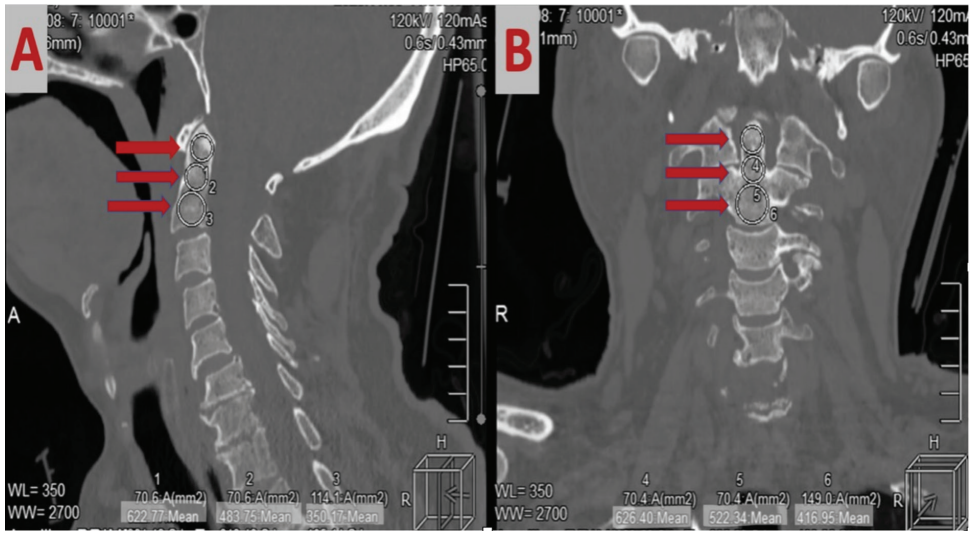

Figure 1: A) Midsagittal, and B) mid-coronal sections. The circles indicated by red arrows, from top to bottom, respectively, encompass the odontoid tip, odontoid neck, and the areas below the odontoid base

as follows: Group 1: 902.2, Group 2: 900, Group 3: 901.3, Group 4: 847.2, Group 5: 770.8, Group 6: 684.3, and Group 7: 639.6. Distribution of mean HU values for the odontoid neck in the sagittal plane across groups is as follows: Group 1: 666.3, Group 2: 636.3, Group 3: 618.8, Group 4: 606, Group 5: 570.4, Group 6: 477.8, and Group 7: 406.3. Mean HU values for the C2 vertebral body segment below the odontoid base were examined in the sagittal plane, and the distribution for each group is as follows: Group 1: 655.9, Group 2: 635.8, Group 3: 615.7, Group 4: 601.3, Group 5: 567.3, Group 6: 465.2, and Group 7: 390.6. The graph illustrating the distribution of sagittal plane HU values for the odontoid tip, odontoid neck, and C2 vertebral body in all patients included in the study is presented in Figure 2. Figure 2 demostrates that HU values decrease with increasing age.

When examining the distribution of mean HU values for the odontoid tip in the coronal plane, Group 1 has a value of 895.6, Group 2: 904.1, Group 3: 899, Group 4: 836.4, Group 5: 762.6, Group 6: 681, and Group 7: 623.9. Examining the distribution of mean HU values for the odontoid neck in the coronal plane, Group 1 has a value of 611.7, Group 2: 612.3, Group 3: 618.9, Group 4: 602, Group 5: 564.3, Group 6: 496.9, and Group 7: 408.5. Examining the distribution of mean HU values for the C2 vertebral body located under the odontoid base in the coronal plane, Group 1 has a value of 660.1, Group 2: 633.2, Group 3: 615.5, Group 4: 600.1, Group 5: 573.7, Group 6: 463.9, and Group 7: 395.8. The graph illustrating the distribution of coronal plane HU values for the odontoid tip, odontoid neck, and C2 vertebral body in all patients included in the study is presented in Figure 3.

There is a significant, negative correlation between age and the HU values measured in the sagittal plane for the odontoid tip, odontoid neck, and C2 vertebral body portion under the odontoid base (the correlation coefficients are -0.795 r, -0.766 r, and -0.789 r, respectively). Similarly, there is a significant, negative correlation between age and the HU values measured in the coronal plane for the odontoid tip, odontoid neck, and C2 vertebral body portion under the odontoid base (the correlation coefficients are -0.836 r, -0.680 r, and -0.802 r, respectively). These results indicate that as age increases, the quality of the odontoid bone decreases.

Discussion

Odontoid fractures are commonly encountered after the age of 65 and are the most frequent axis fractures in the

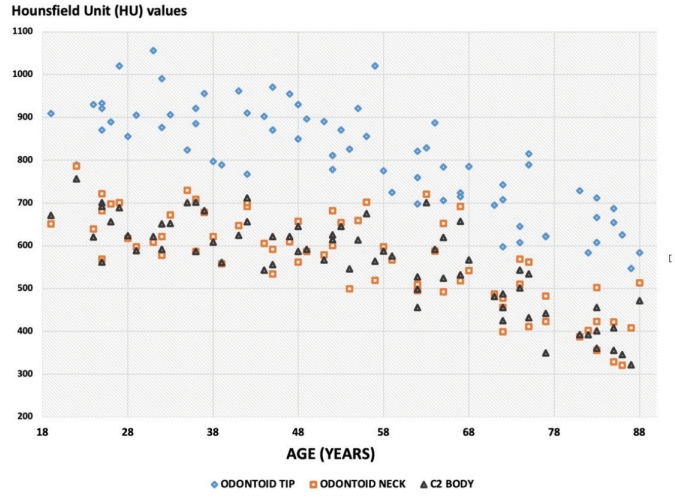

Figure 2: The distribution of sagittal plane Hounsfield unit values for the odontoid tip (blue rectangles), odontoid neck (orange squares), and C2 vertebral body under the odontoid base (black triangles) based on age

C2: Second cervical vertebra

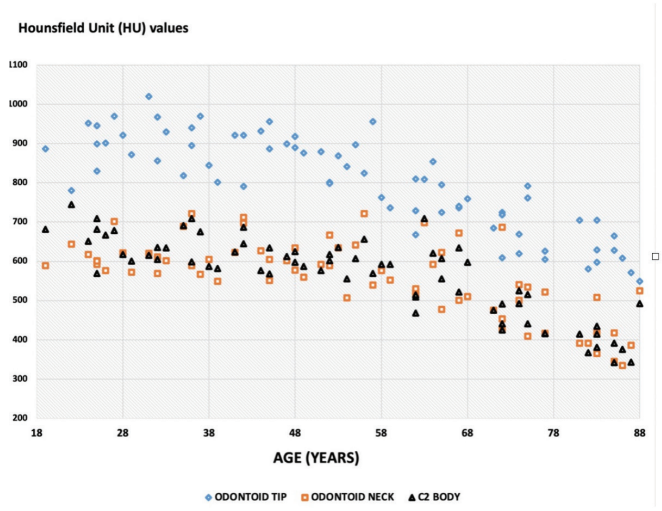

Figure 3: The distribution of coronal plane Hounsfield unit values for the odontoid tip (blue rectangles), odontoid neck (orange squares), and C2 vertebral body under the odontoid base (black triangles) based on age

C2: Second cervical vertebra

elderly population (11). The treatment of these fractures is generally managed through surgical intervention or the use of cervical orthosis (11,12). In the elderly population, surgical treatment carries increased risks and lower success rates due to accompanying medical comorbities and poor bone quality (11). Similarly, non-surgical treatment is more prone to non-union risks due to the same reasons (11). The surgical treatment of odontoid fractures is generally categorized into two main approaches: anterior and posterior techniques (13). The choice of approach for treatment is determined by considering various factors such as the direction of fracture extension, presence of accompanying osteoporosis, bone quality, and the age of the patient (13).

Clinically, lower bone mineral density and bone quality and accompanying osteoporosis is associated with a increased risk of bone fractures (14). To assess bone quality and measure bone mineral density, the most commonly used and widely accepted method today is DXA, considered the gold standard (15). However, numerous recent studies indicate that measurements of HU using CT are correlated with DXA and are highly successful in demonstrating bone quality, fracture risk, the presence of osteoporosis, or the existence of accompanying metabolic bone diseases (15-17). HU values, especially in the femoral neck and lumbar vertebrae, are calculated to investigate bone quality and mineral density, and its success in this regard has been widely recognized (18). HU values have been calculated to investigate the results of various techniques, including C1-C2 posterior fixation, pedicle and lateral mass screwing, translaminar screwing, and have been presented in the literature (16,19).

In the literature, there are many morphometric studies examining the anatomy of the C2 joint (20). In particular, odontoid fracture examination studies using multi dimensional and 3-dimensional CT reconstruction methods have an increasingly more popular place in the literature (21,22). These studies have pioneered radiomorphological studies, which are important in understanding the biophysics of odontoid fractures (23).

In this study, HU values were calculated for the odontoid parts corresponding to the bone regions used in the classification of odontoid fractures, and the changes in these values with increasing age were investigated. Thus, the regions with the highest bone quality of the odontoid bone were identified, and the decline in bone quality in advanced age was demonstrated.

Conclusion

The assessment of bone quality through CT, based on HU values, reveals a significant decrease in the bone quality of both the odontoid bone and C2 vertebral body with increasing age. This finding substantiates the increased occurrence of odontoid fractures in the elderly population when compared to younger individuals.

Ethics

Ethics Committee Approval: This retrospective study was approved by Ankara University Human Research Ethics Committee (decision no.: İ10-705-23, date: 21.11.2023).

Informed Consent: Retrospective study.

Authorship Contributions

Surgical and Medical Practices: B.C.A., Ü.E., Concept: Y.Ş.Ç., Design: Ö.M.Ö., Data Collection and/or Processing: E.B., Literature Search: M.Z., Writing: B.C.A., M.Z.

Conflict of Interest: According to the authors, there are no conflicts of interest related to this study.

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