Trabecular volumetric bone mineral density of the occipital bone at preferred screw placement sites measured by quantitative computed tomography

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INTRODUCTION

Occipitocervical fixation commonly includes the use of occipital plates, and bone screws of at least 8 mm length are recommended for adequate screw purchase.[1-3] The occipital bone reaches its maximum thickness at the external occipital protuberance (EOP).[4,5] Biomechanical studies showed that unicortical screw fixation at the EOP is as strong as bicortical fixation in other locations,[6] possibly highlighting the influence of the trabecular table on pull-out strength. However, studies that reliably quantify trabecular bone mineral density (BMD) in this area and the upper cervical spine are lacking.

OBJECTIVES

Our primary study aim investigated volumetric BMD (vBMD) of the trabecular table at the EOP and the upper cervical vertebrae. Our secondary aim identified age- and sex-related differences in vBMD values at these locations. Given the structural differences between occipital and load-bearing cervical bone, we hypothesized that the trabecular table at the EOP has a higher vBMD than at the upper cervical levels that is less prone to age-related changes.

METHODS

Patients ≥18 years who underwent non-contrast-enhanced computed tomography (CT) of the cervical spine that included the occipital bone up to the EOP between July 2007 and November 2020 at a single academic institution were considered eligible for this study. Trabecular vBMD was assessed by phantomless asynchronously calibrated quantitative computed tomography (QCT) measurements that were performed using Mindways QCT Pro software (Mindways Software, Inc., Austin, TX, USA).[7] Measurements were taken exclusively of trabecular bone at the EOP, both C1 lateral masses, and the C2 vertebral body, avoiding apparent sclerotic regions or diploic veins. An elliptical region of interest (ROI) was placed in the midline at the EOP in axial view for the occipital measurements. In the sagittal view, this resulted in a rectangular ROI of 9 mm in length that was manually adjusted further to cover a potential screw path at the EOP, ideally extending 4.5 mm above and below the region of greatest bone thickness. Measurements of total bone thickness, trabecular and cortical tables were performed on multiplanar reconstructed CT images.

RESULTS

86 patients (female, 37.2%) were included in the final analysis. The patient population was 81.4% Caucasian, with a mean age at CT of 62.3±13.1 years. Total bone thickness at the EOP was 16.7 ± 3.4 mm (range 9.7 - 25.9 mm), with a ratio of trabecular to total bone thickness of 0.44. Overall, trabecular vBMD (mean ± SD) was significantly higher at the EOP than at C1 and C2 (EOP = 612.3 ± 145.8 mg/cm^3, C1 average = 290.3 ± 66.5 mg/cm^3, C2 = 305.8 ± 78.8 mg/cm^3; p < 0.001). Cervical vBMD was significantly greater in men compared to women (Fig. 1A). In individuals older than 65 years of age (n = 39), vBMD was significantly lower at C1 (270.47 ± 67.82 versus 306.83 ± 61.37 mg/cm^3; p = 0.015), and C2 (274.51 ± 82.71 versus 331.59 ± 65.81 mg/cm^3; p = 0.001), but remained equally high at the EOP (610.36 ± 137.86 versus 613.89 ± 153.49 mg/cm^3; p = 0.912) (Fig. 1B). The interobserver reliability was acceptable for the occipital (interclass correlation coefficient (ICC) 0.763) and good for the spinal measurements (0.860).

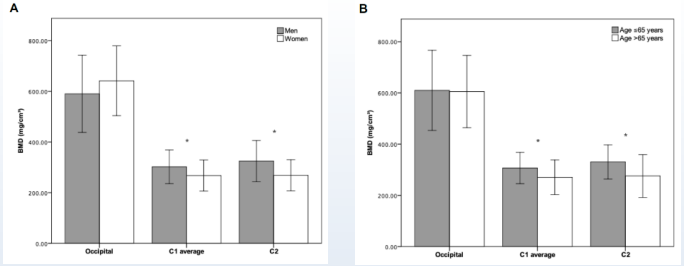

Figure 1. Subgroup analysis of vBMD (mean ± SD) according to sex (A) and age (B) (* indicates statistical significance)

A significant strong correlation between trabecular vBMD of C1 and C2 was observed (r = 0.744; p < 0.001), but only a low correlation between the EOP and C1 (r = 0.295; p = 0.008) and C2 (r = 0.413; p < 0.001) (Fig. 2). No significant correlations were found between vBMD at the EOP and total bone thickness (r = -0.079; p = 0.467) or trabecular table thickness (r = -0.138; p = 0.204). After adjusting for age and stratifying by sex, the following associations in vBMD were found in men: C1 and C2 (β = 0.769; 95% CI 0.710 – 1.169; p < 0.001), C1 and EOP (β = 0.402; 95% CI 0.312 – 1.530; p = 0.004), and C2 and EOP (β = 0.524; 95% CI 0.526 – 1.442; p < 0.001). In women, the associations in vBMD were as follows: C1 and C2 (β = 0.677; 95% CI 0.367 – 0.990; p < 0.001), C1 and EOP (β = 0.250; 95% CI -0.349 – 1.468; p = 0.216), and C2 and EOP (β = 0.461; 95% CI 0.231 – 1.757; p < 0.001).

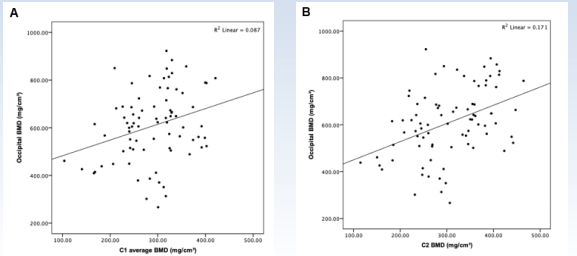

Figure 2. Scatter plots including linear regression lines for BMD: (A) EOP and C1; (B) EOP and C2

CONCLUSIONS

The EOP is characterized by considerable anatomic variability among individuals, and the trabecular table in this location has a significantly higher vBMD than the upper cervical vertebrae. In contrast to the cervical spine, trabecular vBMD at the EOP remains high in aged populations. These results add to previous studies and suggest that unicortical screw fixation in this area might also be considered in patients of advanced age, potentially reducing the risk of injury to the venous sinuses.

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Conflicts of interest disclosure

MM, DAA, LO, JS, have no relevant financial or non-financial interests to disclose.

JAC declares financial interests: Consulting: Covera Health; Globus Medical, Inc; Image Biopsy Lab; Pfizer, Inc; Simplify Medical; Scientific Advisory Board: Carestream, Image Analysis Group;

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