Bone Mineral Density Distribution in the Posterior Wall of the Cervical Lateral Mass

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INTRODUCTION: Cervical laminoplasty using a laminoplasty plate and mini-screws is gaining popularity. A complication of this procedure is loosening and/or backing out of the mini-screw in the lateral mass [1,2]. Bone mineral density (BMD) measured using computed tomography (CT) has been used as a predictor of bone strength [3]. CT osteoabsorptiometry (CT-OAM) has been used to evaluate BMD at arbitrarily locations in the bones in 3D [4-9]. A previous study on BMD distribution in the cervical spines demonstrated that the pedicles had the highest BMD and that laminae and lateral masses showed significantly greater BMD than other cervical anatomical structures except for the pedicles [3]. However, detailed bone density distribution in the lateral mass posterior wall, which is used for mini-screw fixation for the laminoplasty, has not yet been elucidated. This study aimed to analyze the bone density distribution in the posterior wall of the lateral mass using CT-OAM.

METHODS: A total of 120 lateral masses from C3 to C7 were analyzed using preoperative CT images from 12 patients (2F/10M; mean age, 60.5 years) who underwent laminoplasty. This study was approved by an Institutional Ethics Committee. An STL file was created for each vertebra and posterior walls of lateral masses and superior and inferior facet joint surfaces were segmented. Centroids of the superior and inferior facet joint surfaces adjacent to the lateral mass were calculated and an axis connecting these centroids was determined. A cylindrical coordinate system was set with its longitudinal axis oriented along the axis connecting the facet centroids [10]. The segmented STL model of the posterior wall of the lateral mass was converted to a point-cloud dataset. Coordinates of each point of the point-cloud was converted from the CT coordinates to the cylindrical coordinates. CT-OAM analysis was conducted at 0.3-mm intervals until a depth (defined by radius of the cylindrical coordinate system) of 3.0 mm beneath the posterior wall of the lateral mass. The highest Hounsfield Unit (HU) at each point was defined as BMD at that point. The posterior wall was divided into three columns (lateral, center, and medial) and three rows (cranial, center, and caudal), based on which nine zones were defined (**Fig. 1A**). Mean BMD of each lateral mass was compared between right and left sides by a paired t-test. BMD was compared by zones and spinal levels using analysis of variance with Fisher's PLSD post hoc t-tests. P-values of <0.05 were considered to indicate statistical significance. Results are presented as mean ± standard deviation (SD).

RESULTS: The mean BMD at all levels and zones was 1092 ± 433 HU. There was a significant difference between right and left sides ($p = 0.0117$); therefore, all lateral masses were included in the following analyses. The mean BMD was the highest in the entire posterior wall at C4 ($p = 0.0009$, vs. C3; $p < 0.0001$, vs. C5, C6, C7), second highest at C3 ($p < 0.0001$, vs. C5, C6, C7), and lowest at C6 ($p < 0.0001$, vs. C3, C4, C5) and C7 ($p < 0.0001$, vs. C3, C4, C5; $p = 0.0035$, vs. C5) (**Table 1**). Among all zones, BMD in the medial-center zone (zone 6, 1357 ± 443 HU) was the higher than that in all other zones ($p = 0.0149$, vs. zone 3; $p < 0.0001$, vs. zones 1, 2, 4, 5, 7, 8, 9); moreover, BMD in the medial-cranial zone (zone 3, 1226 ± 408 HU) was the second highest and was higher than that in zone 1 ($p = 0.0047$), zone 4 ($p < 0.0001$), zone 5 ($p = 0.237$), and zones 7, 8, and 9 ($p < 0.0001$) (**Fig. 1B, Table 1**). However, BMD in the medial-caudal zone (zone 9, 1067 ± 379 HU) was lower than that in other medial zones ($p = 0.0039$, vs. zone 3 and $p < 0.0001$, vs. zone 6) (**Fig. 1B**, **Table 1**). When split by levels, BMD in the medial-caudal zone (zone 9) was lower than that in the medial-center zone (zone 6) at C3 ($p < 0.0001$), C4 ($p = 0.0053$), and C5 ($p = 0.0091$) (**Fig. 1B**, **Table 1**).

DISCUSSION: The medial region of the lateral mass is typically used for mini-screw fixation of the laminoplasty plate. Among all zones, BMD in the medial-center zone was the highest and that in the medial-cranial zone was the second highest, indicating that the medial-center and -cranial region is suitable for mini-screw fixation during cervical laminoplasty based on bone density. However, BMD in the medial-caudal zone was lower than that in the medial-cranial zone. Overall BMD of the lateral mass in the upper levels were higher than that in the lower levels. When considering lower BMD at lower levels, BMD in the medial-caudal zone at C6 and C7 was only 56-59% of the highest BMD in the medial-center zone at C4. These findings should be considered in the preoperative planning of laminoplasty using mini-screw fixation and implant design. Asymmetric osteoarthritis of the facet joints was observed in the subjects included in this study, which might affect asymmetricity of the BMD in the lateral mass posterior wall. Future studies will investigate relationships between the facet osteoarthritis and the BMD in the lateral mass posterior wall with increased sample size.

SIGNIFICANCE/CLINICAL RELEVANCE: Knowledge of bone mineral density distribution in the posterior wall of the cervical lateral mass would improve surgical procedures using screw fixation in the lateral mass, especially for cervical laminoplasty using a laminoplasty plate, and be used for designing of cervical devices with fixation in the lateral mass.

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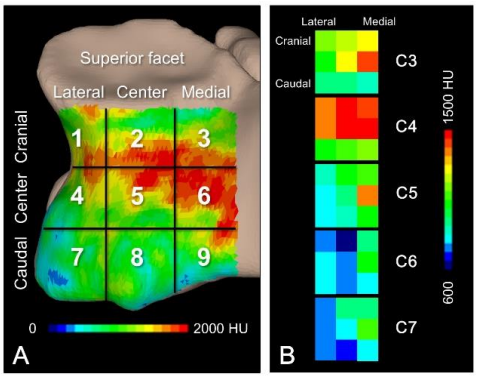

Figure 1 A: Representative (C4 left lateral mass) bone mineral density (BMD) distribution and zoning system. **B:** Mean BMD by levels and zones presented by color codes.

Table 1 Mean bone mineral density (BMD) by levels and zones. Unit; HU, mean (SD).

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Total
C3	1292 (490)	1345 (479)	1343 (363)	1205 (464)	1400 (466)	1514 (399)	995 (263)	1016 (316)	1043 (346)	1239 (435)
C4	1414 (501)	1483 (358)	1467 (391)	1160 (464)	1450 (493)	1649 (437)	1130 (378)	1240 (465)	1293 (431)	1365 (459)
C5	978 (368)	1064 (402)	1254 (499)	891 (376)	954 (381)	1391 (458)	860 (259)	897 (341)	1118 (394)	1042 (420)
C6	805 (267)	773 (340)	1068 (335)	822 (311)	794 (340)	1092 (372)	819 (243)	841 (368)	922 (307)	881 (336)
C7	881 (300)	962 (299)	998 (251)	803 (213)	925 (263)	1137 (282)	804 (253)	853 (273)	981 (317)	931 (288)
Total	1074 (457)	1125 (455)	1226 (408)	1000 (410)	1104 (474)	1357 (443)	924 (306)	969 (383)	1067 (379)	1092 (433)