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Cosmetic

Hyoid Position and Aging: A Comprehensive Analysis Using AI-assisted Segmentation of 282 Computed Tomography Scans

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Background: With neck, aging the cervicomental angle becomes obtuse and may be influenced by hyoid bone aging. An understanding of hyoid position changes with aging will further our understanding of its role in neck contour changes.
Methods: A 3D volumetric reconstruction of 282 neck computed tomography scans was performed. The cohort was categorized into three groups based on age: 20 years or older and younger than 40 years, 40 years or older and younger than 60 years, and 60 years or older and younger than 80 years. The vertical and horizontal hyoid distances in relation to the mandible were calculated for each patient.
Results: A total of 282 patients (153 women, 129 men) were included in the cohort. The age groups were evenly distributed in men and women. Mean hyoid vertical and horizontal distances differed between women and men in all age groups. There was a significant difference in the hyoid vertical distance between 20–39 years old to 40–59 years old in men ($P < 0.01$), and 20–39 years old to 60–79 years old in both genders (women $P = 0.005$, men $P < 0.01$). Hyoid horizontal distance was not affected by age and sex (age and sex: $P > 0.05$), but rather by body mass index (BMI). Every 5 BMI points corresponded to a forward movement of 2 mm.
Conclusions: As individuals age, the hyoid bone descends in both sexes, and an increase in BMI is associated with forward movement. Additional studies are needed to assess the correlation of the hyoid position between upright and supine positions. *(Plast Reconstr Surg Glob Open 2024; 12:e6119; doi: 10.1097/GOX.0000000000006119; Published online 6 September 2024.)*

INTRODUCTION

In 2022, a total of 21,575 neck lifts were performed in the United States, ranking this surgery sixth among all cosmetic face procedures.[1] The majority of interested patients seeking this surgery were aged between 55 and 69 years old.[2] The hyoid plays an important role in neck aesthetics and research examining hyoid position is growing.

Ellenbogen and Karlin described a youthful and attractive cervicomental angle (CMA) as between a 105- and 120-degree angle.[3] The CMA is defined as the anterior inferior angle formed by the intersections of a vertical plane adjacent to the neck and a horizontal submental plane.[4] The position of the hyoid plays a role in defining this angle because it serves as an attachment point for several structures and muscles in the neck, especially the suprahyoid muscles.[3,5,6] A low-lying hyoid would impact the point of transition from the vertical plane to the transverse, as it would affect the tension, contour, and position of the involved muscles, consequently altering the shape of the neck.[7]

An example of this physiological mechanism is observed in various procedures. The digastric corset, unlike the traditional Feldman corset, produced better medial upper neck results due to its ability to elevate the hyoid.[8,9] This upward traction of the hyoid could explain the resulting changes in the CMA. If the hyoid position changes over time, such as an inferior and anterior movement, it implies a less defined CMA and an aged neck.

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Neck aging is multifactorial and is due to changes in skin quality, pre- and subplatysma adipose tissue changes, submandibular gland prominence, and alterations in the platysma muscle. With aging, the platysma bands negatively affect the cervicomental angle through different pathophysiological mechanisms. The contribution of the hyoid bone's position to neck aging and CMA is ill-defined.[10] Understanding the changes in hyoid position with aging helps highlight treatment strategies in neck rejuvenation.[10–16] In this study, we aim to study the hyoid bone positional changes with aging, gender, and body mass index (BMI).

METHODS

Data Collection

Approval for this study was obtained from our institutional review board (18-009730). This study involves a retrospective review of patients aged 20 years or older who underwent head and neck computed tomography (CT) scans at our institution. Only head and neck CT scans with a slice thickness of 0.75 mm or less from January 1, 2011, to January 1, 2023, were included. All patients were in the same supine position and had the same protocol. These CT scans were performed for angiography indications and were available for us to gain further understanding from. None of these studies were performed for hyoid position assessment. Patient medical records were reviewed to extract medical history, height, weight, and BMI. Patients with facial hardware, edentulism, and facial trauma history were excluded. CT scans were segmented using 3D modeling software (Materialise, Belgium) and 3D volumetric reconstructions were performed for the hyoid bone, mandible, and the fourth vertebra.

The mandible-hyoid vertical distance (HVD) was defined as the perpendicular distance from the anterior and superior-most aspect of the hyoid to the inferior border of the mandibular body. Similarly, the mandible-hyoid horizontal distance (HHD) and retrognathion-hyoid distance (RHD) were horizontally measured from the same hyoid reference point to the pogonion and retrognathion, respectively (Fig. 1).

To confirm the reliability of our measurements, a point based on the volumetric center of gravity (PCG) was calculated for all 3D volumetric reconstructions on a per-patient basis (Figs. 2, 3). Horizontal and vertical planes were then drawn for each PCG. The vertical measurement [vertical PCG distance (VPCG)] was defined as the vertical distance from the hyoid PCG plane to the mandibular PCG plane. The horizontal measurement [horizontal PCG distance (HPCG)] was defined as the horizontal distance from the hyoid PCG plane to the C4 PCG plane (Fig. 4). PCG measurements were used to circumvent variability in measurements due to neck position. The PCG point is not significantly affected by changes in head and neck posture. [**See Video (online),** which displays 3D images of the hyoid and mandible PCG points and planes. It also illustrates the vertical PCG distance between these planes.]

Takeaways

Question: Does the hyoid position change with aging?

Findings: A total of 282 patients (153 women, 129 men) had their hyoid position analyzed. Our findings suggest that the hyoid bone moves downward with aging. Additionally, an increase in body mass index is associated with a forward and downward movement of the hyoid bone.

Meaning: Our results demonstrate that, naturally, as individuals age and their body mass index increases, the hyoid impacts the cervicomental angle, causing it to become more obtuse (an anterior and inferior movement). This finding offers surgeons insights into how the hyoid bone contributes to the pathophysiology of neck aging, potentially leading to new approaches for addressing this issue.

Statistical Analysis

Demographic data were summarized as means and SDs. Patients were categorized by gender and further stratified into age groups: 20 years or older and younger than 40 years, 40 years or older and younger than 60 years, and 60 years or older and younger than 80 years. The normality of the data was assessed using the Shapiro-Wilk test and Q-Q plots. Group comparisons for distances were conducted using the independent Student *t* test, Kruskal-Wallis test, ANOVA test, and Tukey HSD test. Linear regression analysis

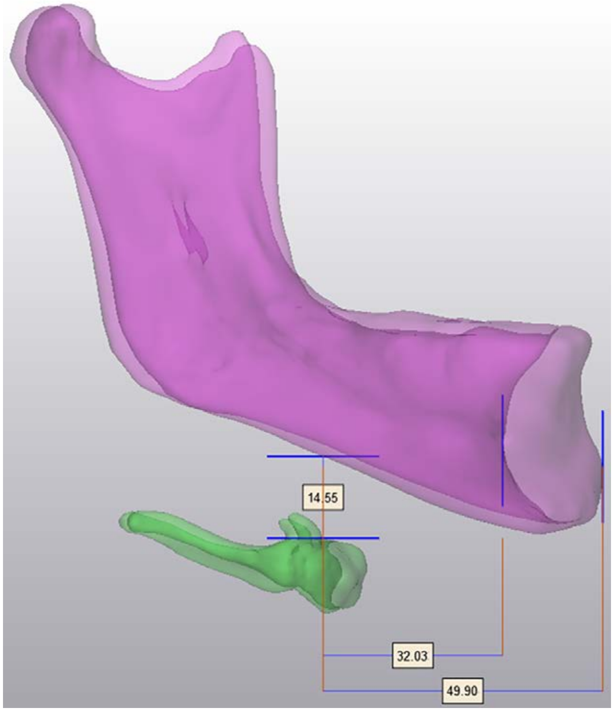

Fig. 1. Vertical and horizontal hyoid measurements. A figure that shows how planes were drawn and distances calculated. The HVD corresponded to the distance from the superior part of the hyoid bone to the inferior border of the mandible (at a 90-degree angle). Conversely, horizontal distances from the same hyoid reference point to the pogonion and retrognathion represented the HHD and RHD, respectively.

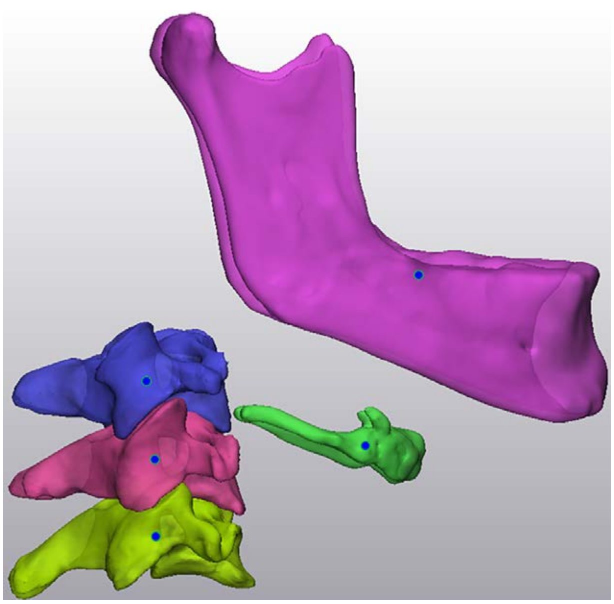

Fig. 2. Lateral view of the PCG based on volume for the mandible, hyoid, and vertebras. This figure demonstrates the lateral view of the center of gravity points based on volume in all analyzed bones.

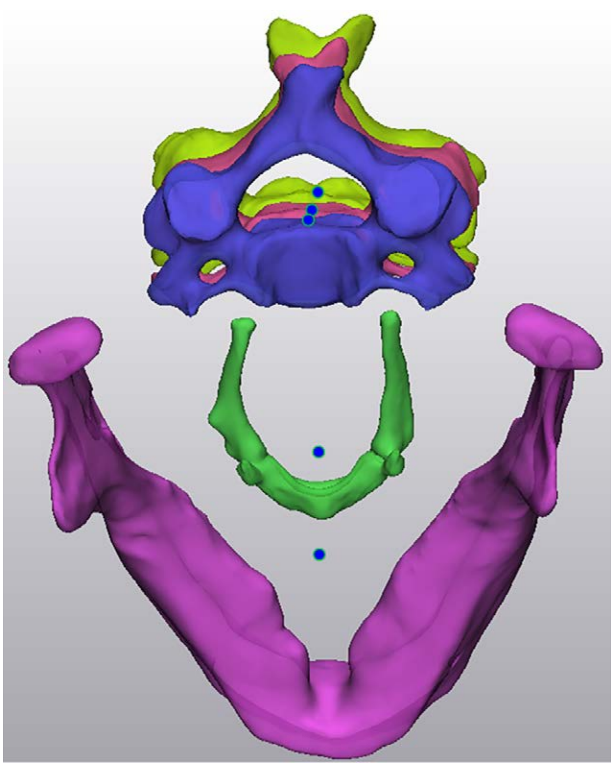

Fig. 3. Superior view of the PCG based on volume for the mandible, hyoid, and vertebras. This figure demonstrates the superior view of the center of gravity points based on volume in all analyzed bones.

was used to explore the relationships between sex, age, and BMI with hyoid position. The significance level was set at a *P* value less than 0.05. All analyses were conducted in R (R Open-Source Software, version 4.1.3).

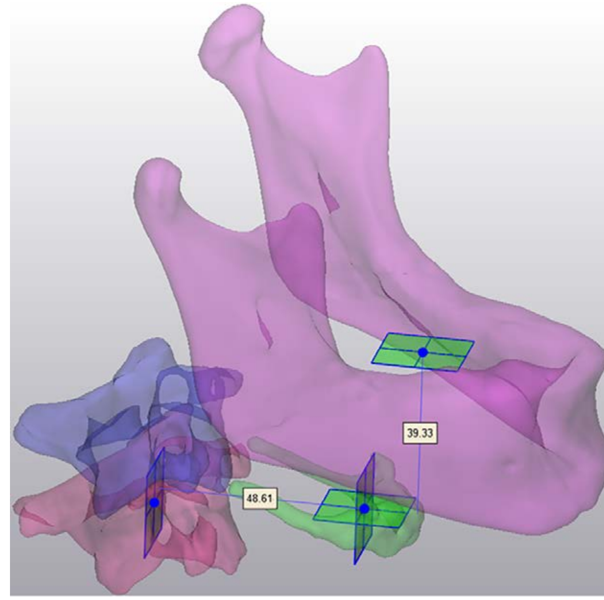

Fig. 4. Vertical and horizontal PCG hyoid measurements with the respective planes. A figure that depicts planes for each PCG point. The distances from the mandible PCG to the hyoid PCG and from C4 PCG to the hyoid PCG represented the vertical and horizontal PCG distances, respectively.

RESULTS

A total of 282 patients, (153 women, 129 men) were included in the study. The mean age was comparable between both sexes [women: 50.3 (16.3) years old versus men: 52.5 (16.4) years old, $P = 0.2$] (Table 1). Both sexes had similar BMI levels across different age groups (women: $P = 0.28$; men: $P = 0.51$). In women, the mean HVD measured 12.6 mm (SD ± 7.4), whereas the mean HHD and RHD were 51.8 mm (SD ± 7.5) and 35.8 mm (SD ± 6.8), respectively. In contrast, in the male group, the average HVD was 18.4 mm (SD ± 8.2), HHD 51.5 mm (SD ± 7.8), and RHD 35.3 mm (SD ± 7.1).

The HVD demonstrated statistical differences between both sexes in all age groups: 20–39 years (men 13.6 mm versus women 10.4 mm, $P = 0.02$), 40–59 years (men: 20.6 mm versus women: 12.7 mm, $P < 0.001$), and 60–79 years (men 20.5 mm versus women 14.8 mm, $P < 0.001$). There was no statistically significant difference when comparing the HHD between genders across the same age groups. Regarding the RHD, only the 20–39 age group reached statistical significance when comparing men and women ($P = 0.02$).

A one-way ANOVA revealed no statistically significant difference between age and HHD, or age and HPCG in our patients. However, a significant difference was observed in the HVD in women ($P = 0.008$) and male subjects ($P < 0.01$). A similar result was found in the VPCG. Multiple comparison tests showed these statistically significant differences emerged when comparing the younger to the older group (Table 2).

Furthermore, linear regression analysis conducted on both groups revealed that sex, aging, and BMI collectively influenced the HVD, whereas the HHD was

Table 1. Demographics in All Groups

	Female				
	Total (n = 153)	20–39 Group (n = 53)	40–59 Group (n = 46)	60 – 79 Group (n = 54)	*P*
Age (mean ± SD)	50.3 ± 16.3 y	31.3 ± 4.5 y	51.2 ± 5.3 y	68.1 ± 5.9 y	
BMI (mean ± SD)	29.5 ± 6.9 kg/m²	29.2 ± 7.6 kg/m²	30.3 ± 7 kg/m²	29.3 ± 6 kg/m²	0.28
	Male				
	Total (n = 129)	20–39 Group (n = 41)	40–59 Group (n = 35)	60–79 Group (n = 53)	*P*
Age (mean ± SD)	52.5 ± 16.4 y	32 ± 5 y	52.4 ± 6.2 y	68.3 ± 6 y	
BMI (mean ± SD)	30 ± 5.3 kg/m²	29.3 ± 4.7 kg/m²	30.6 ± 5 kg/m²	30.1 ± 5.9 kg/m²	0.51

This table summarizes relevant population-level demographic characteristics by sex.

Table 2. One-way ANOVA Test in All Age Groups

	Female			
	20–39 Group (1)	40–59 Group (2)	60–79 Group (3)	Statistical Significance
HVD (mean ± SD)	10.4 ± 7.3 mm	12.7 ± 7.7 mm	14.8 ± 6.6 mm	F(2, 150) = 4.982, *P* = 0.008 **(1 vs 3, *P* = 0.005)**
HHD (mean ± SD)	51.6 ± 7.4 mm	52.6 ± 7.4 mm	51.3 ± 7.7 mm	F(2, 150) = 0.337, *P* = 0.71
RHD (mean ± SD)	34.7 ± 7 mm	36 ± 6.7 mm	36.6 ± 6.7 mm	F(2, 150) = 1.059, *P* = 0.349
VPCG (mean ± SD)	25.5 ± 8.2 mm	28.9 ± 7 mm	28.8 ± 6.4 mm	F(2, 149) = 3.689, *P* = 0.02 (**1 versus 3, *P* = 0.05**)
HPCG (mean ± SD)	41.6 ± 4.4 mm	41.6 ± 4 mm	41.9 ± 4.8 mm	F(2, 149) = 0.1, *P* = 0.905
	Male			
	20–39 Group (1)	40–59 Group (2)	60–79 Group (3)	Statistical Significance
HVD (mean ± SD)	13.6 ± 6.6 mm	20.6 ± 7.6 mm	20.5 ± 8.2 mm	F(2, 125) = 11.46, *P* < 0.01 (**1 versus 2, *P* < 0.01**) (**1 versus 3, *P* < 0.01**)
HHD (mean ± SD)	49 ± 7.8 mm	52.7 ± 7.4 mm	52.5 ± 7.6 mm	F(2, 125) = 3.006, *P* = 0.0531
RHD (mean ± SD)	31.4 ± 7.1 mm	36.5 ± 6.1 mm	37.4 ± 6.5 mm	F(2, 125) = 10.26, *P* < 0.01 (**1 versus 2, *P* < 0.01**) (**1 versus 3, *P* < 0.01**)
VPCG (mean ± SD)	34.7 ± 8 mm	40.2 ± 8.4 mm	41 ± 8.6 mm	F(2, 126) = 7.164, *P* < 0.01 (**1 versus 2, *P* = 0.013**) (**1 versus 3, *P* < 0.01**)
HPCG (mean ± SD)	45.4 ± 3.8 mm	47.3 ± 4.4 mm	47.2 ± 5.5 mm	F(2, 126) = 2.219, *P* = 0.11

All hyoid measurements were compared. Comparative analysis was conducted using an ANOVA test and Tukey HSD test.

Table 3. Linear Regression Analysis

	β Coefficient (95% CI)			
	Age	BMI	Sex	Adjusted R^2
HVD	0.13 (0.08 to 0.19)*	0.33 (0.2 to 0.46)*	5.32 (3.62 to 7.01)*†	0.25
HHD	0.04 (−0.01 to 0.09)	0.4 (0.25 to 0.52)*	−0.6 (−2.3 to 1.1)†	0.1
RHD	0.09 (0.04 to 0.14)*	0.32 (0.2 to 0.44)*	−0.82 (−2.37 to 0.71)†	0.12
VPCG	0.13 (0.07 to 0.18)*	0.21 (0.7 to 0.36)‡	10.6 (8.8 to 12.5)*†	0.38
HPCG	0.02 (−0.01 to 0.05)	0.32 (0.24 to 0.4)*	4.76 (3.8 to 5.7)*†	0.37

Linear regression analysis was conducted to evaluate the effects of sex, aging, and increasing BMI on the position of the hyoid bone.
*$P < 0.01$.
†Female reference.
‡$P < 0.05$.

primarily correlated to BMI. The variation of HVD could be explained by sex, BMI, and age in 25% of cases. Our model further demonstrated specific increases associated with every five BMI points of 1.65 mm in the HVD. With 10 years of aging, the hyoid moved downward by 1.3 mm. Male hyoids were naturally 5.32 mm greater in vertical distance than female hyoids. Additionally, the HHD resulted in an addition of 2 mm for every five BMI points increase (Table 3). Sex and aging did not contribute to the HHD.

DISCUSSION

The hyoid bone serves as an attachment for various suprahyoid and infrahyoid muscles, along with neck ligaments that play a significant role in neck definition. The hyoid bone's position is determined by the combined influence of neck soft tissue, muscle action during swallowing, and neck movements, and although it fluctuates, its position remains within certain limits.[3,5,6,17,18] It has been extensively studied in the context of swallowing pathologies and obstructive sleep apnea due to its relationship with deep structures.[17,19,20] However, few studies have evaluated its impact on the neck aging process.

Analysis of hyoid position in our cohort of patients based on 3D modeling of head and neck CT scans revealed a statistically significant difference in the vertical hyoid position between younger and older groups in both men and women. Similar trends were observed in the middle-aged male group. Our observations align with the findings of Feng et al, who reported a greater HVD in older men.[21] However, it is noteworthy that they did not include a middle-aged group in their study and reported a smaller sample than our study with less power to detect variance in women. Although we found a similar vertical difference in both sexes, an important point to note is that we did not find any difference in the hyoid vertical position between the middle-aged group and the older group in either gender. It is noteworthy that BMI remained consistent across all groups, reflecting a low likelihood of BMI confounding our analysis.

Moreover, our study revealed an age-associated increase in the RHD in both sexes, with only male subjects reaching statistical significance. Unexpectedly, we found a diminution in these measurements with an increase in the RHD. This discrepancy between age groups and measurements is likely attributable to morphological aging changes in the mandible. Shaw et al investigated the aging process of the mandible using 3D modeling in 120 subjects, concluding that mandibular body length significantly decreases with aging.[22] Consequently, this decline contributes to a reduction in horizontal hyoid distance. However, their analysis did not include the retrognathion, which, with bony resorption, may lead to an increase in the RHD.

Subsequent linear regression validated our previous findings, showing that both BMI and aging influence the mandible HVD. However, regarding horizontal distances (mandible HHD, RHD, and horizontal PCG distance), BMI had a greater impact than aging in women. These results are supported by Jo et al, who found a greater HVD in patients with severe obstructive sleep apnea.[20] Given the known relationship between obstructive sleep apnea and increased BMI, it is plausible that BMI contributed to these findings.[23,24]

Although our linear model demonstrated that age, BMI, and sex can influence the hyoid position, it could only explain 25% and 37% of the variations in HVD and HPCG, respectively. This may imply that the hyoid position is highly variable among individuals and not uniformly explained by age, BMI, and sex alone. It reinforces the importance of inherent anatomy and evaluating patients' needs and expectations on a case-by-case basis.

Several studies assessing hyoid position using lateral cephalometric radiographs reported findings consistent with our study. Matsuda et al evaluated the hyoid position in 459 patients and suggested that the hyoid shifted posteriorly and inferiorly with aging.[25] Similarly, Korkmaz et al found that the RHD augmented with increasing BMI.[26] Our study, using CT scans and 3D modeling, provides a more detailed analysis utilizing 3D measurements and confirmatory PCG measurements, allowing us to discern differences that otherwise were not previously observed.

To our knowledge to date, this study represents the largest investigation employing 3D modeling of head and neck CT scans to assess hyoid position. It is important to stress that the PCG distances were consistent with all other linear measurements, confirming the accuracy of measurements. We chose to measure distances using PCG to account for inherent variability in the positions of both the mandible and hyoid. In this context, we selected PCG as one of the measurement methods due to its stability. For instance, a 45-degree angle change in mandibular position would only result in a 1.93 mm alteration in our vertical measurements. Additionally, the center of gravity provides a direct and reliable measurement, eliminating the subjectivity associated with observer judgments.

LIMITATIONS

One possible limitation of our study is that we did not assess patients' photographs to determine the effect of hyoid movement on the CMA. Our model revealed that the vertical distance difference between a 20-year-old female patient and a 70-year-old female patient would be 6.5 mm. Although this represents a minimal vertical variation, it is not possible to state definitively whether it affects neck shape. Prospective studies using multiple scans and lateral photographs throughout life are needed to determine the impact of hyoid position on neck contour.

Another potential limitation of our study is that all our patients underwent CT scans in a supine position. A follow-up study further correlating hyoid position in standing and supine position is necessary to elucidate the influence of body posture (upright or supine) on hyoid position.

CONCLUSIONS

Analysis of hyoid position in 282 supine patients undergoing head and neck CT scans revealed statistically significant differences in hyoid vertical positions between the younger and older subjects in both sexes, as well as among younger and middle-aged men. Additionally, BMI and sex were notable factors influencing hyoid vertical position. The horizontal hyoid position was predominantly influenced by BMI.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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