The Course of the Angular Artery in the Midface: Implications for Surgical and Minimally Invasive Procedures

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Abstract

Background: Previous anatomic studies have provided valuable information on the two-dimensional (2-D) course of the angular segment of the facial artery in the midface and its arterial connections. The third dimension (ie, the depth of the artery) is less well characterized.

Objective: The objective of the present study is to describe the three-dimensional (3-D) pathway of the angular segment of the facial artery and its relationship to the muscles of facial expression.

Methods: The bilateral location and the depth of the midfacial segment of the facial artery was measured using multi-planar computed tomographic (CT) image analyses obtained from contrast agent enhanced cranial CT scans of 156 Caucasians with a mean age of 45.19 ± 18.7 years and a mean body mass index (BMI) of 25.05 ± 4.9 kg/m^2.

Results: At the nasal ala, the mean depth of the main arterial trunk was 13.7 ± 3.7 mm (range, 2.7-25.0 mm) whereas at the medial canthus it was 1.02 ± 0.62 mm (range, 1.0-3.0 mm). This was reflected by the arteries' relationship to the midfacial muscles: at the nasal ala superficial to LAO in 62.0% but deep to the LLSAN in 53.6%; at the medial canthus superficial to the LLSAN in 83.1% and superficial to the OOM in 82.7%.

Conclusion: The results presented herein confirm the high variability in the course of the angular segment of the facial artery. Various arterial pathways have been identified providing evidence that, in the midface, there is no guaranteed safe location for minimally invasive procedures.

In the United States, the number of soft tissue filler injections continues to increase.[1] Similarly, the number of soft tissue filler associated vascular adverse events has likewise increased.[2,3] Recent literature reviews have revealed that until 2015, 98 cases of injection related visual compromise (IRVC) resulting in irreversible blindness were published;[2] however between 2015 and 2018, 48 additional cases were reported.[3] The currently accepted mechanism of soft tissue filler induced IRVC is that the injected material gains access to the arterial circulation via direct intra-arterial injection or via retrograde flow from the external to internal carotid system. In the arterial blood stream, the filler product activates thrombogenic cascades itself or does so via lesions of the intima[4] and can cause end-arterial occlusion via mechanical obstruction.[5] Both mechanisms lead to reduced arterial blood flow and ultimately cause tissue damage. This is most significant in areas with great oxygen consumption (eg, the retina) or in facial regions with limited anastomotic capacity (eg, the nasal tip).

Several recent anatomic reviews described stable and constant locations, both in 2-D and 3-D, of the course of the facial artery.[6–10] Those were (1) anterior to the masseter muscle where the facial artery crosses the mandible, (2) at the modiolus where the artery is attached via a muscular bundle of the buccinator muscle and (3) at the medial canthus where the artery crosses the horizontal midpupillary line superficial to the medial canthal ligament.[11] The arterial segments between those fixed points have been identified to have a high degree of variation including within the nasolabial sulcus and the midface (distance between nasal ala and medial canthus).

Previous anatomic studies have provided valuable 2-D information on the course of the angular segment of the facial artery in the midface and its arterial connections.[9,10,12] However, the third dimension (ie, the depth of the artery) is less well characterized.

The objective of the present study is to describe the 3-D pathway of the angular segment of the facial artery located between the nasal ala and the medial canthus and its relationship to the muscles of facial expression: levator anguli oris (LAO), levator labii superioris alaeque nasi (LLSAN), and orbicularis oculi (OOM). These results should provide clinically valuable information on the pathway of the angular artery and should enhance the precision and safety of surgical and minimally invasive procedures.

METHODS

Study Sample

CT scans were objectively analyzed for the purposes of the study between January and July 2019. Investigated CT scans were sampled from the radiology database of the Research and Practical Center of Medical Radiology of the Department of Health Care, Moscow, Russia. CT scans were previously obtained during routine contrast – enhanced cranial CT examinations. The inclusion criterion was the full visibility of the angular artery between the inferior end of the nasal ala and the medial canthus. The term "angular artery" will be used for that segment of the facial artery cranial to the branching of the superior labial artery.[11] CT scans were excluded from this analysis if previous injections, facial surgery, trauma, or diseases disrupted the integrity of the facial anatomy or affected the specific function of the muscles in the midface. The study was approved by the ethics committee of the Department of Health, Moscow, Russia (Protocol Nr. 5) and the patients gave their informed consent for the use of their CT scans for scientific purposes.

Image Analyses

CT images were generated by a Toshiba Aquilion LB scanner (Toshiba Medical Systems Corporation, Ōtawara, Tochigi, Japan) using the following parameter: field of view 220 mm, slice thickness 0.47 mm, tube current 140 mA and voltage 120 kV.

Analyses relied on bilateral distance measurements and positional descriptions of the angular artery in relation to standardized locations using internal software tools of Intellispace 8.0 (Philips, Koninklijke, Amsterdam, Netherlands). Measurements were conducted using multi-planar 2-D distance measures medial to the infraorbital foramen (Figure 1). Patients were in supine position with relaxed facial expression during the scanning procedure. The following parameters were evaluated bilaterally by radiologists with at least 5 years of experience:

- Length between the inferior end of the nasal ala and the medial canthus in mm. This length was further divided into four equal segments (ie, S1, S2, S3, S4). The start and endpoints of each of the four segments resulted in five measurement points (P1, P2, P3, P4, P5); of those, P1 was at the horizontal level of the medial canthus and P5 was at the horizontal level of the nasal ala (Figure 2).
- Distance between the medial canthus and the angular artery at each measurement point P1 – P5 in mm (Figure 2)
- Number of arteries / branches observed within each segment S1 - S4
- Distance between the skin surface and the main arterial trunk at P1 – P5 in mm

- Position of the angular artery in relation to the orbicularis oculi muscle (OOM) at P1 – P5 (superficial / deep) (Figures 3 and 4)
- Position of the angular artery in relation to the levator labii superiors alaeque nasi muscle (LLSAN) (superficial / deep) (Figures 3 and 4)
- Position of the angular artery in relation to the levator anguli oris muscle (LAO) (superficial / deep) (Figures 3 and 4)

Statistical Analyses

All measurements were performed at least 3 times and validated by 2 independent observers for consistency. Influence of age, gender and BMI on the depth of the main arterial trunk at each measuring point (P1 – P5) was calculated using generalized linear models with robust estimator. Age and BMI were grouped according to the 33.33% and the 66.67% percentile into lower, middle, higher age/BMI groups and differences across groups were calculated using multivariate analysis (ANOVA) with post-hoc Tukey testing. All analyses were conducted using SPSS Statistics 23 (IBM, Armonk, NY, USA) and results were considered statistically significant at a probability level of ≤ 0.05 to guide conclusions.

RESULTS

Demographic Data

A total sample of 156 Russian Caucasian individuals (78 males, 78 females) with a mean age of 45.19 ± 18.7 years (range, 14-89 years) and a mean body mass index (BMI) of 25.05 ± 4.9 kg/m^2 (range, 16.7-47.8 kg/m^2) was investigated. Contrast agent enhanced cranial computed tomographic (CT) images of their midfaces were analyzed resulting a total of 312 measured midfacial segments of the facial artery.

General Description

The mean distance between the medial canthus (P1) and the nasal ala (P5) was 39.34 ± 3.9mm (males: 40.97 ± 3.3mm; females 37.71 ± 3.8mm; $p < 0.001$). The mean extent of each measured segment (S1 – S4) was 9.67 ± 1.5mm (males: 10.23 ± 0.8mm; females 9.15 ± 1.9mm; $p < 0.001$).

Gender Differences

Inconsistent gender differences were observed with and without reaching statistically significant values across the various parameters measured. This was attributed to arterial variation and to multiple-testing effects. Thus, results were not separated by gender in the following.

Number of Arterial Trunks per Segment (S1 – S4)

In 97.8% of the cases in the S1 segment (approximately 1cm inferior to the medial canthus), one arterial trunk was identified, whereas in 2.2% of the cases two arteries were observed. In the S2 segment (approximately 1 - 2cm inferior to the medial canthus), 95.8% had one arterial trunk identified, whereas 3.8% had two arteries and in 0.3% three arteries were observed. In the S3 segment (approximately 2 - 3cm inferior to the medial canthus), 85.3% had one arterial trunk, whereas 13.8% had two arteries and 1.0% had three arteries. In the S4 segment (approximately 3 - 4cm inferior to the medial canthus), 70.8% had one arterial trunk, whereas 27.6% had two arteries, 1.0% demonstrated three arteries and in 0.6% four arteries were observed. None of those measurements displayed statistically significant differences between facial sides. The results are visually summarized in Figure 2.

Course of Main Arterial Trunk

Starting from the nasal ala (P5, approximately 4cm inferior to the medial canthus), in the majority of the cases, the main arterial trunk was observed superficial to the LAO (62.0%), but deep to the LLSAN (53.6%). At P4 (approximately 3cm inferior to the medial canthus), the main trunk was most frequently identified superficial to the LAO (92.0%) and superficial to the LLSAN (89.6%). At P3 (approximately 2cm inferior to the medial canthus), the main arterial trunk was most frequently superficial to the LAO (95.9%) and LLSAN (97.0%) but deep to the OOM (54.9%). At P2 (approximately 1cm inferior to the medial canthus), in the majority of the cases, the main arterial trunk was observed superficial to the LLSAN (91.3%) and superficial to the OOM (74.0%). At P1 (horizontal level of the medial canthus), the main arterial trunk was observed to course superficial to the LLSAN (83.1%) and superficial to the OOM (82.7%). Details on frequencies in relation to the midfacial muscles can be found in Table 1.

Depth of Main Arterial Trunk

At P5, the mean depth of the main arterial trunk (vessel with the largest diameter) was 13.7 ± 3.7mm (range, 2.7-25.0 mm) with 40.4% having a superficial course (a depth < 12.0mm = 1. tertile), 26.3% having an intermediate course (a depth between 12.1 to 15.6mm = 2. tertile) and 33.3% having a deep arterial course (a depth > 15.6mm = 3. tertile). At P4, the mean depth was 8.33 ± 2.8mm (range, 2.6-18.4 mm). 39.9% had a superficial course (a depth < 7.0mm), 57.9% had an intermediate course (a depth between 7.1 to 10.0mm) and 2.3% had a course deeper than 10.0mm. At P3, the mean depth was 4.10 ± 1.9 mm (range, 1.0-11.0mm); 42.0% had a superficial course (a depth < 3.0 mm), 23.4% had an intermediate course (a depth between 3.1 to 4.3mm) and 34.6% had a course deeper than 4.3mm. At P2, the mean depth was 1.79 ± 1.4mm (range, 1.0-8.0 mm); 44.6% had a superficial course (a depth < 1.0mm), 26.9% had an intermediate course (a depth between 1.1 to 2.0mm) and 28.5% had a course deeper than 2.0mm. At P1, the mean depth was 1.02 ± 0.62mm (range, 1.0-3.0 mm). 32.1% had a superficial course (a depth < 0.77 mm), 40.7% had an intermediate course (a depth between 0.78 to 1.0mm) and 27.2% had a course deeper than 1.0mm. Details on frequencies within each tertile between P1 – P5 are given in Table 2 (Figures 5 and 6).

Relationship Between Age, BMI, and Depth of Main Arterial Trunk

Calculating generalized linear models, with adjustment for age and BMI, revealed a variable influence of location on the depth of the main arterial trunk. At the level of the nasal ala (P5), neither age, nor BMI displayed any statistically significant influence on arterial depth (age: $p = 0.090$, BMI: $p = 0.064$). At P4, only age had a statically significant influence (age: $p < 0.001$, BMI: $p = 0.367$). At the other measured locations (ie, more proximal to the medial canthus [P3 – P1]), both factors statistically significantly influenced the depth of the main arterial trunk with higher values for age and BMI being associated with a greater depth, both age and BMI $p \leq 0.027$. Detailed information on the numeric influence is presented in Table 3 given as odds ratio and the respective 95% confidence interval.

DISCUSSION

The major strength of this study is the large sample size with equal distribution of males and females (each n = 78) originating from the Russian Caucasian ethnicity. This is to date the largest sample used (a total of 312 midfacial segments of the facial artery) to investigate the 3-D pathway of the angular artery and to provide clinically valuable information on neighboring structures in relation to the main arterial trunk. Another strength of the study is the non-invasive nature of the measurements performed: contrast agent enhanced CT scanning. Previous studies relied primarily on cadaveric dissections and provided excellent contributions to our understanding of the arterial blood supply of the midface.[9,10,12] However, those studies focused on the arterial pathway and anastomotic connections in two dimensions. A limitation of cadaveric dissections however lies in the process of dissection itself requiring interruption or removal of related anatomical structures. This process often eliminates surrounding landmarks like more superficially located muscles or fasciae that hold significant value to visualizing the artery in living subjects. The present study used the surrounding structures as landmarks to describe the pathway of the main arterial trunk between the nasal ala and the medial canthus and to provide guidance for surgical and minimally-invasive procedures in the midface. This is a novel approach which could have not been achieved utilizing cadaveric dissections.

A limitation of the present study is that all subjects were from the Russian Caucasian community. Results might have been different if other Caucasian, African-American or Asian populations had been investigated. However, there is no available information on the influence of ethnic differences on the 3-D pathway of the angular segment of the facial artery in the midface to allow valid comparisons. Another limitation of the study is the intramuscular pathway of the artery. Despite the enhancement with contrast agent, in some cases the visibility of the main arterial trunk was limited and it was difficult to distinguish. In future studies, MRI or CT scans with higher resolution might be able to provide more detailed information that can be utilized to expand upon the results presented herein.

The results of the present study reveal that at the nasal ala up to four arteries or arterial branches could be identified: one arterial trunk in 70.8%, two arterial trunks in 27.6%, three arterial trunks in 1.0% and four arterial trunks in 0.6% of the cases. This represents the variation in the branching pattern of the angular segment of the facial artery in this location – forming anastomotic connections to the subnasal and alar artery and connecting to branches of the infraorbital, buccal and transverse facial arteries.[11] This specific location (ie, the pyriform fossa) can be considered a high risk zone when injecting soft tissue filler; the probability is increased to enter one of the arteries present and cause a vascular adverse event. However, this location is frequently utilized to treat the nasolabial fold and to reduce the width of the nose.[13] Therefore, these injections should be performed deep, in contact with the bone; results reveal that, in the majority of the cases, the arteries are located in the superficial tertile of the soft tissues – at a depth of less than 12mm. However, 33.3% of the cases had an artery in the deep tertile (ie, deeper than 15.6mm). Therefore, one should always practice pre-injection aspiration, the application of small boluses and slow injections to minimize the risk of vascular adverse events.

At the level of the medial canthus, however, a maximum of two arterial trunks could be identified – 97.8% of the subjects having just one and 2.2% having two. This is confirmatory to current concepts of treating the tear trough where the greatest risk results from the proximity to the angular vein rather than to the angular artery.[8]

The results presented herein confirm the high variability in the course of the angular segment of the facial artery. Various pathways have been identified providing evidence that, in the midface, there is no guaranteed safe location for minimally invasive procedures. Most previous studies provided valuable information on the 2-D course of the facial artery and its branches,[9,10,12] but the present study is the first to add 3-D information. The most frequently observed pathway within our study sample had the main arterial trunk located as follows: at the level of the nasal ala (P5 = 4cm inferior to the medial canthus) between the LAO and the LLSAN. These results confirm previous cadaveric investigations that the artery travels within the roof of the deep pyriform space[14,15] – located between the LAO (= floor) and the LLSAN (= roof).[16] The artery then pierces the LLSAN within the S4 segment to course superficial to the LLSAN and superficial to the LAO at the P4 level (3cm inferior to the medial canthus). Here the artery travels within the pre-maxillary space containing the deep nasolabial fat compartment.[15] Within the S3 segment, the main arterial trunk pierces the LLSAN and travels between the LLSAN and the OOM. From the P3 to P1 levels (< 2 cm inferior to the medial canthus), the artery travels superficial to the LLSAN and superficial to the OOM; in 44.6% of cases, it travels at a depth > 1.0mm at P2 (1cm inferior to the medial canthus) and in 72.8% of cases at P1 (horizontal level of the medial canthus), it is also > 1mm in depth.

The overall depth of the angular segment of the facial artery changed from 13.7mm at the nasal ala to 1.02mm at the medial canthus (Table 3). Calculating generalized linear models, with adjustment for age and BMI, revealed location specific differences in their influence on the depth of the main arterial trunk. At the level of the nasal ala, the depth of main arterial trunk was not significantly influenced by an increase in age or BMI. This can be explained by the fact that, in this location, the muscles of facial expression connect to the overlying dermis. This connection represents the physiologic transition between two different types of subcutaneous arrangement and is present in every individual's face.[17,18] As there is no distinct layer of subcutaneous fat is present at this location (the nasolabial sulcus forms the inferior boundary of the superficial nasolabial fat compartment[19]), the change in age or BMI does not influence the distance between skin surface and main arterial trunk. This is clinically important when injecting soft tissue fillers in this location because treatment depth can be assumed to be unaltered across individuals of various ages and BMIs.

A highly statistically significant relationship was found between increasing age and an increase in the measured distance between skin surface and the main arterial trunk at every measured level cranial to P4. The measured increase in distance should not be attributed to an increase of fat mass; ie, more fat deposition within the facial soft tissues at older age.[15,19] The increased depth should rather be attributed to the descent of soft tissue from cranial to caudal. This descent is an age-related physiologic event and results in a local increase of soft tissues superficial to the main arterial trunk; this ultimately increases the depth of the vessel. This phenomenon was previously observed but misinterpreted as an increase in volume of the superficial fat compartments.[20] An increase in BMI was significantly associated with an increase in depth of the main arterial trunk. The superficial nasolabial fat compartment is located cranial to the nasolabial sulcus and extends medially into lateral nasal wall and cranially to the tear trough.[16,19] An increase in BMI results in an increase in fat mass within that compartment and increases the distance to the measured artery.

When performing minimally invasive injections and surgical procedures in the midface, one should account for changes in the depth of the angular artery and its relationship to surrounding muscles of facial expression. Injecting soft tissue fillers should be performed slowly, with small boluses and with aspiration prior to injection. Treatment should be individualized not just on the basis of a desired cosmetic outcome, but taking into account each patient's demographic data in order to diminish the risk of vascular adverse events.

Injections of soft tissue filler in the medial midface can be utilized into the supraperiosteal plane based on the results of this investigation. The angular artery is located with increasing frequency superficial to the midfacial musculature the closer the artery is to the medial canthus. Being superficial to the muscles identifies the supraperiosteal plane (= sub-muscular plane) as a safer plane, because the artery is located more superficial and separated by muscular tissue. Utilizing sharp-tip needles (as opposed to cannulas) to perform this injection should be favoured in order to reach that plane with greatest accuracy.

CONCLUSION

The results of this large sample and contrast enhanced CT-based analysis confirmed the high variability of the facial arterial vasculature. Due to the large sample size, the most frequently observed pathway of the angular segment of the facial artery could be characterized. Injections at the level of the nasal ala should be performed deep in contact with the bone, however, in 33.3% of the cases, an artery was present in the deep soft tissue tertile. Cranial to the nasolabial sulcus, increasing age and increasing BMI result in a greater depth of the main arterial trunk. Minimally invasive injections and surgical approaches to the midface should account for the changes in arterial depth to avoid arterial vascular adverse events.

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Table 1. The Distribution of the Main Trunk in Relation to the Respective Muscle As Absolute Value (superficial/deep/not defined) and As Percentage

	LAO	LLSAN	OOM
Relation to muscle at P1	-	192/39/81 (61.5%/12.5%/26.0%)	196/41/75 (62.8%/13.1%/24.1%)
Relation to muscle at P2	-	219/20/73 (70.2%/6.4%/23.4%)	213/70/29 (68.3%/22.4%/9.3%)
Relation to muscle at P3	185/8/119 (59.3%/2.6%/38.1%)	289/9/14 (92.6%/2.9%/4.5%)	132/169/11 (42.3%/54.2%/3.5%)
Relation to muscle at P4	231/17/64 (74.0%/5.4%/20.6%)	275/17/20 (88.1%/5.4%/6.4%)	-
Relation to muscle at P5	183/70/49 (62.0%/22.4%/18.9%)	115/143/54 (36.9%/45.8%/17.3%)	-

LAO, levator anguli oris; LLSAN, levator labii superioris alaeque nasi; OOM, orbicularis oculi muscle. Muscles that were either intramuscular or only ambiguously visible were counted as not defined.

Table 2. The Depth of Each Defined Course of the Artery (superficial, intermediate, and deep course), As Well As the Absolute Frequency of the Main Trunk Running in the Respective Course (superficial, intermediate, deep) and Their Relative Frequency in Percentage

	Depth of superficial course	Depth of intermediate course	Depth of deep course	Frequencies of respective course
Course at P1	< 0.77 mm	0.78 - 1.0 mm	> 1.0 mm	126/82/104 (40.4%/26.3%/33.3%)
Course at P2	< 1.0 mm	1.1 - 2.0 mm	> 2.0 mm	124/180/7 (39.9%/57.9%/2.3%)
Course at P3	< 3.0 mm	3.1 - 4.3 mm	> 4.3 mm	131/73/108 (42.0%/23.4%/34.6%)
Course at P4	< 7.0 mm	7.1 - 10.0 mm	> 10.0 mm	139/84/89 (44.6%/26.9%/28.5%)
Course at P5	< 12.0 mm	12.1 - 15.6 mm	> 15.6 mm	100/127/85 (32.1%/4ß.7%/27.2%)

Table 3. Mean Depth of Main Arterial Trunk at P1 – P5 and the Influence of Age and Body Mass Index (BMI) Given As Odds Ratio and the Respective 95% Confidence Interval (OR 95% CI). The Adjusted Probability Value is Given as Orientation.

	Mean (SD) / mm	Influence of age / OR (95% CI)	Significance level of age (adjusted)	Influence of BMI / OR (95% CI)	Significance level of BMI (adjusted)
Depth of artery at P1	1.02 (0.62)	1.01 (1.01 - 1.02)	p < 0.001	1.02 (1.00 - 1.04)	p = 0.027
Depth of artery at P2	1.79 (1.44)	1.03 (1.03 - 1.04)	p < 0.001	1.05 (1.02 - 1.08)	p = 0.004
Depth of artery at P3	4.10 (1.95)	1.03 (1.02 - 1.04)	p < 0.001	1.06 (1.01 - 1.10)	p = 0.017
Depth of artery at P4	8.33 (2.82)	1.03 (1.02 - 1.05)	p < 0.001	1.03 (0.97 - 1.10)	p = 0.367
Depth of artery at P5	13.65 (3.27)	1.02 (0.99 - 1.04)	p = 0.090	1.10 (0.99 - 1.22)	p = 0.064

Figure Legend

Figure 1. (A) Figure showing a transverse CT of a 63-year-old male to identify the facial artery (red arrow) in relation to the predefined locations and the facial musculature. (B) A sagittal CT of a 63-year-old male to identify the facial artery (red arrow) in relation to the predefined locations and the facial musculature. (C) A coronar CT of a 63-year-old male to identify the facial artery (red arrow) in relation to the predefined locations and the facial musculature. (D) 3-dimensional reconstruction of the scanned area.

Figure 2. Schematic drawing showing the length between the inferior end of the ala of the nose (P5) and the medial canthus (P1). This length is divided into four equal segments (ie, S1, S2, S3, S4). The start and endpoints of each of the four segments resulted in five measurement points (P1, P2, P3, P4, P5). Number of arteries/branches (one artery represented by one red line) observed within each segment S1 - S4 have are given within each segment.

Figure 3. (A) Transverse CT image of a 43-year-old female on the left showing the depth and the position of the angular artery at P4 (indicated on the right) in relation to the muscles. (B) Sagittal CT image of a 43-year-old female indicating the position of the artery in its horizontal extent. (C) Schematic drawing showing the segment (S3) in which the angular artery was identified in Figures 3A and 3B. LAO, levator anguli oris muscle; LLSAN, levator labii superioris alaeque nasi muscle.

Figure 4. (A) Transverse CT image of a 58-year-old male on the left showing the depth and the position of the angular artery at P5 (indicated on the right) in relation to the muscles. (B) Sagittal CT image of a 58-year-old male indicating the position of the artery in its horizontal extent. (C) Schematic drawing showing the segment (S4) in which the angular artery was identified in Figures 4A and 4B. LAO, levator anguli oris muscle; LLSAN, levator labii superioris alaeque nasi muscle; OOM, orbicularis oculi muscle.

Figure 5. Bar graph showing the depth of the main trunk in mm at their respective position (P1 – P5) within the different BMI groups. Note how the depth differed significantly between all BMI groups at any position.

Figure 6. Bar graph showing the depth of the main trunk in mm at their respective position (P1 – P5) within the different age groups. Note how the depth differed significantly between all BMI groups at any position.

Figure 1a

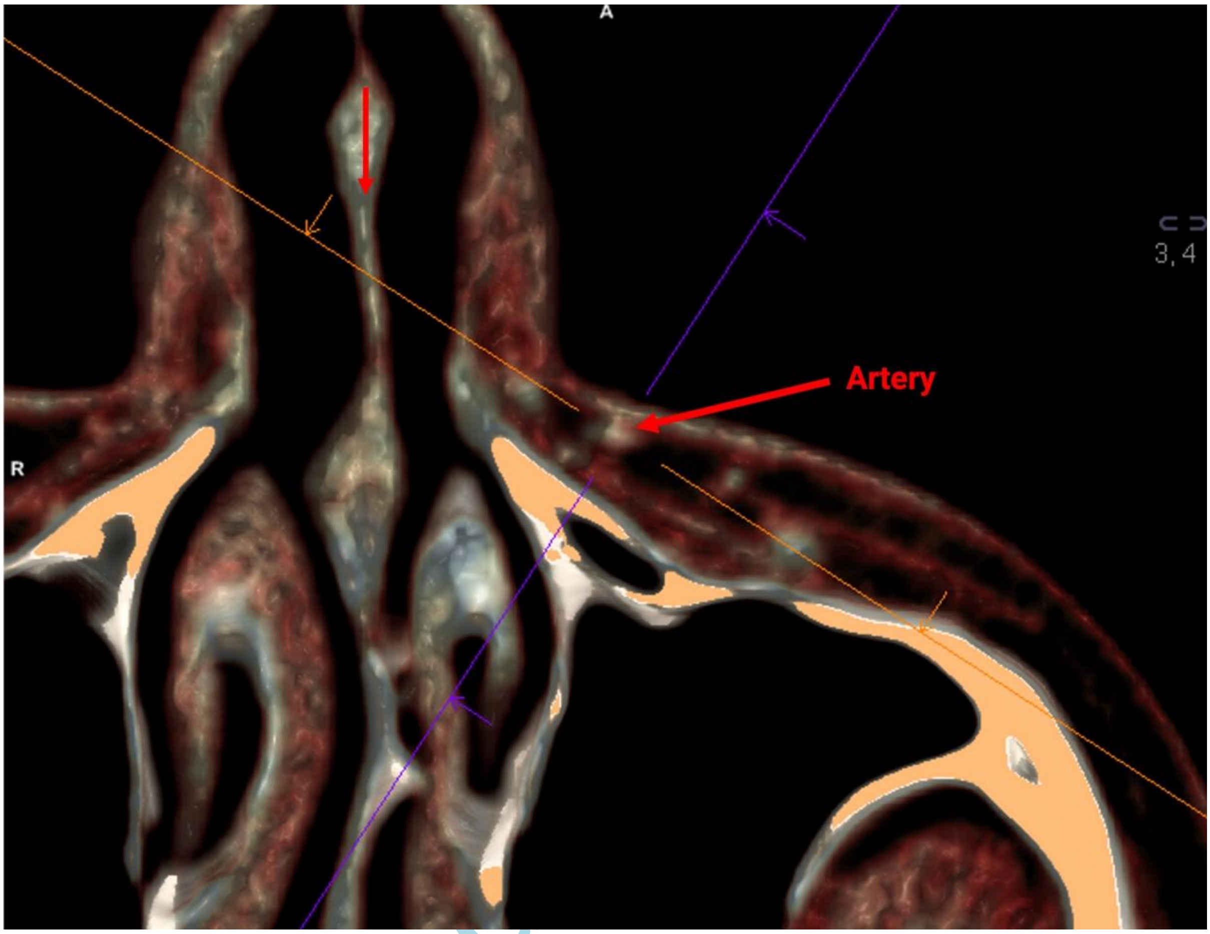


Figure 1b

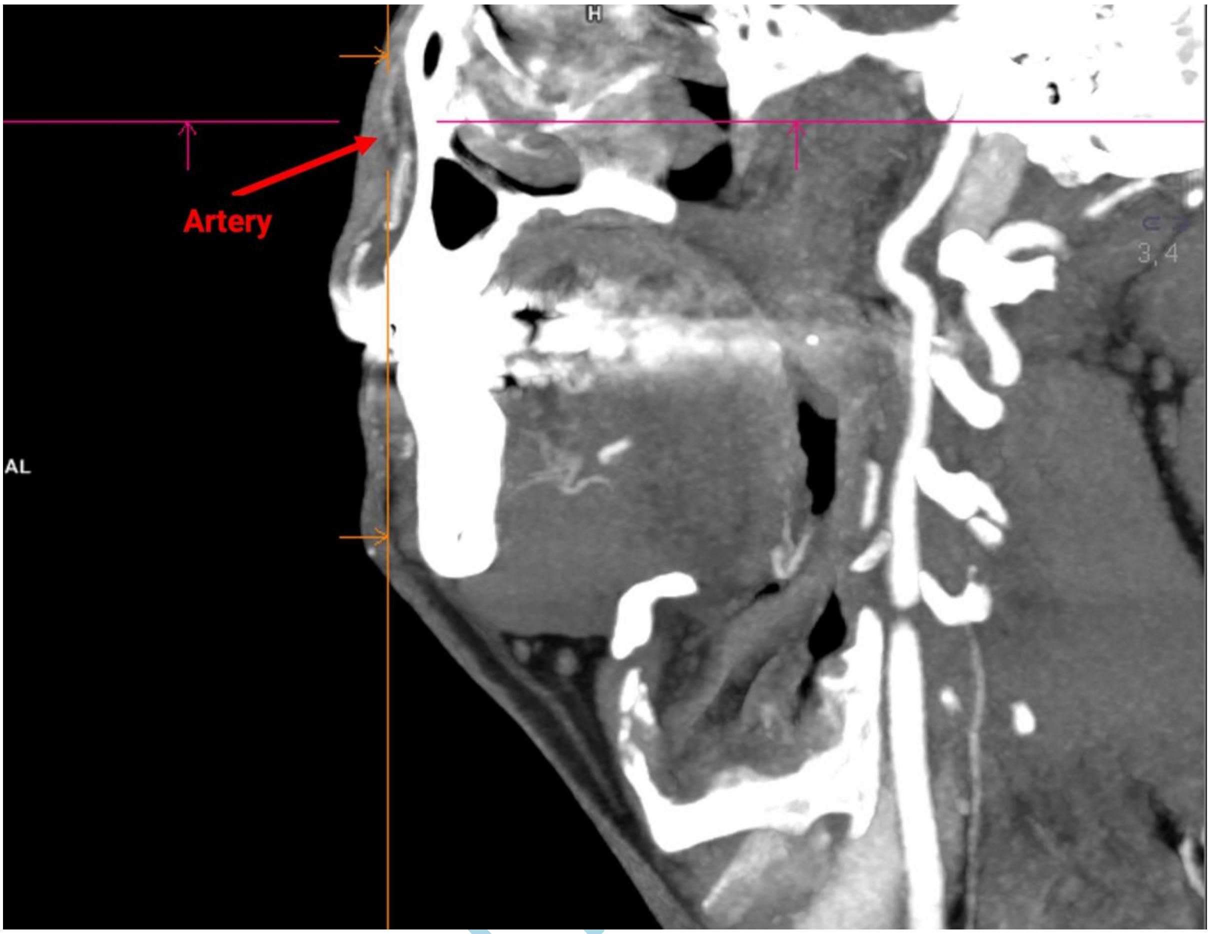


Figure 1c

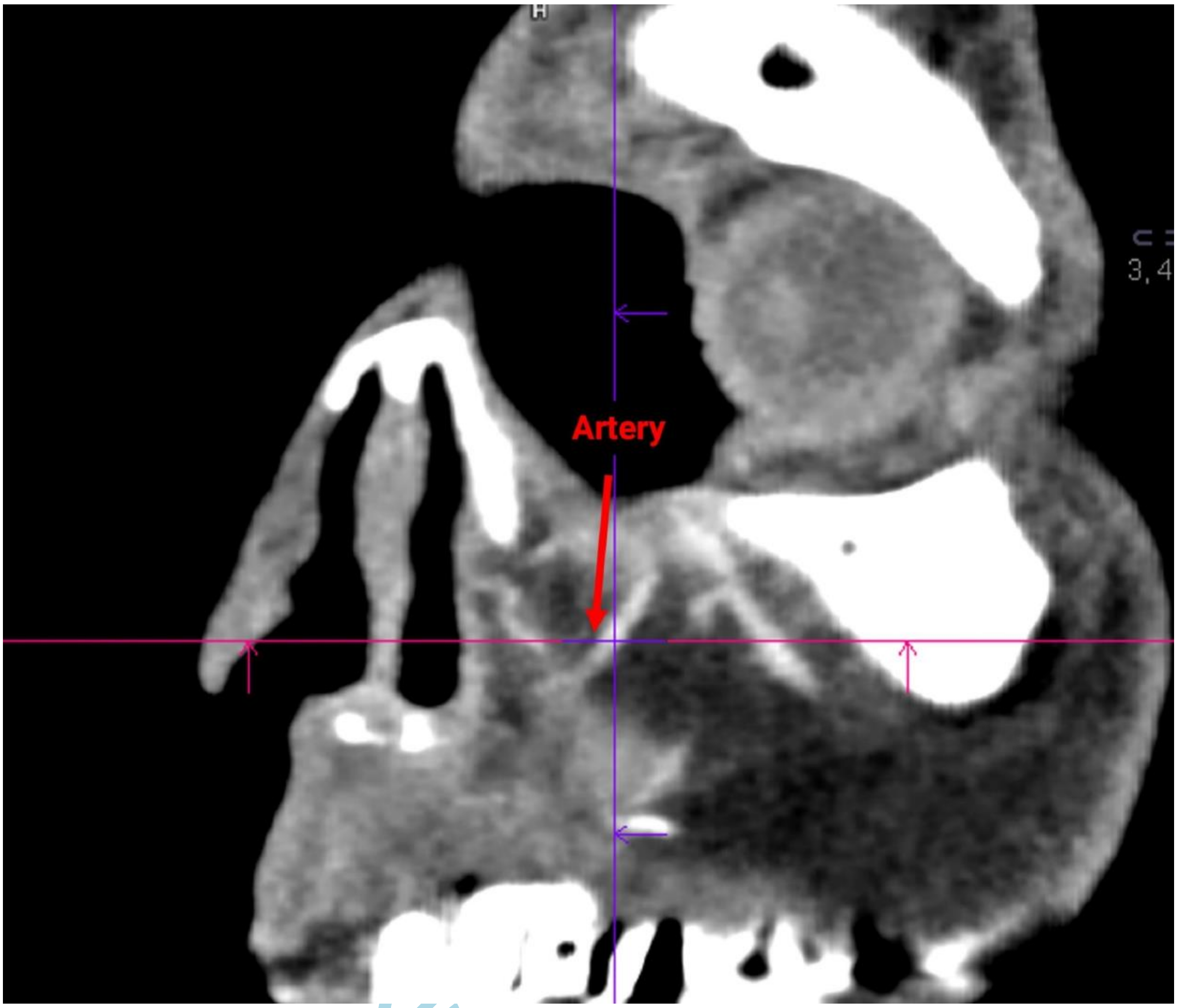


Figure 1d

Figure 2

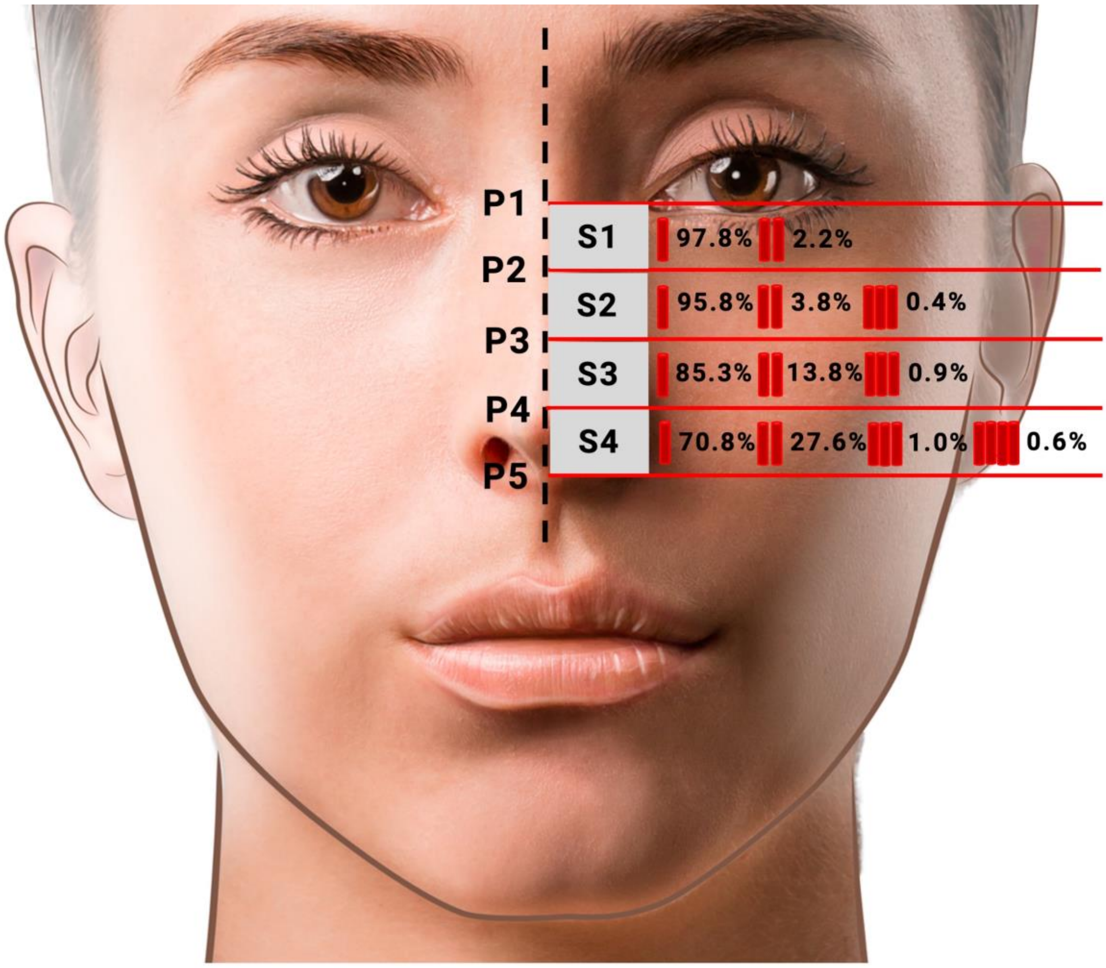


Figure 3a

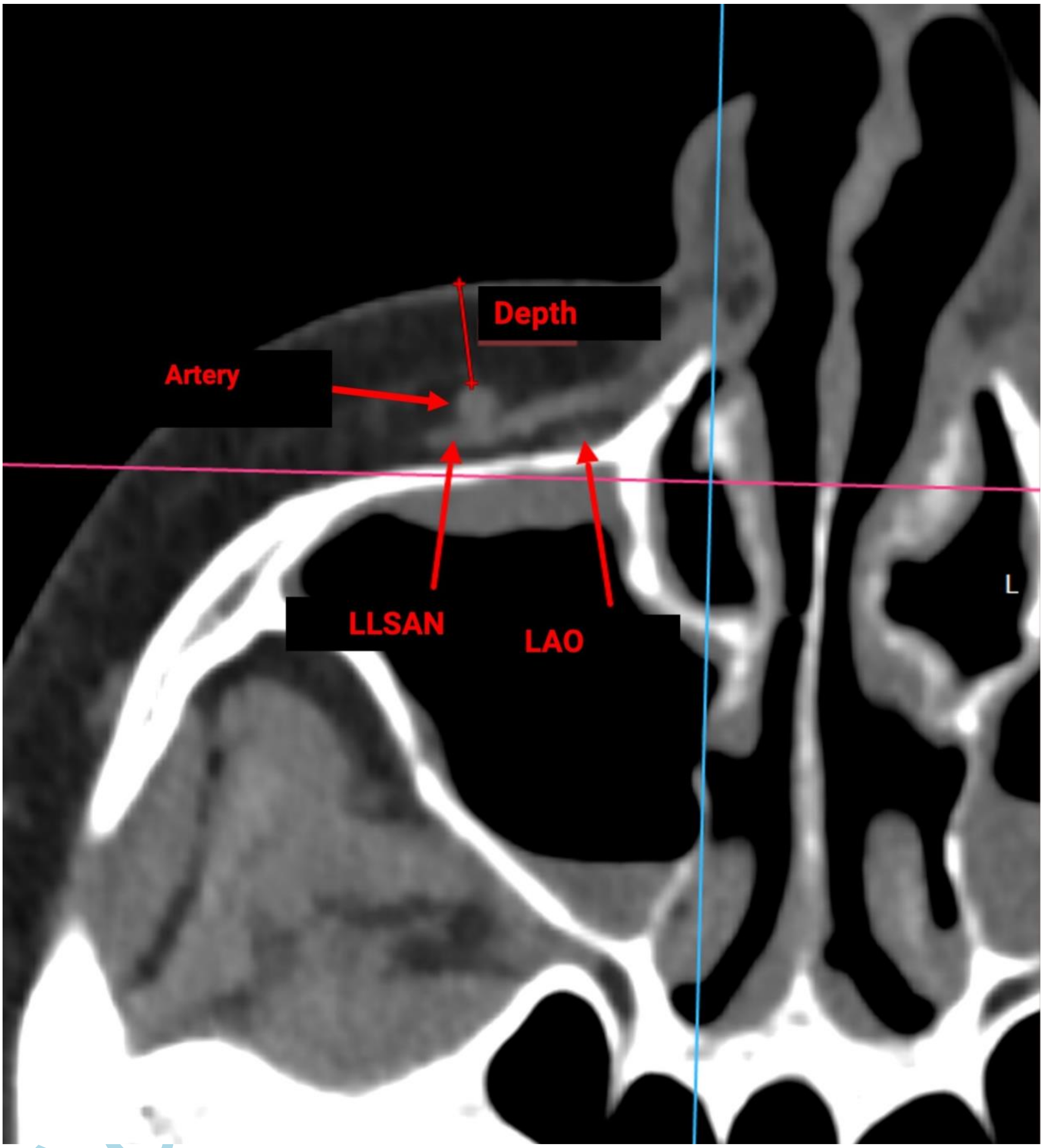


Figure 3b

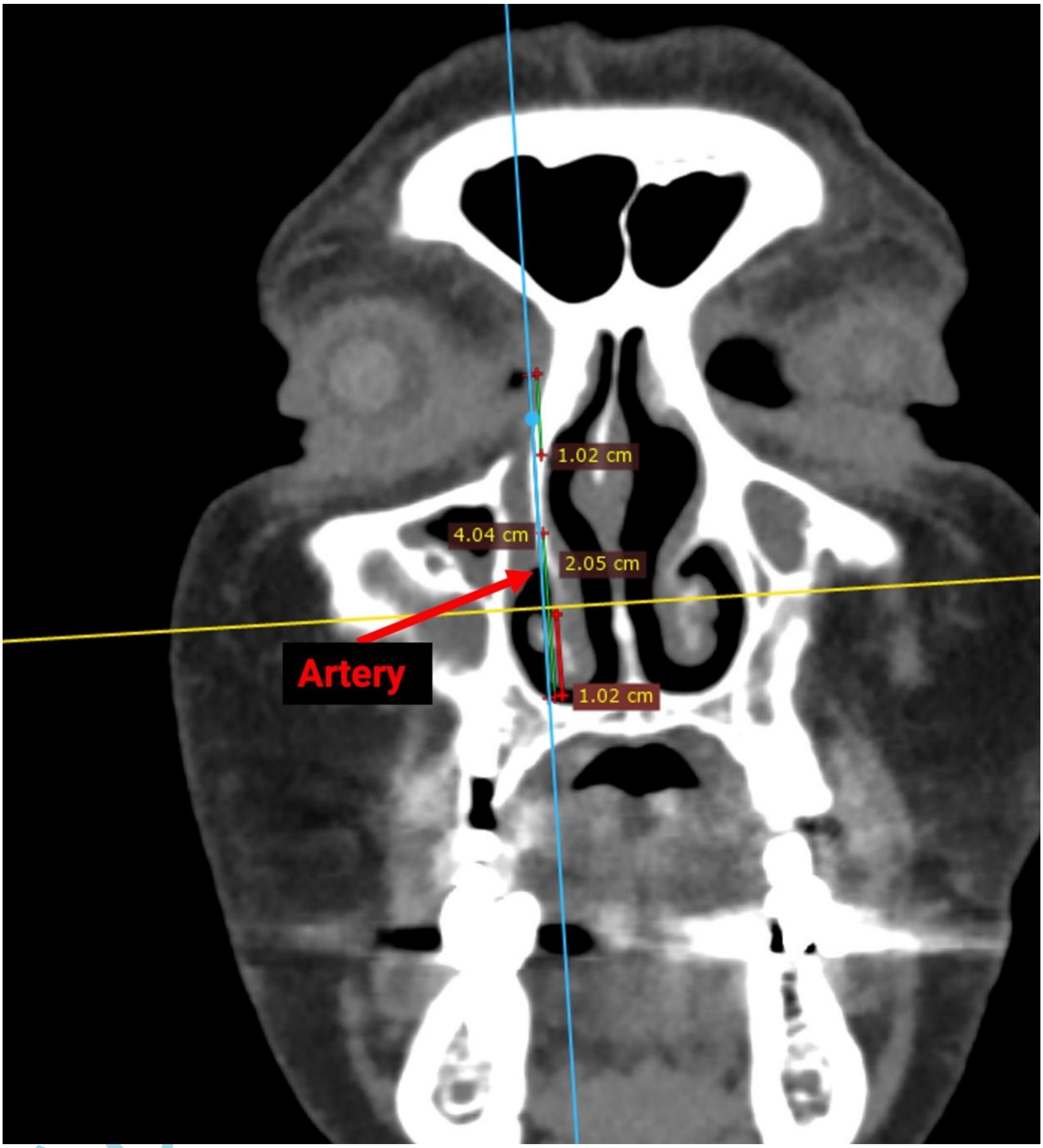


Figure 3C

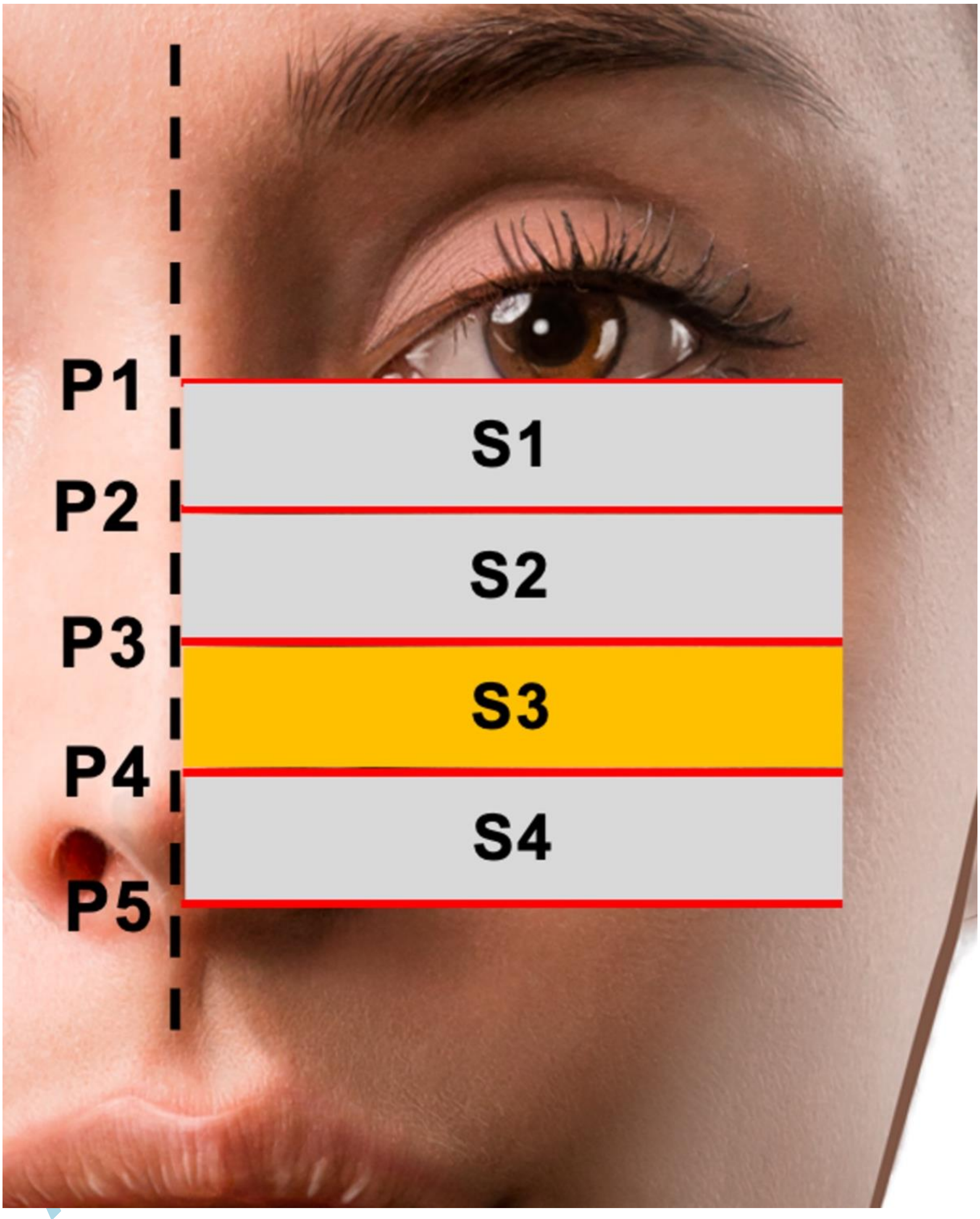


Figure 4a

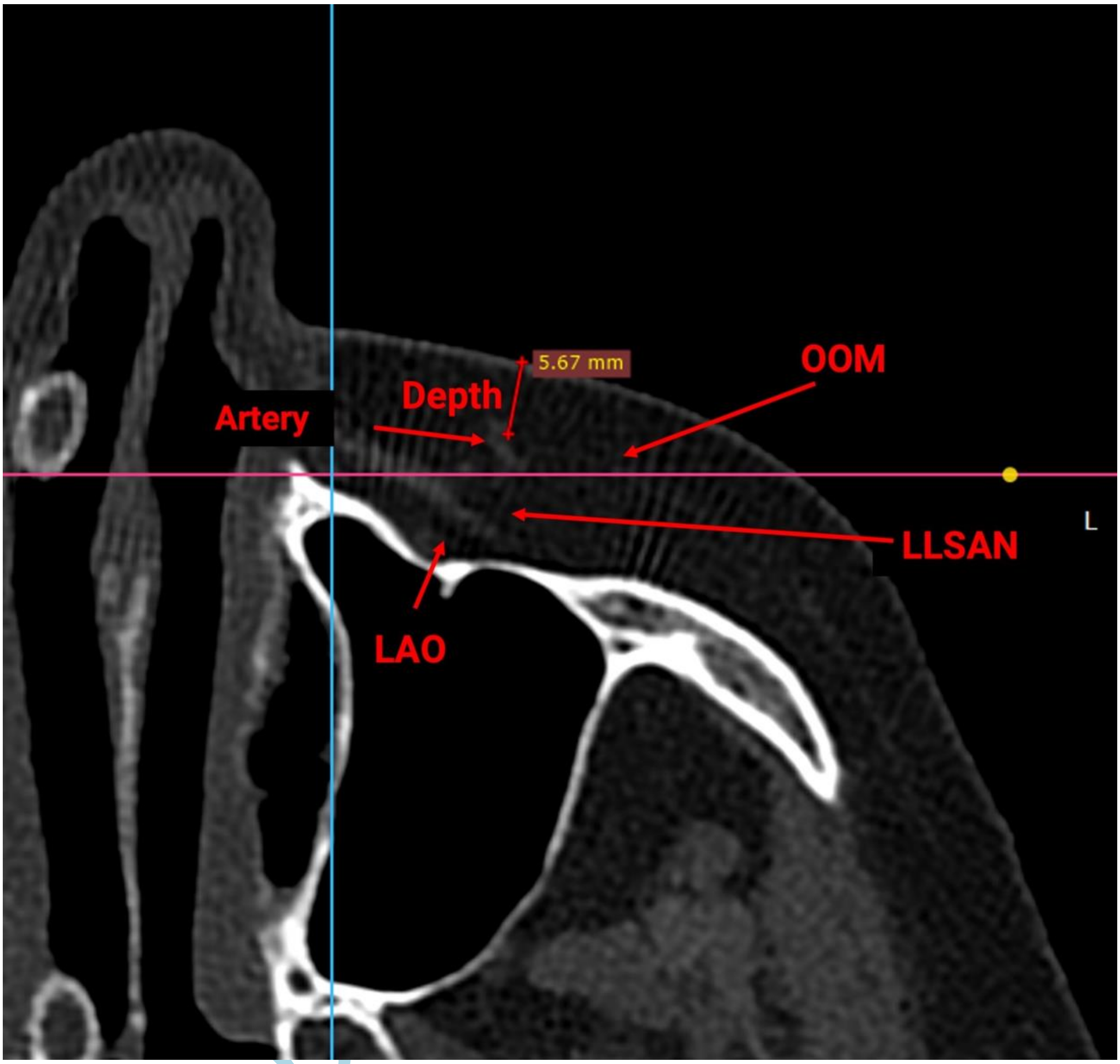


Figure 4b

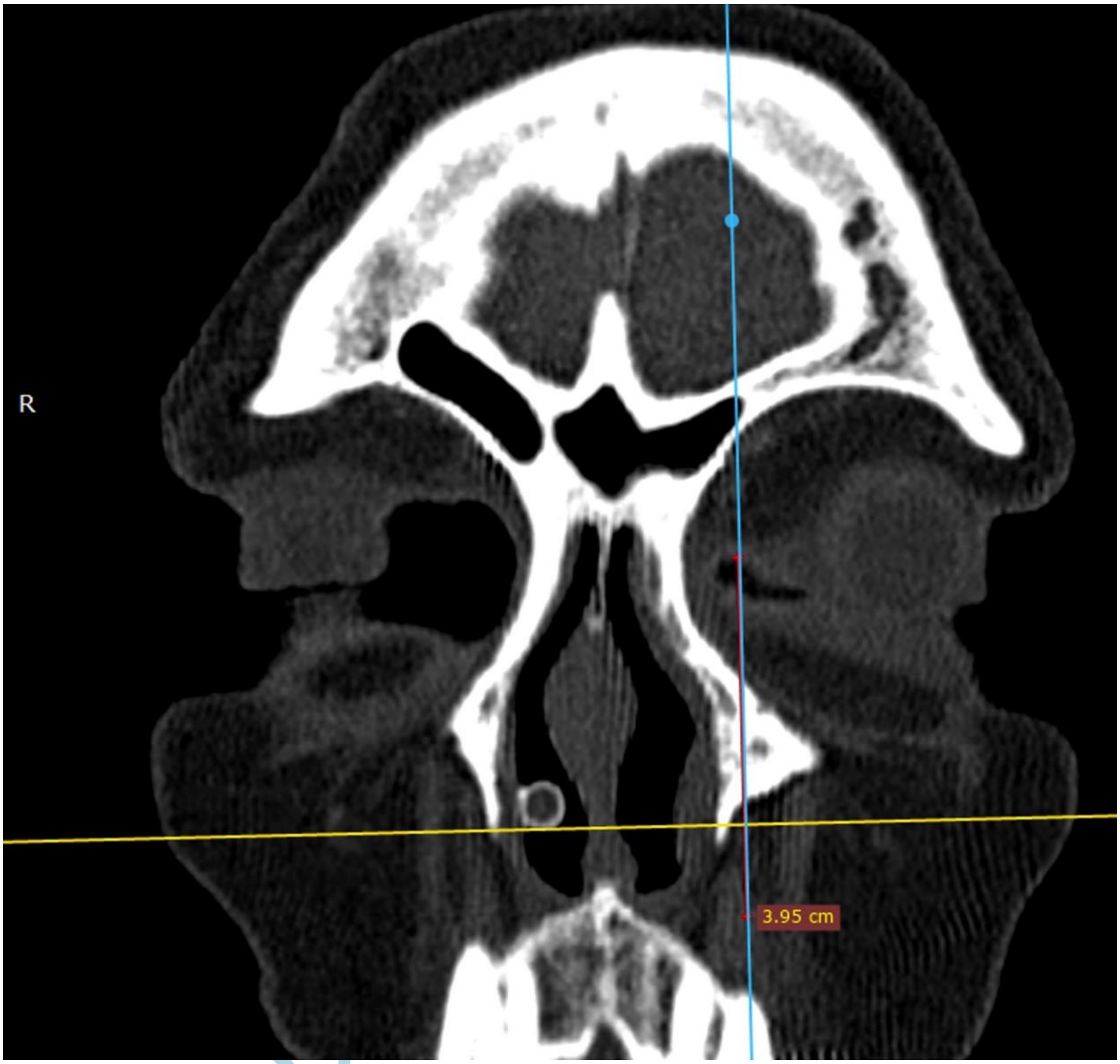


Figure 4C

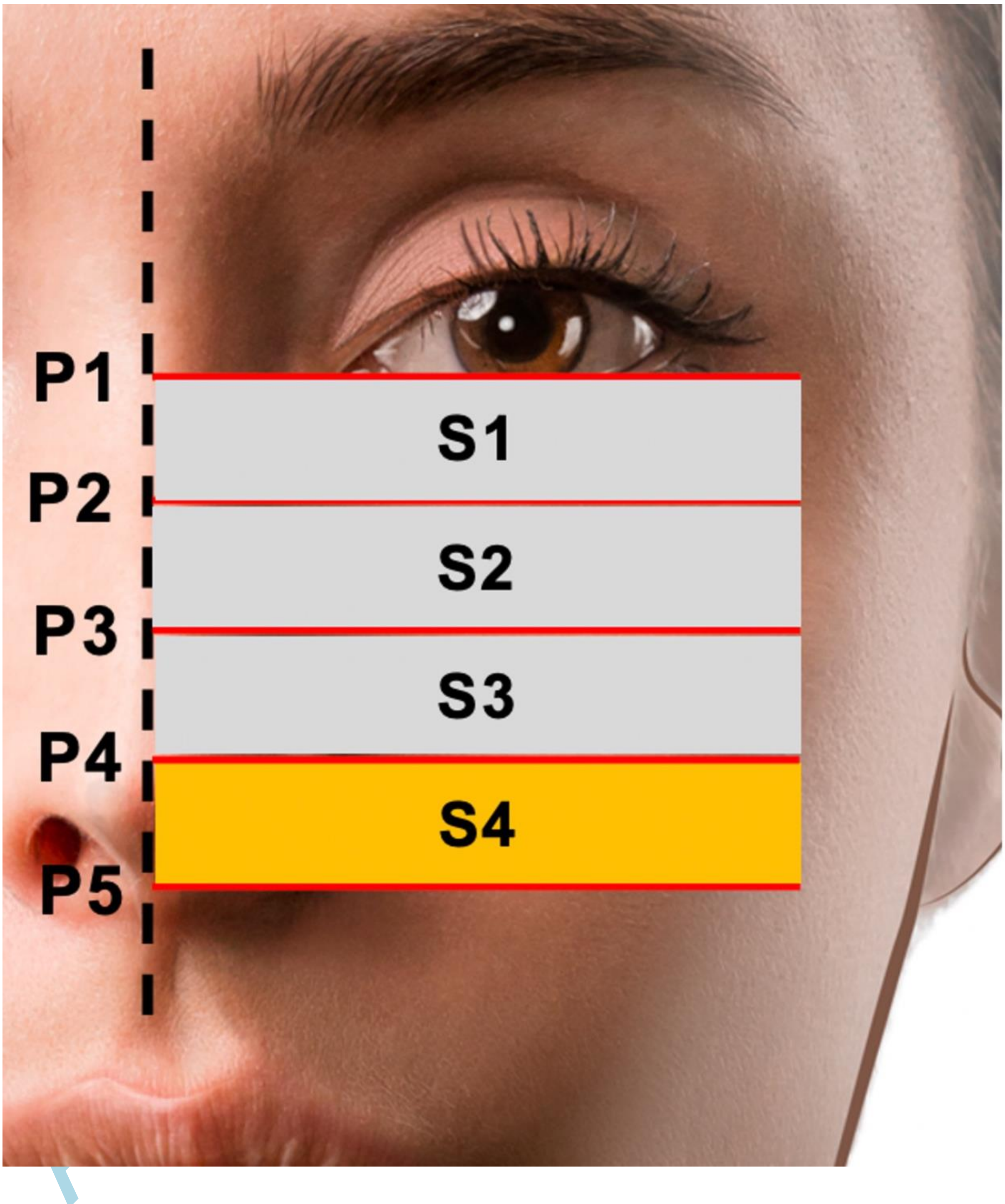
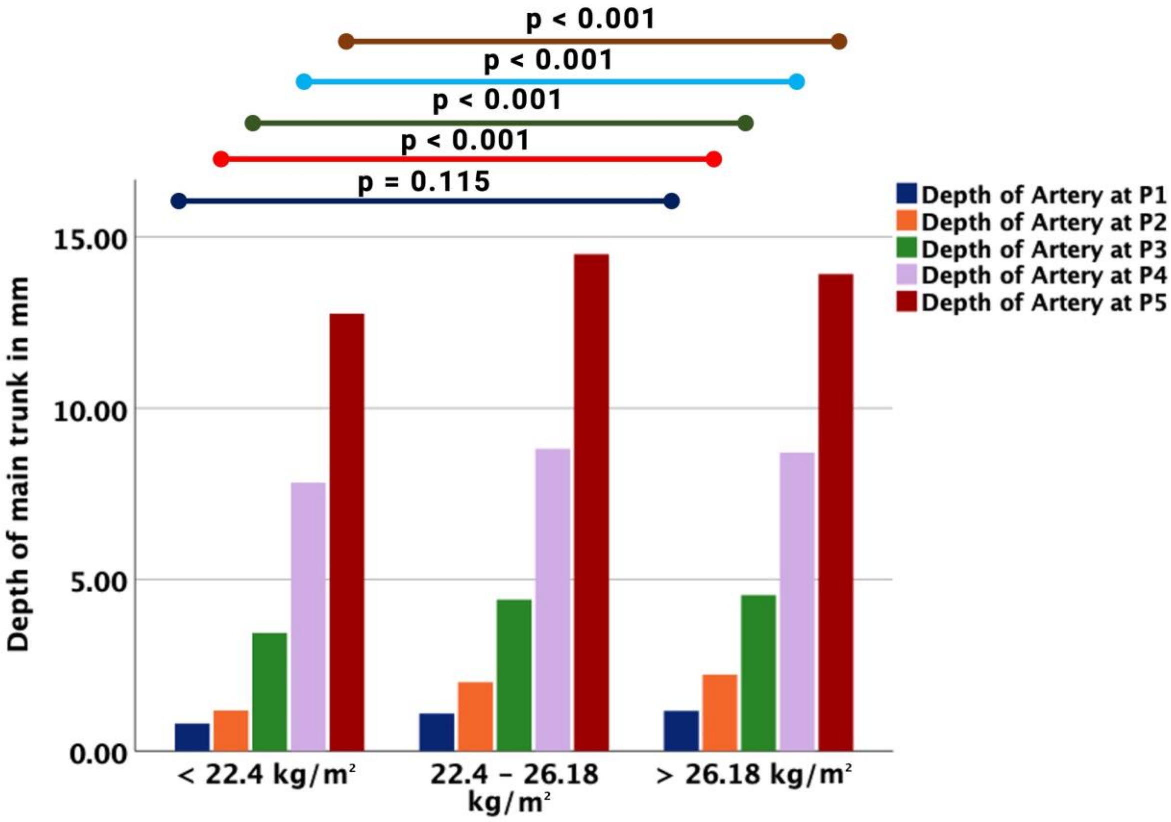
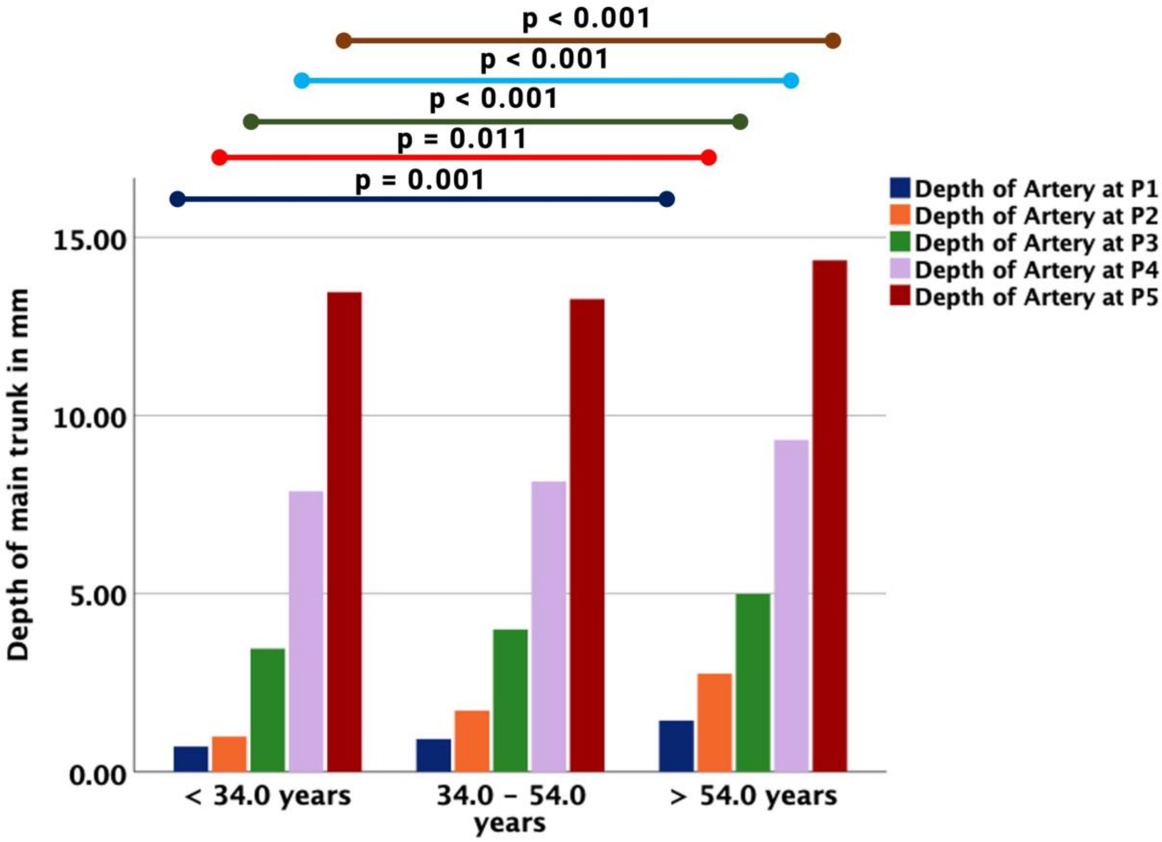


Figure 5



p < 0.001
p < 0.001
p < 0.001
p < 0.001
p = 0.115
Depth of Artery at P1
Depth of Artery at P2
Depth of Artery at P3
Depth of Artery at P4
Depth of Artery at P5
15.00
10.00
5.00
0.00
Depth of main trunk in mm
< 22.4 kg/m²
22.4 – 26.18 kg/m²
> 26.18 kg/m²

Figure 6


p < 0.001
p < 0.001
p < 0.001
p = 0.011
p = 0.001
Depth of main trunk in mm
15.00
10.00
5.00
0.00
< 34.0 years
34.0 – 54.0 years
> 54.0 years
Depth of Artery at P1
Depth of Artery at P2
Depth of Artery at P3
Depth of Artery at P4
Depth of Artery at P5