Three-Dimensional Description of the Angular Artery in the Nasolabial Fold

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Abstract

Background: Due to its arterial vasculature, the nasolabial sulcus is one of the most challenging facial regions to treat when trying to ameliorate the signs of facial aging.

Objective: The objective of the present study is to provide data on the three-dimensional course of the angular artery within the nasolabial sulcus in relationship to age, gender, and body mass index (BMI) to increase safety during minimally-invasive treatments.

Methods: Thee hundred nasolabial sulci obtained from 75 males and 75 females with Russian Caucasian ethnic background (mean age, 45.7 ± 18.7 years; mean BMI, 25.14 ± 4.9 kg/m^2) were analysed. Bilateral multi-planar measurements were based on contrast-enhanced cranial CT-scans.

Results: Up to three arteries could be identified within the nasolabial sulcus: ~ 90% contained one arterial trunk, ~9% had two trunks and ~1% had three trunks; females had more arteries than men. The artery is located at mean depth of 21.6mm at the oral commissure and of 8.9mm at the nasal ala. In 100% of the cases, the angular artery was lateral to the nasolabial sulcus; the smallest distance was at the oral commissure (11.91 ± 7.9mm) and the greatest was at the nasal ala 13.73 ± 3.9.

Conclusion: In contrast to current concepts, the angular artery is not located strictly subdermal to the nasolabial sulcus but at a variable depth, and in 100% of the investigated cases lateral to the nasolabial sulcus. With increasing age, the depth and lateral distance between arteries and sulci reduces significantly, underscoring the need for special caution when injecting this site in older patients.

The nasolabial sulcus is one of the most challenging facial regions to treat when trying to ameliorate the signs of facial aging. The challenges in treating this area arise from the underlying anatomy. The sulcus is an area of adhesion where the muscles of facial expression begin to have a strong connection to the overlying dermis.[1,2] This zone of adhesion results in a change of the subcutaneous architecture where no clear delineation between fat, muscle fibers, connective tissue and skin is evident.[3] This change in subcutaneous arrangement is physiologic and explains why even babies and adolescents present with nasolabial sulci of varying depths. With increasing age, the appearance of the sulcus changes as the cranially located soft tissues descend,[4] pseudo-herniate over the sulcus and create the illusion of a deeper furrow that may be considered undesirable.

There are multiple approaches to improving the appearance of the nasolabial sulci with soft tissue volumizers like fat[5] or hyaluronic acid based fillers.[6–8] A recent anatomic review suggested treating the nasolabial sulcus via intradermal or supra-periosteal product placement to avoid contact with the angular artery located below the skin.[9] Choosing tissue planes where the facial arterial vasculature is not located is thought to increase safety during minimally-invasive filler injections. Avoiding the pathways and planes of the facial arteries is of the utmost importance, as it has been shown that intra-arterial product placement can cause tissue loss and injection related visual compromise (IRVC) of varying degrees including cases of irreversible blindness.[10–12]

The angular artery has been reported to course within the depth of the nasolabial sulcus,[13] however there is a dearth of information regarding accurate measures of depth and lateral distances, and how they may potentially vary with age, gender and body mass index (BMI). Therefore, is the objective of the present study to provide data on the 3-dimensional course of the angular artery within the nasolabial sulcus in relation to age, gender and BMI. It is hoped that by providing a clearer understanding of the arterial pathway in this high risk area may lead to safer aesthetic injections.

METHODS

Study Sample

Computed tomographic (CT) scans from the radiology database of the Research and Practical Center of Medical Radiology of the Department of Health Care, Moscow, Russia, were retrospectively analyzed for the purposes of the present study. The image analysis procedures were carried out between January and July 2019, and utilized scans which were previously obtained during routine contrast – enhanced cranial CT examinations. 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 demographic and CT imaging data.

CT measurements relied on full visibility of the segment of the facial artery running in the depth of the nasolabial sulcus. The segment of the facial artery located within the nasolabial sulcus is termed *facial* artery *before* the branching of the superior labial artery or *angular* artery *after* the bifurcation of the superior labial artery.[9] Due to variations in the superior labial artery branching pattern, various names for the main arterial trunk have been used. However, for the sake of uniformity, the main arterial trunk identified near or in the depth of the nasolabial sulcus will be termed *angular artery* in the following discussion.

Image Analyses

CT scans were acquisitioned via a Toshiba Aquilion LB scanner (Toshiba Medical Systems Corporation, Ōtawara, Tochigi, Japan) with the following scanning parameters: voltage 120 kV, slice thickness 0.47mm, field of view 220mm and tube current 140 mA.

In each CT scan, the nasolabial sulcus was identified on the skin surface by adjusting the soft tissue visibility through Hounsfield unit regulation. The total length of the sulcus was defined as the visible depression extending between the infero-lateral margin of the nasal ala and the lateral aspect of the oral commissure. The total length of the nasolabial sulcus was then sub-divided in 3 equidistant segments (S1, S2, S3) which were bounded by their respective margins (P1, P2, P3, P4) (Figure 1).

All measurements were performed bilaterally using the internal software tools of Intellispace 8.0 (Philips, Koninklijke, Amsterdam, Netherlands). The following parameters were assessed:

- Total length of the nasolabial sulcus, in mm
- Extent of each of the 3 segments, in mm; distance between P1 and P2 = S1; distance between P2 and P3 = S2; distance between P3 and P4 = S3 (Figure 1)
- Number of arteries observed in each segment
- Depth of the main arterial trunk at each measured location, in mm; at P1, P2, P3, P4. Note: depth measurements were performed perpendicular to the maximal depth of the nasolabial sulcus even if the artery was located lateral to the sulcus, as shown previously[9] (Figure 2)
- Lateral distance between the main arterial trunk and a vertical line passing through the maximal depth of the nasolabial sulcus, as shown previously[9] (Figure 2)

Statistical Analyses

Multi-planar measurements (Figures 3 and 4) were repeated 3 times and validated by 2 independent observers for reporting consistency. The relationship between the length of the nasolabial sulcus and patient age, gender and BMI was calculated using bivariate correlations and generalized linear models with robust estimator. The depth of the artery and the distance between the artery and the nasolabial sulcus was calculated using independent students t-test (side and gender differences), bivariate correlations and generalized linear models with robust estimator. Results were considered statistically significant if the difference was $p \leq 0.05$. All tests were run using SPSS Statistics 23 (IBM, Armonk, NY, USA).

RESULTS

Demographic Data

The investigated sample is a subsample of a previously described cohort[14] and consisted of 75 males and 75 females of Russian Caucasian ethnic background having a mean age of 45.7 ± 18.7 years (range, 14-89 years) and a mean BMI of 25.14 ± 4.9 kg/m^2 (range, 16.7-47.8 kg/m^2). Both facial sides were investigated resulting in the analysis of 300 nasolabial sulci. No statistically significant differences between facial sides were detected in any of the measured parameters (all $p \geq 0.333$).

Length of Nasolabial Sulcus

The mean length of the nasolabial sulcus was 31.26 ± 4.0mm (range, 23.0-43.0 mm) in males and 28.84 ± 3.9mm (range, 22.0-42.0 mm) in females with $p < 0.001$ for gender differences. The length of the sulcus was significantly influenced by increasing values of BMI ($p = 0.009$) and by male gender ($p < 0.001$) but not by increasing values of age ($p = 0.559$).

Number of Arteries

The mean number of arteries per segment was significantly different between genders; in every segment investigated (S1 – S3), females displayed a greater number of main arterial trunks: S1 $p = 0.018$, S2 $p = 0.040$, S3 $p = 0.015$. Detailed information is presented in Table 1. Unstratified data in S1 showed that one arterial trunk was found in 91.0%, two arterial trunks in 8.3% and three arterial trunks were found in 0.7% of the investigated cases. In the S2 segment, one arterial trunk was found in 90.3%, two in 8.7% and three in 1.0% of the cases. In S3, one arterial trunk was found in 90.6% and two in 9.4% of the investigated nasolabial sulci (Figure 1).

Depth of the Main Arterial Trunk

The main arterial trunk started deep at the oral commissure and became more superficial toward the nasal ala; P4: 21.61 ± 6.9mm (range, 3.0-43.6 mm), P3: 20.69 ± 6.2mm (range, 9.0-40.4 mm), P2: 15.84 ± 5.88mm (range, 6.0-33.5 mm), P1: 8.93 ± 4.0mm (range, 1.0-26.0 mm). In each measured location, females had a significantly deeper course when compared to males, $p < 0.001$ (Table 2).

Analyzing the frequency of the angular artery within the superficial/middle/deep tertile of the depth of the nasolabial sulcus revealed a homogenous distribution across tertiles (Table 3). This indicates a high variability in the depth of the artery across the investigated sample with men having a more superficial course than females.

A highly statistically significant positive correlation was found between the arterial depths at each consecutive measured location indicating that, despite the high variability in depth (see above), the main arterial trunk followed a constant pathway within its initial depth. From P4 to P3: $r_P = 0.868$, $p < 0.001$; P3 to P2: $r_P = 0.758$, $p < 0.001$; P2 to P1: $r_P = 0.729$, $p < 0.001$.

Utilizing generalized linear models with adjustment for age and BMI, it was revealed that the depth of the main arterial trunk was not influenced by increasing BMI values at P2, P3 and at P4. However, with increasing age there was a statistically significant decrease in distance between the skin surface and the main arterial trunk in those locations.

Position of the Main Arterial Trunk (Lateralization)

In all of the measured cases, the artery was found to course lateral to the nasolabial sulcus. The mean distance to the nasolabial sulcus was as follows: at P1, 13.73 ± 3.9mm (range, 3.8-25.0 mm); at P2, 12.87 ± 6.0mm (range, 1.0-33.0 mm); at P3, 12.81 ± 8.2mm (range, 1.5-40.0 mm); and at P4, 11.91 ± 7.9mm (range, 1.0-36.0 mm). The distance from the arterial trunk to the sulcus was in males at all measured locations statistically significantly greater than the distance in females (Table 4).

Similar to those findings related to depth, a highly statistically significant positive correlation was found in the distance between the artery and the sulcus at each consecutive measured location indicating that, despite the high variability in distance values (see above), the main arterial trunk followed a constant pathway within its initial position. From P4 to P3: $r_P = 0.866$, $p < 0.001$; P3 to P2: $r_P = 0.823$, $p < 0.001$; P2 to P1: $r_P = 0.618$, $p < 0.001$. No statistically significant correlation was found between depth and lateral distance measures; this indicates that the artery did not course in a cluster-like pathway (deep and lateral or superficial and closer to the nasolabial sulcus) with $p \geq 0.098$.

Increasing values of age, but not BMI, reduced statistically significantly the distance between the angular artery and nasolabial sulcus independent of gender when applying generalized linear models.

DISCUSSION

The present study analysed in previously obtained cranial CT scans the course of the angular artery within 300 nasolabial sulci. The results revealed that up to three arteries could be identified independent of their location between the oral commissure and the nasal ala: ~ 90% one arterial trunk, ~ 9% two trunks and ~ 1% three trunks, with females having more arteries per measured segment than males.

One strength of the study is the large number of investigated nasolabial sulci (n = 300); to our best knowledge, this is the largest sample using high resolution CT scans to evaluate the arterial vasculature in the depth of the sulcus. Another strength of the study is the stringent measurement technique, which utilized multi-planar distance measurements for superior accuracy. Of note, the CT scans were obtained with patients in the supine position as is routine for cranial CT scanning procedures. This could have resulted in lateral and/or cranial soft tissue shifting. The conducted measurements however relied on the relationship of the arterial vasculature to the nasolabial sulcus and not on bony or on other non-mobile/fixed landmarks. It is unlikely that the subdermal soft tissues move in a greater or lesser extent than the overlying skin; indicating that if there is any lateral or cranial shift of the facial soft tissue the arterial vasculature moves concomitantly.

A limitation of the study is the retrospective analysis of a cohort exclusively comprised of Russian Caucasian individuals. It is unclear whether these results are extrapolatable to other races/ethnicities. However, the present study is the largest CT based analysis of the angular artery within the nasolabial sulcus and the measurement techniques employed could be used as guidance for future investigations. Studying other ethnicities with the methodology provided herein could yield facilitate their understanding and applicability and reduce the bias between published results. Another limitation of the study is that due to the study set-up, the angular artery was investigated at rest only disregarding soft tissue movements during facial expressions. These soft tissue movements might influence arterial position and course which might lead to results other than presented here.

Future studies will need to investigate the magnitude of these positional changes to ultimately predict angular arterial course more precisely.

The present study is confirmatory in many aspects and provides a deeper understanding of the facial aging process. The presence of a nasolabial sulcus can be observed in babies, adolescents, young adults and the elderly. This is the result of the underlying anatomy; many of the muscles of facial expression attach and form a strong connection to the dermis at the nasolabial sulcus.[3] This attachment between muscle and dermis – along the nasolabial sulcus – forms the inferior boundary of the superficial (subdermal) nasolabial fat compartment.[4,15] With increasing age, the nasolabial sulcus appears deeper and more prominent, but not necessarily longer. This seems to be the result of a relative increase in volume of the facial soft tissues secondary to an age-related facial soft tissue descend especially of the cranially located superficial fat compartments of the medial cheek. In our study, individuals with a higher BMI – but not older age – displayed a longer nasolabial sulcus. This would confirm the above mentioned assumption of the relative increase of facial soft tissues cranial to the sulcus due to an increase in BMI. This increase in BMI could facilitate the descend of the heavier soft tissues [16] resulting in an accumulation of volume cranial to the nasolabial sulcus. This was shown in our study by the increase in length of the nasolabial sulcus upon the influence of BMI but not upon the influence of age. Some common clinical morphological observations are that people with heavy, round faces do not display deep nasolabial sulci. It is often the people with normal to low BMIs – thin people – who display a deep nasolabial sulcus. It is important to note that this is a single-point-in-time, cross-sectional study and not a longitudinal study. It would certainly add valuable information to the literature to follow the same subjects in a longitudinal manner and take the same measurements as they age.

Minimally-invasive aesthetic procedures targeting the improvement of the nasolabial sulcus frequently rely on direct nasolabial augmentation via the injection of fat or other types of soft tissue volumizers. These procedures could potentially result in IRVC[10,11] due to the intra-arterial application of the product. The current belief that the facial/angular artery is located in the immediate proximity of the dermis of the nasolabial sulcus should be reconsidered. Our results reveal that the artery is located at mean depth of 21.6mm at the oral commissure and at a mean depth of 8.9mm at the nasal ala (overall mean, 16.6mm) with shallower depths for males than for females (Table 3). These results indicate that, on average, the artery is not located in the immediate subdermal location; this could provide a valid explanation for why many nasolabial volume augmentation procedures do not result in an IRVC. Nevertheless, these results need to be interpreted with great caution: the range of arterial depth is from 1.0mm to 43.6mm; this shows that the artery *can* be found immediately deep to the dermis. Therefore, one should always practice pre-injection aspiration, a slow injection of small boluses and choose a plane where the arteries are less frequently identified for product deposition: the supra-periosteal plane.

However, the artery seemed to be constant both in its depth and in its course relative to the nasolabial sulcus. Utilizing bivariate correlations showed that the depth in one location along the nasolabial sulcus is significantly correlated to the depth at the next location. This could provide mathematical evidence for a constant rather than a torturous course of the angular artery within/adjacent to the nasolabial sulcus. The depth of the angular artery was reduced in elderly individuals; this is plausible as the facial aging process includes fatty tissue atrophy and volume loss[4,17] and a loss in the thickness of the fatty layers reduces the distance between skin surface and main arterial trunk. Interestingly, individuals with higher BMI did not display a greater depth of the main arterial trunk. This can be attributed to the attachment of the muscles of facial expression to the overlying dermis at the nasolabial sulcus. This zone of adhesion seems to prevent any increase in the thickness of the subcutaneous fat at this location. Consequently, there is no statistically significant relationship between higher BMI and the depth of the main arterial trunk within the sulcus.

Another reason to reconsider the assumption that the angular artery is located immediately below the nasolabial sulcus is the lateral distance measurements between the nasolabial sulcus and the main arterial trunk: in all of the samples investigated, the position of the main arterial trunk was lateral to the nasolabial sulcus. The smallest distance was at the oral commissure (11.91 ± 7.9mm) and the greatest distance to the sulcus was at the nasal ala 13.73 ± 3.9mm. In all of the measured locations, females demonstrated a smaller distance between the nasolabial sulcus and the main arterial trunk. This would be in line with a previous publication which reported on the stable location of the facial artery:[9] crossing the mandibular margin anterior to the masseter muscle and at the modulus. The latter is confirmatory with the results presented herein where the smallest distance between the sulcus and the main arterial trunk was observed at P4 – the level of the oral commissure.

Clinically, this is relevant because the typical dermal access point to inject the nasolabial sulcus is at the caudal end of the sulcus. Here, special care should be taken as the artery could be in close proximity. Anecdotally, clinical aesthetic injectable education has emphasized the need for caution when injecting the nasolabial sulcus near the nasal ala, but training has not similarly focused on the potential dangers when injecting its caudal end. The range of the distance measurements is 1.0 – 36.0mm, providing evidence for the torturous and variable course of the artery when comparing different individuals with each other (not following the main arterial trunk within the same nasolabial sulcus). However, the high correlation coefficients as a result of the bivariate correlations between each consecutive location (P4 to P1) reveal that once the artery courses in close proximity to the nasolabial sulcus it remains, with a statistically significant high probability, close to the sulcus and vice versa.

Injectable filler treatments should be customized based on a patient's age. Utilizing generalized models revealed that with increasing age there was a statistically significantly reduced distance between the nasolabial sulcus and the evaluated main arterial trunk. This finding is consistent with the current understanding of the anatomy of the aging face, as with older age fat tissue mass is lost and the filling material surrounding the arteries is reduced. This results in less protection for the facial vasculature, and as shown in this study in a reduced distance to the nasolabial sulcus. These results would imply that older individuals are at a potential greater risk for IRVCs during injectable treatments of the nasolabial sulcus, as the artery is more superficial and located closer to the sulcus than in younger individuals. This emphasizes again the re-evaluation of the of the subdermal injection technique, which should be exchanged for the supra-periosteal injection technique based on the results of the study. Applying new concepts for facial soft tissue filler injections like the lateral first or the upper face first approach[18] where the temple, the zygomatic arch and/or the malar prominence are targeted first might reduce the necessity to inject the nasolabial sulcus directly. These injections are shown to have an effect on the midfacial soft tissues which can re-position the age-related descend and reduce the aesthetically unpleasing appearance of the nasolabial sulcus.

CONCLUSION

The results of the present study reveal that within the depth of the nasolabial sulcus up to 3 arterial trunks can be identified. In contrast to current concepts, the angular artery is not located strictly subdermally in the nasolabial sulcus but at a variable depth which is greater at the oral commissure than at the nasal ala. Additionally, the artery is located lateral to the nasolabial sulcus at a variable distance with a greater distance at the nasal ala. With increasing age, the depth and the lateral distance between the nasolabial sulcus and the angular artery reduces significantly, underscoring the need for vigilance when injecting soft tissue fillers at this site in older patients. The facial fatty volume loss reduces the tissue surrounding the arteries exposing them and making them more prone for puncture during injectable treatments.

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Figure Legend

Figure 1. Schematic drawing superimposed on a clinical image of a 22-year-old female showing the measurements performed: the location of P1 at the inferolateral margin of the nasal ala and of P4 at the lateral aspect of the oral commissure. The distance between P1 and P4 (the length of nasolabial sulcus) was divided into three equal segments (S1, S2, S3). The number of arterial branches observed within each segment S1 – S3 is given within each segment (one artery represented by one red line). Numbers are not stratified by gender.

Figure 2. Schematic drawing exemplifying the multi-planar measurements performed of the depth and the lateral distance between the angular artery and the skin surface in the nasolabial sulcus. Measurements were performed in perpendicular axes.

Figure 3. 3D rendering of a contrast enhanced cranial CT image of a 63-year-old male patient. Segments (S1 – S3) and measurement points have been visualized (P1 – P4).

Figure 4. Figures exemplifying the multiplanar (sagittal, axial, coronal) measurements of a 63-year-old male patient. (A) A sagittal view with locators (blue and orange lines) centered on the angular artery. (B) An axial view with the locators (red and orange lines) centered on the angular artery. (C) A coronal view with the locators (red and blue lines) centered on the angular artery. (D) The 3D reconstruction and the measured segment (S2) of the respective angular artery.

Table 1. Number of Arterial Trunks Observed Within the Depth of the Nasolabial Sulcus Stratified by Gender

	S1*	S2*	S3*
Male	1.05 ± 0.3	1.07 ± 0.3	1.05 ± 0.2
Female	1.14 ± 0.4	1.15 ± 0.4	1.14 ± 0.3

Statistically significant differences between gender with $p < 0.05$ are marked with an asterisk.

Table 2. Depth of the Main Arterial Trunk Within the Nasolabial Sulcus Stratified by Gender

	P1*	P2*	P3*	P4*
Male	7.35 ± 2.4	12.66 ± 3.8	16.9 ± 3.4	17.67 ± 3.5
Female	10.52 ± 4.6	19.10 ± 5.9	24.79 ± 6.0	26.38 ± 7.2

Statistically significant with $p < 0.001$ are marked with an asterisk.

Table 3. Distribution of the Frequency of the Angular Artery Within the Superficial/Middle/Deep Tertile of the Depth of the Nasolabial Sulcus

	P1*			P2*			P3*			P4*		
	Range (mm)	Male count (%)	Female count (%)	Range (mm)	Male count (%)	Female count (%)	Range (mm)	Male count (%)	Female count (%)	Range (mm)	Male count (%)	Female count (%)
Superficial tertile	< 7.0	85 (56.7)	35 (23.3)	< 12.0	80 (53.3)	21 (14.0)	< 17.0	89 (59.3)	18 (12.0)	< 18.0	87 (58.0)	18 (12.0)
Middle tertile	7.1 - 9.9	38 (25.3)	35 (23.3)	12.1 - 17.9	48 (32.0)	46 (30.7)	17.1 - 21.9	49 (32.7)	39 (26.0)	18.1 - 22.9	53 (35.3)	52 (34.7)
Deep tertile	> 10.0	27 (18.0)	80 (53.3)	> 18.0	22 (14.7)	83 (55.3)	> 22.0	12 (8.0)	93 (62.0)	> 23.0	10 (6.7)	80 (53.3)

Statistically significant differences at each measured location are indicated by asterisks.

Table 4. Lateral Distance of the Main Arterial Trunk to the Nasolabial Sulcus Stratified by Gender

	P1*	P2*	P3*	P4
Male	15.16 ± 3.9	14.58 ± 6.8	14.75 ± 9.6	12.62 ± 9.1
Female	12.27 ± 3.5	11.10 ± 4.4	10.68 ± 5.7	11.03 ± 5.8

Statistically significant results with $p < 0.001$ are marked with an asterisk.

Figure 1

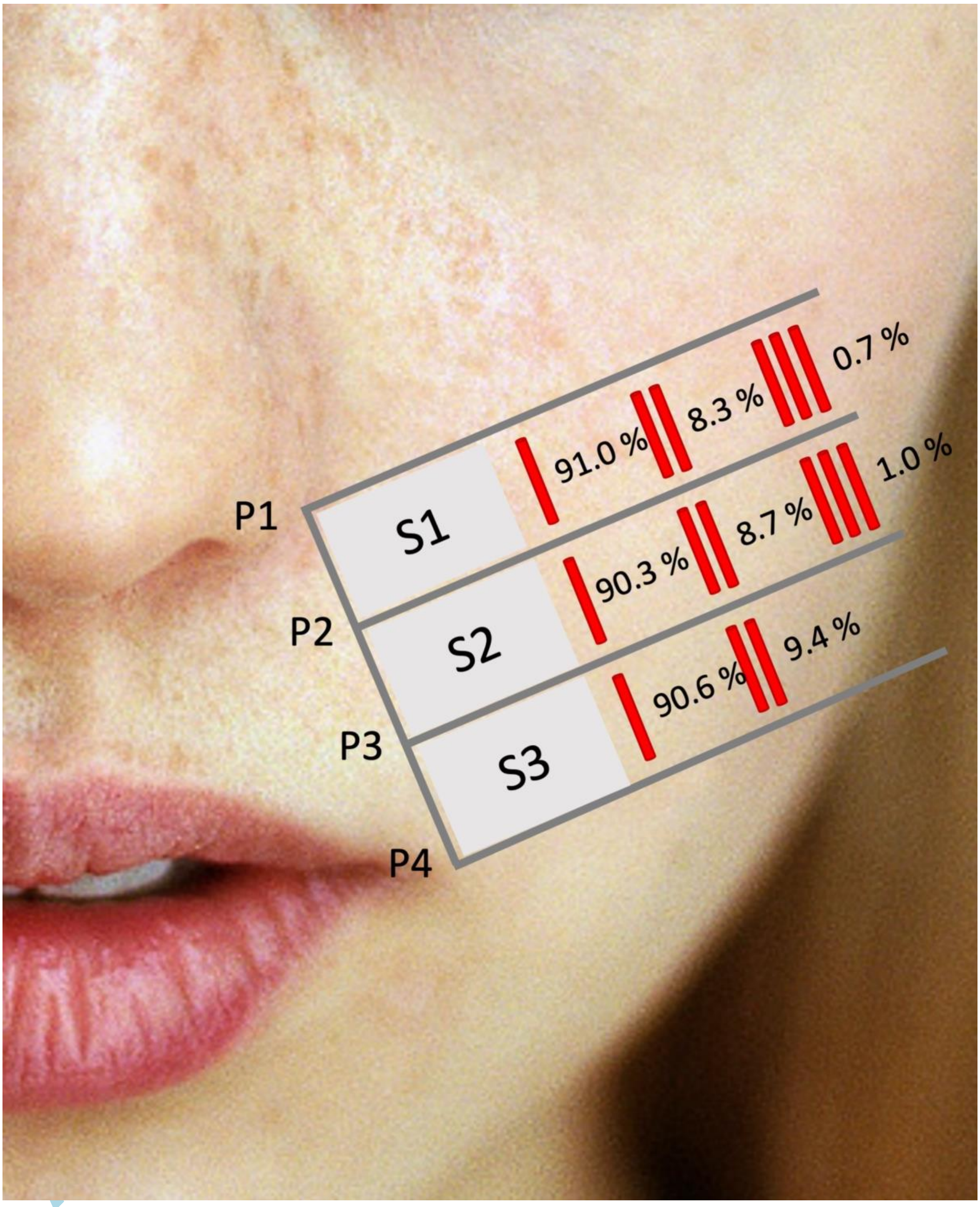

Figure 2

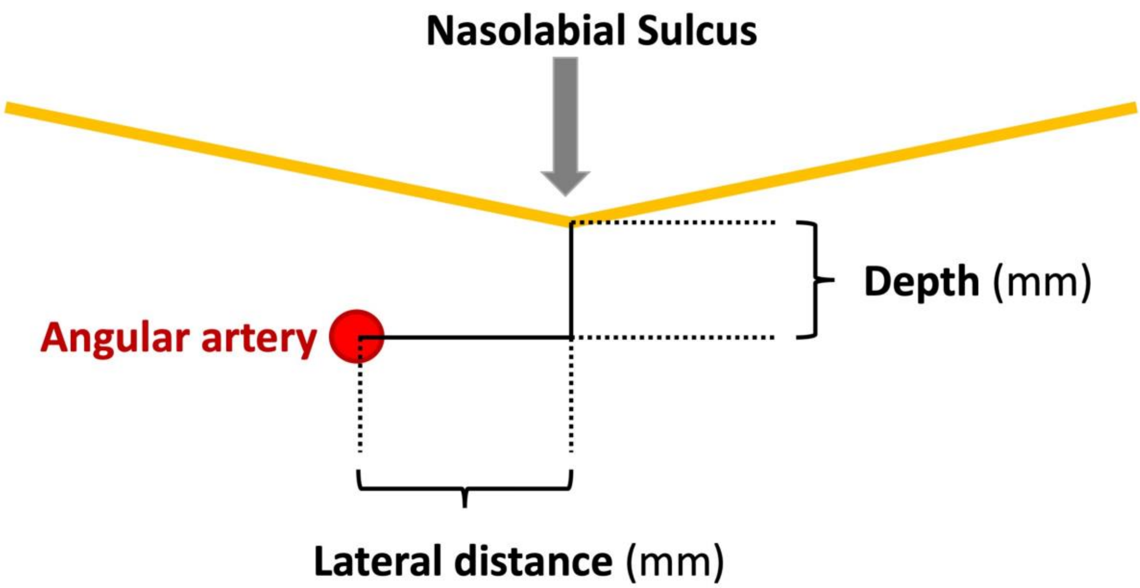
Nasolabial Sulcus
Depth (mm)
Angular artery
Lateral distance (mm)

Figure 3

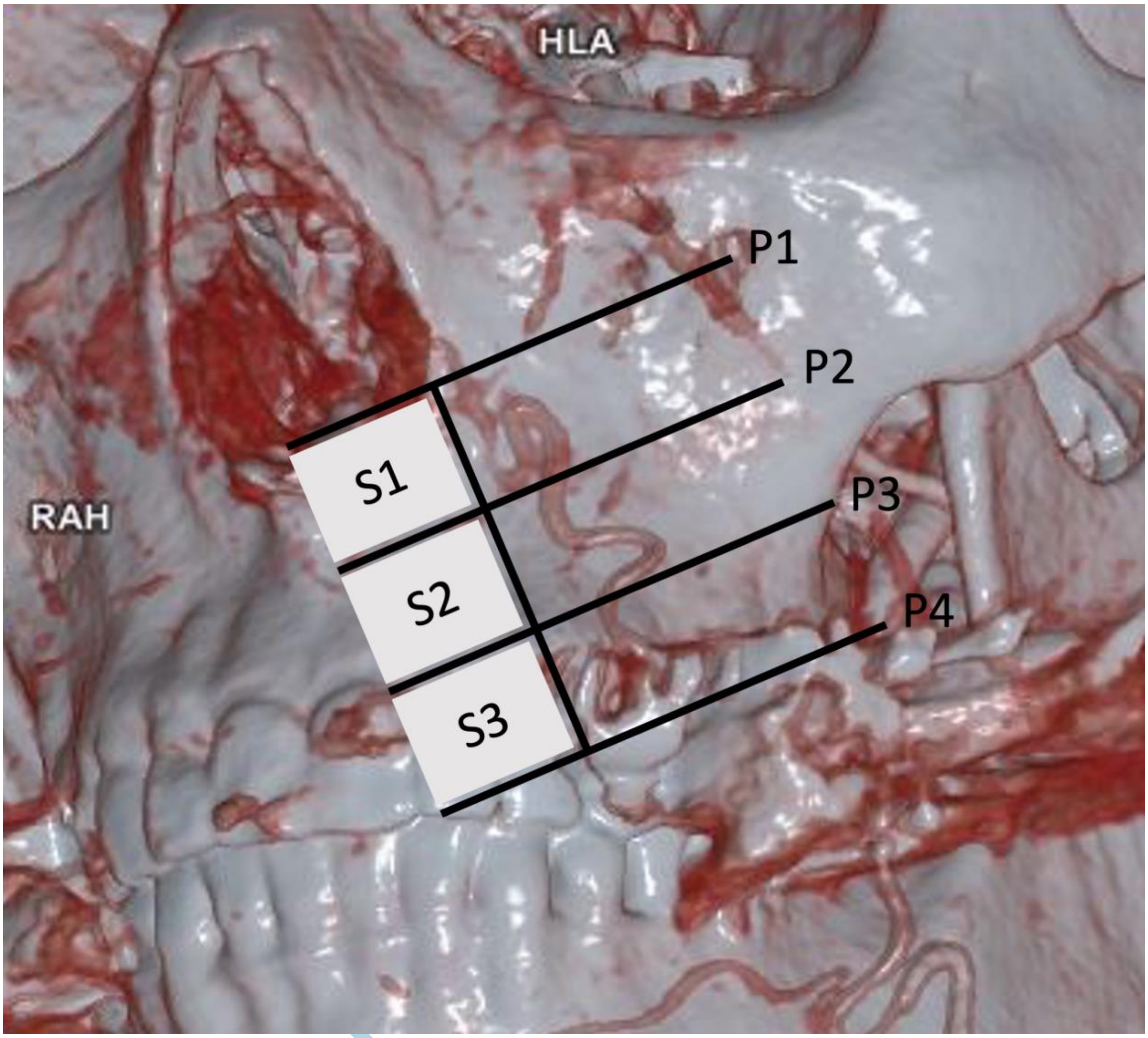

Figure 4a

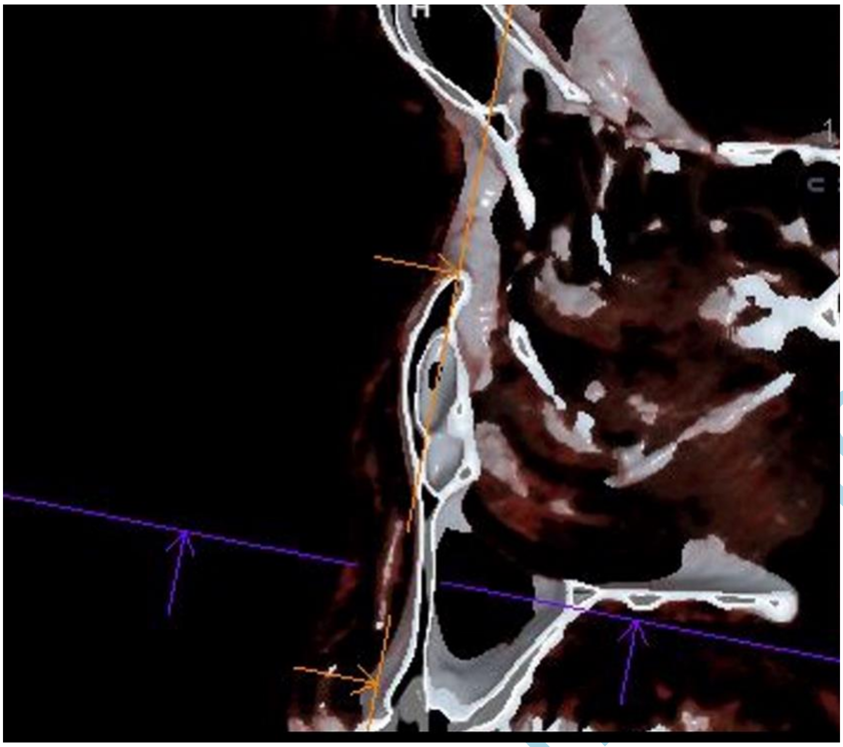

Figure 4b

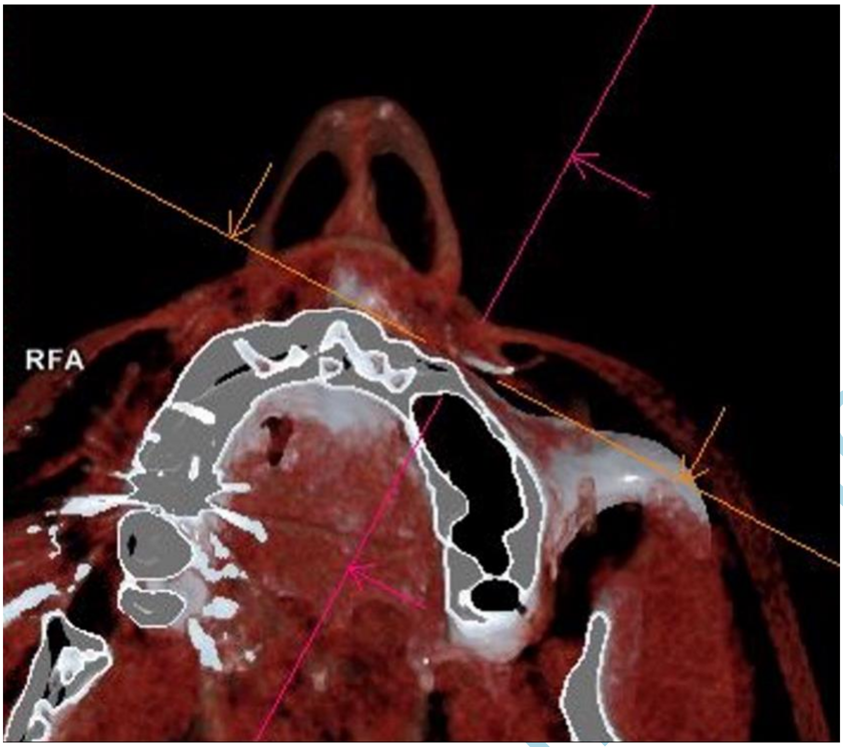

Figure 4c

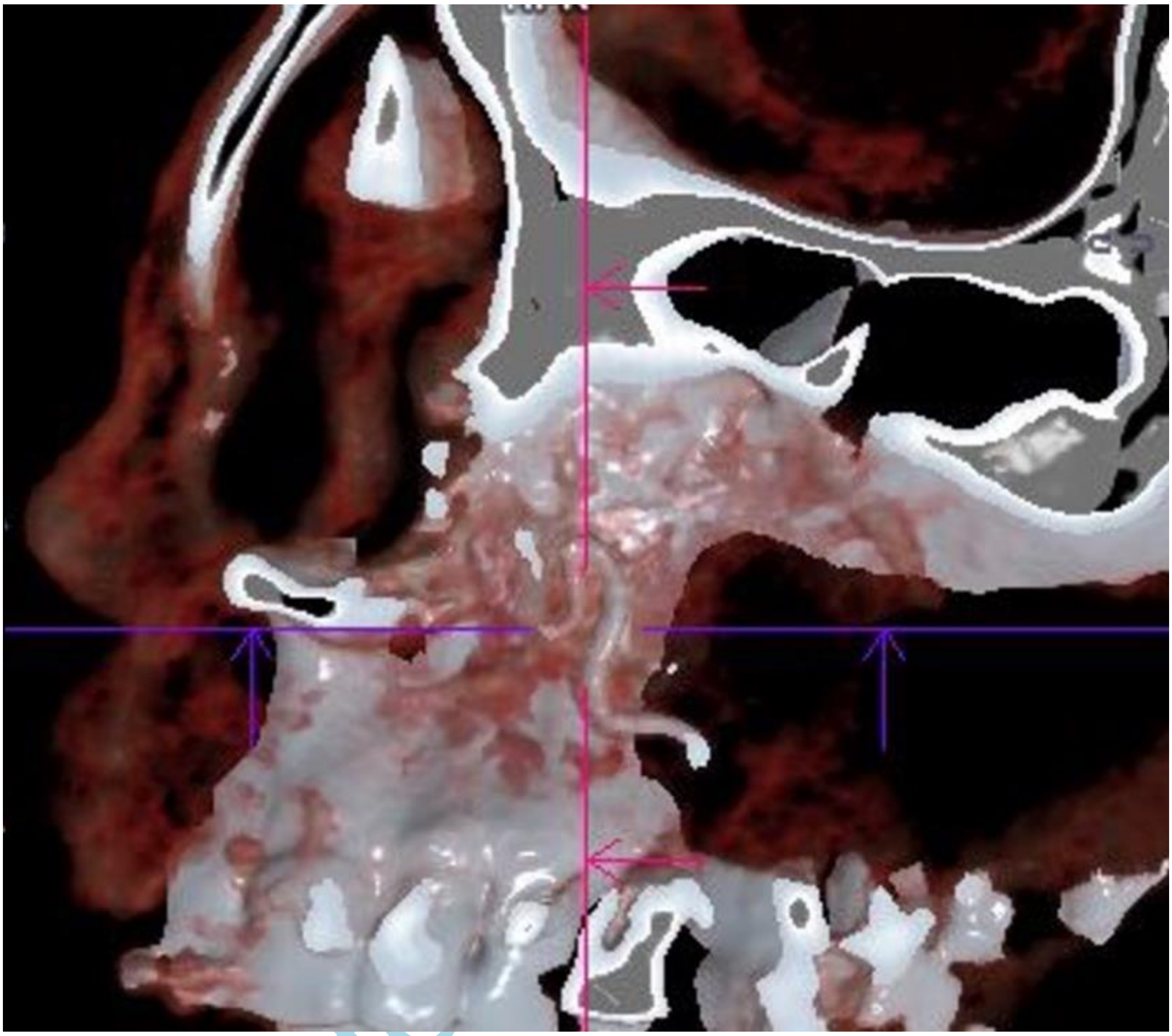

Figure 4d