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Arterial and Nerval Distribution of the Temporal Region for Safe Non-Invasive Treatment

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Arterial and Nerval Distribution of the Temporal Region for Safe Non-Invasive Treatment

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먼저 저를 오늘날 세상에 존재하게 한 근원이자 뿌리인 고인이 되신 아버님께 감사의 인사를 드립니다. 학문적으로 미숙한 저의 해부학 박사학위논문 수여를 위해서 아낌없는 가르침과 조언을 주신 허 경석 교수님과 김 희진 교수님께 감사드립니다.

이 논문이 완성되기 까지 바쁘신 와중에도 힘이 많이 되어주신 병원의 모든 식구들에게도 감사의 마음을 전합니다. 항상 열심히 하며 자기 일처럼 실험을 도와주신 이 규림 선생님과 해부파트 모든 조교선생님들께도 감사의 마음을 전합니다.

그리고 항상 희망과 삶의 목표가 되어 주는 세상에서 가장 사랑하는 저의 반려자 지연과 항상 건강하길 바라는 저의 딸아이 지민에게 사랑을 듬뿍 담아 감사의 인사를 전합니다.

끝으로, 제가 이 자리에 올 때까지 저를 키워주시고 물심양면으로 도와주신 어머니와 항상 옆에서 챙겨주는 누님들, 그리고 제가 학문의 길을 계속해서 정진할 수 있도록 힘들 때 늘 곁에 있어주는 친구들과 형, 동생들에게 이 논문을 바칩니다.

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저자 씀

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Abstract

Arterial and Nerval Distribution of the Temporal Region for Safe Non-Invasive Treatment

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(Directed by Professor Kyung-Seok Hu D.D.S., Ph.D.)

The origin of the temporalis mostly begins with the muscle belly, but continues to the tendon in the middle part of the muscle. The superficial temporal artery (STA, which is the branch of the external carotid artery) can be seen running very thickly on the surface of temporalis. However, the main arteries in the temporalis are the anterior deep temporal artery (ADTA) and posterior deep temporal artery (PDTA), which branch from the maxillary artery, and the deep temporal nerve (DTN) is observed to be running parallel to the branches of the artery.

The temporal region is the site at which various non-invasive treatments for conditions such as temple depression are performed using fillers, while temporalis hypertrophy and tension-type headaches are treated with botulinum toxin (BoNT). However, the less studied area is the deep temporal artery and deep temporal nerve region, where the main blood vessels and nerves are distributed in the temporalis. The purpose of this

study was to observe the nerve distribution pattern within the muscle and to observe its positional relationship to the artery in order to provide guidance for safer and more precise needling. For this study, we performed a traditional anatomical study and sihler's staining.

Twenty-eight hemifaces of cadavers (16 males, 12 females; mean age 79.8) were used for this study. In 18 specimens, ADTA, PDTA and deep temporal nerve (DTN) distributed in the temporalis were carefully dissected and measured. The other 10 stained specimen's temporalis arteries and nerves were analyzed, measured, and compared with cadavers.

In order to perform the measurement, the reference line was set through the zygomatic tubercle (ZT). From this reference line, the distances at the three reference points were measured: T1, eyebrow level; T2, zygomatic tubercle level; T3, zygomatic arch line to ADTA and PDTA. For the analysis of the arteries and nerve distribution pattern, the temporal region was divided into quadrants based on the shape of the temporalis. After analysis, it was confirmed that the arteries and the nerves were concentrated in the quadrant.

The ADTA, PDTA and branches of the DTN were observed in the dissected and stained specimens. The distance between the reference line and ADTA was 3.2 ± 8.6 mm (mean±SD), 4.4 ± 1.5 mm and 4.5 ± 2.1 mm at T1, T2 and T3, respectively. Likewise, the distances to PDTA were 22.8 ± 9.6 mm, 18.5 ± 2.3 mm and 18.1 ± 3.5 mm at each of the reference points. According to the results, it was confirmed that the branch of the ADTA and PDTA was distributed into the wide region in the anterior

interior division. Furthermore, most of the nerve endings were located in the superior division.

The temporal region is complex in that various anatomical structures are spread throughout several layers. For effective and safe non-invasive treatment, it is important to minimize damage to blood vessels and nerves by accurately targeting the target point. As a result of this study, the practice of injecting fillers aimed at an approximate range within 1cm of the zygomatic tubercle has been found to be safe from the possibility of damaging the deep temporal artery. In the case of BoNT injections, they can be performed effectively in the upper part of muscle. Also, it can be possible to inject more precisely at the nerve end by accelerating the temporal line and injecting within 1 cm along the lateral side. This procedure will ensure the most effective targeting of the nerve ending, thereby producing the greatest clinical effect with the minimum amount of BoNT.

Key words : Temporalis, Sihler's staining, Headache treatment, Temple augmentation, Tension-type headache, Botulinum toxin, Filler, Non-invasive treatment

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1. Introduction

The temporalis is one of the representative mastication muscles. This fan shaped muscle originates from the deep surface of the temporal fossa and temporal fascia to insert into the medial and apex of coronoid process and anterior border of the mandibular ramus. The anterior fibers run almost vertically, while the posterior fibers run almost horizontally.

Most anatomy textbooks describe that the arterial supply of temporalis, the anterior deep temporal artery (ADTA), and the posterior deep temporal artery (PDTA) ramify in the second part of the maxillary artery (Watanabe et al., 2016). The middle temporal artery (MTA) ramifies in the superficial temporal artery and is distributed in the temporalis. As explained by Gray's anatomy, the deep temporal artery (DTA) usually branches in two or three sections. The ADTA is distributed in the anterior part of the temporalis in 20%, while the PATA in the posterior part is distributed in 40%. Just above the zygomatic bones, the MTA perforates the temporal fascia and enters the temporalis to be distributed in the middle part of 40% (Standring et al., 2008).

The temporalis innervation is the deep temporal nerve (DTN) that is distributed from the anterior trunk of the mandibular nerve. Usually, three branches occur: the anterior that arises from the buccal nerve, the middle that arises from the anterior trunk of the mandibular nerve, and the posterior that arises with the masseteric nerve. This nerve passes through the lateral pterygoid to enter the deep surface of temporalis.

Based on previous studies, we can refer to the aspect of nerve distribution of temporalis (Choi et al., 2016). However, the relationship between the structures is still unknown.

The temporal region is where the botulinum toxin (BoNT) is injected to provide pain relief from headaches (Carruthers et al., 2001; Göbel et al., 2001). It is important to know the distribution of the nerves and arteries in the area to perform the filler injection of medication to relieve symptoms of aging or to provide cosmetic treatment (Lee et al., 2017).

The traditional cadaveric study can determine the distribution of certain nerves and arteries. However, these structure can only identify the surface of the temporalis, leaving the distribution pattern within the muscle unknown. An anatomical understanding of the structure is essential for safe, non-invasive treatment. Utilizing only the information of the distribution patterns observed superficially on the surface of the muscle cannot be considered a safe clinical approach.

For the above reasons, in this study, Sihler's staining was used to determine the distribution of nerves and arteries in the temporalis. This staining method poses no risk of damaging the nerve endings, and is one of the most effective ways to visually observe the distribution and endings of the nerves (Choi et al., 2016; Won et al., 2011; Yang et al., 2013). Thus, we tried to clarify the positional relationship between the artery and nerve in order to present a guideline for non-invasive treatment.

Utilizing the guideline, clinicians can have an increasingly detailed understanding of the arterial and nerval distribution in the temporalis before performing non-invasive treatment.

1.1. Temple augmentation using filler injection

Temple augmentation refers to a cosmetic procedure on the temporal region that fills with filling material to result in smoother lines in the region. When the patient has congenitally low fat in the temporal region or experiences symptoms of aging, gradual decreases of the soft tissues in the temporal region occurs, indicating a marked depression. As a result, this may cause the temporal region to be depressed, or the skeleton of the zygomatic bone and orbital rim region to be prominent. In this case, various filling materials can be used to ameliorate the situation. Typically, dermal filler injections are used to fill the deficient volume because the injection can be performed easily in a short time. It is also used for various symptoms because it is possible to return to daily life with less pain thanks to such fillers. However, filler injections must be performed very carefully based on anatomical knowledge and clinical experience. The temporal region can be divided into five layers: the skin, subcutaneous tissue, superficial temporal fascia, deep temporal fascia, and temporalis muscle. Various blood vessels are distributed in these areas. If the filler agent is injected into a blood vessel, there is a risk of side effects such as bruising, swelling, and skin necrosis.

Previous studies have identified anatomical structures and suggested guidelines for safe injections. They focused on injections that avoid the STA and middle temporal vein (Jung et al., 2014). However, these studies are limited to the structure of the muscle surface, and the DTA, which is the main vessel distributed in the temporalis, has not been considered.

1.2. Headache treatment using botulinum toxin injection

BoNT-A reportedly has fewer side effects than other commonly used headache-relieving drugs. Also, the BoNT treatment can persist up to 4 months, compared to oral administration drugs and lidocaine injections (Dodick et al., 2004; Chan et al., 2009). Recently, BoNT injections have been widely used as a method to relieve headaches. Headaches can be divided into the primary and the secondary types, developed by a variety of causes. The primary headache is symptom-free without a specific cause, while the secondary headache is due to a specific cause. In the case of a tension-type headache, it is common practice to inject along the trigger point where the patient feels pain in the head and neck area muscles. In the case of migraine headaches, there are 31 BoNT injection points approved by the US Food and Drug Administration. However, there is no scientific evidence to explain how these injection points were determined (Cavallini et al., 2014). These only resulted from the synthesis of the comprehensive studies that have been conducted to an accepted theory. In other words, it is a method of clinicians injecting subjectively based on the patient, rather than scientifically based on nerve distribution patterns or the function of BoNT. If a large amount of BoNT is injected based on an unclear guideline, unexpected symptoms may occur. Most importantly, when performing BoNT injections to the patient, it is important to inject the appropriate amount of agent accurately on the nerve ending points.

Recently, the notion of vascularity that BoNT acts on the nerves and relaxes the hypertension muscles has been suggested. Furthermore, beyond the classical theory, it is suggested that BoNT acts on blood vessels and is effective in the treatment of migraines (Iversen et al., 1990; Drummond et al., 1983). Thus, beyond the existing concept of BoNT injection, a proposal for a new injection point that can be explained by vascularity is needed.

2. Materials and Methods

Part I: Dissection study

Twenty-eight hemifaces of cadavers (28 hemifaces; 16 males, 12 females; mean age 79.8) with no trauma or surgical procedures on the temporal region were used. All of the specimens were fixed, and the arterial distributions of the temporalis were confirmed. In all specimens, red coloring latex (Neoprene; lot No. 307L146, DuPont De Nemours, Puteaux, France) was injected into the common carotid artery before the dissection to enable clear visualization of the arterial distribution.

After removal of the skin, subcutaneous tissue was gradually removed to expose the STA. At this layer, the STA rises to the surface of the temporoparietal fascia, and the MTA is observed to perforate the temporal fascia and branch into the temporalis. After the entry point of the MTA was confirmed, it was conserved very carefully. Following the procedure above, the temporoparietal fascia and deep temporal fascia were removed in order to completely reveal the temporalis, layer by layer.

To more clearly observe the temporalis, the origin area of the masseter was removed from the zygomatic arch to clearly expose all the parts of the zygomatic arch. After that procedure, the anterior and posterior parts of the zygomatic arch were carefully cut off. During this procedure, the branches of the maxillary artery were identified and traced very carefully to clearly identify and preserve the branches of the ADTA and PDTA (**Fig. 1**).

The temporalis was observed in the coronoid process of mandible, and the MTA branches from the trunk of the maxillary artery were exposed to all aspects of the location.

Eighteen specimens were carefully dissected and measured, and the other ten specimens were stained with modified Sihler's staining solution.

There were two removal methods for the temporalis. The first option was to excoriate the tendon part of the temporalis attached to the mandible, while the second option was to cut out and extract the mandible process with the bone.

In order to minimize the damage of the temporalis, we chose to cut the mandible and extract the muscles. As a final step, the periosteal elevator was used to remove all parts of the temporalis with great care to prevent damage to the muscular tissue inserted into the bone.

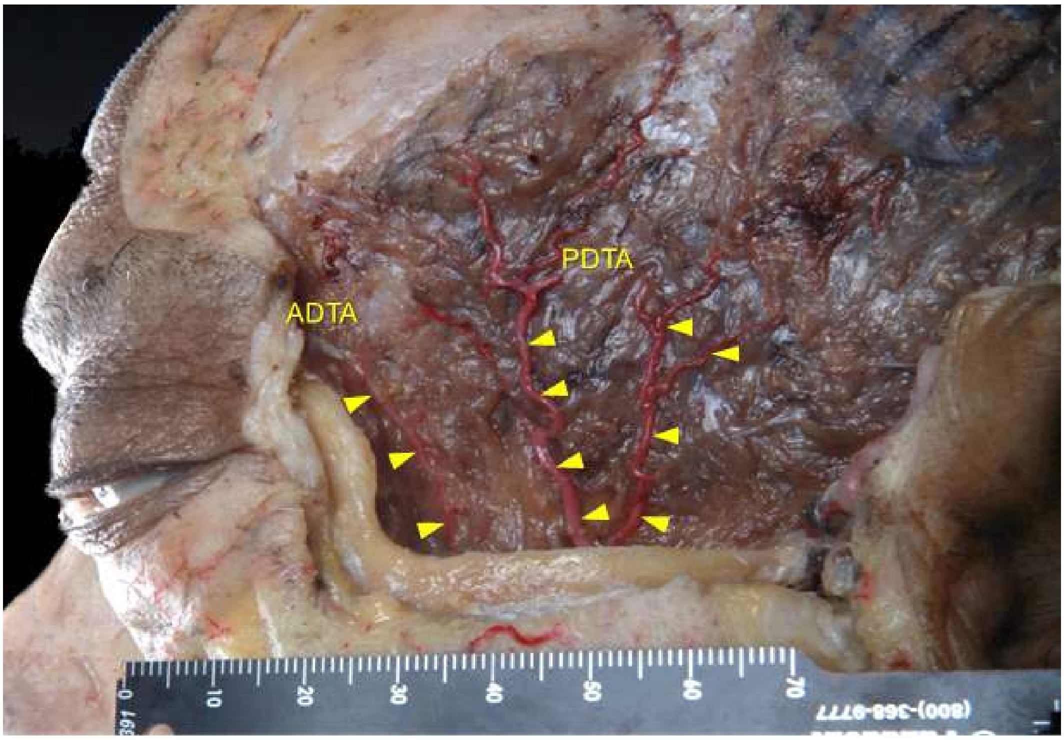

Figure 1. The cadavers injected with red coloring latex were dissected and exposed the ADTA and PDTA. The procedure proceeded very carefully to prevent damage to the originate of the artery. After the bony landmark designated as reference points were completely exposed, photographs were taken and measurements were made using an image analysis program (Image J, National Institutes of Health, Bethesda, MD, USA).

Part II: Modified Sihler's Staining study

Sihler's staining was applied to confirm the nerval distribution pattern of temporalis in this study. The Sihler's staining technique used in this study was modified by Liam et al (1988), Choi et al (2016), and Won et al (2011). The Sihler's staining process is explained with the seven steps below. All steps must be performed very delicately, and the staining process usually takes more than six months to complete.

1. Fixation

The temporalis muscle, which was dissected from the cadaver, was stored in 10% unneutralized formalin (DUKSAN, Ansan, Korea) for 3 to 4 weeks. There is no need to replace the solution, but the storing period should be adjusted depending on the size and thickness of the specimens. Continuous observation was performed.

2. Maceration

The fixed specimens were washed with running water for 1 hour and stored in 3% potassium hydroxide (JUNSEI, Tokyo, Japan) solution. 3% aqueous potassium hydroxide solution contained 0.2 mL of 3% hydrogen peroxide (DUKSAN, Ansan, Korea) per 100 mL. This process usually takes 1 month. The transparency of the specimens was observed and the storing period was adjusted. The solution was replaced with a fresh solution every day.

3. Decalcification

The macerated specimens were kept for 1 month in Sihler's solution I, which comprises of glacial acetic acid (DUKSAN, Ansan, Korea), glycerin (DUKSAN, Ansan, Korea), and 1% aqueous chloral hydrate (Wako, Osaka, Japan) mixed in a 1:1:6 ratios. The solution was replaced weekly.

4. Staining

The decalcified specimens were placed in Sihler's solution II and stored for 3 to 4 weeks. This solution comprises of Ehrlich's hematoxylin (Acros, Morris Plains, NJ, USA), glycerin, and 1% aqueous chloral hydrate mixed in a 1:1:6 ratios. In the case of Temporalis, continuous observation was performed since the size of the specimen is small and the staining proceeds very rapidly. For clear observation, the specimens were observed on a viewing box for X-ray reading.

5. Destaining

The stained specimens were once again placed into the Sihler's solution I to make the stained muscle appear transparent since Sihler's solution II stained not only the nerve to purple, but also the muscle fibers. Thus, the transparency of the muscle was achieved through this step. If the specimens were kept in Sihler's solution II for too long, it could be decolorized to the nerve, so it was continuously observed every 2 hours.

6. Neutralization

The acidified specimens were washed in running water for 30 minutes and then neutralized for about one hour in 0.05% lithium carbonate solution (DUKSAN, Ansan, Korea).

7. Clearing

The specimens were stored in glycerin solution containing thymol crystals. The concentration of glycerin was gradually increased over four steps (40%, 60%, 80%, 100%) until the specimens were finally stored in 100% glycerin.

Measurement Protocol

To analyze the arterial distribution, a reference line was set perpendicularly based on the zygomatic process in the dissected specimens. The distance from the reference line to ADTA and PDTA was measured at the eyebrow level, zygomatic tubercle level, and zygomatic arch level, respectively (**Fig. 2**). The distance was measured using an image analysis program (Image J, National Institutes of Health, Bethesda, MD, USA) at each level.

In addition, the zygomatic process and the posterior border of the external ear were set as the anterior and posterior boundary, while the temporomandibular joint and temporal line were set as the superior and inferior boundary. Collectively, these boundaries divide the temporalis into a quadrant. After dissecting and exposing the ADTA and PDTA, the divisional surface where the arterial trunk and terminal end was also located and confirmed.

The extracted temporalis specimens were subjected to Sihler's staining in seven steps to observe the distribution of nerve and vascular distribution. After completion of the staining, the muscle belly part of the temporalis was demineralized to reveal the clearly visible running of ADTA and PDTA.

The specimens were analyzed in detail on X-ray reading illumination, and photographs were taken to mark the location of the nerve endings in the muscle (**Fig. 3**). Identical to the method of analyzing the artery, the temporal region was divided into quadrants based on the shape of the temporalis, and the most observed division of the nerve endings was confirmed.

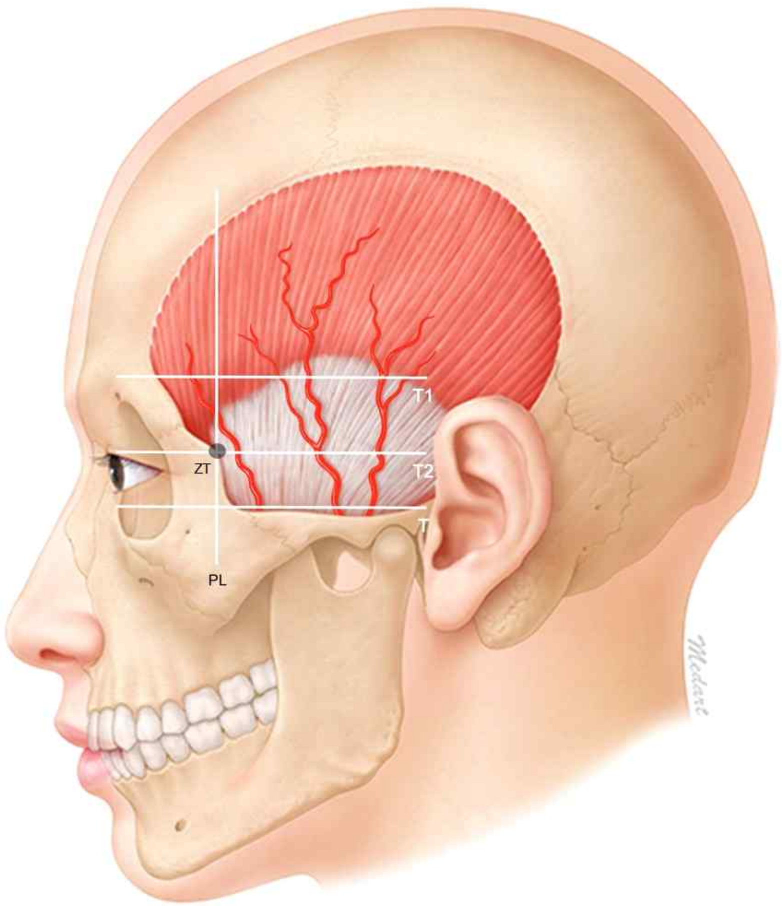

Figure 2. Reference line for measuring the distance of ADTA and PDTA. ZT, zygomatic tubercle, the most protruding point of the zygomatic bone; PL, Parallel lines passing through the ZT; T1, the horizontal line passing through eye brow level; T2, the horizontal line through the zygomatic tubercle; T3, the horizon line passing through zygomatic arch.

Figure 3. The muscle belly part and tendon part are clearly distinguished from the Sihler's stained specimens. The ADTA, PDTA (red arrows) and DTN (white arrows), which are distributed in the temporalis, are observed on the viewing box for X-ray reading. The arteries and nerves run together, and nerve endings are mainly distributed near the poterior upper part of the muscle belly.

3. Results

The arteries observed in the dissected temporalis were reversed and confirmed to be branched from the ADTA and PDTA of the Maxillary artery.

ADTA

Cadaveric study showed that ADTA was located in both the zygomatic arch and zygomatic tubercle levels in the range of about 4.48±2.07 mm and 4.37±1.65 mm, respectively. While on the eyebrow level, ADTA was located in the wide region of 3.20±8.27 mm (**Fig. 4**; **Table 1**).

PDTA

The PDTA was located in a relatively constant region at the zygomatic arch and zygomatic tubercle level, and the distances were 18.08±3.51 mm and 18.5±2.26 mm, respectively. And the arteries was found to be located in a wide region ranging from 22.84±9.75 mm at the eyebrow level (**Fig. 5**; **Table 2**).

According to these results, at the zygomatic tubercle level, ADTA was located up to 7.2 mm and PDTA was located at a minimum of 14.8 mm. In other words, 7 mm to 14 mm can be regarded as an avascular zone at which no deep temporal artery is observed.

In the stained specimens, we observed ADTA and PDTA in the temporalis. And the MTA, the branch of STA on the surface of the temporalis, was distributed in the muscles and anastomosis with the DTA. In addition, the dyed nerve distribution was traced to clearly confirm that the DTN runs with the branches of the ADTA and PDTA (**Fig. 3**).

The results confirm identification and analysis of nerve endings, and analysis points revealed that, in all cases, most nerve endings were located at the posterior upper part of the temporalis.

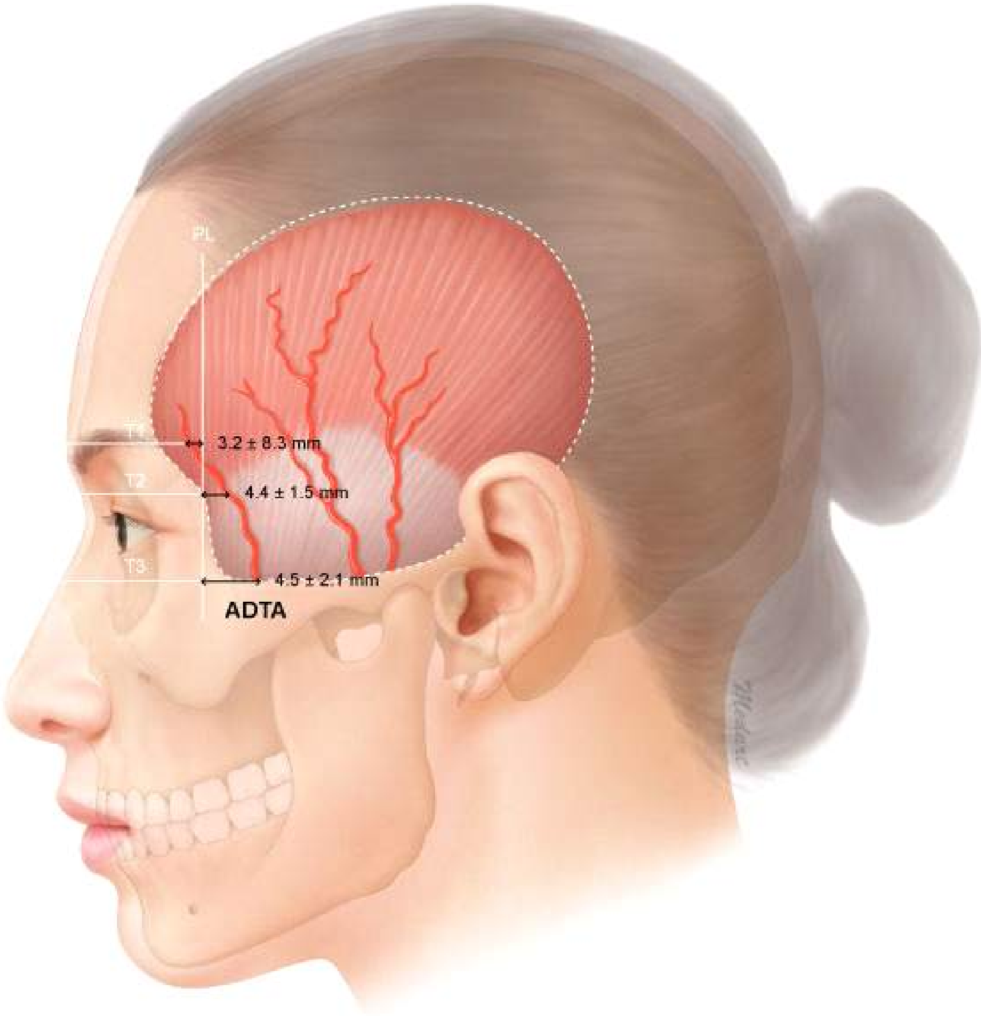

Figure 4. The distance between the perpendicular line (PL) and anterior deep temporal artery (ADTA), in the T1 was 3.2 ± 8.3 mm; in the T2 was 4.4 ± 1.5 mm; in the T3 was 4.5 ± 2.1 mm; T1, the horizontal line passing through eye brow level; T2, the horizontal line through the zygomatic tubercle; T3, the horizon line passing through zygomatic arch.

Table 1. Mean Distances from Perpendicular Line (PL) to the Anterior Deep Temporal Artery (ADTA)

Points	Mean(±SD) Distance, mm	Max. Distance, mm	Min. Distance, mm
At the level of Eyebrow	3.20(±8.27)	14.6	-5.0
At the level of Zygomatic tubercle	4.37(±1.65)	7.2	3.0
At the level of Zygomatic arch	4.48(±2.07)	7.4	2.1

In all cases, ADTA was observed. Measurements were performed on three levels based on parallel lines passing through the zygomatic tubercle. ADTA was located relatively constant within the range of 2.1-7.4 mm and 3.0-7.2 mm at zygomatic arch and zygomatic tubercle levels, respectively. However, at the eyebrow level, it was found to be sporadic in a wide range of -5.0 to 14.6 mm.

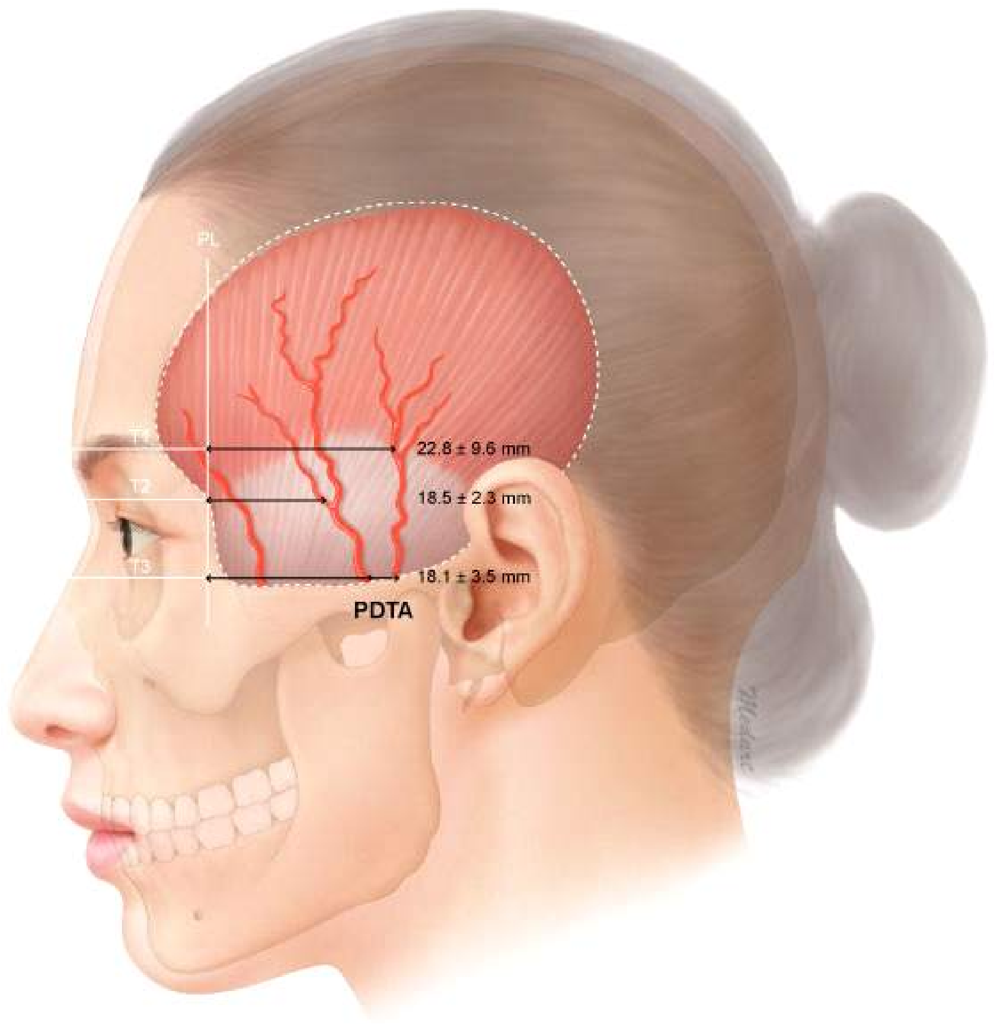

Figure 5. The distance between the perpendicular line (PL) and posterior deep temporal artery (PDTA), in the T1 was 22.8 ± 9.6 mm; in the T2 was 18.5 ± 2.3 mm; in the T3 was 18.1 ± 3.5 mm; T1, the horizontal line passing through eye brow level; T2, the horizontal line through the zygomatic tubercle; T3, the horizon line passing through zygomatic arch.

Table 2. Mean Distances from Perpendicular Line (PL) to the Posterior Deep Temporal Artery (PDTA)

Points	Mean(±SD) Distance, mm	Max. Distance, mm	Min. Distance, mm
At the level of Eyebrow	22.84(±9.75)	34.3	2.1
At the level of Zygomatic tubercle	18.5(±2.26)	20.6	14.8
At the level of Zygomatic arch	18.08(±3.51)	21.5	13.2

In all cases, two main branches of PDTA was observed. Similarly, measurements were performed on three levels based on parallel lines passing through the zygomatic tubercle. PDTA was located relatively constant within the range of 13.2-21.5 mm and 14.8-20.6 mm at the zygomatic arch and zygomatic tubercle levels, respectively. Like the preceding results, at the eyebrow level, it was found to be sporadic in a wide range of 2.1 to 34.3 mm.

4. Discussion

Most skeletal muscles are surrounded by fascia, making it easy to distinguish each structure. In contrast, there is no fascia in the facial muscles as they originate from the bones, and it is difficult to clearly distinguish between their boundaries and location, such as their insertion into the skin. It is located along several unclear layers of muscle blood vessels and nerves. For this reason, it is difficult to specify treatment guidelines for the facial region.

The temporal area is the site where the filler treatments for increasing volume and BoNT treatments for cosmetic procedures and pain relief are performed variously. However, all these procedures are still being performed based on experience.

We already know that ADTA and PDTA are branched from the maxillary artery and distributed in temporalis thanks to many anatomical textbooks. Two main trunks of the ADTA and the PDTA run into the muscle. In addition, we also know that the DTN is distributed in the temporalis out of several trunks, running parallel to the arteries and widely supplied to the muscles (Standring et al., 2008). Although various treatment guides have been proposed, none of the guidelines have been found to prevent damage to blood vessels and nerve structures in the temporalis. So, we wanted to identify whether the commonly used procedures were the safest and most effective ways through anatomical analysis.

We performed a morphological analysis of the fixed cadavers to map the exact location of the arteries and nerves in muscle. At the same time, we performed Sihler's staining to overcome the limitations of a traditional cadaveric study. We also used cadavers injected with red coloring latex to compare the results from both of the studies.

In some cases of dissected specimens, we found that ADTA travels more inward compared to the margin of the zygomatic bone. To determine the point where the arteries were not damaged, we measured the most prominent structure ZT, which is readily identifiable, and palpable structures on the surface of the face.

The temporal region can be divided into five layers and the blood vessels run in a complicated manner throughout multiple layers. The filler products injected near the blood vessels can create pressure to restrict arterial circulation and may cause localized or enlarged skin necrosis along the vascular flow. While it depends on the size of the compressed blood vessels, this is a typical side effect of filler injections. Furthermore, symptoms such as bruising or swelling may occur. Therefore, care must be taken to prevent injection into the blood vessels.

Decrease of the soft tissue volume in the temple area may lead to an aged appearance. Temple augmentation procedures have been frequently performed in patients with depressed temples. Injection of fillers into the temple area can lead to a smoother line from the side of the forehead to the zygomatic prominence.

There are two layers that are generally used clinically for filler injections in the temple area. Moradi et. al suggested the injection plane to be the subcutaneous layer or just deep to the temporoparietal fascia (Moradi et al., 2011). The second layer is just above the bony surface of the temporal fossa. Raspaldo et. al suggested injecting the anteroinferior quadrant, followed by the anterosuperior quadrant in order to avoid facial nerve damage (Raspaldo et al., 2011). According to the results presented in this study, the anterosuperior quadrant of temporalis is in the branch of DTA. The clinician should consider and understand anatomical structures when injecting a filler to this area. Deep injections to this layer can avoid the following three major vascular structures: STA running within the temporoparietal fascia, the middle temporal vein traveling along the intermediate fat pad, and the middle temporal artery giving branches to supply the deep surface of temporalis muscle (Jung et al., 2014; Talmage et al., 2015).

Clinicians should consider the deep temporal arteries while proceeding deep injections to the temple area because these arteries run between the temporalis muscle and the bony surface of the temple area. Intravascular injection to the deep temporal arteries may lead to blindness because the anterior deep temporal artery may potentially lead to anastomosis with the ophthalmic artery (Amans et al., 2014).

The DTA is not fully considered in practice compared to the above requirement. The results of this study showed that ADTA and PDTA were very sporadic at the eyebrow level, but at a relatively constant range at the ZT and ZA levels. At the ZT level, the distance of ADTA and PDTA were 4.37 ± 1.65 mm and 18.5 ± 2.26 mm, respectively. Also, at the

ZA level, ADTA and PDTA were located in 4.48 ± 2.07 mm and 18.08 ± 3.51 mm.

The ADTA and PDTA are branched at the deep part of the temporalis by a single branch, but they rise upwards and divide into several parts, spreading widely throughout the muscles. Through this study, we measured the arterial distribution by quantifying it and, according to the results, 7 mm to 14 mm of the distribution can be judged at the aygomatic tubercle level, to be an avascular zone in which no DTA is observed. To proceed filler injection at the level of the eyebrow, clinicians should be more concerned about the DTA.

In other cases, the temporal region is also the site of various injections of BoNT. When the upper face appears wider and the muscle appears prominent, or when the muscles of the temporal area are excessively protruding while chewing the food, the BoNT is injected to make the muscles contracted. This is because the temporalis is well developed. In this case, clinicians perform a procedure that atrophies the overgrown muscles.

In recent years, BoNT treatment for the relief of headaches has been carried out beyond the cosmetic procedure level. The most common headache in modern people is the primary headache without a systemic disease, of which tension type headache and migraine headache are most common. Most of the modern people have experienced headaches, and various environments such as stress and living environment are suggested as the main causes of the headaches, making it a disease that affects the patients' quality of life. Until now, no definitive treatment has been disclosed, but recent studies have shown that BoNT is very effective.

Through various studies, it has become known that the BoNT can be injected precisely into the distal portion of the nerve to obtain maximum effectiveness. Other previous studies have reported that the effect of BoNT injection on the tendon part of temporalis is significantly reduced (Choi et al., 2016; Lee et al., 2017). According to their results, the tendon part of temporalis is located approximately 45 mm above the jugale. In other words, when the clinician performs a BoNT injection, it has to be targeted in the muscle belly part at least 45 mm above the jugale (Choi et al., 2016).

Based on the results of this study, it was revealed that the ending of the DTN is clearly concentrated in the upper part of the temporalis. The DTN does not spread and distribute to all parts of the temporalis, but rather runs across the muscle and ends at the edge of muscle.

Based on these results, we present a reliable guideline for noninvasive treatment that considers the distribution of arteries and nerve distribution in muscles.

The location of the temporalis muscle can be identified easily by having the patients clench (ie, masticatory movement). This action produces an identifiable impulse that can be determined as the temporal line. Thus, the clinician can identify the superior border of the temporalis by promoting the temporal line through the palpate.

For this procedure, it is desirable to target the injection point to the lateral-inferior side of 1 cm or more because the lateral border of the frontalis is located up to 1 cm to the lateral of the temporal line. However, BoNT acts on the frontalis, which may cause unexpected effects (**Fig. 6**).

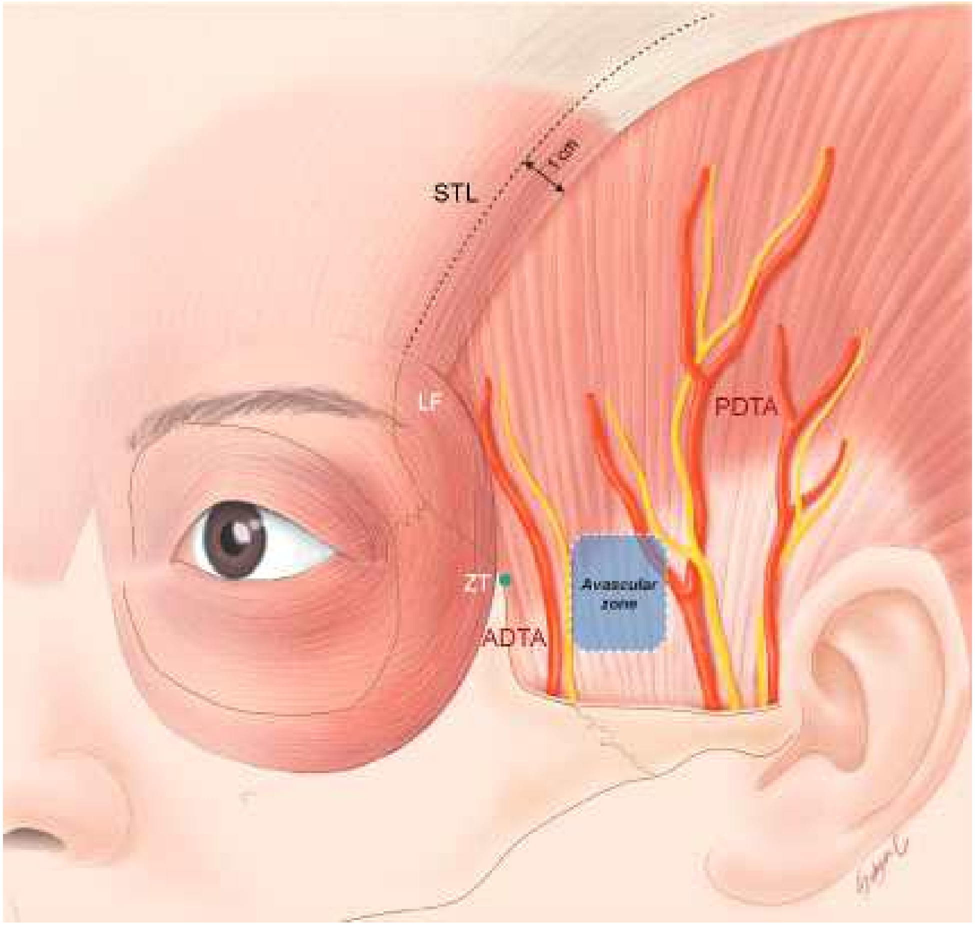

Figure 6. Several steps for non-invasive treatments into the temporalis region. When injecting fillers, clinicians should be aim for an avascular zone where anterior deep temporal artery (ADTA) and posterior deep temporal artery (PDTA) are not located. The zygomatic tubercle (ZT), which is the protruding part of the zygomatic bone, is confirmed by palpation, and it is aimed at 1 cm of the lateral. When performing botulinum toxin (BoNT) injections, the end of the deep temporal nerve should be aimed at the almost edge of the temporalis. First, identify and promote the superior temporal line. The lateral border of the frontalis (LF) is recognized to be extended 1 cm beyond. Therefore, the BoNT is injected along the superior temporal line (STL) with a distance of 1 cm or more.

5. Conclusions

ADTA and PDTA can be used as landmarks to estimate the position of skin surface structures. In this study, we confirmed that ADTA and PDTA are located at a certain distance from each other. When non-invasive treatment is applied to the temporal region to reflect these results, we can minimize side effects and maximize injection efficiency.

Clinicians can easily identify the location of the facial landmark zygomatic tubercle and temporal line in this study through facilitation. In the temporal area, the filler injection targets the deep space between the periosteum and the muscle. Based on the zygomatic tubercle, aiming at 1 cm of the lateral point can significantly reduce arterial injury. The injection of the BoNT is more effective when it is injected while targeting the nerve endings correctly. A simple and effective procedure can be carried out by simple palpation and by injecting a constant distance from the temporal line.

Based on a comprehensive understanding of the results in this study, clinicians are able to safely and effectively perform a variety of non-invasive treatments in the temporal region.

6. References

Standring S: Gray's anatomy 40th edition. Section 4, Churchill Livingstone, Elsevier, 2008

Watanabe K, Shoja MM, Loukas M, Tubbs RS: Anatomy for plastic surgery of the face, head, and neck, Chapter 4, Newyork, Thieme, 2016

Liem RS, Douwe van Willigen J: In toto staining and preservation of peripheral nervous tissue. Stain Technology 63:113 - 120, 1988.

Choi YJ, Lee WJ, Lee HJ, Lee KW, Kim HJ, Hu KS: Effective botulinum toxin injection guide for treatment of temporal headache. Toxins 8(9):265, 2016.

Won SY, Kim DH, Yang HM, Park JT, Kwak HH, Hu KS, Kim HJ: Clinical and anatomical approach using Sihler's staining technique (whole mount nerve stain). Anatomy and Cell Biology 44:1 - 7, 2011.

Yang HM, Won SY, Kim HJ, Hu KS: Sihler staining study of anastomosis between the facial and trigeminal nerves in the ocular area and its clinical implications. Muscle and Nerve 48:545 - 550, 2013.

Jung WS, Youn KH, Won SY, Park JT, Hu KS, Kim HJ: Clinical Implications of the Middle Temporal Vein With Regard to Temporal Fossa Augmentation. Dermatology Surgery 40(6):618 - 23, 2014.

Lee WK, Bae JH, Hu KS, Kato T, Kim ST; Anatomical recommendations for safe botulinum toxin injection into temporalis muscle: a simplified reproducible approach. Surgical and Radiologic Anatomy 39(3):263-269, 2017.

Dodick VW, Blumenfeld A: Silberstein, S.D. Botulinum neurotoxin for the treatment of migraine and otherprimary headache disorders. Clinics in Dermatology 22(1):76-81, 2004.

Chan VW, McCabe EJ, MacGregor DL: Botox treatment for migraine and chronic daily headache in adolescents. Journal of Neuroscience Nursing 41:235 - 243, 2009.

Iversen HK, Nielsen TH, Olesen J: Arterial responses during migraine headache, The Lancet 336:837-839, 1990.

Drummond PD, Lance JW: Extracranial vascular changes and the source of pain in migraine headache. Annals of Neurology 13(1):32-37, 1983.

Cavallini M: The setting of a botulinum toxin treatment service. Neurological Sciences 35(1):49 - 50, 2014.

Carruthers J, Carruthers A: Botulinum toxin (Botox) chemodenervation for facial rejuvenation. Facial Plastic Surgery Clinics of. North America 9:197 - 204, 2001.

Göbel H, Heinze A, Jost WH: Evidence-based medicine: Botulinum toxin A in migraine and tension type headache. Journal of Neurology 248:34 - 38, 2001.

Moradi A, Shirazi A, Perez V: A guide to temporal fossa augmentation with small gel particle hyaluronic acid dermal filler. Journal of Drugs Dermatology 10(6):673-6, 2011.

Raspaldo H, Aziza R, Belhaouari L, Berros P, Body S, Galatoire O, Louarn C, Michaid T, Niforos F, Rousseaux I: How to achieve synergy between volumetry and filling products for global facial rejuvenation. Journal of Cosmetic and Laser Therapy 13:77 - 86, 2011.

Jung W, Youn KH, Won SY, Park JT, Hu KS, Kim HJ: Clinical implications of the middle temporal vein with regard to temporal fossa augmentation. Dermatology Surgery 40(6):618-23, 2014.

Talmage GD, Sunde J, Walker DD, Atlas MD, Gluth MB: Anatomic basis of the middle temporal artery periosteal rotational flap in otologic surgery. The Laryngoscope 126:1426-1432, 2016.

Amans MR, Narvid J, Halbach VV: Intra-arterial chemotherapy for bilateral retinoblastoma via left ophthalmic artery and right anterior deep temporal artery. BMJ Case Report doi: 10.1136/bcr-2014-204549, 2014.

Abstract (in korean)

안전한 비침습적치료를 위한 관자근의 동맥 및 신경분포

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최 광 석

관자근은 관자우묵과 관자근막 깊은 곳에서 두 층으로 일어나 아래턱뼈의 근육돌기로 닿는 근육으로, 아래턱뼈를 위로 올려 입을 다무는 기능을 한다. 대부분의 이는곳은 근육 힘살로 구성되어 있으나 근육의 중간 부위부터는 힘줄을 이루며 달리는 것을 확인할 수 있다. 관자근의 표면에서는 바깥목동맥의 가지인 얕은관자동맥이 매우 굵게 주행하는 것을 관찰할 수 있지만, 관자근에 분포하는 주된 동맥은 위턱동맥에서 분지된 앞깊은관자동맥과 뒤깊은관자동맥이며, 깊은관자신경이 동맥의 가지와 나란하게 주행하는 양상을 보인다.

관자부위는 보툴리눔독소를 이용한 긴장성두통 및 관자근 비대 치료, 필러를 이용한 관자근 함몰 치료 등 다양한 비침습적 치료가 이루어지는 부위이다. 하지만 관자근에 분포하는 주된 혈관과 신경인 깊은관자동맥과 깊은관자신경에 관한 연구가 미비한 실정이다. 본 연구를 통하여 근육 속에서 주행하는 신경분포양상을 관찰하고 동맥과의 위치관계를 규명하여 안전하고 정확한 주사를 위한 가이드라인을 제시하고자 한다.

Latex 가 주입된 한국인과 태국인 시신 28 쪽 (남: 16, 여: 12; 평균나이: 79.8 세)을 사용하였다. 관자근에 분포하는 깊은관자동맥과 신경을 세밀하게

해부하여 계측하였으며, 선별한 시신에서 관자근을 10쪽을 적출하여 Sihler 염색을 시행하였다.

계측은 광대결절을 지나는 수직선을 그어 기준선을 설정하고, 눈썹, 광대돌기, 광대활 선상에서 앞깊은관자동맥과 뒤깊은관자동맥까지의 거리를 계측하였다. 주행양상의 분석을 위해 관자근의 형태를 기반으로 사분할로 구분하였다. 이를 기준으로 시신의 관자근에서 깊은관자동맥의 가지와 종말 부위가 밀집하는 분할을 확인하였다.

해부를 진행한 관자근과 염색된 관자근 표본에서 깊은관자동맥과 신경이 함께 주행하는 양상을 확인하였다. 앞깊은관자동맥은 광대활과 광대돌기 선상에서 3.2±8.6 mm, 4.4±1.5 mm 떨어져 위치하는 것으로 관찰되었으며, 눈썹 선상에서는 4.5±2.1 mm에서 분하였다. 뒤깊은관자동맥은 광대활과 광대돌기 선상에서 22.8±9.6 mm, 18.5±2.3 mm로 비교적 일정한 영역에 위치하였으며, 눈썹 선상에서는 18.1±3.5 (2.1~34.3) mm로 다소 산발적으로 분포하는 것을 확인하였다. 관자근의 앞아래 분할에는 깊은관자동맥의 가지가 넓은 영역으로 분포함을 확인하였으며, 위쪽 분할에 대부분의 신경말단이 위치함을 관찰하였다.

관자부위는 다양한 해부학적 구조물이 여러 층에 걸쳐 복잡하게 위치하고 있다. 효과적이고 안전한 비침습적 치료를 위해 혈관 및 신경의 손상을 최소화하고, 목표한 지점을 정확하게 표적하는 것이 중요하다. 본 연구의 결과, 필러를 시술할 경우 광대돌기 선상에서 약 1cm 내외 지점을 목표로 자입하면 깊은관자동맥이 손상될 위험이 줄어든다. 보툴리눔독소를 시술할 경우 위쪽 분할면에 안전하게 주입하기 위하여, 관자선을 촉진하고 1cm 가쪽의 지점을 따라 주사하면 보다 정확하게 신경말단을 표적한 주사가 가능하다.

핵심되는 말 : 관자근, 쉴러염색법, 일차성두통, 관자근비대, 보툴리눔독소, 필러