Anatomical basis for simultaneous block of greater and third occipital nerves, with an ultrasound-guided technique

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Abstract

Purpose: In some headache disorders, for which the greater occipital nerve block is partly effective, the third occipital nerve is also suggested to be involved. We aimed to establish a simple technique for simultaneously blocking the greater and third occipital nerves.

Methods: We performed a detailed examination of dorsal neck anatomy in 33 formalin-fixed cadavers, and deduced two candidate target points for blocking both the greater and third occipital nerves. These target points were tested on three Thiel-fixed cadavers. We performed ultrasound-guided dye injections into these points, examined the results by dissection, and selected the most suitable injection point. Finally, this target point was tested in three healthy volunteers. We injected 4 ml of local anesthetic and 1 ml of radiopaque material at the selected point, guided with a standard ultrasound system. Then, the pattern of local anesthetic distribution was imaged with computed tomography.

Results: We deduced that the most suitable injection point was the medial head of the semispinalis capitis muscle at the C1 level of the cervical vertebra. Both nerves entered this muscle, in close proximity, with little individual variation. In healthy volunteers, an anesthetic injected was confined to the muscle and induced anesthesia in the skin areas innervated by both nerves.

Conclusion: The medial head of the semispinalis capitis muscle is a suitable landmark for blocking the greater and third occipital nerves simultaneously, by which occipital nerve involvement in various headache disorders may be rapidly examined and treated.

Introduction

In pain clinics, occipital nerve blocks are often performed to alleviate headache disorders. When criteria are applied based on the official classification of headache disorders, established by the International Headache Society (ICHD-3β) [1], headaches relevant to the greater occipital nerve (GON) and/or the third occipital nerve (TON) can be identified to be cluster headache (ICHD-3β: 3.1) [2, 3], cervicogenic headache (ICHD-3β: 11.2.1) [4], occipital neuralgia (ICHD-3β: 13.4) [5-7], headache attributed to craniotomy (ICHD-3β: 5.5, 5.6) [8], tension-type headache associated with pericranial tenderness (ICHD-3β: 2.1.1, 2.2.1, 2.3.1) [3], or headache attributed to cervical myofascial pain (ICHD-3β: A11.2.5) [9, 10]. However, symptoms are often obscure without diagnostic nerve blocks.

In a subset of patients with headaches, it is reported that a selective block may only partly relieve the pain [9]. This partial effect can occur, when the GON and the TON are involved and/or when communicating rami are present between two nerves, at both peripheral and central levels [5]. In fact, in cluster headache [11], and probably in cervicogenic headache [4], a functional connection has been reported to exist between the occipital nerves and the trigeminal nerve distribution. These findings suggested that at least some of the headache disorders listed above might be more efficiently relieved by blocking both the GON and the TON. Thus, by establishing a simple method for simultaneously blocking these nerves, we may provide practical guidance for examining occipital nerve involvement and for controlling the pain.

Previous reports [8, 12] have shown that the GON emerges as the large medial branch of the second cervical spinal nerve dorsal ramus, between the posterior arch of the atlas and the lamina of the axis, below the obliquus capitis inferior muscle (OCI). From there, the GON ascends between the OCI and the semispinalis capitis muscle (SSC), then it pierces the SSC and trapezius muscles, near their occipital attachments. After supplying these muscles, it ascends with the occipital artery, divides into branches, and supplies neural transmission to the skin of the scalp, extending forward

as far as the vertex. The superficial medial branch of the third cervical dorsal ramus, the TON, curves around the lateral and dorsal surfaces of the C2-3 facet joint, which it supplies. Just above the C2 spinal process, the TON turns dorsally to pierce the SSC, splenius capitis, and trapezius muscles, and becomes cutaneous over a small area immediately below the superior nuchal line [12]. However, the mutual relationships between the GON and the TON in each muscle layer remain unknown.

Reportedly, the GON can be blocked at the peripheral [2, 13, 14], intermediate [15], or central level [7] and the TON at the central level [6]. The peripheral approach is to localize the GON for injection blindly with [13, 14]/without [2] identifying the occipital artery with the Doppler method. However, due to the large individual variations in the projection and branching patterns of the GON, a blind injection is not target-specific, and it requires the imprecise use of large volumes of analgesics. The intermediate approach is to identify the GON at the point where it exits the SSC [15], whereas it cannot ensure a block of the TON. In the central approach, the ultrasound-guided method identifying the part of the GON located superficial to the OCI is reported [7]. The only method reported that achieved a selective TON block is a central approach, injection into the lateral surface of the C2-3 facet joint [6, 16]. However, both blocks are deep approaches that require some technical skill [6, 7]. Especially, in obese patients, these approaches may become quite difficult [6]. Thus, to our knowledge, a method for blocking the GON and the TON easily and simultaneously has not been established.

The objective of this study was to establish a methodology for this block. We performed a detailed examination of the neck anatomy in formalin-fixed cadavers, and we deduced potential target points, in the fashion described in a previous study, where the deep cervical plexus and cervical sympathetic tracts were blocked [17]. To verify our deduction, we performed a dye injection study in Thiel-fixed cadavers, guided by an ultrasound system with a linear transducer. Then, we tested the most suitable injection point in healthy volunteers by 3-dimensional computed tomography (3D-CT), after injecting an admixture of local anesthetic and radiopaque material.

Methods

The cadavers were acquired through donations to the Dokkyo Medical University. Before death, the donors signed consent agreements to donate their bodies to be used for clinical studies. The format of these documents followed the requirements of the Japanese law: “Act on Body Donation for Medical and Dental Education.” For the part of the study that involved healthy volunteers, we obtained study approval from the IRB (number: 1643) of Koshigaya Hospital, Dokkyo Medical University, and written informed consent from all participants.

Topographic anatomy in formalin-fixed cadavers

First, we examined the anatomy of 33 Japanese formalin-fixed cadavers (right side only), including 15 males and 18 females, with a median age at death of 82 (range 59-100) years. At the nuchal level, we defined four muscular layers, represented by the OCI, the SSC, the splenius capitis, and the trapezius muscles. We examined the spatial relationships between the GON and the TON in each muscle layer.

Second, on the dorsal surface of the OCI, we examined the locations of the descending branches of the occipital artery and vein, the GON, and the TON by using the same cadavers. For each structure, we measured the position along the muscle belly, as the distance (mm) from the origin of the muscle (C2 spinous process).

Third, at the SSC layer, we also measured the distances between the GON and the TON at their entrance to and at their exit from the SSC.

Ultrasound-guided dye injection in Thiel-fixed cadavers

We designed a practical protocol for efficiently blocking the GON and the TON. Based on our data from the formalin-fixed cadavers (described below), we deduced two candidate target points, where the GON and the TON ran in close proximity with relatively little individual variation. The first target point was at the dorsal surface of the OCI, and the second was within the medial head of

the SSC. We examined these points in three Thiel-fixed cadavers that were compatible for ultrasound examinations [18]. We injected ~5 ml of water-based acrylic dye (Liquitex, International Art Materials Trade Association, NC) into each target points (n=3 for each point), guided by an ultrasound system with a 13-6 MHz linear type transducer (SonoSite M-Turbo, Fujifilm, Tokyo, Japan).

For injection at the first target point, we followed the method described by Greher et al. [7] with a minor modification (Fig. 1). Briefly, the ultrasound probe was placed on either side of the mastoid process horizontally, and then moved down the neck slowly, by which the C1 transverse process could be easily located under the hairline. Next, the probe was rotated slightly (the medial end was positioned more caudally than the lateral end) to identify the spinous process of C2, always bifid. This position was parallel to the long axis of the OCI. Within the plane of imaging, to visualize the entire shaft and tip (in-plane technique)[19], a 23-G puncture needle was then inserted beneath the lateral border of the probe, and advanced medially, until the needle tip was positioned exactly on the dorsal surface of the OCI. Then, 5 ml of dye was injected at the midpoint of the OCI.

For injection at the second target point (Fig. 2), we employed a horizontal orientation of the probe on either side of the nuchal ligament at the C1 level of the cervical vertebrae. By this, the medial head of the SSC, which was separated from the lateral head by the tendinous septum as stated in the result (Fig. 2B, C, white line), could be readily identified. By in-plane technique [19], a 23-G puncture needle was then inserted from the midline at the C1 level beneath the lateral border of the probe, and advanced laterally, until the needle tip was positioned within the medial head of the SSC. Then, 5 ml of dye was injected. We did not identify the TON and the GON, because it was practically very difficult to align the plane of imaging with the TON (not shown). It is only possible to image nerves that run parallel or oblique to the transducer [19], and the TON pierced the SSC nearly perpendicular to the transducer, as described in the Results.

Ultrasound-guided anesthetic injection in healthy volunteers

Three volunteers received a 5 ml injection of a mixture containing iopamidol (1 ml) and 1% mepivacaine (4 ml) into the deduced target point. The blockade of either the GON or the TON was examined with pinprick and cold tests on the skin areas innervated by these nerves, according to previous reports [6, 12]. In detail, at the level of the superior nuchal line, we examined the central area, within 10 mm from the external occipital protuberance, to test blockade of the TON; from that point, we moved laterally, 20-30 mm, to test blockade of the GON. For the 3D-CT helicoidal scan of the head and neck, we employed a volume-rendering technique to characterize the spread of the injected local anesthetic.

Results

Spatial relationships between the GON and TON and the OCI

In 33 formalin-fixed cadavers (Fig. 3), upon exposing the OCI, we could identify the GON in all cases; we identified the TON in 32 cases. In 32/33 cases (97%), the GON was located on the dorsal surface of the OCI, between the C1 and C2 levels. In one case (3%), a branch of the GON pierced the OCI.

We also examined relationships between the nerves and blood vessels on the dorsal surface of the OCI (n=33 cadavers) (Fig. 4). The mean length of the OCI from the muscle origin (C2 spinous process, located on the midline) to its insertion (C1 transverse process) was 54.0 ± 4.7 mm. The GON passed through the OCI at a point 24.0 ± 2.9 mm from the muscle origin, and the nerve diameter was 5.0 ± 1.8 mm. The occipital artery, a branch of the external carotid artery, descended through the OCI at a point 51.0 ± 8.2 mm, and the arterial diameter was 2.0 ± 0.5 mm. The occipital vein passed through the OCI at a point 14.1 ± 3.4 mm, and the vein diameter was 6.9 ± 1.0 mm, indicating that the occipital vein was in a vicinity to the GON, running ~10 mm medial to the GON.

Of note, we discovered a previously unknown, thick, fascia-like septum, between the SSC and the OCI (Fig. 3A) in all cases (100%), which was readily observed in Thiel-fixed cadavers (Online Resource 1, described below). This septum was attached to the C2 spinous process and separated the TON tract from the GON tract and the OCI. When the TON was examined after removing this septum, the TON passed through the OCI at a point 12.0 ± 5.0 mm from the muscle origin, and the nerve diameter was 4.0 ± 1.9 mm (Fig. 4). This indicated that the actual distance of the GON and the TON was ~12 mm although both were separated by the fascia-like septum.

Spatial relationships between the GON and TON and the SSC

In 33 formalin-fixed cadavers, upon exposing the SSC, we could identify the GON in all cases and the TON in 32 cases. The GON entered the SSC medially, at a level between the atlas and the occipital condyles (Fig. 3A), in 32 of 33 cases (97%), and exited at a level near the superior nuchal

line (Fig. 3B). In the one remaining case (3%), the GON divided into two branches, and one branch pierced the SSC, but the other ascended medially along the SSC muscle, without piercing it. In 31 of 32 cases (96.9%), the TON entered and exited the SSC at the C2 level, indicating that it pierced the SSC at an angle nearly perpendicular to this muscle. In one case of this SSC-piercing type, the TON divided into two branches within the SSC. In the one remaining case (3.1%), the TON did not pierce the SSC, but ascended medially along this muscle.

Of note, the SSC has two heads, the medial part is the biventer cervicis, and the lateral part is the complexus [20]. We discovered that the two heads were separated by a previously unknown, thick, tendinous septum, which was clearly visible in Thiel-fixed cadavers with ultrasound imaging and by dissection (described below). Both the GON and TON pierced the medial head of the SSC, which was separated from the lateral head by this membrane, and in most cases, their entrance points to the SSC were in close proximity to each other (Fig. 3A). The actual distance of the entrance points between the GON and the TON was 25.5 ± 5.6 mm, while the distance of their exit points from the SSC was longer, being 34.2 ± 8.8 mm (n = 17).

Spatial relationships between the GON and TON and the splenius capitis muscle

In 33 formalin-fixed cadavers, upon exposing the splenius capitis muscle, we could identify the GON in 28 cases and the TON in 31 cases. In 22 of 28 cases (78.6%), the GON did not pierce the splenius capitis, but ascended medially along this muscle (Fig. 3B, C). In six of 28 cases (21.4%), this muscle was pierced by the GON (not shown).

In 29 of 31 cases (94%), the TON pierced the splenius capitis at a level between C1 and C2 (Fig. 3B, C). In the remaining two cases (6%), the TON did not pierce this muscle, but ascended in the space between this muscle and the SSC.

Spatial relationships between the GON and TON and the trapezius muscle

In 33 cases, upon exposing the trapezius muscle, we could identify the GON in all cases and the TON in 30 cases. Both the GON and the TON pierced the trapezius, after dividing into several branches (Fig. 3D), and terminated in the skin.

In 32 of 33 cases (97%), the GON pierced the trapezius at the level of the superior nuchal line. In the one remaining case (3%), the GON ascended along the lateral margin of the trapezius.

In 29 of 30 cases (96.7%), the TON pierced the trapezius at a level between C1 and C2. In the one remaining case (1/30; 3.3%), after dividing into two branches, one branch pierced the trapezius and the other ascended between the SSC and trapezius without piercing the trapezius.

Ultrasound-guided dye injection in Thiel-fixed cadavers

Concerning the two candidate target points, one was on the dorsal surface of the OCI, the actual distance of the GON and the TON was ~12 mm although both were separated by a thick fascia-like septum (Fig. 4, Online Resource 1A, B). Another was in the medial head of the SSC where the actual distance of the entrance points between both nerves was ~26 mm (Fig. 3A).

In all three Thiel-fixed cadavers, dye injections at the first target point (n=3), the dorsal surface of the OCI (Fig. 1), caused the dye to stay in the compartment of the GON tract, but it did not spread into the TON compartment (Online Resource 1C). As noted in formalin-fixed cadavers (Fig. 3A), the TON tract was separated from the GON tract and the OCI by a fascia-like septum (Online Resource 1A, B). The inhibition of dye infiltration into the TON tract by this fascia-like septum suggested that anesthetic injection into this point blocks only the GON and blocking of the TON may be difficult.

Dye injections at the second target point (n=3), the medial head of the SSC (Fig. 2), caused the dye to stay in the medial head, and dye surrounded both the GON and TON tracts (Online Resource 2C). As described in formalin-fixed cadavers, the medial and lateral heads of the SSC were separated by a tendinous septum (Online Resource 2A, B), which was noted in the ultrasound

images as a thick, white line between the medial and lateral heads of the SSC (Fig. 2B, C). Dye did not spread into the lateral head of the SSC (Fig. 2C).

Therefore, we considered that the second target point, but not the first point is the best place for blocking of both the GON and TON and decided to perform healthy volunteer study only at the second target point.

Ultrasound-guided injection of anesthetic and contrast medium at the second target point in healthy volunteers

A 3D-CT scan showed that the contrast medium was confined to the medial head of the SSC (Fig. 5). Sensory blocks of both nerves, the TON at the central area within 10 mm from the external occipital protuberance and of the GON at the lateral area 20-30 mm from that point were observed in all volunteers. It was noteworthy, that identifying the SSC medial head and the anesthetic injection, guided with ultrasound imaging, can be performed very easily within a few minutes.

Discussion

We performed a detailed examination of dorsal neck anatomy in formalin-fixed cadavers and Thiel-fixed cadavers. Figure 6 shows a summary schematic diagram of the results. That examination led to the deduction of a candidate target injection point for blocking both the GON and the TON. These findings were confirmed in healthy volunteers, by scanning with 3D-CT and the sign of sensory block after injecting an admixture of local anesthetic and radiopaque material.

In Thiel-fixed cadaver study, the first target point we deduced seemed to have some difficulty to block the TON because of the presence of a thick, fascia-like septum, which inhibited the spread of injected dye to the compartment that held the TON. To achieve the TON block, it might be possible to penetrate the septum with a large volume of local anesthetic, but that would increase the risk of anesthetic absorption into the vein, which represents an adverse side effect. This risk was corroborated by the finding that the occipital vein was in close proximity to the GON at this point (Fig. 4).

On the other hand, the second target point, which we deduced and decided to examine in healthy volunteer study, had some advantages: First, both the GON and the TON entered the medial head of the SSC, in close proximity, with little individual variation. Second, because the SSC is large and thick and its medial head is separated by the thick septum from the lateral head, this target point is easily identifiable by ultrasound. By injecting into this point, in Thiel-fixed cadavers, the dye surrounded both the GON and the TON and stayed within the medial head. Our findings of the tendinous septum between the two heads of the SSC as well as the fascia-like septum between the SSC and the OCI have not been reported to our knowledge; therefore, we consider these to be novel anatomical findings.

In healthy volunteers, the injection solution was confined to the medial head of the SSC, and a small amount of local anesthetic (i.e., 4 ml) could produce an effective block. In fact, the thick tendinous septum separating the medial and lateral heads of the SSC may enable the anesthetic to be confined to the vicinity of both nerves, leading to an efficient nerve block. This method is the

intermediate approach, which requires less skill compared to the central approach [6, 7] with a performance time of only a few minutes, because the SSC is located more superficially and identifying its medial head is very easy. Therefore, occipital nerve involvement in various headache disorders may be rapidly examined and treated by this technique. This method may be cost-efficient and profitable in medical economics.

Concerning the intramuscular injection of anesthetics, injection into the piriformis muscle is often performed in chronic low back and sciatic pain patients [21]. We also previously reported anesthetic injection into the longus capitis muscle for blocking both the deep cervical plexus and the cervical sympathetic trunk [17]. Although a direct injection of anesthetic into the muscle may lead to myotoxicity, the degree of risk is dependent on the toxicity of the local anesthetic and the dose, frequency, and interval of the injection. Long-acting bupivacaine and ropivacaine is reported to show myotoxicity [22]. However, multiple injections of short-acting mepivacaine into the longus colli muscle did not manifest any clinical signs of cervical myopathy [23]. Trigger point injections in the treatment of headache disorders using procaine is reported to be the least likely associated with myonecrosis [10]. Taken together, these reports indicate that ultrasound-guided intramuscular injections of anesthetics are efficient and practical methods for peripheral nerve blocks and that mepivacaine-induced myopathy (if it occurs) might only occur at a subclinical level.

In conclusion, our present study indicated a new method for simultaneously blocking the GON and the TON. By this method, occipital nerve involvement in various headache disorders may be rapidly examined and treated. The first target point may be applicable for a single block of the GON. However, our findings require support from future clinical studies. Several approaches are available for a single block of the GON or the TON. Therefore, it is important to select the method most suited to the purpose for each case.

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Conflict of Interests Statement

Ken Kariya has no conflict of interest.

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FIGURE LEGENDS

Fig. 1. Ultrasound image of ultrasound-guided injection at the first target point, the dorsal surface of the OCI (obliquus capitis inferior muscle) in the Thiel-fixed cadaver. **(A)** Schematic drawings show the site of the injection between the OCI and the SSC (semispinalis capitis muscle) in the nuchal region. The injection point is (*left*) at the dorsal surface of the OCI, ~3 mm lateral to the GON (greater occipital nerve), in which injected dye is shown; (*middle*) the needle passes through the SSC and (*right*) through the splenius capitis muscles. TON, third occipital nerve. **(B, C)** Ultrasound images of an oblique section of the neck from the C2 to C1 level show the inserted needle (light blue). The tendinous septum of the SSC (white line) is drawn for comparison to Fig. 4. (**B**) Before dye injection; **(C)** after the dye injection, the space between the OCI and the SSC became enlarged. When dissected, dye was restricted to the compartment that holds the GON (see Fig. 2C).

Fig. 2. Ultrasound image of ultrasound-guided injection into the second target point, the medial head of the SSC (semispinalis capitis muscle) in a Thiel-fixed cadaver. **(A)** Schematic drawings show the site of the injection within the three muscle layers in the nuchal region. The injection point is (*left*) on top of the SSC, on the medial side of the septum (white line), in which injected dye is shown; (*middle*) the needle passes through the splenius capitis and (*right*) through the trapezius muscles. GON greater occipital nerve; TON, third occipital nerve. **(B, C)** Ultrasound images of a transverse section of the neck at the C1 level show the inserted needle (light blue) and the tendinous septum (white) between the medial and lateral heads of the SSC. (**B**) Before dye injection; **(C)** after the dye injection, the medial head of the SSC became enlarged, but not the lateral head.

Fig. 3. Spatial relationships between the GON (greater occipital nerve) and TON (third occipital nerve) and four muscle layers in the neck. (*Left panels*) Representative photographs of neck dissections are

shown at different layers. (*Right panels*) The same photographs are shown with cartoons and labels that identify the GON (yellow) and TON (light green) tracts in the obliquus capitis inferior (OCI, brown), semispinalis capitis (SSC, purple), splenius capitis (light blue), trapezius (yellow brown), and sternocleidomastoid (orange) muscles. (**A)** At the OCI layer, the GON is located at the dorsal surface of the OCI (brown). Both the GON and the TON enter the median head of the SSC in close proximity, in most cases. The SSC is lifted medially with the forceps. A fascia-like septum (white, only partly remained) is located between the GON and the TON; **(B)** At the SSC layer, the GON exits the SSC at a level near the superior nuchal line. The TON exits the SSC and enters the splenius capitis at a level between C1 and C2. **(C)** At the splenius capitis layer, the TON exits the splenius capitis at its medial border, and the GON ascends medially, along the splenius capitis. **(D)** At the trapezius layer, two branches each (red circles) of the TON and the GON exit the trapezius at its medial border.

Fig. 4. Relationships between nerves and blood vessels at the dorsal surface of the OCI (obliquus capitis inferior muscle). Removing the fascia-like septum (transparent light brown) that covers the OCI revealed the third occipital nerve (TON, green), the occipital vein (light blue), the greater occipital nerve (GON, yellow), and the occipital artery (red). (*Inset Table*) The mean distances from the origin of the muscle (mm, mean ± SD, n= 33) were calculated for the TON, occipital vein, GON, and occipital artery. The occipital vein was in a vicinity to the GON at this point. The fascia-like septum separated the TON tract from the GON tract and the OCI.

Fig. 5. Representative images of a scanographic reconstruction of the neck with 3D-CT images, after injection of a mixture of iopamidol and mepivacaine into the medial head of both sides of the SSC

(semispinalis capitis muscle), in a healthy volunteer. Outlines of the SSC are drawn (purple) in the transverse images. The contrast medium was confined to the injected site.

Fig. 6. A schematic summary diagram shows the spatial relationships between both the greater occipital nerve (GON, yellow) and the third occipital nerve (TON, light green) and the different muscle layers. Both the GON and TON entered the medial head (purple) of the SSC (semispinalis capitis muscle) in close proximity to each other. The GON and OCI (obliquus capitis inferior muscle) but not TON were covered by the fascia-like septum (light brown).

Online Resource 1. Gross image of an ultrasound-guided dye injection into the dorsal surface of the OCI (obliquus capitis inferior muscle) in a Thiel-fixed cadaver. **(A)** Schematic drawing indicates the orientation of the fascia-like septum (white lattice) that covers the greater occipital nerve (GON, yellow) and the dorsal surface of the OCI (brown); (*left*) dorsal view, (right) sagittal view. Injected dye (green) is shown beneath the fascia-like septum. **(B, C)** Serial photographs of a dissected cadaver (*left*) and the same photographs with labels (*right*). SSC, semispinalis capitis muscle. (**B**) The fascia-like septum (white) covers the GON (yellow) and the dorsal surface of the OCI (brown). The third occipital nerve (TON, light green) was located outside of this septum, in a compartment separate from the GON. **(C)** Dye was restricted to the compartment that holds the GON (yellow).

Online Resource 2. Gross image of an ultrasound-guided dye injection into the medial head of the SSC (semispinalis capitis muscle) in a Thiel-fixed cadaver. **(A)** Schematic drawing shows the greater occipital nerve (GON, yellow) and the third occipital nerve (TON, light green) piercing the medial head of the SSC (latticed purple). (*Left*) dorsal view, (*right*) sagittal view. Injected dye (green) is shown in the medial head. **(B)** The tendinous septum (pink) is readily seen between the

medial (latticed purple) and lateral (purple) heads of the SSC. The middle and cranial parts of the SSC are cut transversely to show the tendinous septum and the fascia-like septum (light brown). **(C)** At the medial head (latticed purple) of the SSC, both the GON and TON are surrounded by the dye (green). In this case, the TON divided into two branches within the SSC.