Simple ways to dissect ciliary ganglion for orbital anatomical education

By

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Summary: In the case of anatomical dissection as part of medical education, it is difficult for medical students to find the ciliary ganglion (CG) since it is small and located deeply in the orbit between the optic nerve and the lateral rectus muscle and embedded in the orbital fat. Here, we would like to introduce simple ways to find the CG by 1): tracing the sensory and parasympathetic roots to find the CG from the superior direction above the orbit, 2): transecting and retracting the lateral rectus muscle to visualize the CG from the lateral direction of the orbit, and 3): taking out whole orbital structures first and dissecting to observe the CG. The advantages and disadvantages of these methods are discussed from the standpoint of decreased laboratory time and students as beginners at orbital anatomy.

Introduction

The ciliary ganglion (CG) is one of the four parasympathetic ganglia in the head and neck region located behind the eyeball between the optic nerve and the lateral rectus muscle in the apex of the orbit (Siessere et al., 2008). There are three types of nerve fibers entering the CG, i.e., sensory fibers from the nasociliary nerve, sympathetic fibers from nerve plexuses surrounding the internal carotid artery or ophthalmic artery, and parasympathetic fibers from the oculomotor nerve (Sinnreich, Nathan, 1981; Izci, Gonul, 2006; Hamel et al., 2012). Only the parasympathetic fibers synapse in the CG. The postganglionic fibers called short ciliary nerves run through the posterior pole of the eyeball and innervate the sphincter pupillae muscle and a ciliary muscle, which contract pupil size or release tension of the zonular fibers for accommodation, respectively (Bayramlar et al., 2004). Besides these functions, the CG also regulates ocular blood flow, aqueous humor production, and intraocular pressure (Neuhuber, Schrodl, 2011). It is necessary for medical students to understand the structure of the CG during their anatomical dissection course. As the CG is very small and embedded in the orbital fat with a pale yellow color, it is difficult for the students to identify the CG in the dissection course for the first time and with limited time. In addition, there are few clear pictures in anatomical textbooks showing the morphology of the CG. There are some scientific articles concerning how to visualize the CG, but they are mostly based on the clinical approaches rather than based on the anatomical procedure for medical students (Izci, Gonul, 2006; Siessere et al., 2008; Hamel et al., 2012; Lovasova et al., 2013). Therefore, we would like to introduce some simple approaches to visualize the CG in the orbit in the setting of an anatomic dissection laboratory.

Material and Methods

The subjects in the present study were 64 human cadavers (32 males, 32 females, age from 42 to 99 years) submitted to the 2016 (33 cases) and 2017 (31 cases) anatomical dissection course of Akita University Graduate School of Medicine. All procedures employed in this work complied with the ethical standards of national guidelines on human experimentation and were approved by the relevant ethical institutional committees (No.1846), which are based on the Declaration of Helsinki in 1995, as revised in 2000.
Before dissecting the orbit, the dura mater was taken off from the anterior and middle cranial fossa, especially in the anterior surface of the petrous part of the temporal bone where the trigeminal ganglion is located. Three branches of the trigeminal nerve could then be clearly observed. After removal of the orbital surface of the frontal bone and the upper edge of the superior orbital fissure of the sphenoidal bone, the first division of the trigeminal nerve (the ophthalmic nerve) and some of its branches could be observed running beneath the semi-translucent periorbita. The frontal nerve, supraorbital nerve, supratrochlear nerve, and lacrimal nerve could be readily searched after removing the periorbita (Fig. 1). Dissection of the orbit in detail was processed in three different ways as follows:

1. **Superior approach**

   After opening the periorbita, we could identify the frontal, supraorbital, and supratrochlear nerves in the upper part of the orbit (Fig. 1). By tracing the infratrochlear nerve back to the ophthalmic nerve, the nasociliary nerve could be dissected and observed as one of its branches. Then, on the surface of the superior oblique muscle, the trochlear nerve was dissected and observed and traced its root to the cavernous sinus in the middle cranial fossa (Fig. 2). Further, the oculomotor nerve between the optic and abducens nerves was separated through the cavernous sinus and the common tendinous ring, and then the superior and inferior branches were dissected (Fig. 3). The abducens nerve located lateral to the oculomotor nerve, entering the lateral rectus muscle at its medial surface, was also dissected and observed. After dissecting and observing these structures of the orbit, the CG was dissected and observed superiorly by tracing from the sensory root of the nasociliary nerve and the parasympathetic root of the inferior branch of the oculomotor nerve. The CG is located near the orbital apex between the optic nerve and the lateral rectus muscle (Fig. 3).

2. **Lateral approach**

   After opening the periorbita, we dissected the apex of the orbit and separated the individual cranial nerves that enter the orbit, i.e., the oculomotor nerve, trochlear nerve, ophthalmic nerve, and abducens nerve, as mentioned above. The lateral rectus muscle was transected after the lateral wall of the orbit was removed and the lateral view of the orbit was exposed. Carefully removing the orbital fat, the CG could be identified directly and clearly between the optic nerve and the lateral rectus muscle (Fig. 4).

3. **Removal of whole orbital contents**

   Structures in the orbit were all taken out including extra-ocular muscles and related cranial nerves, the eyeball, and the arteries and veins, and the CG was dissected with related nerve roots.

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**Fig. 1.** The superior view of the orbit after removing the periorbita. The green circle indicates the common tendinous ring which should be carefully dissected to separate the cranial nerves entering the orbit.

- AEA, anterior ethmoidal artery; AEN, anterior ethmoid nerve; FN, frontal nerve; IFN, infratrochlear nerve; LPSM, levator palpebrae superioris muscle; SOM, superior oblique muscle; II, optic nerve.

**Fig. 2.** The superior view of the orbit. Cranial nerves entering the orbit were separated.

- FN, frontal nerve; LRM, lateral rectus muscle; NCN, nasociliary nerve; SOM, superior oblique muscle; II, optic nerve; III, oculomotor nerve; IV, trochlear nerve; VI, abducens nerve.
4. Statistical analysis

In order to compare which approach is better for the students to visualize the CG in the first two approaches, the students in a second-year class were randomly divided into two groups, with one group dissecting the orbit by the superior approach and the other by the lateral approach. They were given 4 hours in the laboratory to dissect the orbit. Students responded to a questionnaire related to observation of each structure. Fisher’s exact test with two-tailed P value was performed using the Statistical Package for Bioscience (SPBS ver 9.86; Murata and Yano, 2002). The value of $p < 0.05$ was considered as statistically significant.

Results

1. Superior approach

The nerves entering the orbit could be clearly observed at the superior orbital fissure. The trochlear nerve was located on the superior oblique muscle. The sensory branches of the ophthalmic nerve such as the frontal nerve, supratrochlear and infratrochlear nerves, anterior ethmoidal nerve, and lacrimal nerve could be observed. The superior and inferior branches of the oculomotor nerve and the branches of the ophthalmic nerve were readily observed running through the superior orbital fissure and the common tendinous ring. The abducens nerve was located lateral to the oculomotor nerve. The other extraocular muscles such as the superior oblique muscle and, the medial rectus and lateral rectus muscles could be clearly observed after retracting the superior rectus and the levator palpebrae superiors muscle located at the upper part of the orbit. But careful retraction of the eyeball was necessary to observe the inferior rectus muscle and the inferior oblique muscle located beneath the eyeball. The nerves innervating these muscles could also be identified including the trochlear nerve, the superior and inferior branches of the oculomotor nerve and the abducens nerve. With this approach, the CG could be identified between the optic nerve and the lateral rectus muscle. The sensory root of the nasociliary nerve usually runs into the CG from the superior posterior direction. The parasympathetic root of the inferior branch of the oculomotor nerve usually runs into the CG from the inferior posterior direction. The short ciliary nerves with postganglionic fibers were located between the CG and the posterior pole of the eyeball. The CG was oblong and flat-shaped, located perpendicularly beside the optic nerve near the orbital apex (Fig. 3).

2. Lateral approach

When the lateral rectus muscle was transected and the cutting endings were retracted backward or forward, respectively, the lateral view of the orbit was expressed clearly. After carefully picking off the orbital fat in the posterior part of the orbit, the CG could be directly observed as flat-shaped, leaning on the optic nerve, with...
the sensory root from the nasociliary nerve and with the parasympathetic root from the inferior branch of the oculomotor nerve. The short ciliary nerves from the CG to the posterior pole of eyeball were also clearly observed (Fig. 4).

3. Removal of whole orbital contents

All structures in the orbit were taken out, such as extra-ocular muscles and related cranial nerves, the eyeball, and arteries and veins. These structures could be easily dissected and observed. The CG and related nervous roots could be found when retracting the lateral rectus muscle or the superior rectus and levator palpebrae superioris muscles.

4. Statistical analysis

In order to ascertain which approach is better to find the CG, students in the 2016 and 2017 second-year class were separated randomly into two groups. One group dissected the orbit from the superior approach and the other from the lateral side to visualize the CG within 4 hours in the cadaveric dissection laboratory. Students responded to a questionnaire on a list of observations for each structure. The results of the responses by students showed that most of the orbital structures were observed, including extra-ocular muscles and related cranial nerves, but it was difficult for them to find the CG. Students using the lateral approach tended to more successful finding the CG than those using superior approach, although no significant correlation was detected. An interesting result was that detection rate of the inferior branch of the oculomotor nerve was significantly higher in the superior group as compared with the lateral group ($p = 0.025$). The results of the questionnaire are summarized in Table 1.

### Discussion

During orbital anatomical dissection, the most difficult process encountered by the students was to find the CG (Table 1). The other structures, such as extra-ocular muscles, ophthalmic artery, or the nerves entering the orbit, were less difficult for them (Table 1). In the present research, three kinds of approaches were tried to find the CG: superior approach, lateral approach, and removal of whole orbital contents. Each approach has its own advantages and disadvantages. It is important for students to know that, before dissecting the orbital structures, separating the relative nerves outside the orbit is essential to help understand their locations and their roots entering the superior orbital fissure, and finally to their target extra-ocular muscles.

In the first approach, dissecting the orbit from above, all the nerves innervating the extra-ocular muscles were

| Structure | lateral approach | superior approach | Fisher’s exact test |
|-----------|-----------------|------------------|-------------------|
| MBFN      | 61              | 3 62             | 1.000             |
| LBFN      | 59              | 5 59             | 1.000             |
| StN       | 54              | 10 54            | 1.000             |
| INN       | 57              | 7 59             | 0.763             |
| AEN       | 56              | 8 53             | 0.620             |
| PEN       | 37              | 27 40            | 0.718             |
| IV        | 59              | 5 61             | 0.718             |
| LN        | 57              | 7 61             | 0.324             |
| SbIII     | 52              | 12 54            | 0.815             |
| IbIII     | 47              | 17 57            | 0.025*            |
| VI        | 60              | 4 63             | 0.365             |
| NeN       | 64              | 0 61             | 0.244             |
| CG        | 46              | 18 41            | 0.449             |
| LCN       | 40              | 24 34            | 0.371             |
| SCN       | 53              | 11 49            | 0.510             |
| LPSM      | 63              | 1 64             | 1.000             |
| SRM       | 64              | 0 63             | 1.000             |
| SOM       | 64              | 0 64             | 1.000             |
| MRM       | 62              | 2 64             | 0.248             |
| LRM       | 63              | 1 63             | 1.000             |
| IOM       | 44              | 20 47            | 0.697             |
| IOM       | 42              | 22 42            | 1.000             |

*Fisher’s exact test with two-tailed p value was performed using the Statistical Package for Bioscience (SOBS ver 9.68; Murata and Yano, 2002).

* Probability value of $p < 0.05$ was regarded as statistical significant.
distinguished from one another in order. This could help
the students understand how these nerves pass through
the superior orbital fissure and enter the orbit to their
target muscles. Then students could find the CG by trac-
ing along the sensory root from the nasociliary nerve, or
along the parasympathetic root from the inferior branch
of the oculomotor nerve, without removing any orbit
structures except some orbital fat. However, it is not easy
for students to find the CG in a single day or one after-
noon in the curriculum, because its size is small and its
shape is flat with a pale yellowish color, and it is usually
attached to the optic nerve. Sometimes it is located near
the orbital apex, making the field of view very narrow. It
is our impression that, some experience is needed to find
the CG with this approach.

In the second approach, transecting the lateral rectus
muscle, students can directly observe the CG from the
broad side, without cutting off any other extra-ocular
muscles. The CG is usually flat-shaped, with its broad
surface leaning on the optic nerve just opposite to the
lateral rectus muscle. The other cranial nerves in the
orbit could be clearly observed. The parasympathetic and
sensory roots of the CG and the postganglionic short cil-
inary nerves were also easily visible from the side. In our
experience, the second approach is easier than the supe-
rior approach to find the CG in the dissection laboratory
by students as beginners. As showing in Table 1, in the
case of the inferior branch of the oculomotor nerve, the
superior approach was significantly better than the lateral
approach.

When the whole orbital structure was removed from
the orbit first, students could identify the CG between the
optic nerve and the lateral rectus muscle. In this way, they
did not need to worry about destroying the CG during
dissection, but it was difficult to maintain their original
locations, and the positional relationships among orbital
structures were lost. The third approach might be the last
choice for students to search for the CG.

The CG contains three roots from different nervous
system: the sensory root from the nasociliary nerve, the
sympathetic root from the internal carotid plexus within
the cavernous sinus (Hamel et al., 2012), and the para-
sympathetic root from the inferior branch of the oculo-
motor nerve. Since it is located in the narrow space of the
orbit, lesions of the neighboring structures could injure
the CG (Izci, Gonul, 2006). Several surgical roots at this
position are targeted for treatment (Gonul, Timurkaynak,
1998), and the patients will complain of mydriasis and ac-
commodative palsy (Bodker et al., 1993; Bayramlar et al.,
2004; Hamel et al., 2012). Thus, detailed knowledge
about the orbit and the CG is important. Our methods for
orbital anatomic dissection might be beneficial for recog-
nizing the structure and for medical education.

**Conclusion**

Comparing the three methods of dissection for finding
the CG, we think that the lateral approach is the best one
for medical students in the orbit anatomical dissection
classroom, because it provides the widest view of the CG
after transecting the lateral rectus muscle.

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**Conflicts of interest**

The authors declare that they have no conflicts of interest.

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Abbreviations

FN, frontal nerve
LBFN, lateral branch of frontal nerve
MBFN, medial branch of frontal nerve
StN, supratrochlear nerve
ItN, infratrochlear nerve
AEN, anterior ethmoidal nerve
PEN, posterior ethmoidal nerve
IV, trochlear nerve
LN, lacrimal nerve
SbIII, superior branch of oculomotor nerve
IbIII, inferior branch of oculomotor nerve

VI, abducens nerve
NeN, nasociliary nerve
CG, ciliary ganglion
LCN, long ciliary nerve
SCN, short ciliary nerve
LPSM, levator palpebrae superioris muscle
SRM, superior rectus muscle
SOM, superior oblique muscle
MRM, medial rectus muscle
LRM, lateral rectus muscle
IRM, inferior rectus muscle
IOM, inferior oblique muscle