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ORIGINAL ARTICLE

Patterns of attachment of the myodural bridge by the rectus capitis posterior minor muscle

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Abstract The myodural bridge was first described by Hack in 1995 and was thought to be related to chronic cervicogenic headaches. For a long time, few studies revealed the patterns of the myodural bridge considering the rectus capitis posterior minor muscle. In this study, P45 plastination technology and anatomical dissection were performed on head specimens, and four different terminal region types of the rectus capitis posterior minor muscle were observed, including the posterior atlanto-occipital interspace, posterior arch of the atlas and posterior atlanto-axial interspace. We propose that the myodural complex structures in the posterior atlanto-occipital and posterior atlanto-axial interspace have cooperative effects on cerebrospinal fluid and work together. This force might be an important source for the circulation of cerebrospinal fluid.

Keywords Chronic cervicogenic headache · Circulation of cerebrospinal fluid · Myodural bridge · Plastination technology · Rectus capitis posterior minor muscle

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Introduction

The human suboccipital region is one of the most complicated and is composed of the basis cranii, atlas and axis (Kontautas et al. 2005). Furthermore, the suboccipital musculature maintains the head-and-neck posture and movement and also transmits force to the spinal dura and junctions (Hack et al. 1995).

Based on the activities in the suboccipital region, flexion and extension have been shown to be assisted by the atlanto-occipital and atlanto-axial junction (Hiatt and Gartner 1987). These two junctions are surrounded by the deep muscles and ligaments. However, the articular discs and interspinous ligaments have not been included in this region (Chang et al. 1992; Johnson et al. 2000). The rectus capitis posterior minor muscle (RCPmi) is located in the deep muscles of the suboccipital triangle (Tagil et al. 2005) and medial to the rectus capitis posterior major muscle (RCPma). It is oriented from between the inferior lineae nuchae and upper foramen magnum, innervated by cervical nerves C1–C2 (McPartland and Brodeur 1999). In 1995, the myodural bridge was proposed by Hack et al. (1995). It is a dense connective tissue bridge situated between the RCPmi and spinal dura and perpendicular to the spinal dura in all specimens. Some of them are observed to be fused to the posterior atlanto-occipital membrane, attaching to the dura as one unit. The continuity of the fibers may assist in resisting dural infolding from the movement of the head and neck (Kontautas et al. 2005).

In the last 20 years, many studies have suggested that the RCPmi is correlated with chronic cervicogenic headaches (Thompson 1995; McPartland et al. 1997; Alix and Bates 1999; McPartland and Brodeur 1999; Hack and Hallgren 2004; Nash et al. 2005; Fernández-de-las-Penas et al. 2008). When pathological changes occur in the

RCPmi, abnormal forces are transmitted from the myodural bridge to the pain-sensitive spinal dura, resulting in cervicogenic pain (Mitchell et al. 1998; Alix and Bates 1999).

The purpose of our study was to determine the presence of the myodural bridge and examine its patterns of attachment using P45 plastination technology and gross anatomical dissection. Additionally, confirming the hypothesis about this structure could provide physicians with useful information.

Materials and methods

Nineteen adult head-neck specimens were used in this study. All were donated to Dalian Medical University for anatomical teaching and research.

This study was approved by the Ethics Committee (Dalian, China).

P45 sheet plastination

Fourteen adult head-neck specimens were sliced in sagittal sections. The P45 sheet plastination procedure was applied as follows:

Slicing

The embalmed head-neck specimen was frozen at −70 °C for 2 weeks. After freezing, 3-mm-thick sagittal slices were made with a high-speed band saw.

Bleaching

All slices were rinsed with running water overnight and then immersed in 5 % hydrogen peroxide overnight.

Dehydration

After bleaching, the slices were dehydrated by the freeze substitution method. First, the slices were precooled at 5 °C. Then they were placed in the first bath of 100 % acetone at −25 °C for 1 week. They were then transferred into a second bath of 100 % acetone at −15 °C for 10 days. Then they were put into 100 % acetone at room temperature for 1 week. After that, the slices were finally submerged in fresh 100 % acetone at room temperature. After a week, slices were taken out for impregnation.

Casting and forced impregnation

This was referred to as a flat chamber method. The flat chamber consisted of two plates of 5-mm tempered glass, flexible latex tubing and several large fold-back clamps. The slices were placed between two glass plates. Then the molds were filled with polyester (Hoffen polyester P45, China) via a funnel. The components of Hoffen polyester P45 were mixed at 1000 ml of polyester P45 monomer to 10 g of P45a to 30 ml of P45b to 5 g of P45c. The P45a and P45c were used as a plasticizer. The P45b was a hardener for sheet plastination.

After casting, the filled mold was placed upright into a vacuum chamber at room temperature for impregnation. The absolute pressure was slowly decreased to 20, 10, 5 and 0 mmHg according to the release of bubbles. Then pressure of 0 mmHg was maintained until bubbling ceased. Duration of impregnation was more than 8 h.

Curing

After the vacuum had been released, the top of the mold was clamped with large fold-back clamps, and the sheet was ready for curing.

The sheets were cured with heat in a water bath. They were placed upright in the 40 °C water bath for 3 days.

Cutting and sanding the molds

After curing, the slices were taken from the flat chamber and covered with adhesive plastic wrap for protection. A band saw was used to cut and trim the plastic along the edges about 1 mm outside of the slices. Then, a wool sander was used to remove the sharp edges of the slices, and the sheets were ready for use.

Dissection of the head and neck

Five donated adult cadavers (3 males, 2 females) were dissected. After removal of the skin, superficial fascia and deep muscles in the suboccipital region, the RCPmi was exposed. Then the RCPmi was removed from its origin, and a layer-by-layer dissection was performed, exposing the structure of interest. The relationship between the RCPmi and spinal dura was defined. Photographic documentation was recorded with a Canon EOS 450D camera, using a Canon EF-S 18–55-mm f/3.5–5.6 IS zoom lens.

Results

Observations using P45 plastination technology

In each of the 14 P45 plastinated slices, it was observed that the RCPmi originated from the interior of the inferior lineae nuchae, running continuously toward the posterior cervical region. The tendon of the RCPmi partly terminated in the posterior atlanto-occipital membranes and was fused to the spinal dura. Moreover, part of the tendon terminated in the region of the posterior arch of atlas and atlanto-axial interspace, which was different from previous research records.

From the P45 plastinated slices, three different terminal regions of the RCPmi were found: (1) the posterior atlanto-occipital interspace; (2) posterior arch of atlas; (3) posterior atlanto-axial interspace. According to this finding, the terminations of the RCPmi could be classified into four different types.

Type I

The tendon of the RCPmi only terminated in the posterior arch of the atlas. The ratio of type I was 7.1 % (1/14) (Fig. 1a).

Type II

The tendon of the RCPmi terminated in both the posterior atlanto-occipital interspace and posterior arch of the atlas. The ratio of type II was 42.9 % (6/14) (Fig. 1b).

Type III

The tendon of the RCPmi terminated in the posterior arch of the atlas and posterior atlanto-axial interspace. The ratio of type III was 7.1 % (1/14) (Fig. 1c).

Type IV

The tendon of the RCPmi terminated not only in the posterior atlanto-occipital interspace and posterior arch of the atlas, but also the posterior atlanto-axial interspace.

The ratio of type IV was 42.9 % (6/14) (Fig. 1d).

Observations from anatomical dissections

In five specimens, the tendons of the RCPmi firmly terminated in the posterior arch of the atlas. In 2 of 5 specimens, the RCPmi also terminated in the posterior atlanto-axial interspace and the dense tendon was fused to the dorsal cervical spinal dura (type III) (Fig. 2). In 1 of 5 specimens, the RCPmi was attached to the posterior atlanto-occipital interspace (type II) (Fig. 3).

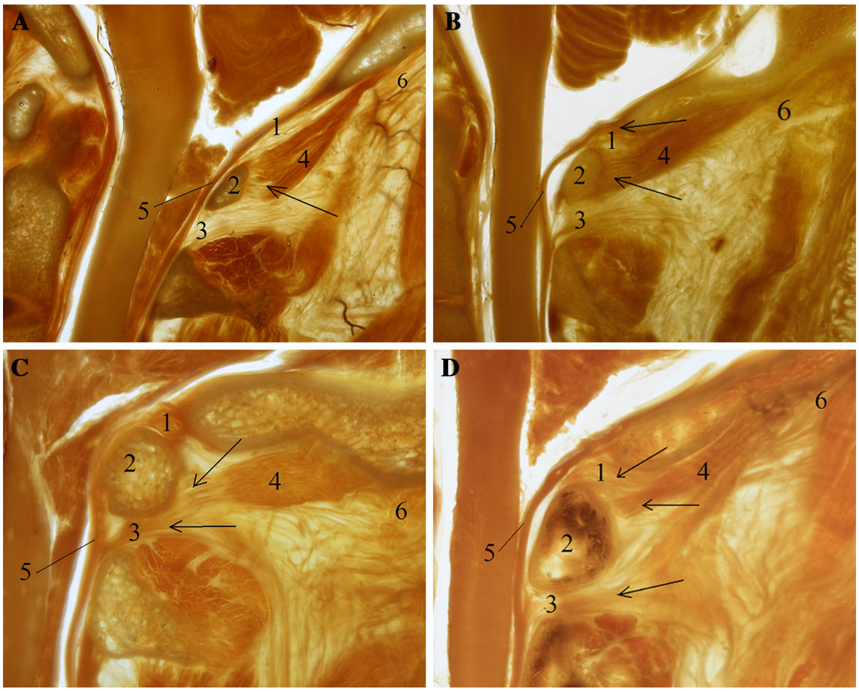

Fig. 1 Drawing of the suboccipital region (*mid-sagittal view*). *1* Posterior atlanto-occipital interspace; *2* posterior arch of the atlas; *3* posterior atlanto-axial interspace; *4* rectus capitis posterior minor muscle (*RCPmi*); *5* cervical spinal cord and dura mater (*straight line*); *6* inferior lineae nuchae. All terminations are indicated by *arrows*. **a** Type I: a mid-sagittal plastination slice of the suboccipital region. The RCPmi originated from the interior of the inferior lineae nuchae, only terminating in the posterior arch of the atlas (*2*). **b** Type II: the RCPmi terminated in both the posterior atlanto-occipital interspace (*1*) and posterior arch of the atlas (*2*). **c** Type III: the RCPmi terminated in the posterior arch of the atlas (*2*) and posterior atlanto-axial interspace (*3*). Besides, a strong posterior atlanto-occipital membrane was observed, attaching to the spinal dura. **d** Type IV: the RCPmi terminated in the posterior atlanto-occipital interspace (*1*), posterior arch of the atlas (*2*) and posterior atlanto-axial interspace (*3*)

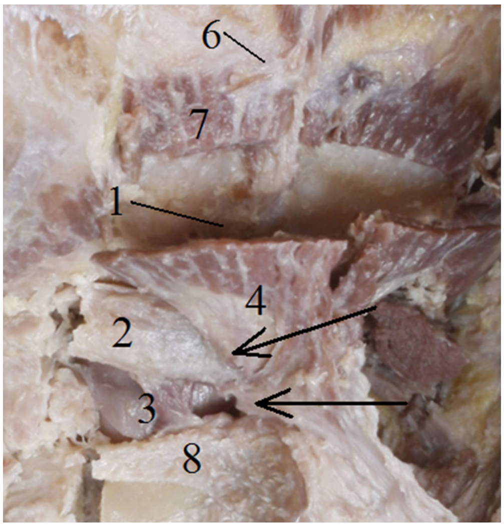

Fig. 2 View of the suboccipital region from the posterior lateral aspect. *7* Occipital bone; *8* axis. The RCPmi was firmly partly attached to the posterior atlanto-axial interspace and merged together with surrounding fibers to the spinal dura (type III)

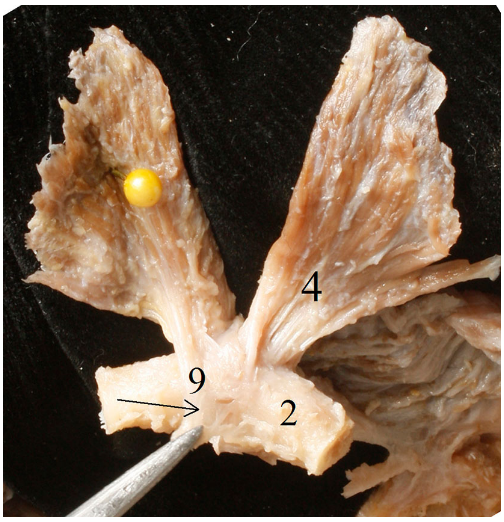

Fig. 3 This showed the anterior excision of the RCPmi, myodural bridge (*9*) and atlas (*2*) as one unit. These structures were removed from their origin. The RCPmi was attached to the posterior arch of the atlas, and part of it terminated in the posterior atlanto-occipital interspace, reaching the spinal dura through the myodural bridge. The myodural bridge is indicated by an *arrow*

Discussion

The suboccipital region has become an area of interest in the last 30 years. Many studies have tried to define the relationships among the RCPmi, posterior atlanto-occipital membrane and ligamentum nuchae (Nash et al. 2005).

The major difficulty in studying the structure of the RCPmi is that its delicate structure lacks a clear demarcation from the surrounding tissue and thus is easily damaged during gross dissection. To overcome this problem, P45 plastination technology was used. Combined with anatomy dissection, the results presented here redress the inconsistencies and deficiencies regarding the structural arrangement of the RCPmi and provide a new schematic view of its anatomic configuration. Generally speaking, more tissue details could be seen. During the plastination process, the degreased adipose tissue of the specimen made it specimen clear and transparent for observation. Based on these unique advantages, P45 plastination technology acts as a bridge between histology and gross dissection and provides clear sectional knowledge to overcome the limitations of histological sections.

Previously, most researchers found the track of the RCPmi in the posterior atlanto-occipital interspace. Hack et al. reported that the RCPmi and spinal dura mater may be linked via tendon continuity through the posterior atlanto-occipital interspace (Hack et al. 1995). Alix et al. had similar suggestions (Alix and Bates 1999; Dean and Mitchell 2002; Nash et al. 2005). In this study, we found that the myodural bridge of the RCPmi existed not only in the posterior atlanto-occipital interspace, but also in the region of the posterior atlanto-axial interspace, and it terminated in the spinal dura mater, respectively. These results provide useful information about the myodural bridge.

Some researchers have speculated that the RCPmi plays an important role in chronic cervicogenic headaches. In order to confirm this etiological mechanism, many studies have been done and some hypotheses proposed. Elliott et al. pointed out that in cases of chronic cervicogenic pain the RCPmi contained significant amounts of fatty infiltration, possibly due to damage of the suboccipital musculature (Elliott et al. 2005, 2006, 2008). Kumar suggested that many pain-sensitive structures surrounding the cervical spinal dura could transmit some pain originating from it (Kumar et al. 1996). Alix and Bates suggested that the spinal dura's potential role in cervical headaches may be that it is innervated by the C1–C2 spinal nerves and projected to the trigeminal nucleus, where it could gather painful inputs from the head. In addition, the myodural bridge may also apply traction directly to the pain-sensitive spinal dura through the foramen magnum (Alix and Bates 1999). However, the mechanism of the headache related to the myodural bridge is still unclear.

Different from previous suggestions, a new hypothesis has been proposed about the function of the myodural bridge. We speculate that the myodural bridge may be related to the circulation of cerebrospinal fluid (CSF). Many researchers have suggested that the circulatory force of the CSF originats from the choroid plexus, circulatory system and respiratory system (Greitz et al. 1993). Besides these factors, we suppose that the myodural bridge has an important influence on the circulation of CSF. The contraction of the RCPmi may create a pulse that travels to the spinal dura mater through the myodural bridge and change the negative pressure of the subarachnoid space. The cerebellomedullary cistern (cisterna magna), internal to the mentioned dura mater, is large enough to influence the circulation of CSF. These muscles in this region may work together in one "pump action." Clinically, a chronic headache may be caused by the changes in the CSF circulation when abnormal changes occur in the RCPmi.

Some researchers have revealed that the ligamentum nuchae and obliquus capitis also participate in the composition of the myodural bridge (Dean and Mitchell 2002; Pontell et al. 2013). Some researchers also defined the to be named ligament and vertebrodural ligament and their possible effects on the CSF circulation (Zheng et al. 2014). We proposed that myodural-complex structures in the posterior atlanto-occipital and posterior atlanto-axial interspace have a cooperative effect when the head and neck move. More study of this structure is needed to confirm this hypothesis.

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Conflict of interest The authors declare that they have no conflicts of interest.

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