This study was designed to examine the obliquus capitis inferior (OCI) muscle from a gross anatomical perspective. The objective was to isolate and identify the OCI myodural bridge, while examining its course and contributing elements. An earlier study of the posterior cervical spine briefly reported a connection between the OCI and the cervical dura mater. To the best of our knowledge, a study has not yet been conducted specifically on this muscle and its relation to the dura mater. In this study, the suboccipital regions of nine embalmed cadavers were dissected. A total of 14 OCI muscles were isolated for examination. All findings were documented via photograph. Of the 14 OCI muscles isolated, all emitted fibrous tissue bands from the anterolateral portion of the muscular belly. These fibers attached to the posterolateral cervical dura mater by route of the atlantoaxial interspace. The OCI myodural bridge appeared to coalesce with the rectus capitis posterior major myodural bridge, giving the appearance of a single atlantoaxial structure that links these two muscles to the dura mater. In conclusion, the OCI was attached to the dura mater in all of the 14 muscle specimens. We hypothesize that the OCI myodural bridge may play a physiological role in monitoring dural tension and preventing dural infolding. It may also contribute to certain clinical symptoms manifesting from alterations in dural tone.

Key words: obliquus capitis inferior; myodural bridge; atlantoaxial interspace; cervical dura mater

INTRODUCTION

Over the past 30 years, the posterior cervical intervertebral spaces have received an increasing amount of attention in scientific literature (Kahn et al., 1992; Hack et al., 1995; Humphreys et al., 2003; Scali et al., 2011). Examination of human cadavers revealed that these interspaces contain intricate connections between suboccipital musculature and the cervical dura mater (Kahn et al., 1992; Hack et al., 1995, 1996, 1997; Nash et al., 2005; Scali et al., 2011). Studies of this region suggest that the suboccipital muscles emitting these fibrous tissue bridges integrate motion of the upper cervical spine and craniovertebral joint with that of the outermost layer of the meninges (Hack et al., 1995; Hallgren et al., 1997; McPartland and Brodeur, 1999; Scali et al., 2011, 2012). All these reports are beginning to reveal what may be one of the human body’s more complex regions of anatomy. It has been suggested that pathological conditions involving dural adhesions and excessive dural tension may be simulated by these muscle-dura connections, as well (Hack et al., 1995; Alix and Bates, 1999; Hack and Hallgren, 2004; Tagil et al., 2005; Fernandez-de-las-Peñas et al., 2007; Grgic, 2007; Scali et al., 2012). These myodural connections may, therefore, play a role in clinical symptoms that may only be partially understood at this time.

Within the atlantooccipital interspace, the anterior fascia of the rectus capitis posterior minor (RCPmi) contributes to the atlantooccipital myodural bridge (Hack et al., 1995; Humphreys et al., 2003; Nash et al., 2011).
The RCPmi fascia fuses with the posterior atlantooccipital mem-
brane and continues on to merge with the postero-lateral
cervical dura mater (Nash et al., 2005; Zumpano et al.,
2006; Kahkeshani and Ward, 2012). This myo-
dural bridge has been examined with gross (Hack et al.,
1995; Kahkeshani and Ward, 2012), microscopic
(Nash et al., 2005; Zumpano et al., 2006), and radi-
ographic (Humphreys et al., 2003; Hack and Hallg-
ren, 2004) modalities. This recent anatomical finding
may play a physiological role in preventing dural infolding and monitoring dural tension (Hack et al.,
1995; Hallgren et al., 1997; Rutten et al., 1997).
Additionally, tense forces transmitted through this
anatomical connection may contribute to the patho-
mechanics of cervicogenic headache (Hack et al.,
1995; Alix and Bates, 1999; Hack and Hallgren,
2004). In one instance, sectioning the RCPmi myo-
dural bridge provided relief in a case of intractable
cephalgia (Hack et al., 2004). In 2011, a study was conducted on the rectus
capitis posterior major (RCPma) myodural bridge.
This study documented the anatomical attachment
of the RCPma to the posterior aspect of the cervical
dura mater (Scali et al., 2011). In 2012, a histori-
ological study conducted on the RCPma myodural bridge
supported the continuity of this soft tissue connec-
tion with both the RCPma and the dura mater (Scali
et al., submitted). This myodural connection may also be represented by structures visible on MRI (Scali et al., 2012). Although current anatomical text reports that the yellow ligament (ligamentum fla-
vum) covers the anterior boundary of the atlantoax-
ial interspace (Standring, 2008), these recent reports on the RCPma refute this (Scali et al., 2011). Aside from possibly serving to monitor dural tension throughout movements of the head and neck, the RCPma may play a role in cervical pathologies via a similar mechanism to that suggested of the RCPmi (Scali et al., 2011). Nevertheless, these myodural connections from the RCPmi and RCPma are becom-
ing increasingly noteworthy in anatomical literature.
In 1992, a study of the posterior intervertebral interspaces briefly reported that the obliquus capitis inferior (OCI) muscle also attaches to the dura mater (Kahn et al., 1992). This attachment was once again mentioned in a study on the RCPma myodural attachment in 2011 (Scali et al., 2011). To the best of our knowledge, there has not been a study con-
ducted specifically on the OCI myodural bridge. The objective of this study is to examine a convenience sample of cadaveric specimens for the presence of a soft tissue communication between the OCI and the cervical dura mater. Additionally, we aim to examine its course and composition from a gross anatomical perspective and hypothesize as to what the function of this connection may be.

MATERIALS AND METHODS

A convenience sample of four cadavers was obtained from the Department of Anatomical Scien-
ces at St. George's University, School of Medicine. An additional sample of five cadavers was obtained from the Department of Anatomy at Logan College of Chiropractic. A total of nine embalmed cadavers (four male, five female) were dissected for the pur-
purpose of this study. Due to prior dissection, four cadaveric specimens were only examined unilater-
ally. The specimens were preserved using a formal-
lin-alcohol-phenol mixture. Specimens with signs of cervical surgery or trauma were excluded from this study. All guidelines were followed for use of cadav-
eric material in research. Photographic documenta-
tion was recorded with a Nikon D-40 camera, using a Nikon DX AF-S Nikkor 18–55 mm 1:3.5-5.6 GII detachable lens.

Each dissection began with removal of soft-tissue structures superficial to the vertebral column in order to prepare each specimen for a partial laminc-
tomy. The muscular structures of the suboccipital tri-
gle and the RCPmi remained intact as to preserve the area of interest. Using a Stryker Autopsy 810 (Stryker, Kalamazoo, MI) saw, gross anatomical cuts were performed bilaterally along the laminae, from the third (C3) to sixth (C6) cervical vertebrae. Following this procedure, the posterior vertebral elements were removed to reveal the contents of the vertebral canal from C3 to C6.

Using a surgical scalpel, the RCPma and OCI were detached from the spinous process of the second cervical vertebrae (C2). The muscular attachment sites of the RCPma and OCI were also excised from the inferior nuchal line and transverse process of the first cervical vertebrae (C1), respectively. The excision of these bony attachments was performed bilat-

erally.

A midsagittal cut was made on the spinous pro-
cess of C2 using a Dremel 200-1/15 two-way rotary (Robert Bosch Tool Corporation, Mt. Prospect, IL) with a 426 1-1/4 in fiberglass-reinforced cutoff wheel attachment. Following this procedure, sagittal cuts were then made along the laminae bilaterally. It was then possible to remove the posterior arch of C2 allowing visualization of the structures traversing the atlanto-axial interspace from a posterior perspective. The OCI, soft tissue bridge, and 2 cm × 2 cm section of dura mater were excised as one continuous struc-
ture and placed into a buffered solution for future histological analysis.

RESULTS

From the nine cadavers dissected, 14 OCI muscles were isolated (six male, eight female). In all 14 OCI muscles, fibrous tissue continuous with the anterior fascia of the OCI projected anteriorly and inferiorly from the anterolateral portion of the OCI muscular belly. The connective tissue traversed through atlan-
toaxial interspace and attached to the postero-lateral aspect of the cervical dura mater between the first and second cervical vertebrae (Fig. 1). The RCPmi and RCPma myodural bridges were also identified in all of the dissections.

On further examination, the OCI myodural bridge appeared to coalesce with the RCPma myodural bridge in each of the 14 OCI specimens. From a
gross perspective, both the OCI and RCPma emitted soft tissue fibers that contributed to what appeared to be a single atlantoaxial myodural bridge (Fig. 2). Excision of the RCPma and its soft tissue bridge revealed that the OCI remained continuous with the dura mater via a soft tissue bridging structure (Fig. 3). It was, therefore, determined that the OCI was attached to the posterolateral cervical dura mater in all the 14 of the OCI specimens.

Although the OCI and RCPma muscles are each connected to the dura mater, the proximity of their myodural connections leads to the appearance of a single atlantoaxial myodural bridge that links both these muscles to the dura mater. It should also be noted that the yellow ligament (ligamentum flavum) did not bound the anterior limit of the atlantoaxial interspace. This space was occupied by the atlantoaxial myodural bridge.

**DISCUSSION**

The posterior cervical musculature integrates the fine movements of the atlantooccipital joint with the rest of the upper cervical spine. Namely, the muscles of the suboccipital triangle and the RCPmi are involved in flexion, extension, rotational, and translational movements of the cervical vertebrae and occiput (Standring, 2008). The results of this study support the fact that three of these suboccipital muscles, the OCI, RCPma, and the RCPmi, are fixed to the dura mater via soft tissue bridges (Kahn et al., 1992; Hack et al., 1995; Scali et al., 2011; Fig. 4). Knowing that these muscles attach to the protective covering of the central nervous system, it seems unlikely that their functions are limited to craniovertebral movement.

It has been proposed that the suboccipital myodural connections of the RCPma and RCPmi serve to monitor dural tension (Rutten et al., 1997; Scali et al., 2011). In one case, proprioceptive fibers were visualized arising in the cervical dura mater, coursing through the myodural bridge (MDB) proceeds to communicate with the posterior aspect of the dura mater (Dura) between the atlas (C1) and the axis (C2). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]
through the RCPma myodural bridge and continuing within the RCPma muscle belly (Scali et al., submitted). If the RCPma and RCPmi myodural bridges do receive input from the dura mater, the OCI myodural bridge may function in a similar manner, and these soft tissue bridges may collectively function to assist with dural tension monitoring. Because the OCI functions as an ipsilateral rotator (Standring, 2008), and most rotation of the neck occurs at the atlantoaxial joint (Bates, 1991), the OCI may contribute to dural tension monitoring throughout these movements.

From a clinical perspective, the RCPma and RCPmi myodural bridges have been suggested to play a role in conditions resulting from excess dural tension, namely, cervicogenic cephalgia. Hypertrophy of these muscles may result in excess tension on the dura mater through the myodural bridges manifesting clinically as head pain (Hack et al., 1995; Alix and Bates, 1999; Hack and Hallgren, 2004; Scali et al., 2011). The OCI myodural bridge may be involved in similar pathophysiology. Additionally, studies have demonstrated convergence between the upper three cervical nerves and the trigeminal nucleus (Bogduk, 2001). As the infratentorial dura mater is innervated by the upper cervical nerves, pain arising from the cervical

Fig. 3. Image depicts an excised section of the obliquus capitis inferior (OCI) that communicates with the dura mater (Dura) by way of the OCI myodural bridge (MDB). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Fig. 4. Image depicts the excision of the rectus capitis posterior minor (RCPmi) muscles, rectus capitis posterior major (RCPma) muscles, obliquus capitis inferior (OCI) muscles, and the posterior aspect of the cervical dura mater (Dura) as one complete unit. All muscles were removed from their origin and insertion points before the posterior aspect of the dural sleeve was excised. One complete structure was removed consisting of the six muscles and the dura mater. All six muscles remained attached to the dura mater by their respective myodural bridges. The right OCI myodural bridge is labeled by an asterisk (*). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]
dura due to excess tension may be referred through the distribution of the trigeminal nerve (Bogduk, 2001). Should the myodural bridges of the RCPma, RCPmi, and OCI become firmly implicated in dural pathology, this scenario may contribute the clinical relevance of these structures.

The RCPma and RCPmi myodural bridges have also been suggested to prevent dural infolding, especially during extension movements of the head and neck (Hack et al., 1995; Rutten et al., 1997). As the OCI, RCPma, and RCPmi myodural bridges are of similar structure, they may act together to maintain dural posture during these movements. Atrophic changes in any of these muscles may, therefore, contribute to misalignment of the dura mater during movements of the upper cervical spine (Hallgren et al., 1997; Rutten et al., 1997).

Limitations of this study include the lack of histological analysis of the OCI myodural bridge and the small sample size used in this study. Additionally, four cadavers only had a single intact OCI muscle, and these specimens could not be examined for bilateral continuity of the OCI with the cervical dura mater. As this is a newly reported structure, thorough examination is warranted to determine its prevalence in the population and further examine its composition.

In summary, our study reports that the OCI muscle attaches to the cervical dura mater via a fibrous tissue connection that travels through the atlantoaxial interspace. Defining the OCI myodural bridge may serve to augment prior anatomical knowledge of the craniocervical region. Gross identification of this structure is especially important with respect to dissection, anatomical instruction, and even surgical procedure. Additionally, the OCI myodural bridge may contribute to pathological conditions arising from dural tension in a similar manner to the RCPma and RCPmi myodural bridges. The presence of these connections suggests that the suboccipital region is an area of complex anatomy and further exploration is encouraged.

ACKNOWLEDGMENTS

The authors thank Kathleen Bubb, MD, and graduate student Patrick Battaglia for assisting with cadaveric dissections. They also thank anatomical illustrator Danny Quirk for his contribution of the original anatomical artwork that accompanies this manuscript.

REFERENCES


