

Anatomical Parameters of the Rectus Capitis Posterior Major and Obliquus Capitis Inferior Muscles Based on an Oblique Sagittal Magnetic Resonance Scan Method

Parámetros Anatómicos de los Músculos Recto Posterior Mayor de la Cabeza y Oblicuo Mayor de la Cabeza Basados en un Método Oblicuo Sagital de Exploración por Resonancia Magnética

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SUMMARY: The deep suboccipital muscles has been shown to connect the spinal dura mater via dense connective tissue termed the myodural bridge (MDB). The MDB has both physiological and clinical implications. Data on morphological and imaging anatomical parameters of the deep suboccipital muscles are scarce. In this study, T2-weighted images of rectus capitis posterior major (RCPma) and obliquus capitis inferior (OCI) of 109 healthy adults were obtained by 0-degree sagittal and 30-degree oblique sagittal continuous MRI scanning of the head and neck of the subjects. Sectional area parameters of the RCPma and the OCI were measured. The 0-degree sagittal section was measured with 5 mm bias from the median sagittal plane, the sectional area of the RCPma was $186.34 \pm 55.02 \text{ mm}^2$ on the left, and $202.35 \pm 59.76 \text{ mm}^2$ on the right. The sectional area of OCI was $221.72 \pm 68.99 \text{ mm}^2$ on the left, and $224.92 \pm 61.34 \text{ mm}^2$ on the right; At the section with 30-degree bias from the oblique sagittal plane, the sectional area of RCPma was $183.30 \pm 42.24 \text{ mm}^2$ in males, and $133.05 \pm 26.44 \text{ mm}^2$ in females. The sectional area of OCI was $254.81 \pm 46.20 \text{ mm}^2$ in males, and $167.42 \pm 27.85 \text{ mm}^2$ in females. Significant sex difference exists in the sectional areas of the RCPma and OCI, the values of the male subjects were predominantly larger ($P < 0.05$), however there were no age-related significant difference. The sectional area of RCPma is bilateral asymmetric, the RCPma on the right side is larger than that of the left side ($P < 0.05$), but the OCI is bilaterally symmetric ($P > 0.05$). The MRI image features, imaging anatomical data and sexual dimorphism of the RCPma and the OCI are presented in this study. This imaging anatomical data will be useful for functional and clinical studies on the RCPma, OCI, and the MDB.

KEY WORDS: Suboccipital region; Rectus capitis posterior major (RCPma); Obliquus capitis inferior(OCI); Imaging anatomy parameters.

INTRODUCTION

The deep suboccipital muscles including the rectus capitis posterior major (RCPma), rectus capitis posterior minor (RCPmi), obliquus capitis superior (OCS), and obliquus capitis inferior (OCI), located between the inferior nuchal line of the occipital bone and the dorsal aspect of the axis, are indispensable in maintaining head posture and in proprioception. Hack *et al.* (1995) first proposed the concept of the myodural bridge (MDB) as a dense fibrous connection between the RCPmi, posterior atlanto-occipital membrane (PAOM) and dura mater (DM) Hack *et al.*, 1995. Subsequent researches have shown that the RCPma (Scali *et al.*, 2013),

OCI (Pontell *et al.*, 2013) and ligamentum nuchae (LN) participate in forming the MDB. Researchers believe that these deep suboccipital muscles via the MDB perform important physiological roles such as preventing DM in folding, keeping the cerebellomedullary cistern patent and maintaining the normal flow of cerebrospinal fluid (CSF), transmitting DM tension and adjusting head posture (Hack *et al.*, 1995). Recently, Sui *et al.*, proposed that the MDB may be a dynamic source of CSF circulation (Sui *et al.*, 2013; Zheng *et al.*, 2014). Some clinical studies suggested that there is a relationship between the deep

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suboccipital muscles and headache (McPartland *et al.*, 1997; Fernández-de-Las-Peñas *et al.*, 2007, 2008). To understand the morphology and human distribution characteristics of RCPmi/RCPma and OCI, imaging anatomical data is significantly meaningful in functional studies of the MDB, especially in identifying pathologic changes of the deep suboccipital muscles.

Based on the MRI imaging on healthy adults, Xu *et al.* (2013) provided an imaging reference values of the length and sectional area of the RCPmi in male and female subjects. However, morphological data on the RCPma and OCI in healthy adults have not been reported to date. In this study, T2-weighted MRI images were used to measure the RCPma and OCI in healthy adults. This study provides morphometric data on RCPma and OCI in healthy adults, and lays a foundation for functional and clinical research on the suboccipital muscles.

MATERIAL AND METHOD

Approval for this study was obtained from the Ethics Committee for Research of Basic Medical College of Dalian Medical University. One hundred and nine (109) healthy adults including 47 males (age range from 19 to 70 with an average of 40.0 ± 14.1 years) and 62 females (age range from 20 to 67 years with an average of 38.1 ± 13.9 years) participated in this study.

Scanning equipment and parameters. A 0.35T MRI scanner (BTI-035, Shengzhen Basda Medical Apparatus Co., Ltd.) was used with a neck coil phased array. The scanning sequence T2WI/FSE (TR/TE 3,200 ms/ 115 ms) was employed with a thickness of 5 mm, interval of 1 mm, 256 X 279 matrix, 272 X 272 mm view field, and two activations.



Fig 1. The MR scanning reference lines and bilateral T2WI image with 5 mm bias from the median sagittal plane. A. The MR scanning reference lines B. Left T2WI image with 5 mm bias from the median sagittal plane C. Right T2WI image with 5 mm bias from the median sagittal plane. Δ Cross section of RCPma. \leftarrow Cross section of OCI

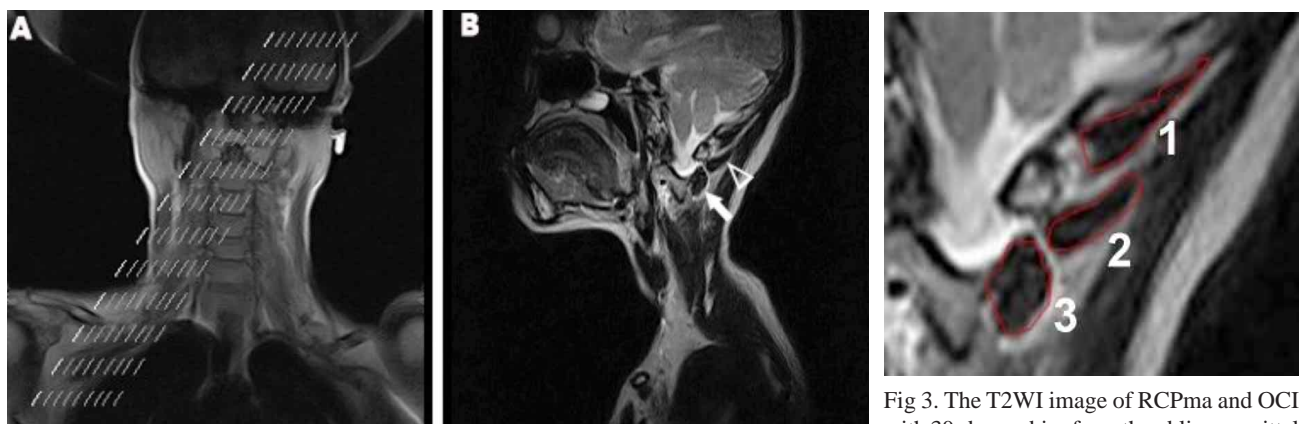


Fig 2. The MR scanning reference lines and T2WI image including suboccipital muscles with 30-degree bias from the oblique sagittal plane. A. The MR scanning reference lines B. T2WI image with 30-degree bias from the oblique sagittal plane including suboccipital muscle. The sectional area of RCPma is maximum. Δ Cross section of RCPma. \leftarrow Cross section of OCI.

Fig 3. The T2WI image of RCPma and OCI with 30-degree bias from the oblique sagittal plane (The sectional area of RCPma is maximum). 1. RCPmi, 2. RCPma, 3. OCI; The range of area measurement representing the muscle cross-section was outlined by the red line.

Image acquisition. Bilateral 0-degree (sagittal) and 30-degree oblique sagittal scanning sectional areas of RCPma and OCI was imaged by T2-weighted scanning as stipulated by Xu *et al.* The bilateral 0-degree (sagittal) scanning sectional area of RCPma and OCI has five millimeter bias from the median sagittal plane, and the 30-degree oblique sagittal scanning sectional area of RCPma and OCI is in the plane with the maximum area of RCPma.

Table I. The sectional area of the RCPma with 0-degree bias from oblique sagittal plane (mm²).

Value	Left (n=109)	Right (n = 109)
Ranges	93.14-353.10	92.01-391.73
95%° confidence intervals	175.90-196.79	191.01-213.70
Mean±SD	186.34± 55.02	202.35± 59.76
P value		0.000

Table II. The sectional area of the OCI with 0-degree bias from oblique sagittal plane. (mm²).

Value	Left (n=109)	Right (n = 109)
Ranges	110.63-403.67	111.77-390.85
95%° confidence intervals	208.62-234.82	213.27-236.57
Mean±SD	221.72± 68.99	224.92± 61.34
P value		0.368

Table III. The sectional area of the RCPma with 30-degree bias from oblique sagittal plane. (mm²).

Value	Male (n = 47)	Female (n = 62)
Ranges	118.38-276.58	77.90-206.75
95%° confidence intervals	171.19-195.40	126.33-139.76
Mean±SD	183.30± 42.24	133.05± 26.44
P value		0.000

Table IV. The sectional area of the OCI with 30-degree bias from oblique sagittal plane. (mm²).

Value	Male (n = 47)	Female (n = 62)
Ranges	166.52-359.56	119.10-229.73
95%° confidence intervals	241.25-268.38	160.35-174.50
Mean±SD	254.81± 46.20	167.42± 27.85
P value		0.000

Table V. The comparison of sectional area of the RCPma with 30-degree bias from oblique sagittal plane in different age groups. mm²

Value	Male(n = 47)		Female(n = 62)	
	≤45years old(n=32)	>45years old (n=15)	≤45years old(n=40)	>45years old (n=22)
Ranges	124.9-273.2	118.38-276.58	77.9-206.8	99.6-202.9
95%° confidence intervals	136.73-202.07	146.69-213.91	134.4-159.7	138.9-168.2
Mean±SD	169.4±26.5	180.3±34.8	147±37.9	153.6±30.3
P value		0.47		0.519

Measurement of RCPma and OCI sectional area. The boundary of selected sagittal and oblique sagittal scanning images of RCPma and OCI was identified via MR Workstation PACS system, and the sectional area of the muscles was measured automatically.

Analysis of data. The range, 95 % confidence interval, mean, and standard deviation of the morphological parameters of the RCPma and OCI were calculated. Comparisons between the sexes were tested using OneWay ANOVA analysis and the bilateral symmetry of muscles were tested using a paired sample T-test. A p value of less than 0.05 indicated a statistically significant difference.

RESULTS

The MR images of 109 healthy adults were collected via 0-degree (sagittal) and 30-degree oblique sagittal MRI scanning angle of the nape. In the section with 5 mm bias from the median sagittal plane, the RCPma is a narrow triangle or prolate spindle shaped, the parameters of sectional area are 93.14-353.10 mm² on the left and 92.01-391.73 mm² on the right with a significant difference (P<0.05). (Table I). The OCI is found to be spindle shaped, and the sectional area parameters are 110.63-403.67 mm² on the left and 111.77-390.85 mm² on the right with no significant difference (P>0.05) (Table II). In the section with 30-degree bias from the oblique sagittal plane, the RCPma has the shape of an elongated triangle, the sectional area parameters are 183.30± 42.24 mm² in males and 133.05± 26.44 mm² in females with a significant sex difference (P<0.0) (Table III). The OCI is oval shaped, the sectional area parameters are 254.81± 46.20 mm² in males and 167.42± 27.85 mm² in females with a significant sex difference (P<0.05) (Table IV). The sectional areas of RCPma and OCI present no significant difference between the group greater than 45 years old and less than or equal to 45 years old in males or females. (Tables V and VI).

Table VI. The comparison of sectional area of the OCI with 30-degree bias from oblique sagittal plane in different age groups. mm²

Value	Male(n = 47)		Female (n = 62)	
	≤45years old(n=32)	>45years old (n=15)	≤45years old(n=40)	>45years old (n=22)
Ranges	116.52±359.56	120.45±330.57	119.1±229.73	123.57±219.49
95%°confidence intervals	211.53-258.16	187.48-272.01	160.89-179.10	144.54-187.21
Mean±SD	234.8±61.29	229.75±66.51	169.9±27.31	165.87±33.58
P value	0.814		0.669	

DISCUSSION

This study collected the T2-weighted MR images of the RCPma and OCI of 109 healthy adults via 0-degree (sagittal) and 30-degree oblique sagittal continuous MRI scanning. The MR image features and imaging anatomical data of RCPma and OCI was acquired. Significant sex difference was found in the sectional areas of RCPma and OCI respectively, those of males were significantly higher than females. Xu *et al.* also found significant sex differences in the MRI parameters of RCPmi. In this study, we also found that the RCPma was bilateral asymmetric, the sectional area on the right is larger than that of the left, but the OCI is symmetric. The discrepancy in the left and right RCPma may be influenced by head posture and handedness. The sectional areas of RCPma and OCI present no significant difference between the group greater than 45 years old and less than or equal to 45 years old. Studies by Xu *et al.* found that the parameters of the RCPmi was not age related which implies that the deep suboccipital muscles do not significantly atrophy due to normal aging.

Since the concept of the MDB was conceived Hack *et al.*, (1995), the functions of the deep suboccipital muscles have been extended. The MDB is proposed to prevent DM folding, maintaining patency of the subarachnoid space and the normal flow of cerebrospinal fluid(CSF), transmitting tension of DM and adjusting the head position (Hack *et al.*, 1995; Scali *et al.*, 2015). Recently, Sui *et al.* proposed that the MDB may be a dynamic source of CSF circulation in the spinal subarachnoid space (Sui *et al.*; Zheng *et al.*). The RCPmi is connected to the cervical spinal dura mater via the MDB through the PAOM (Hack *et al.*, 1995; Rutten *et al.*, 1997; Alix *et al.*, 1999; Nash *et al.*, 2005; Zumpano *et al.*, 2006; Scali *et al.*, 2015; Yuan *et al.*, 2016) and the RCPma and OCI is connected to the cervical spinal dura mater via the MDB through the posterior atlanto-axial membrane (PAAM) (Hack *et al.*, 1995; Rutten *et al.*; Alix *et al.*; Nash *et al.*; Zumpano *et al.*; Scali *et al.*, 2005; Yuan *et al.*). The connections between these structures are speculative anatomic bases for the above functions and may be of clinical significance. Literatures put forward that chronic headache

is associated with pathological changes of the MDB and RCPmi (McPartland *et al.*; Alix *et al.*; Fernández-de-Las-Peñas *et al.*, 2007, 2008), when lesion occurs in the RCPmi, and the DM which is pain sensitive is pulled, headache may occur (Hack *et al.*, 2004) This study presented the MRI image features, imaging anatomical data and sexual dimorphism of RCPma and OCI. Moreover, this imaging anatomical data will be useful for functional and clinical studies on RCPma, OCI, patients with muscular atrophy and neck pain, and the MDB.

CONCLUSION

The study presented the MR image features and imaging anatomical data of the RCPma and OCI in healthy adults. Significant sex difference exist in the RCPma and OCI muscles respectively. However, there was no age-related significant difference. This study also showed that the RCPma is bilaterally asymmetric.

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RESUMEN: Se ha demostrado que los músculos suboccipitales profundos conectan la duramadre espinal a través del tejido conectivo denso denominado puente miodural (PMD). El PMD tiene implicaciones tanto fisiológicas como clínicas. Los datos sobre los parámetros anatómicos y morfológicos y de imagen de los músculos suboccipitales profundos son alarmantes. En este estudio, se obtuvieron imágenes ponderadas en T2 del músculo recto posterior mayor (RCPma) y del músculo oblicuo mayor de la cabeza (OCI) de 109 adultos sanos, mediante una exploración de la cabeza y el cuello sagital de 0 grados y sagital oblicua de 30 grados. Se midieron los parámetros de área seccional del RCPma

y el OCI. La sección sagital de 0 grados se midió con un sesgo de 5 mm desde el plano mediano, el área de la sección de la RCPma fue $186,34 \pm 55,02 \text{ mm}^2$ a la izquierda y $202,35 \pm 59,76 \text{ mm}^2$ a la derecha. El área seccional de OCI fue $221,72 \pm 68,99 \text{ mm}^2$ a la izquierda y $224,92 \pm 61,34 \text{ mm}^2$ a la derecha. En la sección de 30 grados desde el plano sagital oblicuo, el área de la sección de RCPma fue de $183,30 \pm 42,24 \text{ mm}^2$ en los hombres, y $133,05 \pm 26,44 \text{ mm}^2$ en las mujeres. El área seccional de OCI fue de $254,81 \pm 46,20 \text{ mm}^2$ en varones y $167,42 \pm 27,85 \text{ mm}^2$ en mujeres. Existe una diferencia significativa según el sexo en las áreas seccionales de la RCPma y la OCI, los valores de los sujetos masculinos fueron predominantemente mayores ($P < 0,05$). Sin embargo, no hubo diferencia significativa relacionada con la edad. El área de la sección de RCPma es bilateral asimétrica, la RCPma en el lado derecho es más grande que la del lado izquierdo ($P < 0,05$), pero el OCI es bilateralmente simétrico ($P > 0,05$). Las características de la imagen de resonancia magnética, los datos anatómicos de imágenes y el dimorfismo sexual de la RCPma y la OCI se presentan en este estudio. Estos datos anatómicos de imágenes serán útiles para estudios funcionales y clínicos en RCPma, OCI y PMD.

PALABRAS CLAVE: Región suboccipital; Músculo recto posterior mayor de la cabeza; Músculo oblicuo mayor de la cabeza; Imágenes.

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