

# Anatomical Parameters of the Rectus Capitis Posterior Minor Muscle Based on a New Magnetic Resonance Scan Method

Parámetros Anatómicos del Músculo Recto Posterior Menor de la Cabeza  
Basado en un Nuevo Método de Escaner con Resonancia Magnética

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**SUMMARY:** The past findings confirm that the Rectus Capitis Posterior minor (RCPmi) is connected to the cervical spinal dura mater via the Myodural Bridge (MDB) through the posterior atlanto-occipital interspace. It is hypothesized to perform some functions. Furthermore, some clinical studies found that the pathology of RCPmi might be related to chronic headaches. But few studies were related to the morphological parameters of the RCPmi. It would be conducive to performing clinical researches on the RCPmi and MDB. To explore the optimal section for measuring the RCPmi by MRI and provide imaging anatomy parameters of the RCPmi for clinical research. The RCPmi was measured in the dissection of 10 formalin-fixed cadaver specimens. The morphological parameters of the RCPmi were obtained. Based on these parameters, T2-weighted images of the RCPmi were collected from 109 healthy adults by using the MRIs with different oblique sagittal scanning angles. The parameters of length and area of the RCPmi on the scanning sections were measured using MRI workstation and Mimics software. The length of RCPmi reached a maximum at 30 degrees scanning leaned from the posterior median line through the dens of the axis in oblique sagittal section. At this scanning section, the length of RCPmi was  $21.2 \pm 2.6$  mm in males and  $19.3 \pm 2.4$  mm in females and the area of RCPmi was  $91.9 \pm 27.2$  mm<sup>2</sup> in males and  $73.3 \pm 22$  mm<sup>2</sup> in females. These parameters of RCPmi were present with significant gender differences ( $P < 0.05$ ) but was not age related. Thirty degrees leaned from the median line was suggested to be the optimum scanning angle to display the RCPmi in oblique sagittal section. The reference values of length and area of the RCPmi were established for studies of hypertrophy or amyotrophy of the RCPmi.

**KEY WORDS:** Suboccipital region; Rectus capitis posterior minor muscle (RCPmi); Imaging anatomy parameters;

## INTRODUCTION

The suboccipital region is a complex anatomical structure with the rectus capitis posterior major (RCPma), the rectus capitis posterior minor (RCPmi), and the obliquus capitis inferior (OCI) as part of an important anatomical structure in this region for connecting with the dura mater via the myodural bridge (MDB) (Hack *et al.*, 1995; Pontell *et al.*, 2013; Scali *et al.*, 2013; Su *et al.*, 2013; Zheng *et al.*, 2014). In the past 20 years, it was proposed that through the MDBs the RCPmi might perform some physiological functions, like protecting the spinal cord from dural enfolding (Chang *et al.*, 1992; Hack *et al.*; McPartland *et al.*, 1997; Fernández-de-Las-Peñas *et al.*, 2008; Pontell *et al.*), placing

tension to the dura under (Chang *et al.*; McPartland *et al.*; Rutten *et al.*, 1997; Fernández-de-Las-Peñas *et al.*, 2008;), maintaining the integrity of the subarachnoid space (McPartland *et al.*; Fernández-de-Las-Peñas *et al.*, 2008), and working as a pump via the MDBs to provide power for CSF circulation (Su *et al.*; Zheng *et al.*; Yuan *et al.*, 2016). Furthermore, Some clinical studies found that the pathology of the suboccipital muscles, for instance atrophy or swelling of the RCPmi, might be closely related to chronic cervical headaches (McPartland *et al.*; Alix & Bates, 1999; Fernández-de-Las-Peñas *et al.*, 2007; Fernández-de-Las-Peñas *et al.*, 2008). Although the RCPmi has been studied with emphasis

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on their physiological and pathological significance, there is a paucity of data in the imaging anatomical parameters of this muscles. Therefore, the purpose of this study was to provide imaging anatomical parameters of the RCPmi by anatomical dissections and MRI imaging.

## MATERIAL AND METHOD

Approval for this study was obtained from the Ethics Committee for Research of Basic Medical College of Dalian Medical University.

Measurement of the RCPmi in dissected neck specimens. Ten formalin -fixed adult male cadaveric specimens were dissected at the suboccipital region. The superficial structures of the upper back were removed to expose RCPmi from their point of origin to insertion; then morphological parameters of the RCPmi were measured. The measurements include the length of medial and lateral margins of RCPmi and the angle between them, and the width of the origin and insertion of RCPmi (Fig. 1). Based on the angle value, the length of the RCPmi along the angle bisector was measured (Fig. 1).

MR imaging measurement of the RCPmi in volunteers. One hundred and nine healthy adults (47 males and 62 females, age range from 19 to 70 years with an average of  $39.2 \pm 14.1$  years) were included in the study. No pathological changes were found in the necks of volunteers.

Informed consent was obtained from all volunteers.

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.

The left RCPmi was imaged by T2-weighted scanning with seven kinds of scanning angles separately, including 0, 25, 30, 35, 40, 45, and 50 degrees. The 0 degree scanning section was five millimeters left to the median sagittal plane and the others pivoted on the dens of the axis (C2) and turned to left with 25, 30, 35, 40, 45, and 50 degrees respectively (Fig. 2). The oblique sagittal plane T2-weighted images of RCPmi according to scanning degrees were collected. After that, the length of RCPmi was measured by MR workstation. The section with the longest RCPmi was selected as the optimal one to show. And then in this section, the area of RCPmi was measured by Mimics software 16.0 (Belgium), and the whole length of the RCPmi from origin to insertion was measured as well (Fig. 3).

**Analysis of data.** The range, 95 % confidence interval, mean, and standard deviation of the morphological parameters of the RCPmi were calculated. Comparisons between the adjacent angles, sexes or age groups were tested using One-Way ANOVA analysis and a paired sample T-test. A p value of less than 0.05 indicated a statistically significant difference.

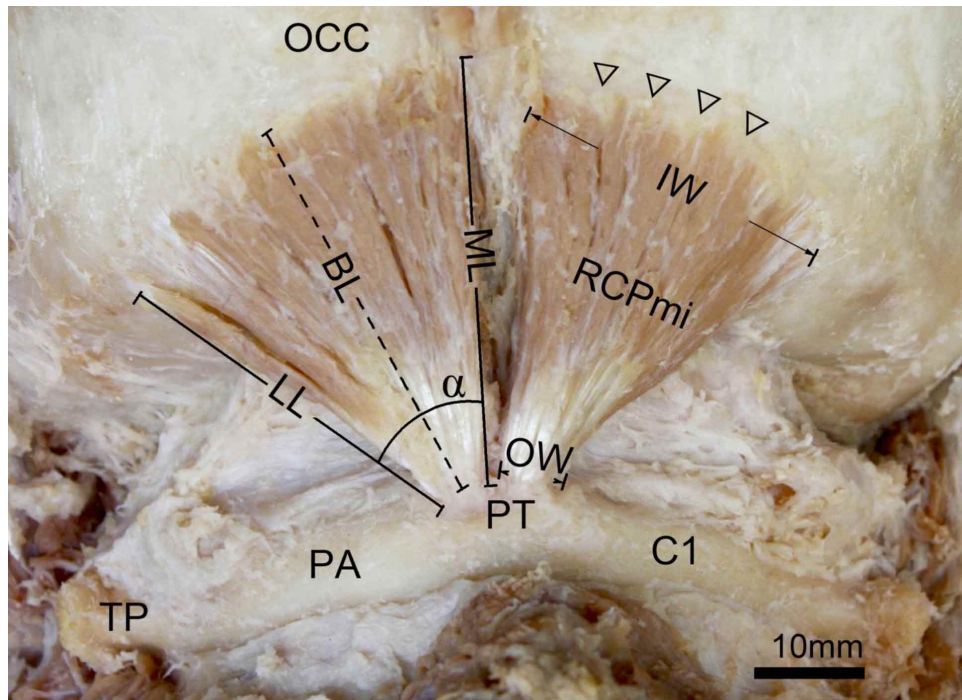


Fig. 1. Measurements of the RCPmi in a case of the specimens (dorsal and inferior view). The  $\alpha$  was an angle between the medial and lateral margins of the RCPmi. The LL showed the length of the lateral margin, and the ML showed the length of the medial margin of the RCPmi. The BL showed the length of the RCPmi along its angle bisector. The OW showed the width of the origin of RCPmi, and the IW showed the width of the insertion of the RCPmi. OCC, the occipital bone. RCPmi, the rectus capitis posterior minor.  $\nabla$ s, the inferior nuchal line, the insertion of the RCPmi. PT, the origin of the RCPmi, the posterior tubercle of the atlas arch. PA, the posterior arch of the atlas. TP, the transverse process of the atlas. C1, the atlas.

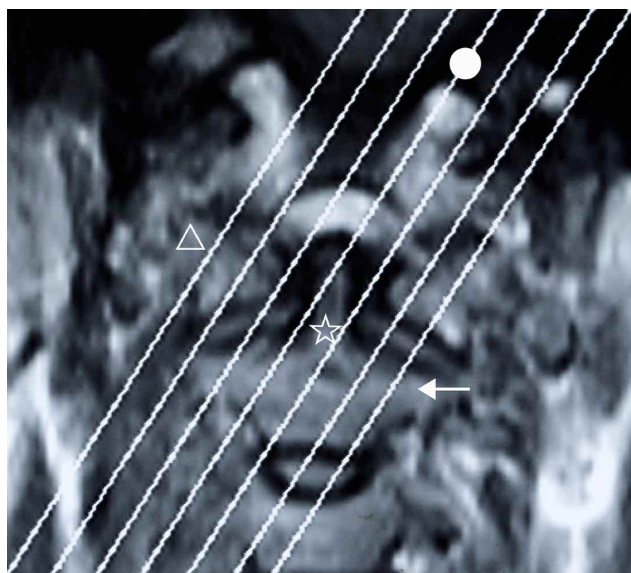


Fig. 2. Definition of MR scanning reference lines, a case of 30 degree scanning. ●, showing the 30 degree scanning line through the dens of axis. \*, the dens of axis. Δ, the atlas. ←, the axis. In each scanning, the T2 weighted image, which passed through the dens of the axis, was collected for measurements.

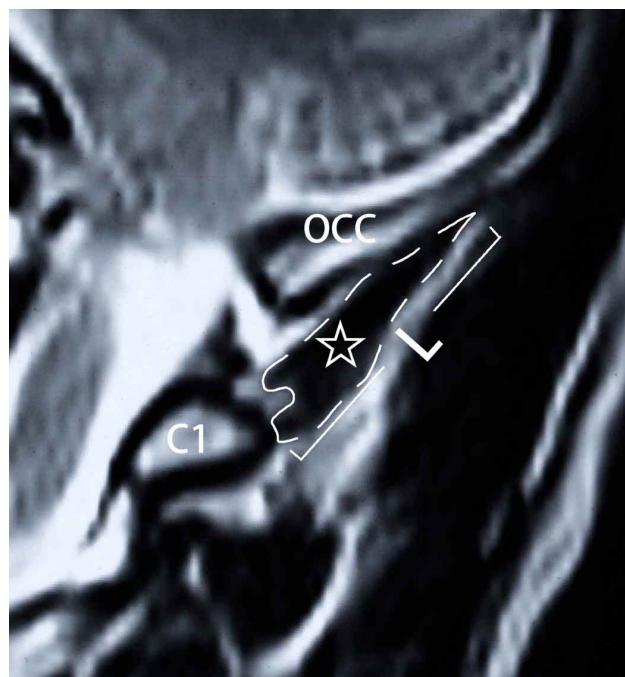


Fig. 3. A case of T2WI image of the RCPmi with thirty-degree bias from the oblique sagittal plane. The RCPmi (?) is presented in the region of low signal. The L showed the length of the RCPmi and the range of its area measurement was outlined by the dotted line. OCC, occipital bone. C1, the atlas.

## RESULTS

Anatomical parameters of RCPmi measured in dissected specimen. In the suboccipital region, the RCPmi

was exposed from the posterior tubercle of the atlas to the inferior nuchal line of the occipital bone. It was found to be

Table I. Anatomical parameters of the RCPmi in male adult cadaver specimens (n=17 sides).

Value	Angle _ (degree)	ML(mm)	LL (mm)	BL (mm)	OW (mm)	IW (mm)
rangs	55.0-72.0	20.5-39.2	18.6-42.2	15.8-36.2	5.5-11.0	17.7-34.9
95% confidence intervals	58.5-62.9	24.4-29.6	21-28	25.2-30.3	7.2-8.7	24.9-29.6
Mean±SD	60.7±4.4	27.0±5.0	24.5±6.8	27.8±5.0	7.9±1.4	27.2±4.6

Note: the LL showed the length of the lateral margin, and the ML showed the length of the medial margin of the RCPmi. The BL showed the length of the RCPmi along its angle bisector. The OW showed the width of the origin of RCPmi, and the IW showed the width of the insertion of the RCPmi.

Table II. Length of the RCPmi with different oblique sagittal sections (mm).

Rang	95% confidence intervals	Mean±SD	Rang	95% confidence intervals	Mean±SD
15.2-27.1.	18.7-20.3	19.5 ± 2.7	12-22.5	17-18.2	17.6 ± 2.3
13.6-25.3	18.9-20.4	19.7 ± 2.6	12.4-23.4	17.3-18.4	17.9 ± 2.2
15.7-26.7	20.5-22	21.2 ± 2.6	12.4-24	18.7-19.9	19.3 ± 2.4
15-24.3	18.8-20.2	19.4 ± 2.4	11.6-23.3	16.9-18.1	17.5 ± 2.3
14.1-23.3	17.7-19	18.4 ± 2.2	10.7-22.5	15.9-17.1	16.5 ± 2.3
13.9-22.4	17-18.2	17.6 ± 2.1	10.2-21.4	15.1-16.3	15.7 ± 2.2
12.4-23.3	15.9-17.2	16.6 ± 2.2	7.3-20.3	14.2-15.4	14.8 ± 2.3

Note: \*there were statistical significances in the length of the RCPmi between adjacent scanning angles ( $P < 0.05$ ) except that between the 0 and 25-degree groups ( $P > 0.05$ ).

a fan shaped muscle with  $60.7 \pm 4.4$  degrees. The medial margin of the RCPmi lateral to the posterior median line was  $27.0 \pm 5.0$  mm long and the lateral margin was  $24.8 \pm 6.8$  mm long. The length of the RCPmi along the angle bisector was  $27.8 \pm 5.0$  mm. And the widths of the origin and insertion of the RCPmi were  $7.9 \pm 1.4$  and  $27.2 \pm 4.6$  respectively. The anatomical parameters of the RCPmi are summarized in Table I. In addition, RCPmi was absent on either sides of one of the subjects. Consequently, the RCPmi of only 17 specimens were accounted for.

**Imaging anatomical parameters of the RCPmi.** Based on the multi-angles scanning, Length of the RCPmi was measured in variation scanning sections and shown in Table II. It was found that the length of RCPmi varied according to variation of the scanning angles. The length of RCPmi was significantly different between adjacent scanning angles except between the 0 and 25 degrees. At 30 degrees scanning,

the length of RCPmi reached a maximum. Consequently, this oblique sagittal scanning angle could be regarded as the optimum to reveal the RCPmi. At this angle, its length was  $21.2 \pm 2.6$  mm in males and  $19.3 \pm 2.4$  mm in females with a significant sex difference ( $p < 0.05$ ). In addition, the length of the RCPmi from its origin to insertion was  $26.2 \pm 3.3$  mm in males and  $23.1 \pm 2.6$  mm in females with a significant sex difference ( $P < 0.05$ ) (Table III).

Furthermore, the sectional area of the RCPmi at 30 degrees scanning was measured with  $91.9 \pm 27.2$  mm<sup>2</sup> in males and  $73.3 \pm 22.0$  mm<sup>2</sup> in females. The sex difference was statistically significant ( $P < 0.05$ ) (Table IV). In order to explore age changes in the RCPmi, the male and female groups were further divided into two age groups, greater than 45 years old and less than or equal to 45 years old respectively. There were no age changes in the length and area of the RCPmi in males and in females (Tables V, VI).

Table III. The whole length from origin to insertion of the RCPmi with 30-degree oblique sagittal plane.

Value	Male (n = 47)	Female (n = 62)
Ranges	18.3-33.3	16.5-29.8
95% confidence intervals	25.2-27.1	22.5-23.8
Mean±SD	26.2±3.3	23.1±2.6
F value		29.629
P value		0.000

Note: the unit of the area was mm<sup>2</sup>.

Table IV. The sectional area of the RCPmi with 30-degree oblique sagittal plane.

Value	Male (n = 47)	Female (n = 62)
Ranges	41.7-156.2	30.8-128.3
95% confidence intervals	84.0-99.9	67.8-78.9
Mean±SD	91.9±27.2	73.3±22.0
F value		15.581
P value		0.000

Note: the unit of the area was mm<sup>2</sup>.

Table V. Aging change of the length from origin to insertion of the RCPmi with 30-degree oblique sagittal plane.

Value	Male (n = 47)		Female (n = 62)	
	≤45 years old (n = 32)	>45 years old (n = 15)	≤45 years old (n = 40)	>45 years old (n = 22)
Ranges	18.3-33.3	21.9-29.4	16.6-29.8	16.5-26.8
95% confidence intervals	24.9-27.5	24.8-27.4	22.4-24.1	21.7-23.8
Mean±SD	26.2±3.7	26.1±2.3	23.3±2.7	22.8±2.4
F value		0.002		0.545
P value		0.961		0.463

Note: the unit of the area was mm<sup>2</sup>.

Table VI. Aging change of the sectional area of the RCPmi with 30-degree bias from the sagittal plane.

Value	Male (n = 47)		Female (n = 62)	
	≤45 years old (n = 32)	>45 years old (n = 15)	≤45 years old (n = 40)	>45 years old (n = 22)
Ranges	45.8±158.2	41.7±132.1	34.1±109.6	30.8±128.3
95% confidence intervals	86.3±105.4	68.2±98.7	66.9±80.6	62.2±83.0
Mean±SD	95.8±26.5	83.5±27.5	73.8±21.5	72.6±23.4
F value		2.172		0.038
P value		0.147		0.847

Note: the unit of the area was mm<sup>2</sup>.

## DISCUSSION

In the past 20 years, the findings confirm that the RCPmi is connected to the cervical spinal dura mater via the MDB through the posterior atlanto-occipital interspace (Hack *et al.*; Scali *et al.*, 2013; Pontell *et al.*; Su *et al.*; Zheng *et al.*). It is hypothesized to perform some physiological functions, such as protecting the spinal cord from dural enfolding (Hack *et al.*; Pontell *et al.*; Chang *et al.*; Fernández-de-Las-Peñas *et al.*, 2008; McPartland *et al.*), placing tension to the dura under (Rutten *et al.*, 1997; Chang *et al.*; Fernández-de-Las-Peñas *et al.*, 2008; McPartland *et al.*), maintaining the integrity of the subarachnoid space (Fernández-de-Las-Peñas *et al.*, 2008; McPartland *et al.*), and working as a pump via the MDBs to provide power for CSF circulation (Su *et al.*; Zheng *et al.*; Yuan *et al.*). Furthermore, Some clinical studies found that the pathology of RCPmi for instance atrophy or swelling, might be closely related to chronic cervical headaches (McPartland *et al.*; Alix & Bates; Fernández-de-Las-Peñas *et al.*, 2007; Fernández-de-Las-Peñas *et al.*, 2008).

In this study it was found that the RCPmi covered the posterior atlanto-occipital interspace and was fan-shaped with a  $(60.7 \pm 4.4)$ -degree central angle. It presented with significant length variations according to the variation of the scanning angles by the MRI. As a result, it was suggested that the 30-degree scanning angle in T2-weighted images might be optimum for showing the RCPmi because the length of the RCPmi was the longest in this oblique sagittal section. In this study, a reference value of imaging anatomical parameters of the RCPmi was set up on the basis of the scanning section of 30-degree angle: the length of the RCPmi was  $21.2 \pm 2.6$  mm in male and  $19.3 \pm 2.4$  mm in female, and the area of the RCPmi was  $(91.9 \pm 27.2)$  mm<sup>2</sup> in male and  $(73.3 \pm 22.0)$  mm<sup>2</sup> in female. The length and area parameters of the RCPmi were found with significant sex differences and without any age difference.

Furthermore, the whole length of RCPmi was  $26.2 \pm 3.3$  mm, measured from its origin and insertion in 30-degree MRI images. It was similar to the length with  $27.8 \pm 5.0$  mm measured along the angle bisector of the RCPmi in dissected specimen. This showed that the method of MRI measurement of the RCPmi was appropriate in this study.

Many anatomical studies have focused on the connections of RCPmi in the past (Hack *et al.*; Rutten *et al.*; Yuan *et al.*; Alix & Bates; Elliott *et al.*, 2005; Zumpano *et al.*, 2006; Hallgren, 2014; Hallgren *et al.*, 2014; Scali *et al.*, 2015), while few studies were related to the morphological parameters of the RCPmi. In this study, a quantitative MRI

measurement of the RCPmi was developed and a reference value of imaging anatomical parameters of the RCPmi was set up. The results of this study lay basis for basic and clinical research on the RCPmi and its MDB.

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**RESUMEN:** Hallazgos previos confirman que el músculo rector posterior menor de la cabeza (mRPMC) está conectado a la duramadre cervical por medio del puente midural (PMD) a través del espacio intermedio atlanto-occipital posterior. Se plantea la hipótesis de su capacidad para realizar algunas funciones. Además, estudios clínicos encontraron que la patología del mRPMC podría estar relacionada con dolores de cabeza crónicos. Sin embargo, pocos estudios se relacionaron con los parámetros morfológicos del mRPMC. Se buscará realizar investigaciones clínicas sobre el mRPMC y el PMD, además de explorar la sección óptima que permita medir el mRPMC por resonancia magnética (RM) y que permita obtener la imagen adecuada para la identificación de los parámetros anatómicos del mRPMC en la investigación clínica. Se midió el mRPMC durante la disección de 10 especímenes, correspondientes a cadáveres fijados con formalina. Se obtuvieron los parámetros morfológicos del mRPMC. Basándose en estos parámetros, se estudiaron imágenes ponderadas en T2 del mRPMC de 109 adultos sanos, utilizando las resonancias magnéticas con diferentes ángulos de exploración sagital oblicua. Los parámetros de longitud y área del mRPMC en las secciones de exploración se midieron utilizando la estación de trabajo del equipo de RM y el software Mimics. La longitud del mRPMC alcanzó un máximo de 30 grados de exploración, inclinado desde la línea mediana posterior, a través del eje en la sección sagital oblicua. En esta sección la longitud del mRPMC fue  $21,2 \pm 2,6$  mm en los hombres y  $19,3 \pm 2,4$  mm en las mujeres, y el área del mRPMC fue  $91,9 \pm 27,2$  mm<sup>2</sup> en los hombres y  $73,3 \pm 22$  mm<sup>2</sup> en las mujeres. Se observaron diferencias significativas de sexo en estos parámetros del mRPMC ( $P < 0,05$ ) sin embargo estos no estaban relacionados con la edad. Se sugirieron 30 grados inclinados a partir de la línea mediana como el ángulo óptimo de exploración para mostrar el

mRPMC en la sección sagital oblicua. Los valores de referencia de longitud y área del mRPMC se establecieron para estudios de hipertrofia o amiotrofia del mRPMC.

**PALABRAS CLAVE: Región suboccipital; Músculo recto posterior menor de la cabeza; Parámetros de anatomía de imagen; Resonancia magnética.**

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